AERODYNAMIC PRELIMINARY ANALYSIS SYSTEM II

PART II   USER'S MANUAL

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SUMMARY

An aerodynamic analysis system based on potential theory at subsonic/ supersonic speeds and impact type finite element solutions at hypersonic conditions is described. Three-dimensional configurations having multiple non-planar surfaces of arbitrary planform and bodies of non-circular contour may be analyzed. Static, rotary, and control longitudinal and lateral-directional characteristics may be generated.

The analysis has been implemented on a time sharing system in conjunction with an input tablet digitizer and an interactive graphics input/output display and editing terminal to maximize its responsiveness to the preliminary analysis problem. CDC 175 computation time of 45 CPU seconds/Mach number at subsonic-supersonic speeds and 1 CPU second/Mach number/attitude at hypersonic conditions for a typical simulation indicates that the program provides an efficient analysis for systematically performing various aerodynamic configuration tradeoff and evaluation studies.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF ILLUSTRATIONS

LIST OF SCREENS

LIST OF SCREENS (CONTINUED)

LIST OF TABLES

LIST OF ABBREVIATIONS AND SYMBOLS

A	Angle of attack
APAS	Aerodynamic Preliminary Analysis System
AR	Aspect ratio
B	Angle of side slip
b	Span. See figure 3-2
C	Chord. See figure 3-10
$\bar{c}$, CBAR	Mean aerodynamic chord
CK	Airfoil form factor coefficient for linear thickness ratio term
<CR>	Terminal carriage return
C_R	Root chord. See figure 3-2
CRL	Component reference line
C_t	Tip chord. See figure 3-2
D1,...	Flap 1 deflection,...
FF	Component form factor
FRL	Fuselage reference line
HABP	Hypersonic Arbitrary Body Program
M,Mach	Mach number
OK	APAS ready mode
PERIM	Perimeter
{SP}	Terminal space bar
S	True surface area
S_{wet}	Wetted area
T/CR	Root chord maximum thickness ratio
T/CT	Tip chord maximum thickness ratio

X( ),A( ),W/H   Station, cross-sectional area, width/height ratio. See Table 3

X-Area   Cross-sectional area

X,Y,Z   Axial, lateral, vertical cartesian body axis coordinates

XO,YO,ZO   Section origin

XRO,YRO,ZRO   Component origin

X-STAT   X station

XTRANS/LENG   Transition distance as a fraction of component length or chord

λ Surface taper ratio

$\Lambda_{L.E.}$ Leading edge sweep-degrees

Γ Dihedral angle-degrees

{ }   Letter in brackets is the indicated screen input for a cross-hairs command

$\rightarrow$ Keyboard input

α Angle of attack-degrees

β Angle of side slip-degrees

P   Roll rate - rad/sec

Q   Pitch rate - rad/sec

R   Yaw rate - rad/sec

SECTION 1

INTRODUCTION

A subsonic-supersonic-hypersonic aerodynamic analysis was developed by integrating the Aerodynamic Preliminary Analysis System[1,2] (APAS) and the inviscid force calculation modules of the Hypersonic Arbitrary Body Program[3] (HABP). The former analysis was extended for non-linear vortex forces using a generalization of the Polhamus analogy. The resulting interactive system developes appropriate aerodynamic models from a single input geometry data base and has a run/output format similar to a wind tunnel test program. A description of the pertinent theory is presented in Part I.

The user's manual has been organized to sequentially cover the principle system activities of a typical application. That is, geometric input/editing, aerodynamic evaluation, and post analysis review/display. Sample sessions are provided for each to illustrate the specific tasks involved. This text is followed by a comprehensive command/subcommand dictionary that is used to operate the system.

It is recommended that new users perform the sample cases or their equivalents. Speed should not be a consideration initially. Obtaining desired simulations often requires repeating steps several times. Like any tool, practice is required. Since the system provides several alternative ways to process a job, the user is encouraged to experiment in order to determine which paths best suit his needs.

A well trained analyst can evaluate a configuration in one working day. Since most of the aerodynamic analysis is performed in background, three sessions are typically required. The first is associated with geometry input and checkout, the second with run schedule setup, and the third with display of results and preparation of additional runs if necessary.

SECTION 2

SYSTEM OVERVIEW

APAS II is the third evolution of a system which began with an interrogative response approach and evolved into a command oriented system in order to reduce user response demand. Although not as easy to learn as the former its productivity is far superior. In addition, it has the ability to operate over a wide range of sophistication by accessing fewer or more options on a particular problem.

The system structure is presented on figure 2-1. The program flow is from left to right. In general, the procedure is a fairly straight forward pattern of input, storage, preview, analysis, and review. Input data processing and execution order for CDC computer architecture is shown on figure 2-2. System activity and command/subcommand relationships are summarized on figure 2-3. Input manipulation, and verification of geometry (balloons one through four) is described in section 3. The interactive analysis and run set up for background evaluation (balloon five) are detailed in section 4. Display of aerodynamic results (balloon six) are described in section 5. Utility commands (balloon seven) are provided to maintain geometry file identification and set or modify various system defaults. A detailed system command/subcommand dictionary is presented in section 6 and can be referred to directly by the experienced analyst.

APAS II was implemented on an IBM 370-168 and subsequentially converted to a CDC CYBER 175. The system contains three separate programs: the interactive input/output program, the subsonic-supersonic analysis program, and the hypersonic analysis program. In addition to this single computer version, the interactive program was converted to a prime mini-computer using a UT-200 protocol to communicate with its CDC host computer where the analysis programs are executed.

The interactive program uses Tektronix PLOT10 software for graphics display and a 4014 model Tektronix graphics terminal with a large tablet. Enhanced graphics is recommended over smaller less equipped scopes. The data transmission rate to the interactive terminal should be at least 1200 BAUD (120 characters per second) and preferably at 9600 BAUD for best results.

2
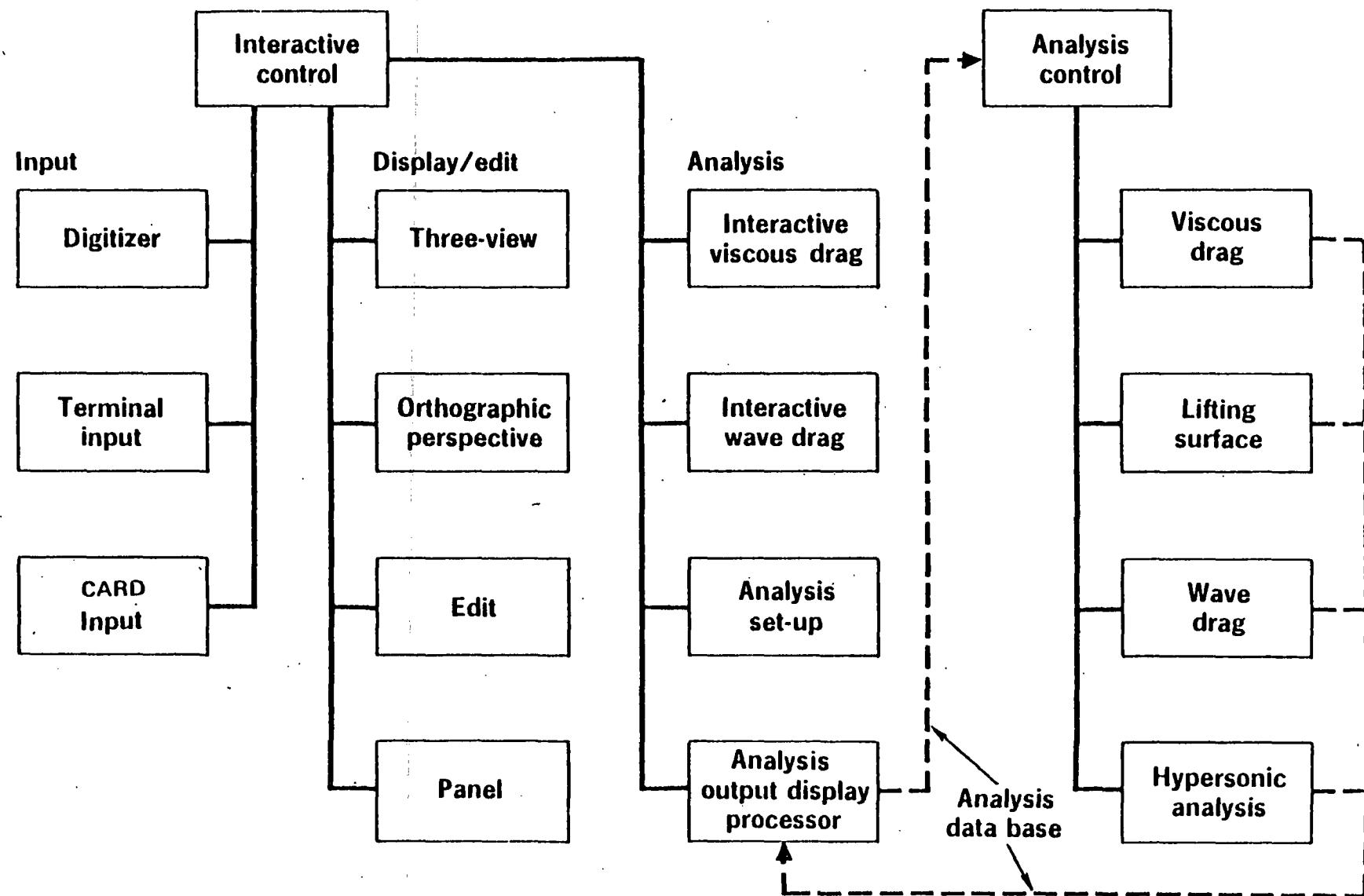
Figure 2-1. APAS II Organization

PRIME MINICOMPUTER

CDC-MAINFRAME

CARD-IMAGE DATA TRANSFER ──┐

```
┌─────────────────────────┐        ┌─────────────────────────┐      ┌─────────────────────────┐
│   INTERACTIVE SYSTEM     │───────▶│  CARD-IMAGE PROCESSOR   │─────▶│   ANALYSIS PROCESSOR    │
└─────────────────────────┘        └─────────────────────────┘      └─────────────────────────┘
```

EXECUTION
ORDER

```
┌──────────┐   ┌──────────┐
│ RANDOM   │   │ RANDOM   │
│ ACCESS   │   │ ACCESS   │
│ GEOMETRY │   │ OUTPUT   │
│ FILE     │   │ FILE     │
│ (G)      │   │ (O)      │
└──────────┘   └──────────┘
```

```
┌─────────────────────────────────────────────┐
│        INTERACTIVE SYSTEM                     │
│                                               │
│   ┌─────┐  ┌─────┐   ┌───────────┐            │
│   │ (G) │  │ (O) │   │ CARD-IMAGE│            │
│   │     │  │     │   │ PROCESSOR │            │
│   └─────┘  └─────┘   └───────────┘            │
└───────────────────────────────────────────────┘
```

UDP	1
WAVE DRAG	2
VISCOUS	3
HABP	4

```
┌─────────────────────────┐
│  CARD-IMAGE PROCESSOR    │
└─────────────────────────┘
```

4
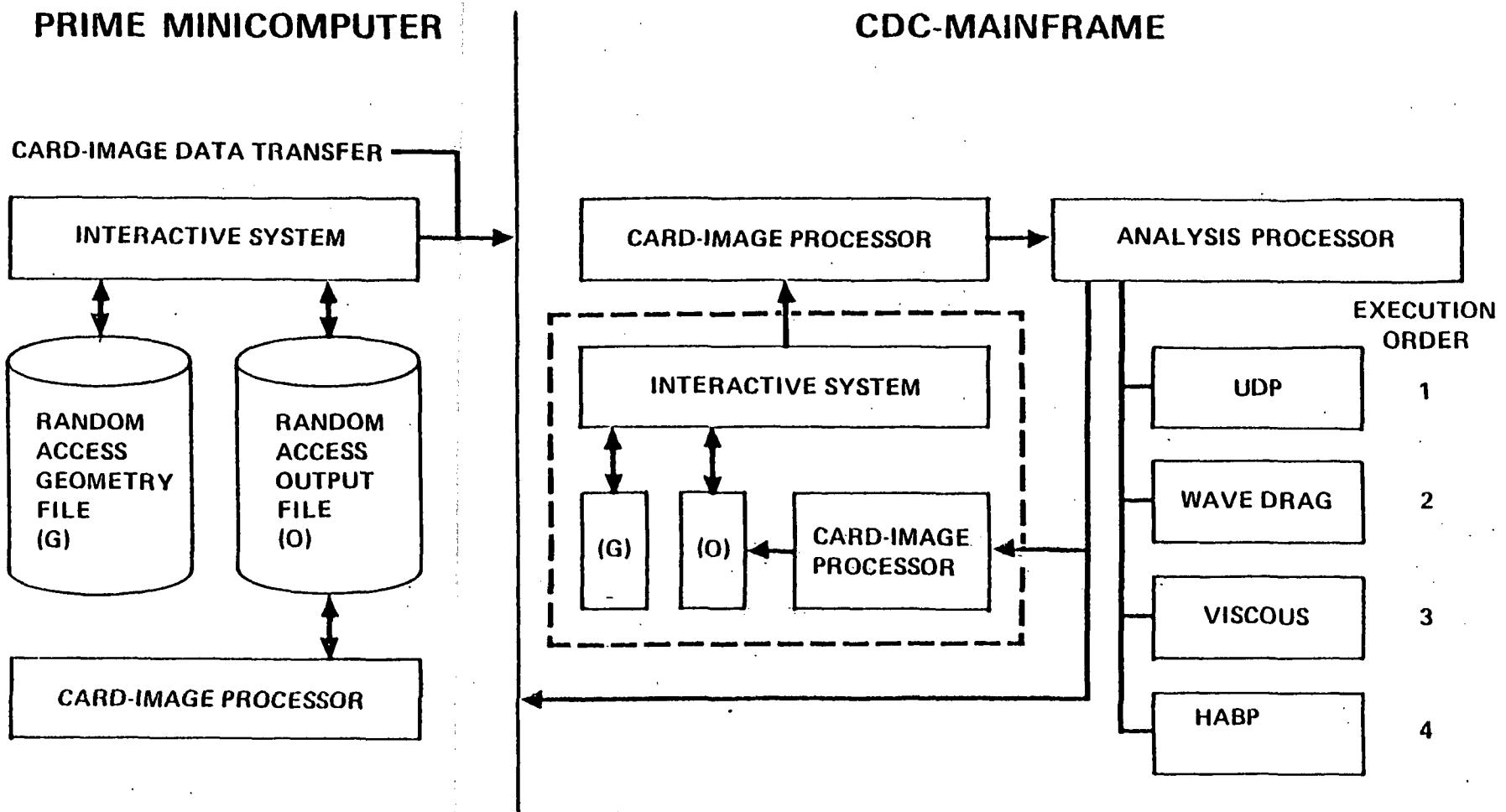
Figure 2-2. APAS II input data processing and execution order for CDC architecture
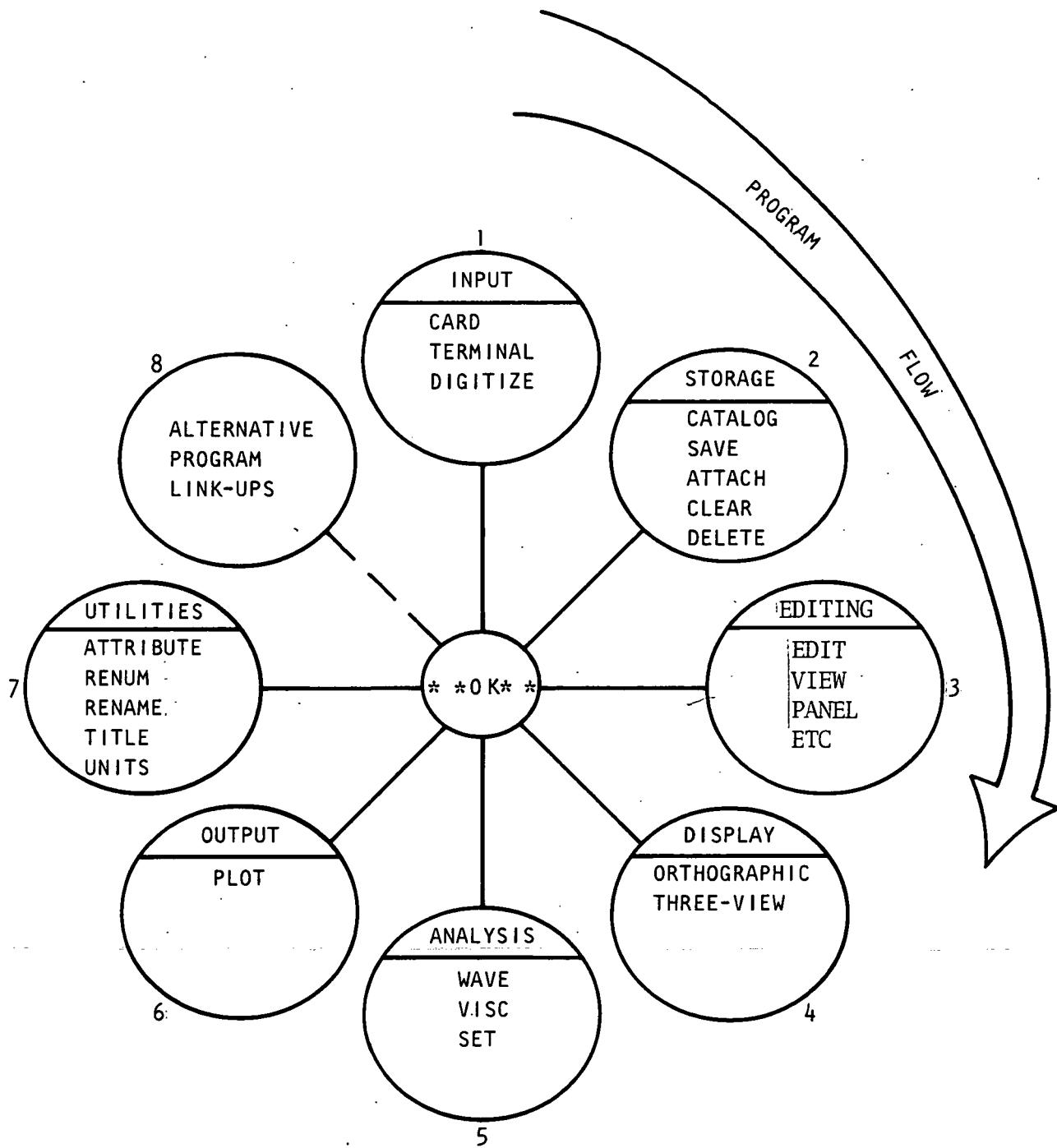
Figure 2-3.   System activity and command/subcommand relationships

SECTION 3

GEOMETRY

Geometric simulation and input procedures for APAS II are described. Supporting interactive display and editing activities are defined. Two work sessions of increasing complexity are provided to illustrate these system tasks for the beginning user.

A multiple body/surface component description was adopted for air vehicle definition. This approach facilitates arrangement studies, regional modification or replacement and the evaluation of component contributions and interactions. In addition, aerodynamic analysis sensitivities may be established by variation of component force algorithms were pertinent.

Geometric input is by one of three ways; simple data via keyboard input (TERMINAL), the digitizer (DIGIT), and card image (CARD). Storage format is independent of the input method. A vehicle can, therefore, be composed of components defined in a variety of ways without incurring problems with geometric compatability provided a common system of units is used.

The typical procedure is to input a particular component, display and edit it as necessary, and then catalogue it in the permanent file. The task is repeated for each vehicle component.

Activity concerned with user controlled geometric/aerodynamic model interfaces is subsequently initiated. Typical tasks involve linking of sub assemblies to form a vehicle body component and definition of surface-flap-shell paneling. The remaining aerodynamic model definitions are developed under automatic directive.

A common geometric data base is used to develop the subsonic-supersonic and hypersonic aerodynamic models. It can be reused since it is not altered during analysis model definition.

User configuration of the system is initiated by reviewing the display, edit, units, and file title defaults and changing the directives as desired. The ATTRIBUTE and TITLE commands of section 6 are used for this purpose and provide the following prompts.

```
        **OK**
——————► attribute

        PRESENT USER DEFAULTS:
            FILE   OPERAND FOR COMMANDS ---------->: PERMANENT
            ANGLE  OPERAND FOR DISPLAY COMMAND --->: YAW= 90.00 PITCH=  0.0   ROLL= 90.00
            UNIT   OPTION FOR  UNITS COMMAND ----->: METERS
            VIEW   OPERAND FOR DISPLAY COMMAND --->: THREE VIEW
            LINE   TYPE OPTION FOR DISPLAY COMMAND : STICK
            VIEW   OPERAND FOR EDIT/LIST SUBCOMMAND: FULL DISPLAY

            ENTER: 'CR' - NO CHANGE
                   1   - FILE   OPERAND
                   2   - ANGLE OPERAND FOR DISPLAY COMMAND
                   3   - UNIT   OPTION  FOR UNITS   COMMAND
                   4   - VIEW   OPERAND FOR DISPLAY COMMAND
                   5   - LINE   TYPE OPTION FOR DISPLAY COMMAND
                   6   - VIEW   OPERAND FOR EDIT/LIST SUBCOMMAND
——————►
        **OK**
——————► title
        PRESENT TITLE IS: APAS SAMPLE SESSION GEOMETRY FILE
        ENTER: NEW TITLE OR  'CR'
——————►
        **OK**
```

Interrogation of the various ATTRIBUTE options provide the following menu.

```
1
 ENTER:  1 - PERM, 2 - WORK, OR 3 - COMP


2
 ENTER ANGLES: YAW,PITCH,ROLL


3
 ENTER:  1 - METERS, 2 - INCHES, OR  3 - CENTIMETERS


4
 ENTER:  1 - ORTHOGRAPHIC OR  2 - THREE VIEW


5
 ENTER:  1 - HIDDEN PANEL  OR  2 - STICK FIGURE


6
 ENTER:  0 - FULL DISPLAY, 1 - SUPRESS PRINT.  OR  2 - SUPPRESS DISPLAY
```

7

COMPONENTS

A component in APAS is defined as an object which can be spatially defined using a set of similar concatenated cross sections. Geometric and analysis components are used. The former approximates a portion of the physical vehicle. Analysis components are simulations of geometric components or specialized constructions. Examples are slender bodies and interference shells respectively.

A cross section of a component is, in general, an ordered set of points which, when connected, will form a closed area either by nature of the points themselves or by the symmetric and reflection properties of the component illustrated in table 1. The component symmetry/reflection codes are assigned during digitizing and can be changed by using the EDIT/PARAMETER subcommand.

Each cross section can be broken into segments to further delineate component physical characteristics. See figure 3-1. Each cross section of a component has the same number of segments and are used to define contour corners and unwetted regions such as wing-body and nacelle-body connections. Wetted and unwetted segments are designated by +1 and -1 respectively during digitizing and can be changed using the EDIT/PARAMETER subcommand.

Numerically-similar points on each cross section are connected. Point one of section one is connected to point one on section two and so on, providing a simple and convenient three-dimensional component construction.

There are five basic components used in APAS. They are bodies, surfaces, slender bodies, interference shells, and field points. A description of each follows.

GEOMETRIC

Bodies (Types 1 and 2)

A body refers to a geometry construction whose primary function is to provide containment volume in a configuration. The fuselage (or major pieces thereof), nacelles, auxiliary fuel tanks, and engine pods are body components. Type 1 bodies are aircraft centerline components. Type 2 bodies are offset (from the aircraft centerline) components. The SLENDER command is the only command in APAS which makes use of the distinction between type 1 and 2 bodies.

Surfaces (Types 3 and 4)

A surface is a component such as wings, verticals, strakes, canards, horizontals, and ventrals. The distinction between types 3 and 4 is whether the reference planform is based on the root-to-tip area (type 3), such as a vertical or a ventral, or on the full trapezoidal area (type 4), as in a wing or horizontal. See figure 3-2.

Each airfoil of a surface component must start and end at the leading edge. They usually have two segments. If a surface has a blunt trailing edge, segment two will be the trailing edge, and the lower surface will be segment three. A surface with only one segment is permitted (see figure 3-3) and can be used to represent a zero thickness camber plane.

8

Table 1. Component Symmetry Parameters

——— Stored boundary

----- Generated by symmetry directive

Codes
1   Non-reflective
2   Reflective
+   Asymmetric
-        Symmetric

Reflective Asymmetric

Code = 2

Example: Fuselage

            Fuselage-Nacelle
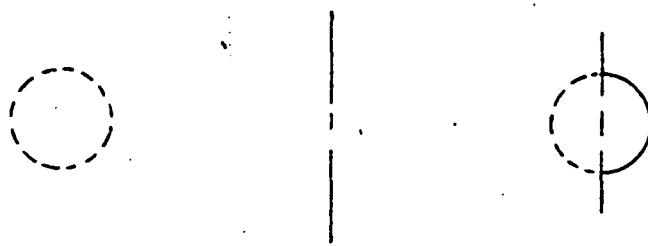
Reflective Symmetric

Code = -2

Example: Missiles

            Podded Nacelles

Aircraft
℄

Component
℄

Aircraft
℄

Non-reflective Asymmetric

Code = 1

Example: Centerline Vertical

Reflective Asymmetric

Code = 2

Example: Winglets or

            Twin verticals

Aircraft
℄
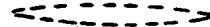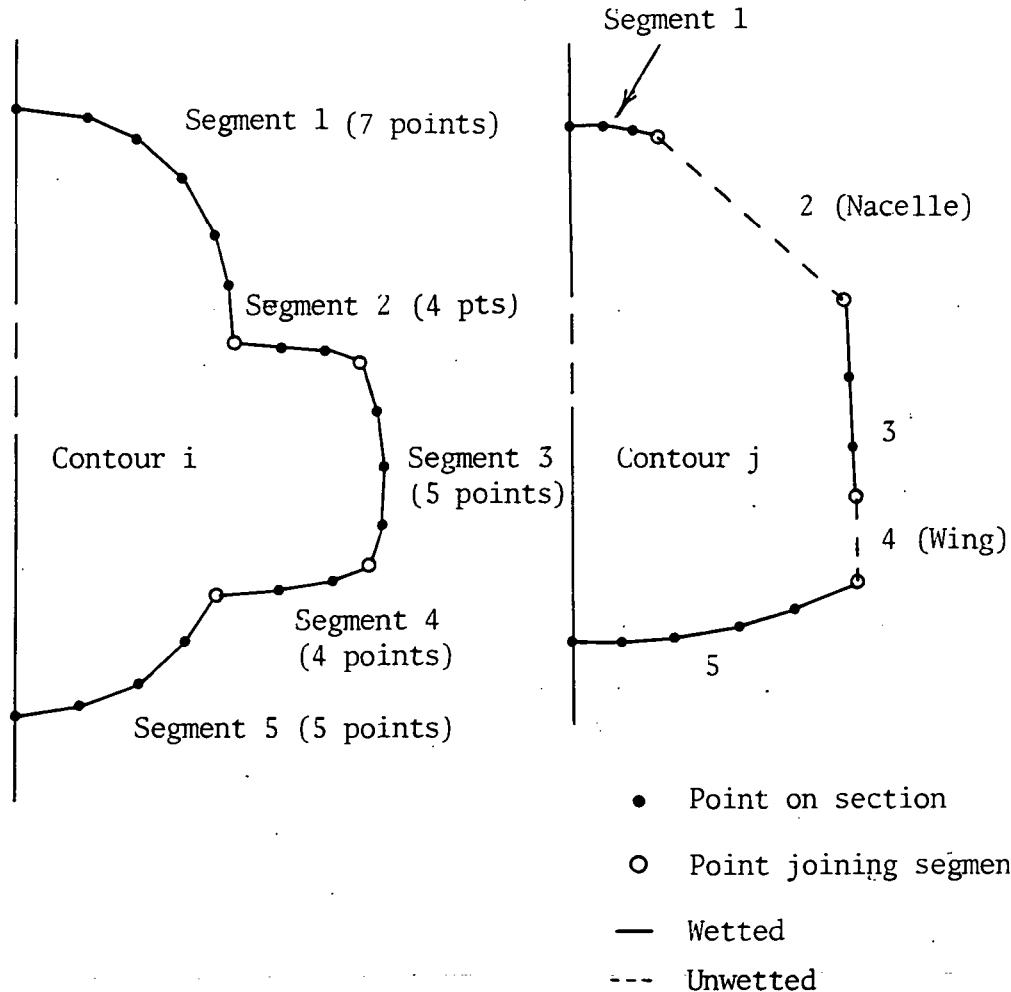
Figure 3-1. Cross-section segmentation

Segment 1 (7 points)

Segment 2 (4 pts)

Contour i

Segment 3 (5 points)

Segment 4 (4 points)

Segment 5 (5 points)

Segment 1

2 (Nacelle)

Contour j

3

4 (Wing)

5

● Point on section

○ Point joining segments

— Wetted

--- Unwetted
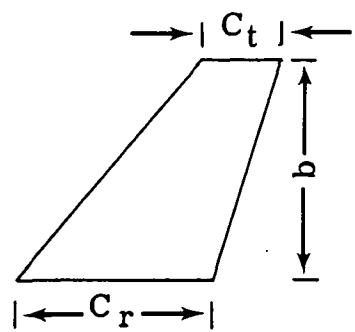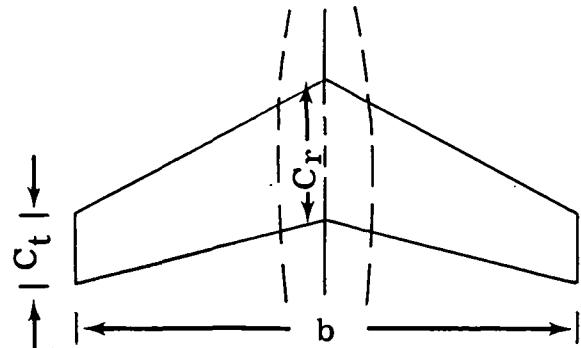
TYPE 3   TYPE 4

Figure 3-2 Surface components
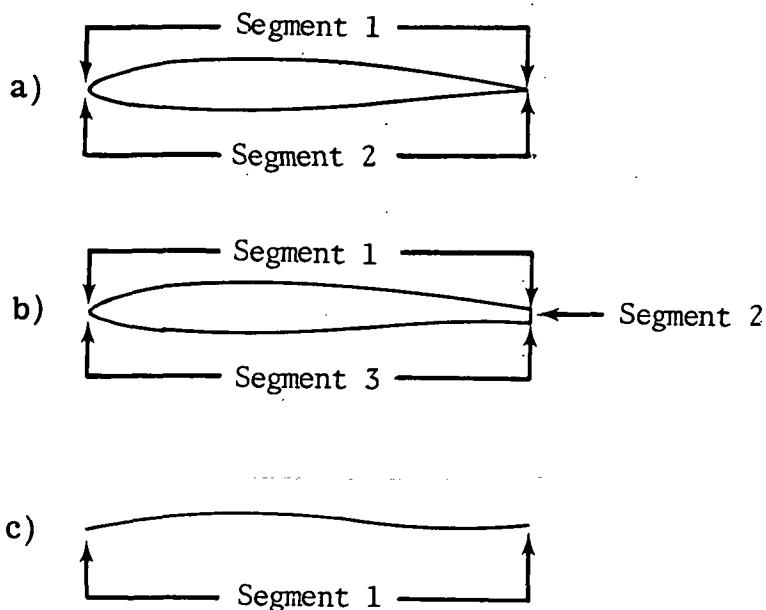
Figure 3-3 Airfoil segmentation
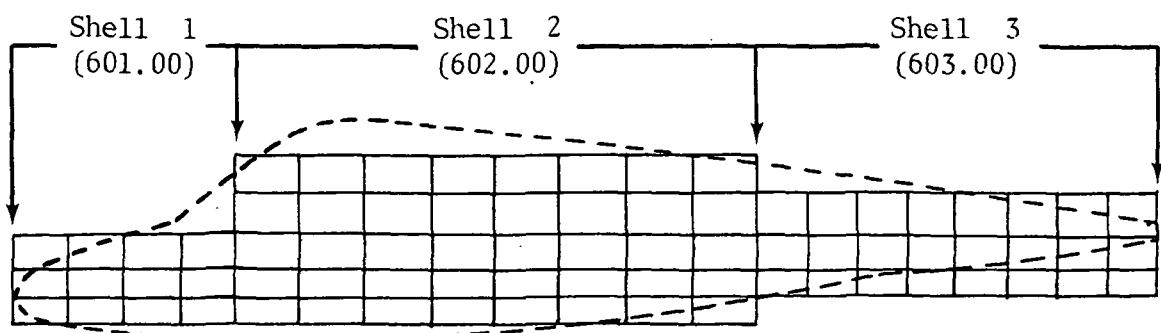
Figure 3-4   Multiple interference shells use
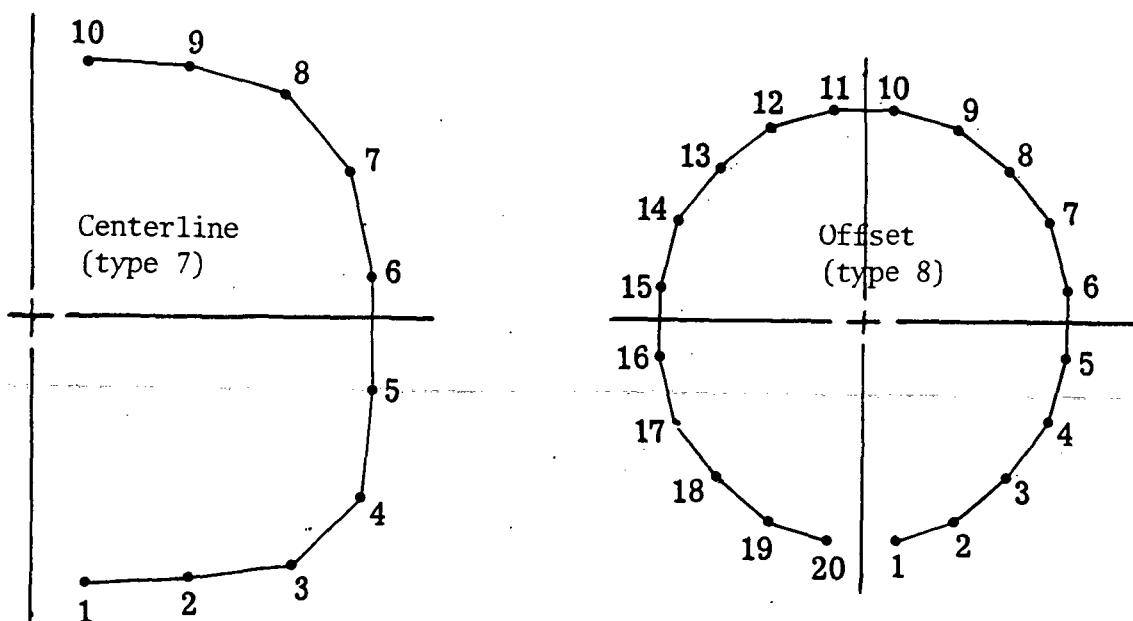
Figure 3-5   Typical slender body cross sections

ANALYSIS

Interference Shell (Type 5)

This component is one of the special analysis constructions used in APAS.
It is required with a slender body to account for carryover loads induced on the body
by adjacent components. This construction is not required if a flat plate simulation
of a body is used.

Interference shells are constructed using the INTERFERENCE command. They are one
segment non-circular cylinders and are formed by use of symmetry parameters or closing
the construction on itself. By concatenating two or more shells, figure 3-4,
longitudinal variations in body cross sections can be accommodated. Each shell section
must have a contour point where an adjacent surface attaches. An automatic tolerance
matching procedure is provided to make the connection. Multiple interference shells
are numbered consecutively from the associated body starting with the most forward
shell component.

Slender Bodies (Types 7 and 8)

This component satisfies the subsonic-supersonic analysis requirement of uniform
cross-sectional point spacing and is used to simulate type 1 and 2 components. They
are constructed using the SLENDER command. The merging of major pieces can also be
performed to develop a contiguous component. Figure 3-5 illustrates typical cross-
sections for centerline (type 7) and offset (type 8) cases.

An interference shell must be constructed for each slender body except for a body
alone case.

Field Points (Type 9)

A specified array is used to define the locations at which off-body flow conditions
are desired. The CARD command is used to input up to 40 such points. Inlet analysis,
missile drop simulations, etc. are typical analysis problems which make use of this
option.

NUMBERING

Component numbering is used to control the order in which components are processed
and the connectivity between components. It provides the user with freedom in
organizing his configurations, but adds the responsibility to exercise care in
numbering components.

In general, components should be separated by category; i.e., bodies, nacelles,
wings, verticals, etc as indicated in table 2.

Table 2

Component Numbering

COMPONENT NUMBER	COMPONENT TYPE
1.00-99.00	Bodies
100.00-199.00	Nacelles
200.00-299.00	Wings
300.00-399.00	Verticals
400.00-499.00	Horizontal/canards
500.00-599.00	Ventrals/fins
600.00-699.00	Slender body/interference shells
1000.00	External stores
9999.00	Maximum component number

Each component can be assembled from up to 6 subcomponents. The following examples are combinations which are typical.

1.	Forward Fuselage	Mid Fuselage	Aft Fuselage	POD
	10.00	11.00	12.00	13.00

2.	Inboard Wing	Outboard Wing
	200.00	201.00

3.	Slender Body	Interference Shell
	600.00	601.00

The rule for component combinations is to start the group on a multiple of 10, the value zero not being valid. The most forward or inboard subcomponent is placed first, followed by the next outboard, or aft subcomponent. By following a logical numbering system, the user will find managing his geometry files easier and also usable by other people.

CONFIGURATIONS

A set of components comprising a complete vehicle definition for analysis is defined as a configuration. A geometry file may contain more than one configuration, and a given component may be used to assemble more than one arrangement. As an example, the file listing of figure 3-6 contains two configurations shown broken out to the right.

PERMANENT GEOMETRY FILE	
NUMBER	NAME
1.00	FORWD. FUSE
2.00	AFT FUSE
200.00	WING 37.16 SQ M
210.00	WING 41.81 SQ M
300.00	VERTICAL
400.00	CANARD 9.29 SQ M
410.00	CANARD 12.08 SQ M
600.00	SLENDER BODY
601.00	INTER. SHELL

CONFIGURATION 1	
1.00	FORWD. FUSE
2.00	AFT FUSE
200.00	WING 37.16 SQ M
300.00	VERTICAL
400.00	CANARD 9.29 SQ M
600.00	SLENDER BODY
601.00	INTER. SHELL

CONFIGURATION 2	
1.00	FORWD. FUSE
2.00	AFT FUSE
210.00	WING 41.81 SQ M
300.00	VERTICAL
410.00	CANARD 12.08 SQ M
600.00	SLENDER BODY
601.00	INTER. SHELL

Figure 3-6   Two configurations from a single geometry file.

65A0XX

64A0XX

SUPERCRITICAL

30-70 HEX

BI-CONVEX
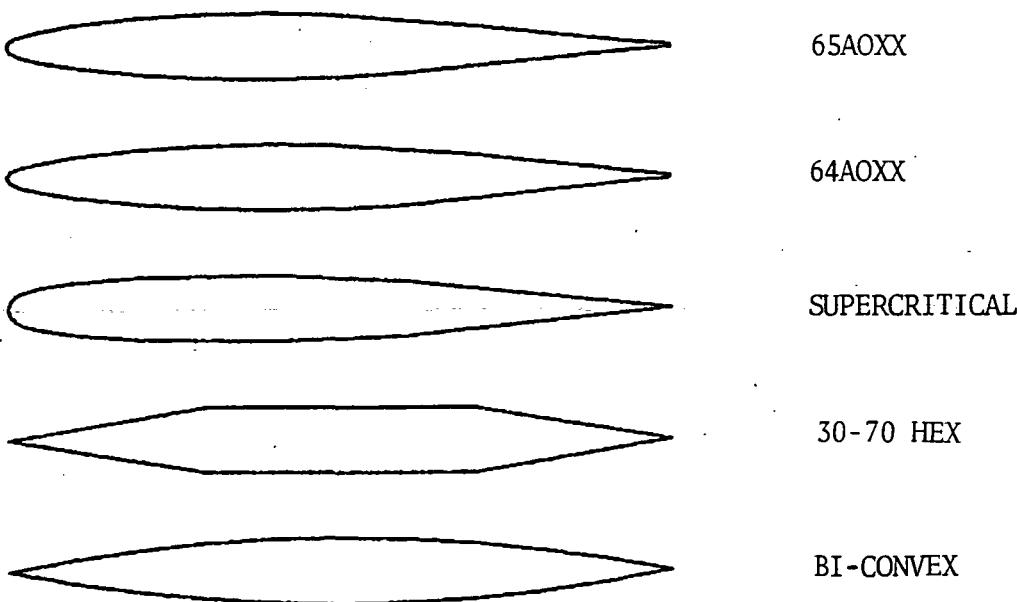
Figure 3-7   TERMINAL airfoil sections command.

INPUT

Three levels of geometry input sophistication are available in APAS. They are (1) keyboard entry of simple shapes, (2) keyboard selection of shapes from a user-compiled card image file, and (3) digitizing arbitrary shapes.

SIMPLE

The TERMINAL command allows the user to define simple geometries by typing basic descriptive parameters into the system.

Body components (types 1 and 2) are input by selecting control points (e.g. pilot station, engine face, and base) and specifying the x-station, cross-sectional area and the section width to height ratio. One segment full ellipse, half ellipse, rectangular, and triangular contour options are available.

Surface components (types 3 and 4) are input by defining aspect ratio, area, taper ratio, sweep, and dihedral. The analyst then specifies the wing section (five different types, figure 3-7) and the root and tip thickness ratio.

The CARD command provides an alternate means of inputting simple vehicle geometry. Components are constructed from similar type of data as TERMINAL, except that the user has greater control of section locations and, in the case of surfaces, upper and lower surface contours. A complete description of CARD input is provided in appendix A.

ARBITRARY

Digitizing requires a limited amount of information keyed in by the operator. The majority of the data is defined using a graphic tablet and digitizing pen. A component is constructed by sequentially digitizing a series of sections, starting from the nose and proceeding to the tail for a body or from root to tip for a surface. Adding or replacing sections on an existing component does not have an order restriction.

The reference point for a body cross-section is usually taken as the configuration fuselage reference line (FRL), figure 3-9. Offset components can be digitized using a component reference line (CRL) and positioned relative to the configuration using the component origin, Xo, Yo, Zo. Entering the reference point is step I in digitizng a body section. Step II digitizes points around the section, starting at the top of the section and working outboard around to the bottom of the section for a type 1 (centerline) component or back to the top point for a type 2 (offset) component. Segment joining points are specified (figure 3-8, section 1) by double point. If more than two segments converge at one location (figure 3-8, section 2), a point is entered for each segment. A total of five is required for this case.

16

Legend (Figure 3-8):
⊕ Reference Point
• Single Point
○ Double Point
□ Quintic (5) Point
CRL Component Reference Line
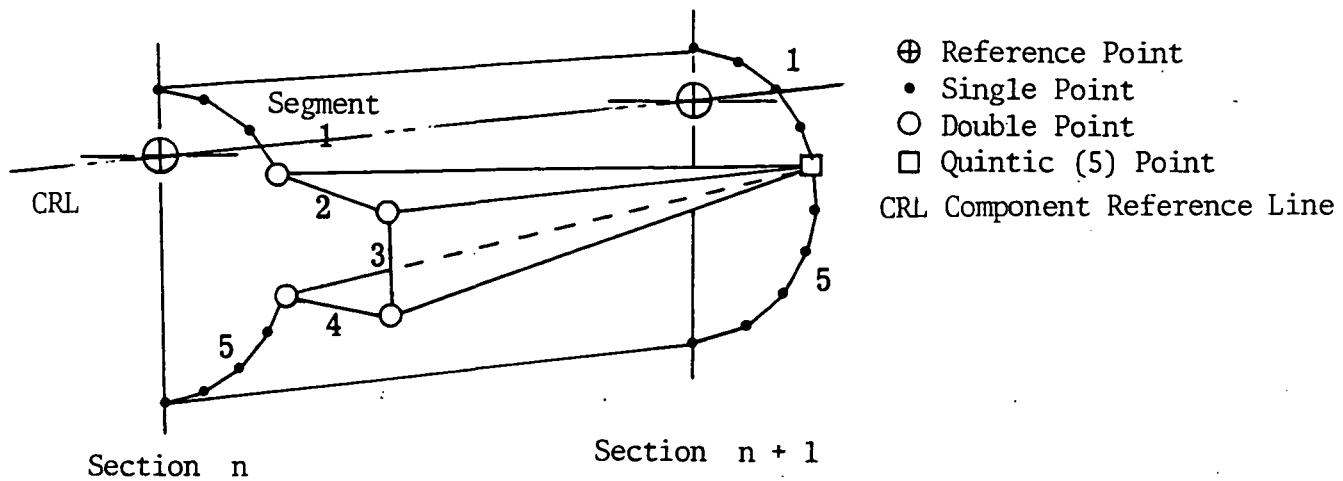
Figure 3-8   Digitizing points for sections having converging segments.

NOTE: SECTION PURPOSELY
SELECTED AT FLAP BOUNDARY

Legend (Figure 3-9):
-------- Selected Chordlines
— — — Transfer Lines
○   Step II Point
△   Step III Point
□   Step IV Point
\   Indicates Vertical
FRL   Fuselage Reference Line
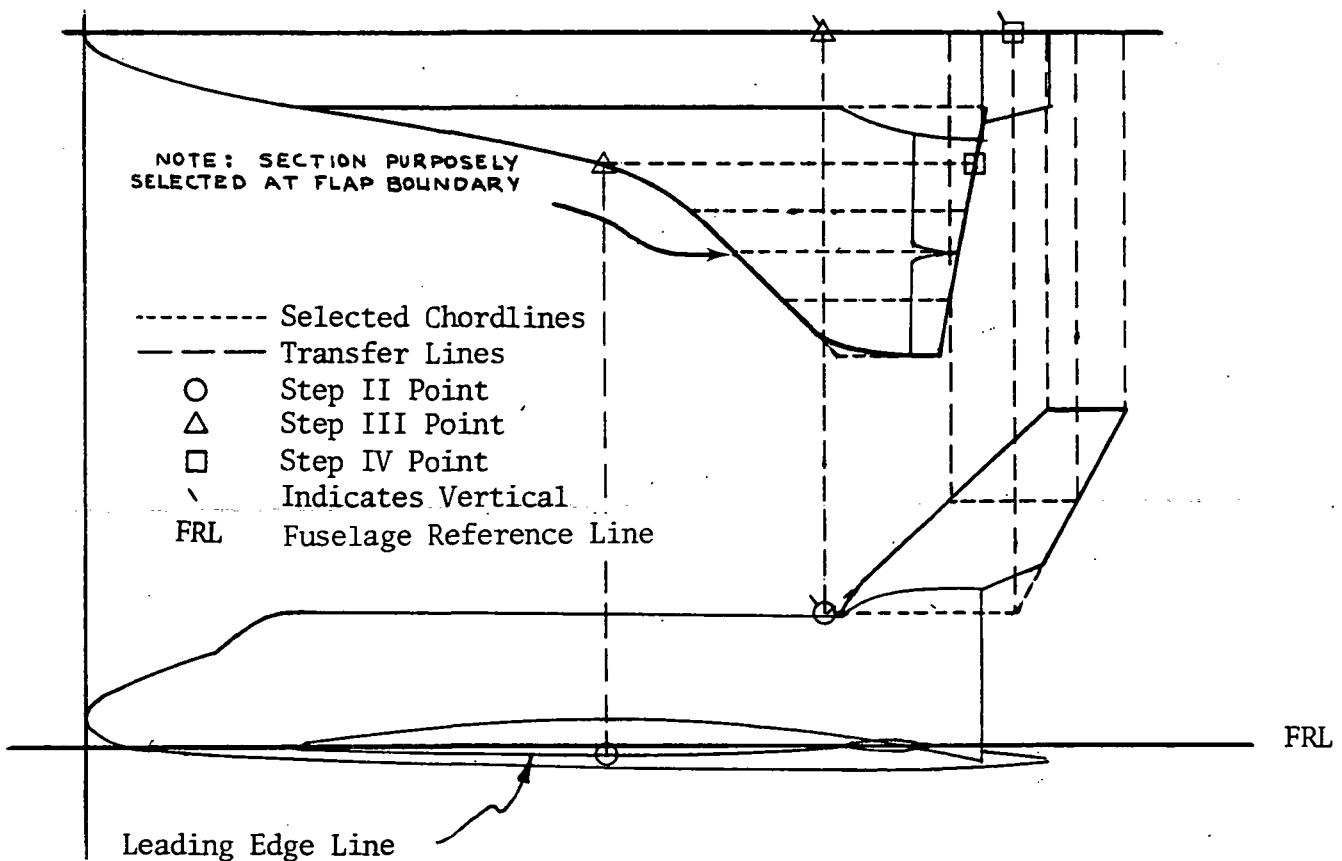
Figure 3-9   Preparing surfaces for digitizing

17

At the end of each section digitizing, an entry from the keyboard is required to end the section. If the user has made a mistake, he can enter the letter R and carriage return, and the input will reset back to step I. If the letter S is entered, the section ends normally, the section is displayed on the screen, and the reference coordinates X_0, Y_0, and Z_0 are printed. If the user enters the letter X, Y, or Z, the current X_0, Y_0, and Z_0 from digitizing is printed on the screen, and the user has the option of accepting these or entering his own values. This ends the section loop. The user is asked to re-enter the section, enter a new section, or end the component.

Surface definition has two levels of input complexity. The lowest is based on the use of scaled airfoils from a 65A0XX default section or scaling an input section for the surface. The user defines the planform by entering a sequential set of section maximum-thickness ratios, origins, and chord lines. This is a repeated four-step process for the default or preselected section and a seven-step process for the digitized section option. The basic (four-step) process is:

Step I: Enter maximum thickness (t/cmax) ratio from the keyboard. A positive t/cmax will scale the default or previously input section, zero t/cmax or carriage return will return a section of the same t/cmax. Negative t/cmax activates the airfoil digitizer mode. The input section will be scaled to the chord length input in steps III and IV. If the t/cmax of the digitized section differs from the absolute value keyed in by more than 15-percent, the digitized thickness ratio is then scaled such that t/cmax matches the keyed-in value. This option allows the user to digitize standard airfoil sections.

Step II: After entering t/cmax, the tablet will be initialized, and the user will enter the z or height location of the chord line from the side view of the configuration drawing. (see figure 3-9).

Step III: The next point to enter on the chord line is the X-Y location of the leading edge. This is entered from the top view on the configuration drawing. This is visually straight forward for a wing or horizontal. The points in steps III and IV are also entered from the top view for a vertical surface end. In this case, it is helpful to draw the chord lines to be used in a vertical surface in the side view then transfer the end points onto the top view for digitizing. (See figure 3-9).

Step IV: The final point defines the chord length (trailing edge) of the chord line. All surface chord lines run parallel to the X-axis in APAS. The leading edge of a surface has been arbitratily selected to define the chord line reference plane.

This completes the surface section loop. In summary, step I enters t/cmax, step II digitizes the Z leading edge, step III digitizes the X-Y leading edge, and step IV digitizes the X trailing edge. This process is sequently repeated from the root to tip.

18

If the t/cmax entered in step I is negative, three additional steps·are performed, and a true view of each airfoil desired is required. It does not have to be the same scale as the configuration drawing. A larger scale is preferred for improved digitizing accuracy. The sections do not have to be oriented on the tablet in any particular manner because steps V and VI will define the true reference system of the airfoil.

Step V: Digitize the leading edge point on the section reference line. (See figure 3-10, left side.) This point establishes the vertical location of the section. It is also an axis point for orienting the section in its true X-Z viewing space.

Step VI: Digitize the trailing edge point on the section reference line. (See figure 3-10, right side.) This point locates the axial trailing edge location for scaling the section chord to match the chord line. It is also the second point for orienting the section in its true viewing space.
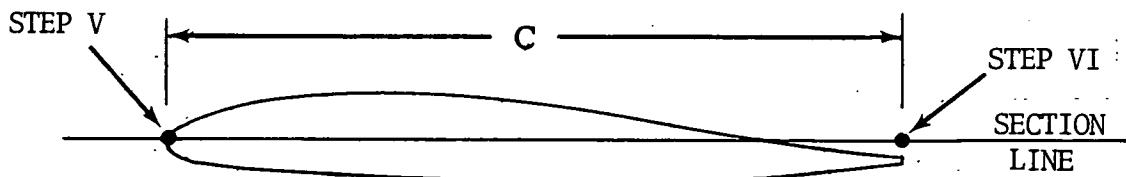
Figure 3-10 Airfoil reference line

Step VII: Digitize the airfoil chordwise by starting at the leading edge. At the trailing edge, a double point is entered (for a two-segment surface) to indicate the segment brake between the upper and lower surfaces. For a blunt trailing edge (three-segment surface), a double point is entered at both trailing edge points. If a blunt trailing edge ceases to exist at a given section, a triple point is required to indicate a null segment at the trailing edge. The user then enters either an R (to repeat steps V through VII only) or an S (to end the section normally) and carriage return from the keyboard. The section thus entered becomes the default section replacing whatever section was previously stored as the default. This is the end of the digitized section input process. The user can return to step I for the same section, a new section, or end the component.

19

PROCESSING

Detailed descriptions of the APAS geometry processing procedures are presented in Appendix B. Point spacing may be based on constant curvature, constant fractional arc length or a combination of these algorithms. Linear, second-order, or least-squares smoothing interpolation is available.

Digitized body sections and the hypersonic panel model utilize a point spacing criteria based on 50% constant curvature and 50% constant fractional arc length.

Digitized cross-section segments are interpolated using the second-order or least-squares method. For surface sections, an algorithm is provided in the least squares method to incorporate the radius at the leading edge.

Section insertions are constructed by interpolating along common points (e.g., point 7 of section 8 to point 7 of section 9) with linear or second-order fits.

Surface camber and thickness are determined using a piecewise least-squares fit to provide smooth distributions and slopes on a grid defined by input geometry points. Linear interpolation is used to determine the panel coordinates and boundary conditions at control point locations.

DISPLAY

Three-view and orthographic visualization is available in the DISPLAY command to establish the acceptability of the geomety. Each has special features which help to locate problems. In addition to trouble shooting, these displays are used as a permanent record of the geometry for documentation purposes. Some artistic capabilities have consequently been included.

The three-view mode permits examination from the three standard angles as indicated on figure 3-11. In addition section cuts can be constructed and displayed using the graphics cursor.

The orthographic projection provides the ability to view geometry at user specified angles as indicated on figure 3-12. Windowing permits zooming in on a given area (figure 3-13) to investigate a problem or check the region more closely. A perspective capability is available to provide alternate views (figure 3-14) of a vehicle or group of components and also as an aide in generating underlays for artist renderings. A hidden panel algorithm can be activated in the orthographic projection to help define geometry problems masked by the standard stick figures. See figure 3-15.

EDITING

The EDIT command is used to correct or refine component geometry and update a vehicle undergoing development. A primitive capability exists to alter a component so that the impact of size and shape changes on aerodynamics can be evaluated. A second principal function is to define subsonic-supersonic analysis paneling and flap boundaries.

Sections can be scaled, translated, deleted or inserted using a combination of graphics cursor and keyboard input of the type of operation desired. Additional capabilities are zooming into a problem area, multicomponent viewing, and several other graphical aids designed to improve visual editing capabilities. These cursor guided functions are combined into the EDIT/VIEW subcommand.

Alternative keyboard subcommands are provided to digitly correct, translate, scale, delete, or insert, component sections singly or in sequential groups.

The PARAM subcommand adjusts component segment parameters (wetted or unwetted), and origin values.

Surface finite-element definition required for the subsonic-supersonic analysis and control surface boundaries for the hypersonic analysis are developement using the PANEL subcommand of EDIT.

Default paneling of each surface construction in APAS is provided. Type 3 surfaces have five spanwise and five chordwise uniform panels. Type 4 surfaces have 10 by 10 evenly spaced panels. Interference shells (type 5) have 10 chordwise and one spanwise panel between each set of contour points.

PANEL allows the user to develop a finite element model which is generally independent of the chordwise and spanwise input geometry. The user may also specify sets of panels as control surfaces. PANEL uses a planview of the surface as its working display. The planform is partitioned into a set of regions with a specified number and type of finite elements. The spanwise region boundaries are determined by the input airfoil sections themselves or the root and tip if desired.

COMPONENT MANAGEMENT

Components are stored on a random or direct-access device, depending on the computer installation. This allows the user to work with them in a fast and efficient manner. Components are accessed in numerical order even though they are stored in the order in which they are cataloged.

There are three geometry files attached to APAS. They are the permanent, component, and local. The permanent file is used to store configuration geometry and is catalogued for future use. The component file is used to store pieces of geometry which are used in several vehicles, such as engine pods, missiles and external tanks. The local, or work file is used to place selected components from the permanent and/or component files for interactive analysis or set up for the background mode. All components for execution must be present in the local file at the time of job execution. APAS commands for component manipulation are ATTACH, CATALOG, CLEAR, COPP, COPY, DELETE, SAVE, and the SAVE subcommand in EDIT.

ATTACH takes components from the permanent or component file and adds non-redundant components to the local file. CLEAR, purges the local file. It is useful for clearing the work (local) file for another configuration.

CATALOG adds new components to a file, protecting any old components with the same number. SAVE, on the other hand, will write over an existing component or enter a new one if an identical number is not found in the file directory.

COPY allows a user to copy a component within a file. COPP allows a component from the component or local file to be copied into the permanent file and has the same protections as CATALOG.

DELETE removes components from a file. The file must be specified. This protects the user from destroying components from the wrong file.

APAS SAMPLE SESSION GEOMETRY FILE
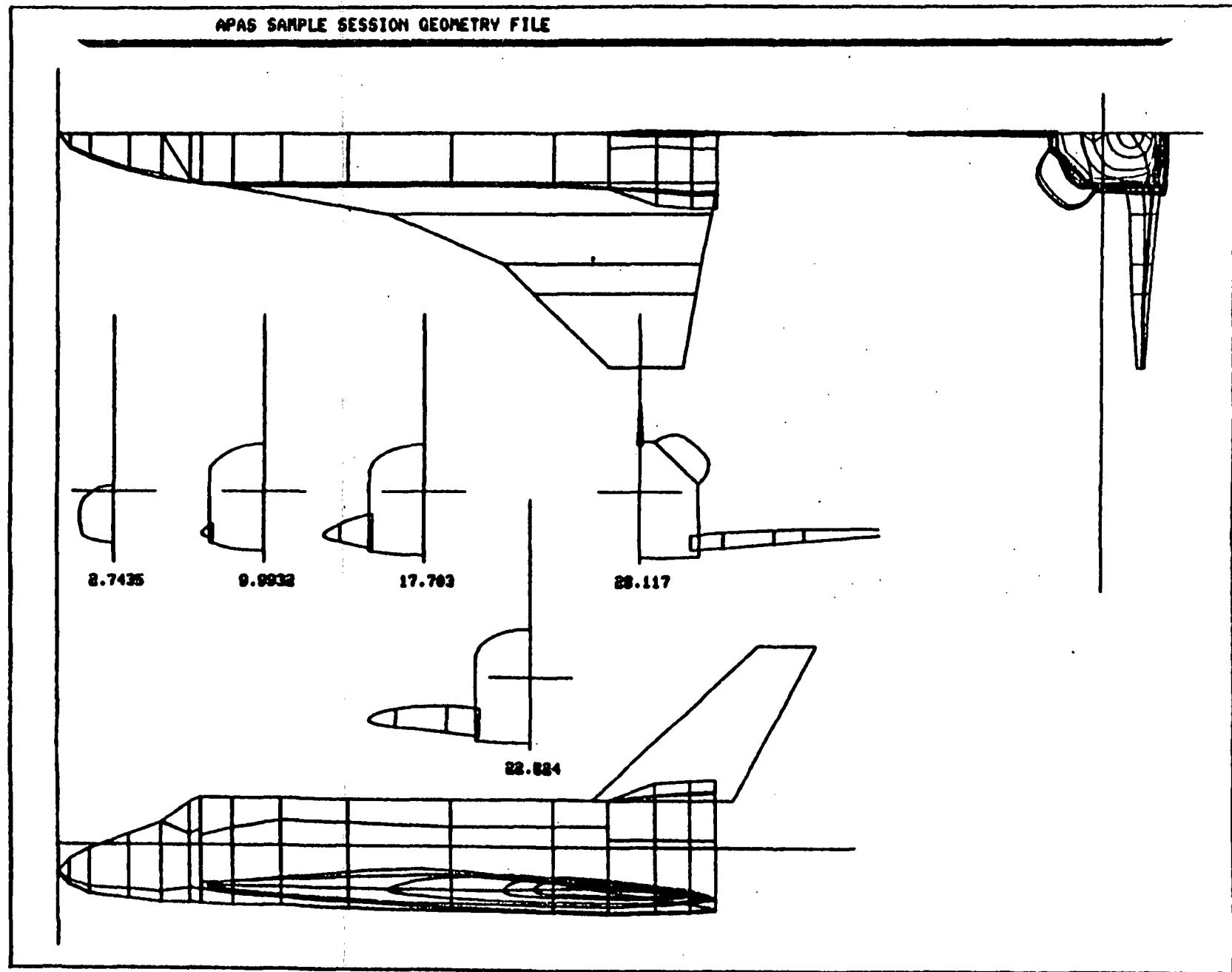
Figure 3-11. Three view display

YAW PITCH   ROLL
30.0 -30.0   0.0
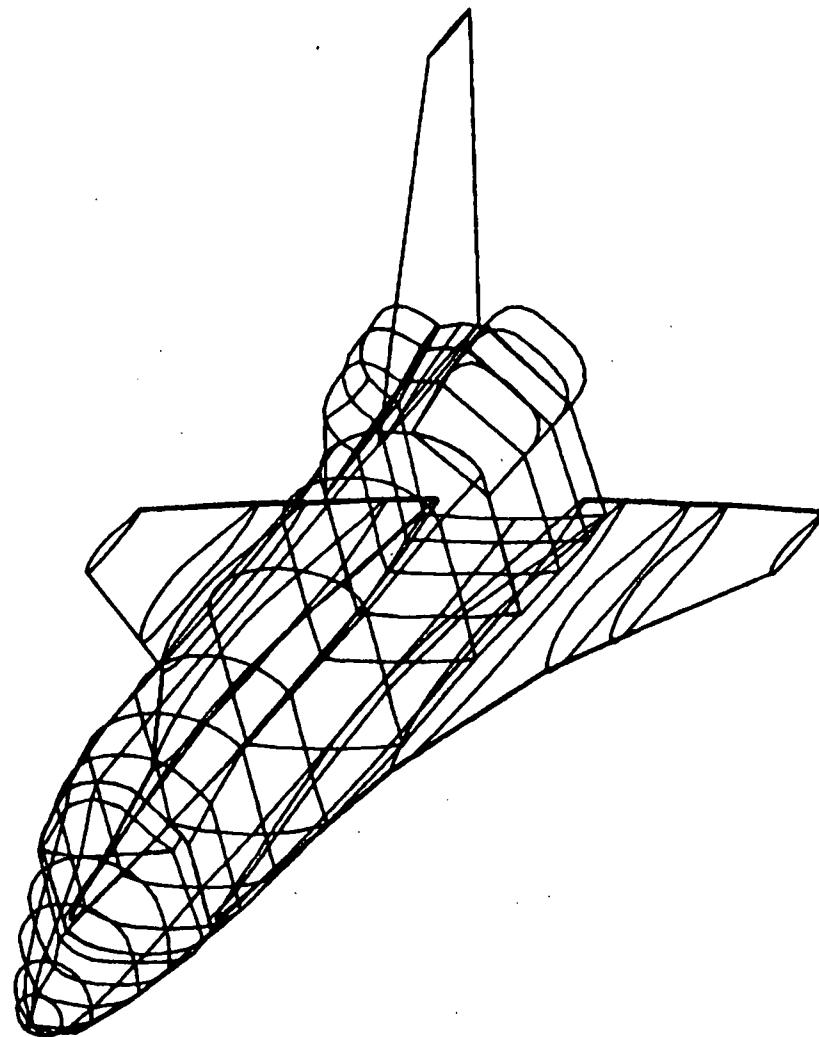
Figure 3-12. Orthographic display

24

APAS SAMPLE SESSION GEOMETRY FILE

YAW   PITCH   ROLL
90.0   0.0   0.0
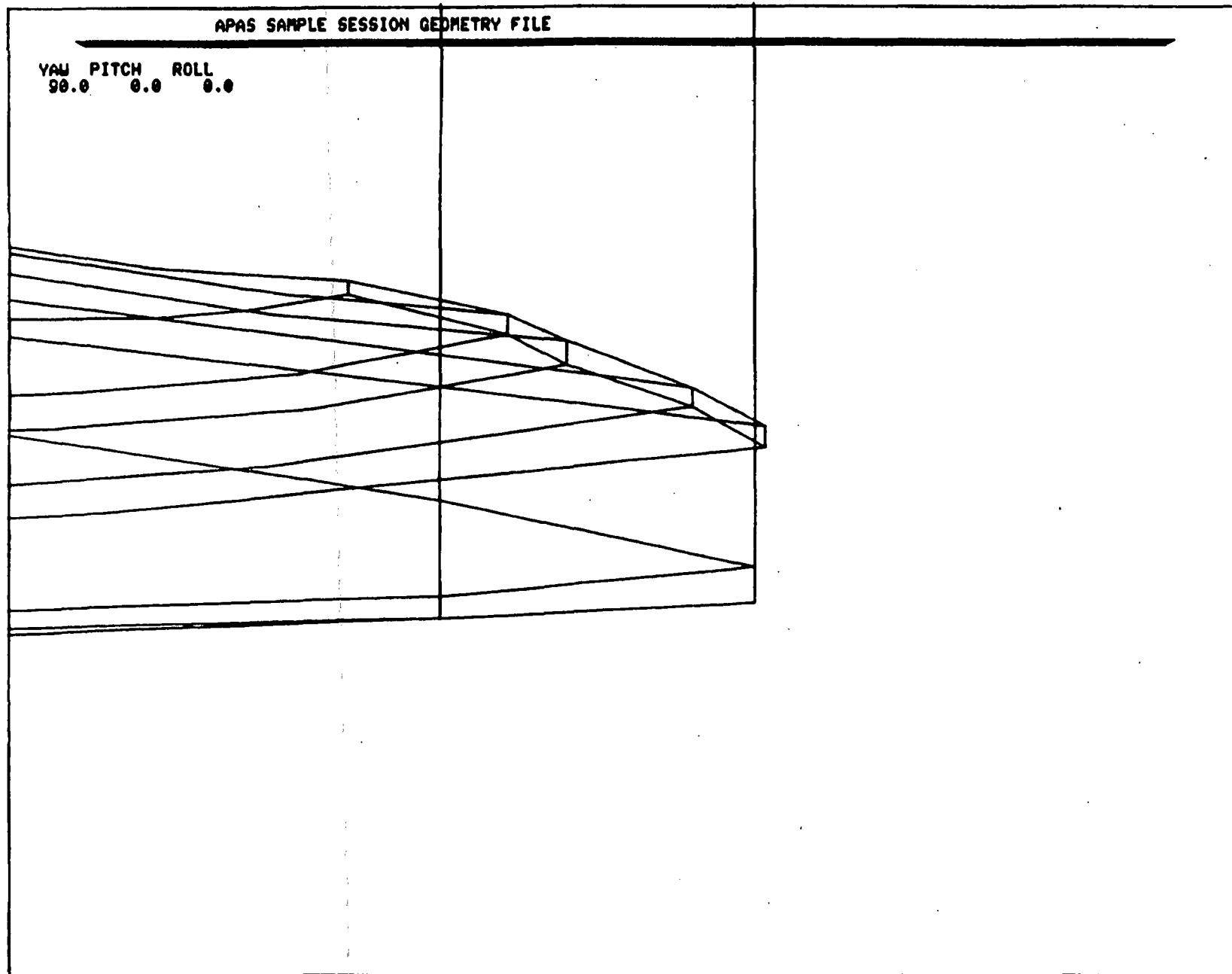
Figure 3-13.   Windowing into a potential trouble area.

APAS SAMPLE SESSION GEOMETRY FILE

```
  YAW  PITCH   ROLL
  30.0  -30.0    0.0
: VIEWING DISTANCE:    30.0
```
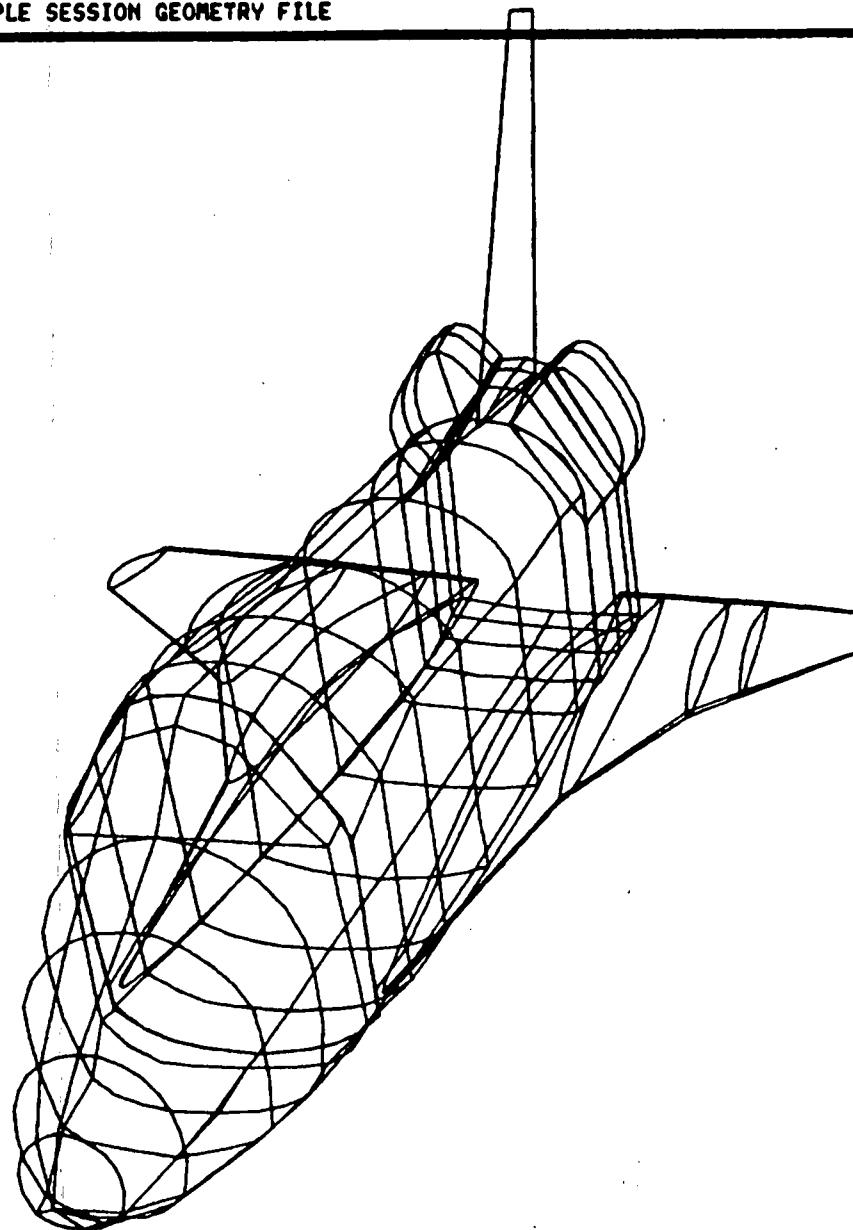

Figure 3-14. Perspective viewing

APAS SAMPLE SESSION GEOMETRY FILE

YAW PITCH   ROLL
30.0 -30.0   0.0
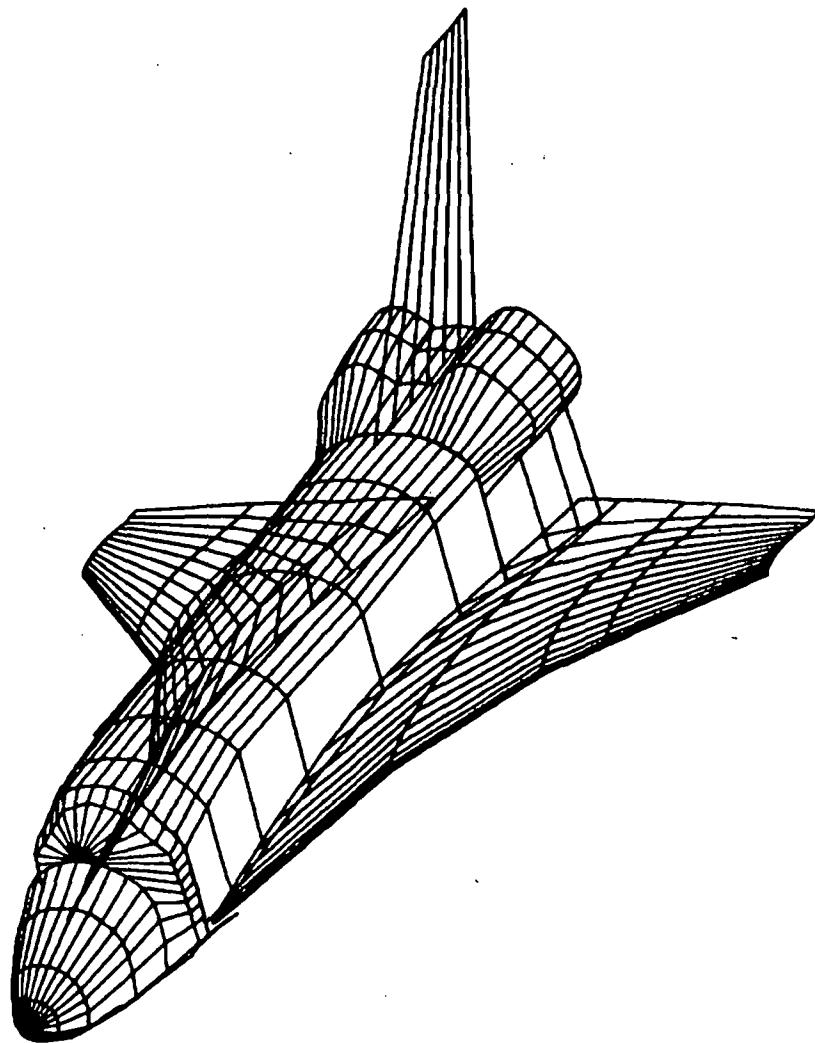
Figure 3-15. Hidden panel display

SAMPLE SESSIONS

Geometry input functions are illustrated in sessions 3-1 and 3-2.

Each session is structured to illustrate a wide range of APAS capabilities. Selectively bypassing certain complexities progressively reduces the level of user expertise required, and those areas which can be delayed are pointed out in the text.

Prior to initiating any session, a preplanning effort is spent defining the specific work that will be done in order to minimize the amount of sitting time. This will assure that terminal usage is spent primarily on effort requiring the computer.

Two cases are investigated. A simple, conceptual vehicle is input using the TERMINAL command in session 3-1. It is subsequently shaped and modified using the EDIT command and subcommands. The second case, session 3-2, digitizes the space shuttle vehicle. Differences between the two models, in terms of the type and amount of input work required, will become apparent from the discussions.

SIMPLE CONFIGURATION (SESSION 3-1)

Read the function descriptions of TERMINAL and EDIT in the command dictionary, section 6.

For this section, it is assumed that the gross geometric characteristics of a manned recoverable space vehicle have been defined from an independent study. The data available may include a minimum cross-section area of the cargo bay, volume of crew compartment and other vehicle equipment, fuel volume required, wing and empennage size, etc. The user will define a set of geometric parameters from this data base which can be entered in APAS using the TERMINAL command to define the vehicle.

Geometric Preliminaries

Input for bodies is in the form of vehicle station, cross-section area, and width/height ratio for key locations on the body. A table of these values is set up which will be used later in APAS. Table 3 presents the pertinent fuselage information.

Table 3 Simple body input data

Station (m)	Area (m^2)	Width/Height	Description
5.59	0	.88	Nose
11.68	20.65	.88	Crew station
15.24	28.39	.88	Max cargo section
33.02	30.97	.88	Max cargo section aft
38.10	43.87	.88	End of body

Surfaces are created using the parameters of planform area, aspect ratio, taper ratio, leading-edge sweep, and dihedral. The pertinent characteristics for the wing and tail are summarized in table 4.

Table 4 Simple surface input data

S (m^2)	AR	λ	Λ_{LE}	Γ	Section	T/CR	T/CT	Surface
249.91	2.3	.20	45°	3°	64AOXX	.04	.03	Wing
38.80	1.65	.40	45°	90°	HEX	.03	.03	Vertical

Additional information required for each component includes the component number and name, the origin of the component, and its orientation in space.

APAS Preliminaries

Once the configuration component geometric tabulations are complete, the user is ready to logon and run APAS. In the present case, the session is initialized using a new geometry and output file. The title of the file is entered as "APAS SAMPLE SESSION GEOMETRY FILE," screen 3-1.

The ready mode on APAS is indicated by the symbol **OK** to distinguish it from the normal operating mode of the computer system. The commands required to execute this session are all accessed from the "OK" mode. It is not necessary to use the EXIT command to terminate this session.

Fuselage Input

The first component to input is the fuselage because data from it will determine the wing and vertical tail attachment points.

The data of table 3 are keyed in (see screen 3-1) for the fuselage. Two options are available for inputting cross-section data. The number of cross sections (five in this case) were specified instead of entering all the data on one line. Note that more than one section can be entered on a line; e.g., sections 2 and 3. When the last section has been entered, the maximum height and half-breadth from the centerline is printed. These characteristics will be used later for attaching surfaces to the fuselage.

A component should be cataloged or saved immediately after it is created in order to avoid its inadvertent loss. The SAVE command can be used when no other component with this number exists in the permanent file. CATALOG, however, is the safer storage command because it checks the file for another component having the same number.

The user next enters EDIT and selects the VIEW (VI) subcommand to display the fuselage, bottom of screen 3-1.

```
                    ENTER TITLE FOR NEW DATA FILE:
                    opns sample session geometry file
                    IIOKII
 ──►  terminal
                    I ENTER COMPONENT YAW,PITCH,ROLL :
 ──►  <CR>
                    0.0    0.0    0.0  DEFAULTS SELECTED

                    I  1 FULL SURFACE
                    I  2 HALF SURFACE
                    I  3 FULL ELLIPSE
                    I +4 HALF ELLIPSE UP    -4 HALF ELLIPSE DOWN
                    I  5 RECTANGLE
                    I +6 TRIANGLE UP        -6 TRIANGLE DOWN
                    I  E END
 ──►  3
                    I INPUT COMPONENT NAME:
 ──►  simple fuselage
                    I INPUT COMP NUMBER:
 ──►  1.0
                    I BODY COMPONENT
                    XRO,YRO,ZRO
 ──►  0,0,0
                    I NUMBER OF CROSS SECTION OR
                    I X(1),A(1),W/H(1)...... X(NCS),A(NCS),W/H(NCS)
 ──►  5
                    I ENTER SETS OF (X,A,W/H) FOR  5 CROSS SECTION
 ──►  5.59 0.0 0.88
                    ?
 ──►  11.68 20.65 0.88 15.24  28.39  0.88
                    ?
 ──►  33.02 30.97 0.88
                    ?
 ──►  38.10 43.87 0.88

                    MAXIMUM HEIGHT ABOVE COMP. REF. LINE:    3.9836

                    MAXIMUM HALF BREATH OF COMPONENT    :    3.5055
                    IIOKII
 ──►  catalog
                    IIOKII
 ──►  edit 1.0
                    EDITII
 ──►  vi
```

Screen 3-1 - TERMINAL input of a simple fuselage

Screen 3-2 presents the fuselage as it was created from key input. At this point, the user can accept this component and proceed to the input on screen 3-6 (text beginning on page 33) or progressively modify it on screens 3-3 through 3-5. Screen 3-3 shows the fuselage as it appears after using the graphics cursor to translate selected body sections. The menu of options is in the upper right of the screen. Options I and F interpolate the section at the location chosen with the vertical cursor. Sections can be inserted only between the nose and tail and out of the proximity of other sections. A programmed alarm will sound if an errant key is entered, or a cursor rule is violated. Options D through L are one-step functions locating the nearest section to the vertical graphics cursor on which to operate. Option D deletes that section. Options T and B scale the section vertically until the top or bottom respectively matches the Z-location indicated by the horizontal cursor. Options U and L translate the section vertically until the top (upper) or bottom (lower) respectively matches the location indicated with the horizontal cursor.

MENU OF KEY FUNCTIONS

INSERT - 2ND ORDER   : I
INSERT - LINEAR   : F
DELETE   : D
SCALE TOP TO CURSOR   : T
SCALE BOTTOM   '   : B
MOVE UPPER TO CURSOR : U
MOVE LOWER TO CURSOR : L
TRANSLATE COMPONENT   : M
OVERWRITE   : O
REPAINT   : R
ZOOM   : Z
WIDE   : W
END   : E
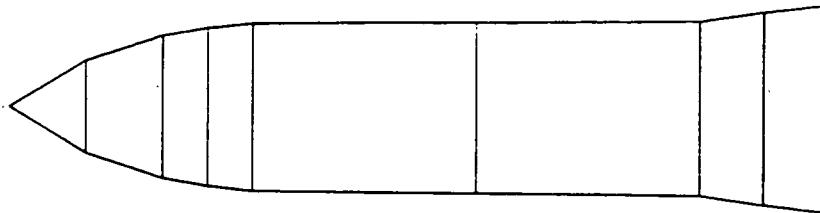
Screen 3-2 Simple fuselage display

Option M translates the entire component. The cursor is positioned and the letter M is entered. The cursor is now positioned to a new location and M is entered again. A translation vector is defined with the two entrees, and the EDIT component is translated and displayed in its new location.

Option O displays (overwrites) the edited component on top of the screen image already present. Option R repaints the entire screen image, including auxiliary components, if any. The point entered with option Z forms one corner of the window into which the user wishes to zoom in on. The next entry from the cursor forms the opposite corner and completes the box. Option W doubles the amount of real space viewed on the screen, leaving the EDIT component centered on the screen.

MENU OF KEY FUNCTIONS

INSERT - 2ND ORDER   : I
INSERT - LINEAR   : F
DELETE   : D
SCALE TOP TO CURSOR   : T
SCALE BOTTOM   '   : B
MOVE UPPER TO CURSOR : U
MOVE LOWER TO CURSOR : L
TRANSLATE COMPONENT   : M
OVERWRITE   : O
REPAINT   : R
ZOOM   : Z
WIDE   : W
END   : E
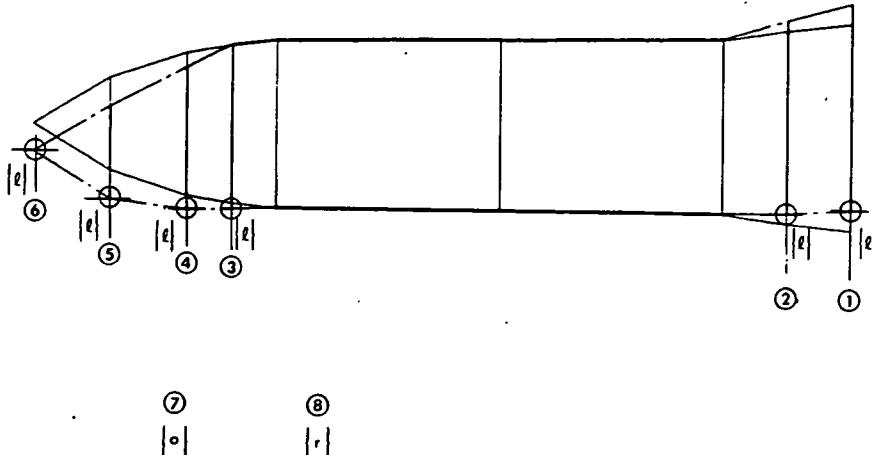
Screen 3-3 Fuselage modification by section translation.

31

The modifications of screen 3-3 are made with the L-key to translate selected sections, forming the bottom line of the fuselage (steps 1 through 6). The changes are reviewed with the overwrite key (o, step 7), producing the single dashed display of the changes, and the screen is repainted (r, step 8).

In screen 3-4, two sections have been inserted between sections 1 and 2 and 2 and 3 of the original fuselage to improve the nose definition. A series of top scalings (t, steps 3 through 5) and a bottom scaling (b, step 6) round out the original conical nose shape. A section translation (ℓ, step 7) corrects a small error from the previous screen. An overwrite is performed (o, step 8) to check the changes, and a repaint to view the final adjustment in screen 3-5. The user then ends the view mode (e, step 1), saves the fuselage (step 2), and ends the EDIT mode. For clarity, the last entry on screen 3-5 is repeated at the top of screen 3-6.

APAS SAMPLE SESSION GEOMETRY FILE

SIMPLE FUSELAGE

MENU OF KEY FUNCTIONS

INSERT - 2ND ORDER   : I
INSERT - LINEAR   : F
DELETE   : D
SCALE TOP TO CURSOR   : T
SCALE BOTTOM   : B
MOVE UPPER TO CURSOR : U
MOVE LOWER TO CURSOR : L
TRANSLATE COMPONENT   : M
OVERWRITE   : O
REPAINT   : R
ZOOM   : Z
WIDE   : U
END   : E
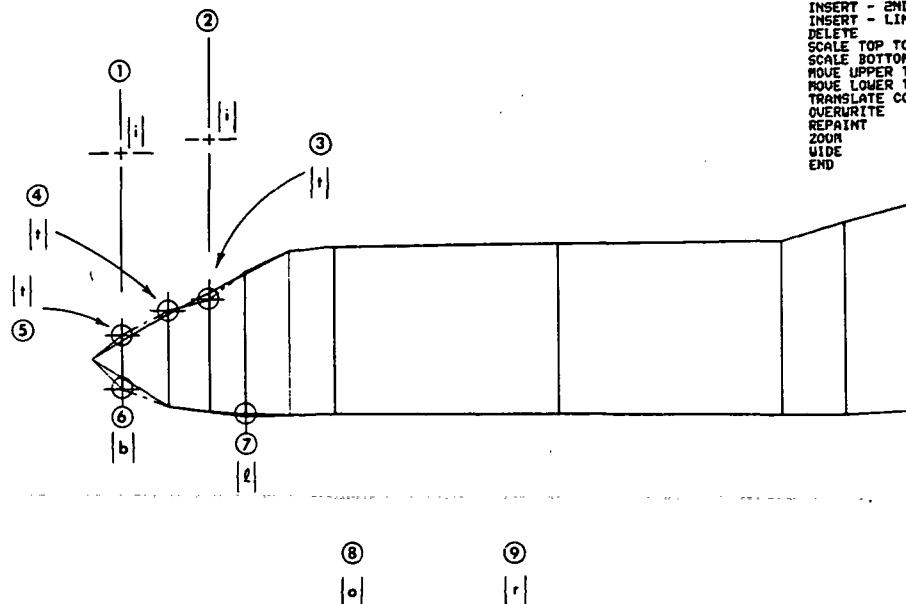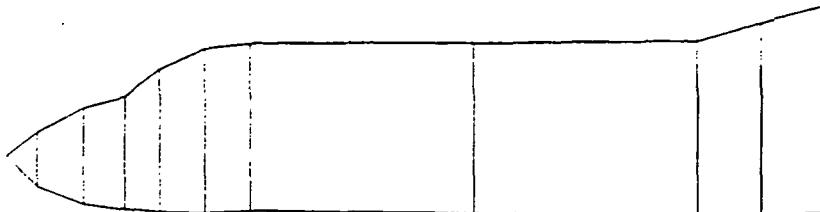
Screen 3-4   Inserting sections and modifying
fuselage nose.

Screen 3-5 Viewing and saving modified simple fuselage

Wing Input

    Screen 3-6 illustrates the steps involved in constructing a simple wing from
the data of Table 4, using the full-surface option of TERMINAL. Referring to
the bottom of screen 3-1, use is made of the maximum half-breadth and height to
initially locate the wing-fuselage lateral and vertical attachment Yo(root) of
3.30 m and Zo(root) of -3.05 m were selected for this purpose.

Screen 3-6   TERMINAL input of simple wing

After keying in the wing and cataloging it, the EDIT command is entered for the wing (component 101.00), using the fuselage (component 1.00) as an auxiliary component. The VIEW subcommand in EDIT is selected and the work shifts to screen 3-7.

APAS SAMPLE SESSION GEOMETRY FILE   SIMPLE WING

                                                                          MENU OF KEY FUNCTIONS

                                                                          INSERT - 2ND ORDER   : I
② ——→ EDIT::   INSERT - LINEAR   : F
                                                                          DELETE   : D
                                              ①   SCALE TOP TO CURSOR   : T
                                                                          SCALE BOTTOM   •   : B
                                          | • | MOVE UPPER TO CURSOR : U
                                                                          MOVE LOWER TO CURSOR : L
                                                                          TRANSLATE COMPONENT   : M
                                                                          OVERWRITE   : O
                                                                          REPAINT   : R
                                                                          ZOOM   : Z
                                                                          WIDE   : W
                                                                          END   : E
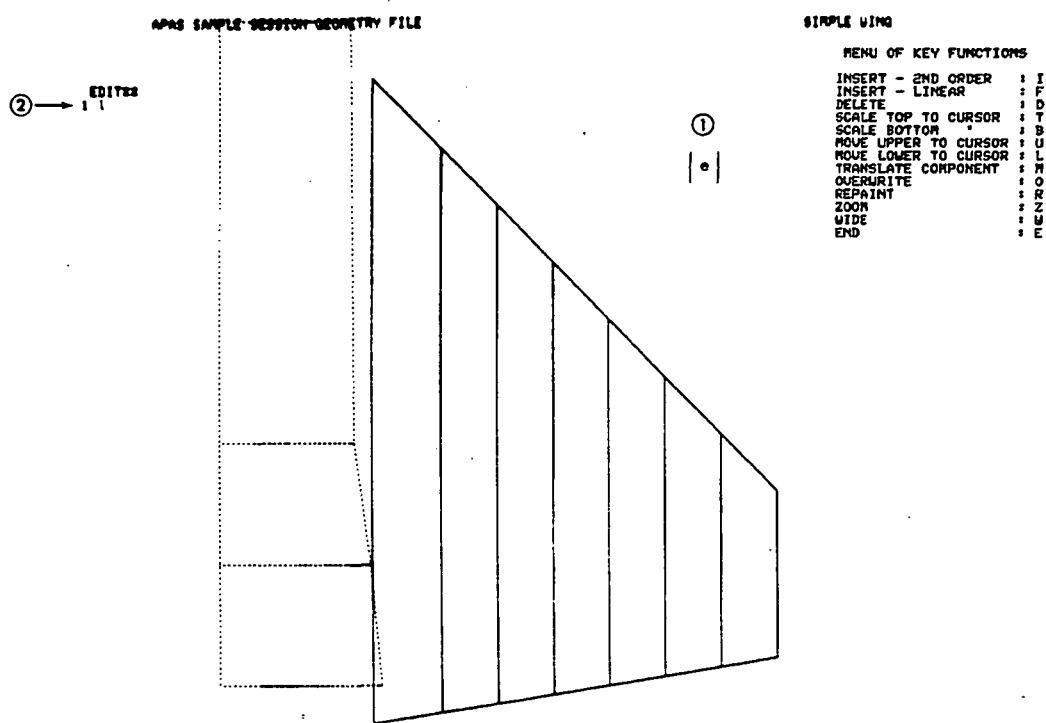
Screen 3-7 Wing viewing using auxiliary component.

The user elects to line up the root trailing edge of the wing with the end of the fuselage. This is accomplished by the steps outlined in screens 3-7 and 3-8.

Ending the view mode (e, step 1, screen 3-7), the user lists the first section by keying the section number and the letter ℓ (step 2). This display (screen 3-8) provides a tabulation of the airfoil coordinates for section 1. The trailing edge point should be at x = 38.10 m. Its present location is at 5.891 m (point 16) plus an xo of 33.02 m or 38.911 m. To correct the wing, a dx of -0.811 m is applied to all the stations (1, 99, all). The user now returns to the view mode (screen 3-9). To save space, the original view (screen 3-7) was widened in steps 1 and 2, and the final screen with a full view of the fuselage is shown.

1	-7.654	0.000	0.000	17	5.891	-0.001	-0.028
2	-7.586	0.006	0.109	18	5.214	-0.004	-0.073
3	-7.484	0.009	0.166	14	4.536	-0.008	-0.144
4	-7.315	0.012	0.228	20	3.182	-0.015	-0.284
5	-6.985	0.016	0.315	21	1.827	-0.022	-0.423
6	-6.301	0.023	0.433	22	0.473	-0.028	-0.544
7	-4.945	0.030	0.578	23	-0.881	-0.033	-0.634
8	-3.590	0.034	0.654	24	-2.236	-0.035	-0.676
9	-2.236	0.035	0.676	25	-3.590	-0.034	-0.654
10	-0.881	0.033	0.634	26	-4.945	-0.030	-0.578
11	0.473	0.028	0.544	27	-6.301	-0.023	-0.433
12	1.827	0.022	0.423	28	-6.985	-0.016	-0.315
13	3.182	0.015	0.284	29	-7.315	-0.012	-0.228
14	4.536	0.008	0.144	30	-7.484	-0.009	-0.166
15	5.214	0.004	0.073	31	-7.586	-0.006	-0.109
16	5.891	0.001	0.028	32	-7.654	0.000	0.000

Screen 3-8   Translating the wing
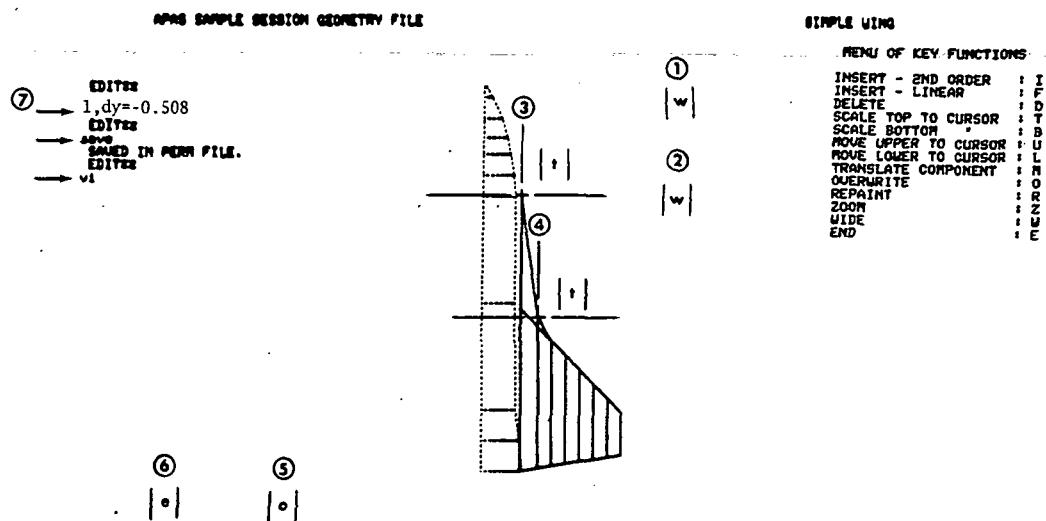
Screen 3-9 Increasing the viewing space and modifying
the wing leading edge.

The translate function, T, is now used to modify the wing leading edge (t, steps 3 and 4). The changes are checked using overwrite (o, step 5). Note that the root chord does not attach to the side of the body. The user ends the view mode (e, step 6) and moves the root section (section 1) inboard an estimated 0.508 meters (step 7). The work is then saved (the original component is written over), which reevaluates the wing extents since the planform has been changed. The wing is then viewed (screen 3-10) to verify the final changes. The user ends from EDIT/VIEW and produces a three-view display on screen 3-11.
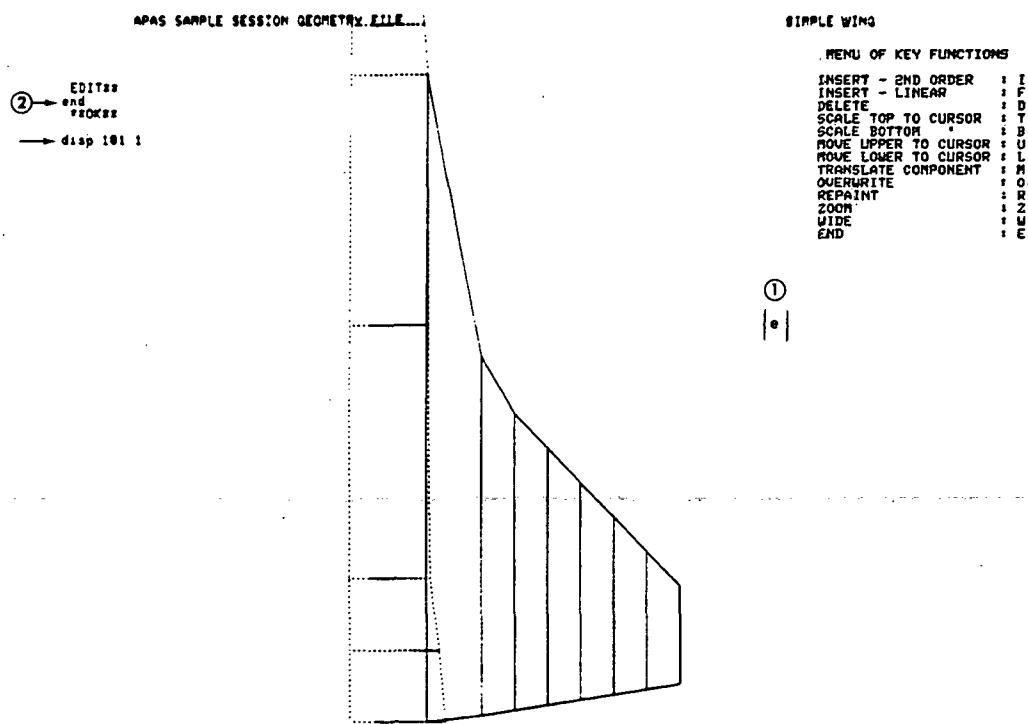
Screen 3-10 Final view of simple wing modifications
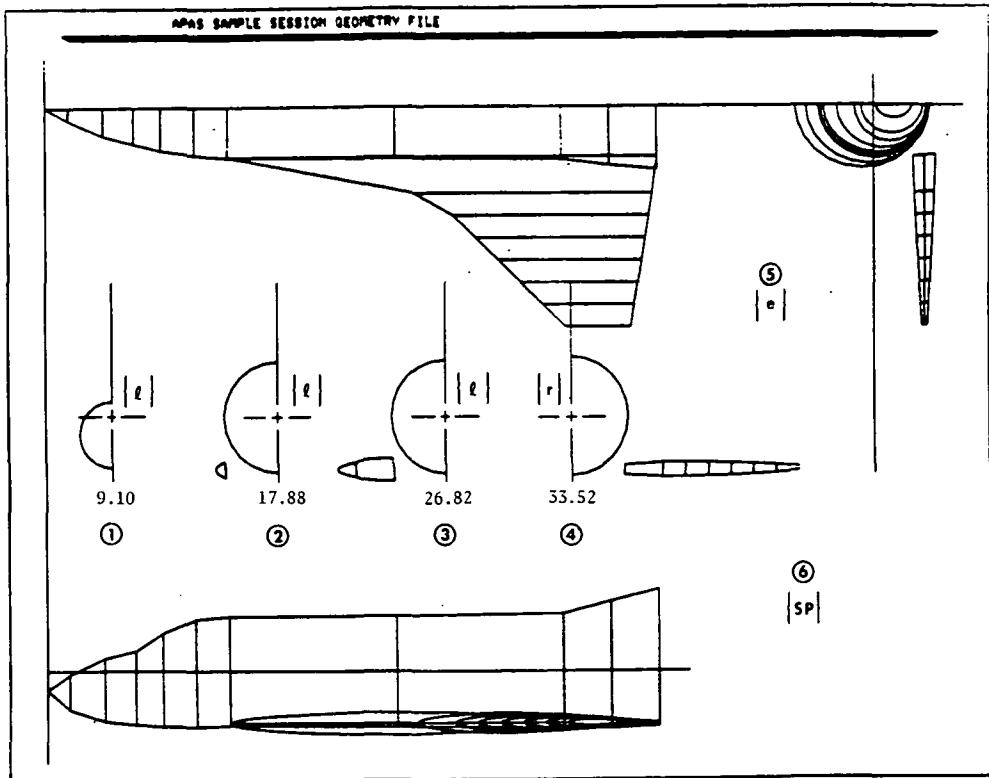
Screen 3-11 Three-view of simple wing and fuselage.

Four cross-section cuts are made, three to the left (ℓ, steps 1 through 3) and one to the right (r, step 4). Step 5 ends the cross-section mode, at which point the contours are filled in. A copy can now be taken. Step 6 returns the program to the "OK" mode.

Note the gap between the wing and fuselage in screen 3-11. The analyst decides to correct the fuselage and uses the EDIT/XH crosshairs subcommand to flatten the sides and bottom to match the wing. The crosshairs operation is a two-step process; the first entry locates the nearest point and the second its new location. Steps 1 and 2 of screen 3-12 show the translation of point 12, steps 3 and 4 move point 11, etc. for section 11. The space bar {SP} is the most convenient way to enter the point, and an "o" will end the cross-hairs function either on the translate entry (step 10 for example) or the following entry as was done here.

The user lists the modified section in screen 3-13 with print suppressed and uses the crosshairs to readjust points 8 through 12 slightly (not illustrated). The final section is shown in screen 3-14. A print suppressed listing of section 10 is now requested (screen 3-15). The user now realizes that a simpler method to accomplish the same results at section 11 are the first two entries on screen 3-15. In the first entry, the z-values at points 8 through 13 were set
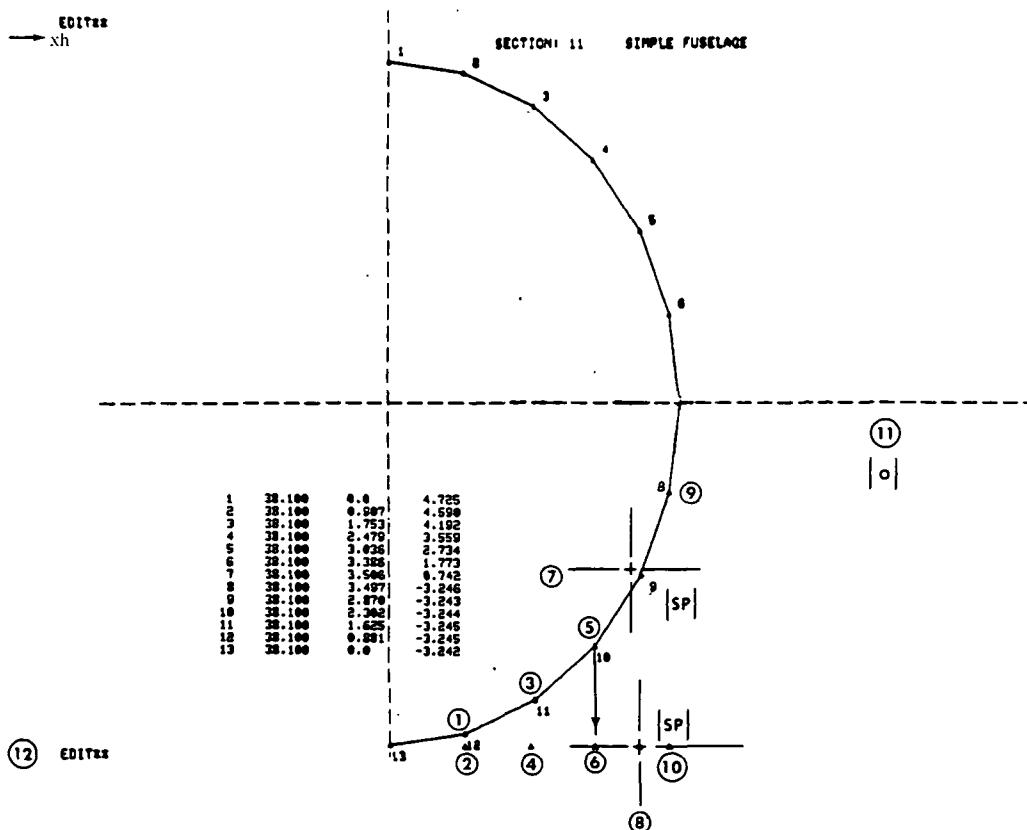
Screen 3-12 Modifying a fuselage section using the EDIT/XH
crosshair subcommand.
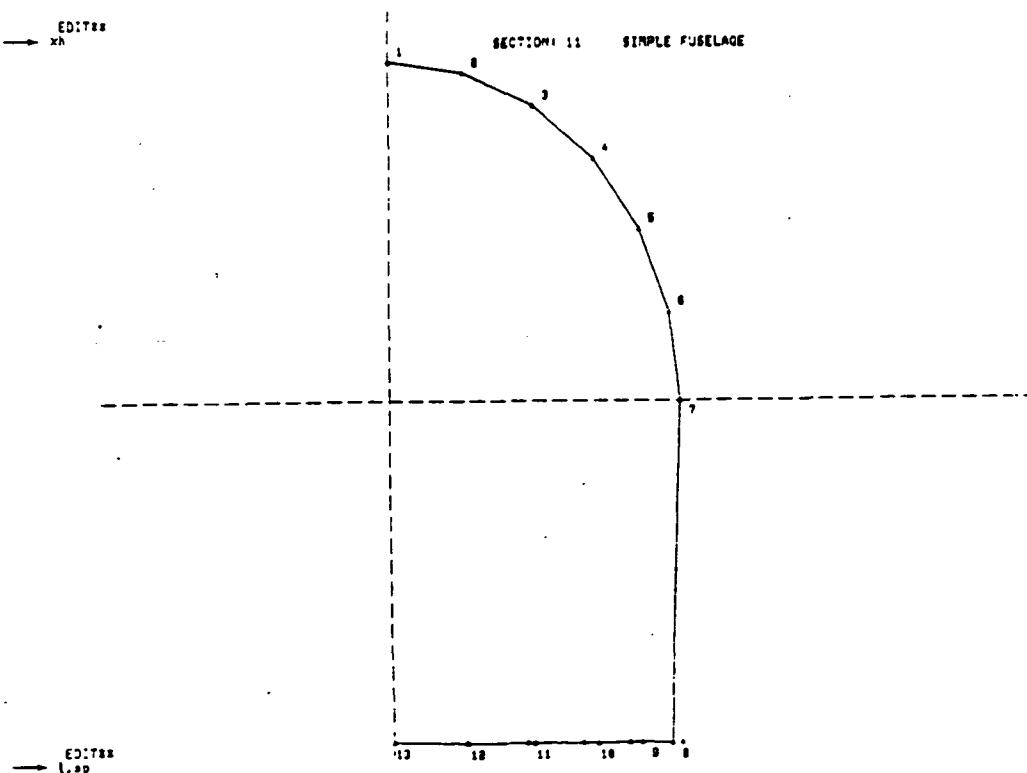
Screen 3-13 Modified cross section from Screen 3-12

38
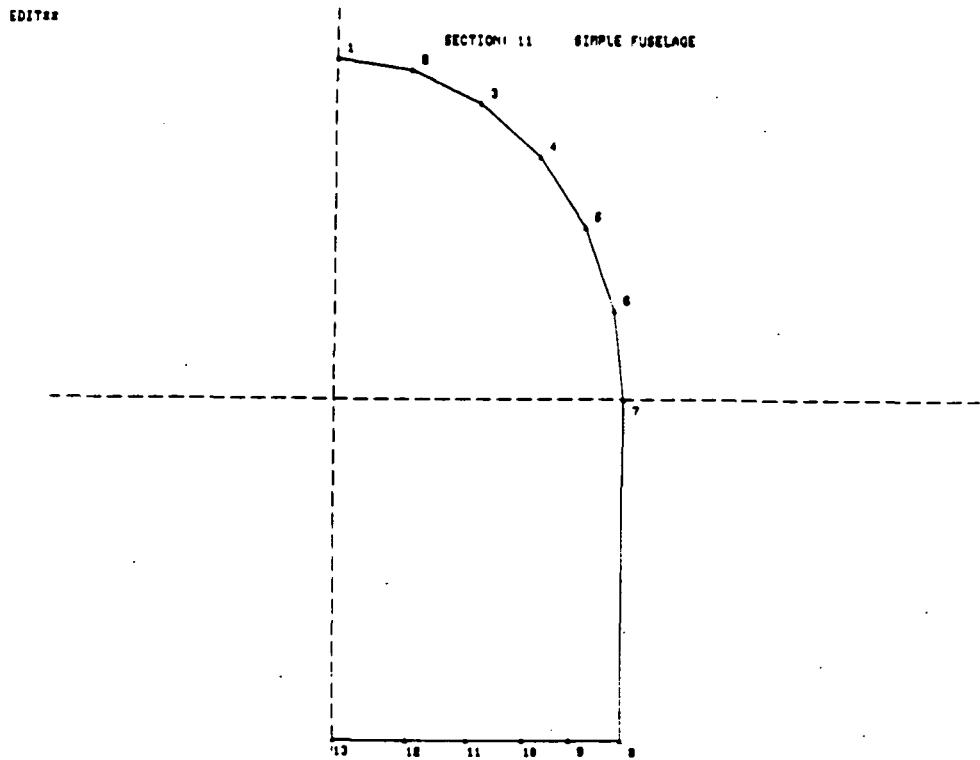
Screen 3-14 Final view of modified cross-section

equal to the z at point 13. In the second entry, the y-value of points 8 through
8 were changed to the y at point 7. The resulting section modification is displayed
on screen 3-16. Four additional (sections 6 through 9) modification entries are
shown on screen 3-16. Section 6 is listed on screen 3-17 and the crosshairs mode is
used to move points 8, 9, and 10 (arrows, bottom of section) to round off the
lower corner. On screen 3-18 the z- value of point 10 is matched to point 11 to make
sure the bottom is flat. The user then saves the fuselage and ends edit. The final
entry on screen 3-18 is to obtain an orthographic projection of the components (no
components listed) at angle 0 for yaw, pitch, and roll. A view from the nose is shown
on screen 3-19.

On screen 3-20, the user has displayed the wing and fuselage interface. It is
decided to move the wing up one-half the root chord maximum thickness to improve
the intersection (screen 3-21). By using the PARAMETER (P) subcommand in EDIT,
the user increases the wing z origin by 0.686 meters. In the parameter mode, a
carriage return retains the old values, and the user enters a carriage return until
prompted for the origin input (fifth arrow). To adjust only Zo, he enters a comma
to keep Xo, a comma to keep Yo, and the new Zo value of -2.362 meters. The wing
is saved, EDIT is ended, and a three view display of all components in the
permanent file (the user's default file) is made on screen 3-22.

39
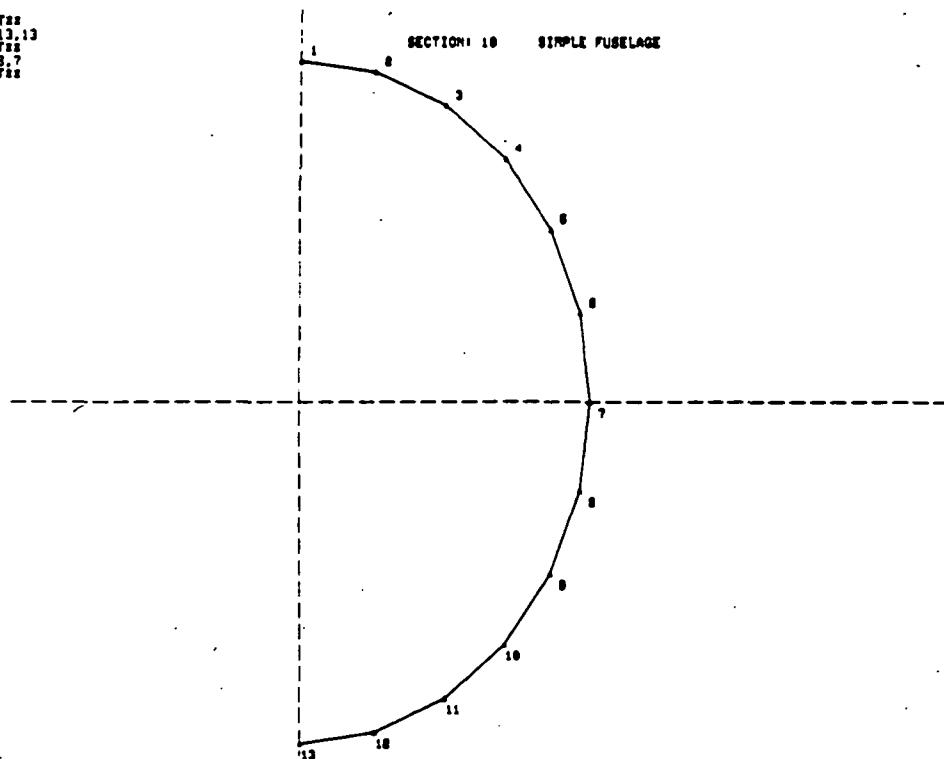
Screen 3-15 Modifying a cross section using the Z and Y
subcommands of EDIT.
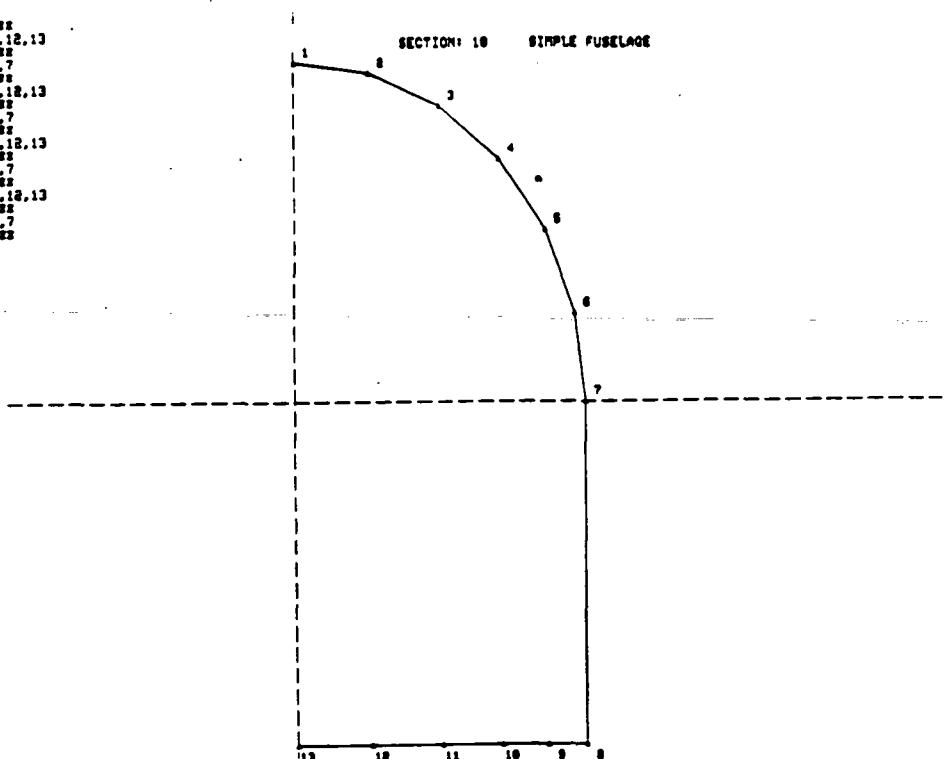
Screen 3-16 Modified section from Screen 3-15 and Z and Y
changes to sections 9, 8, 7, and 6.
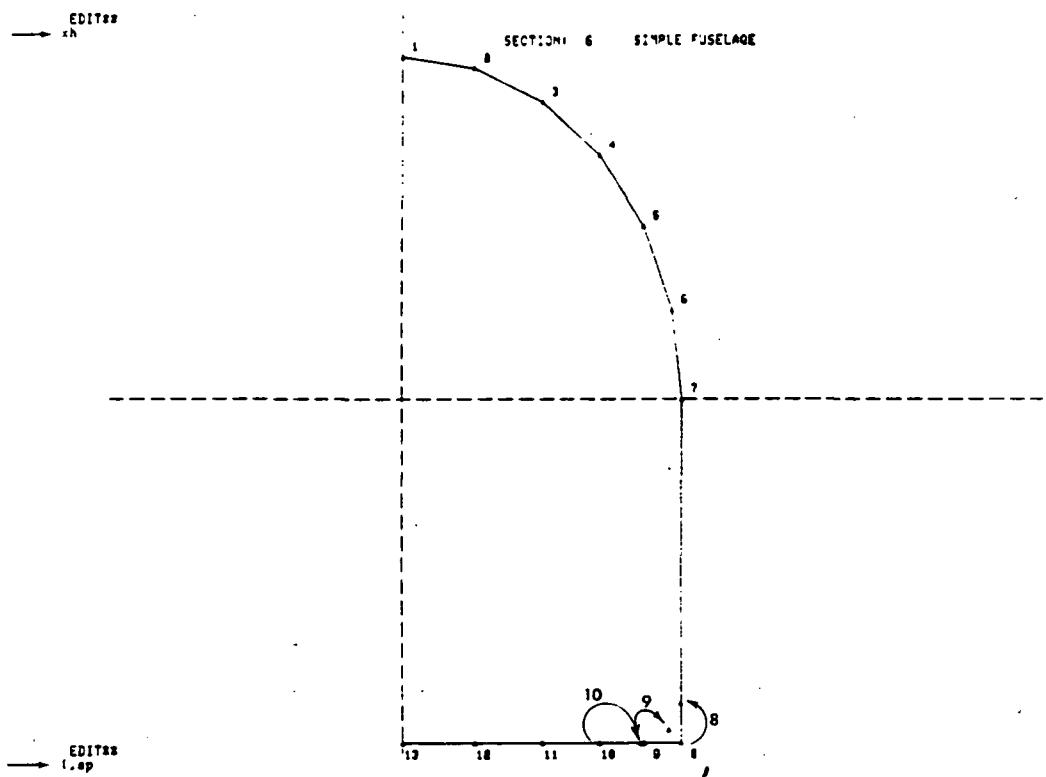
Screen 3-17 Rounding off the bottom of section 6
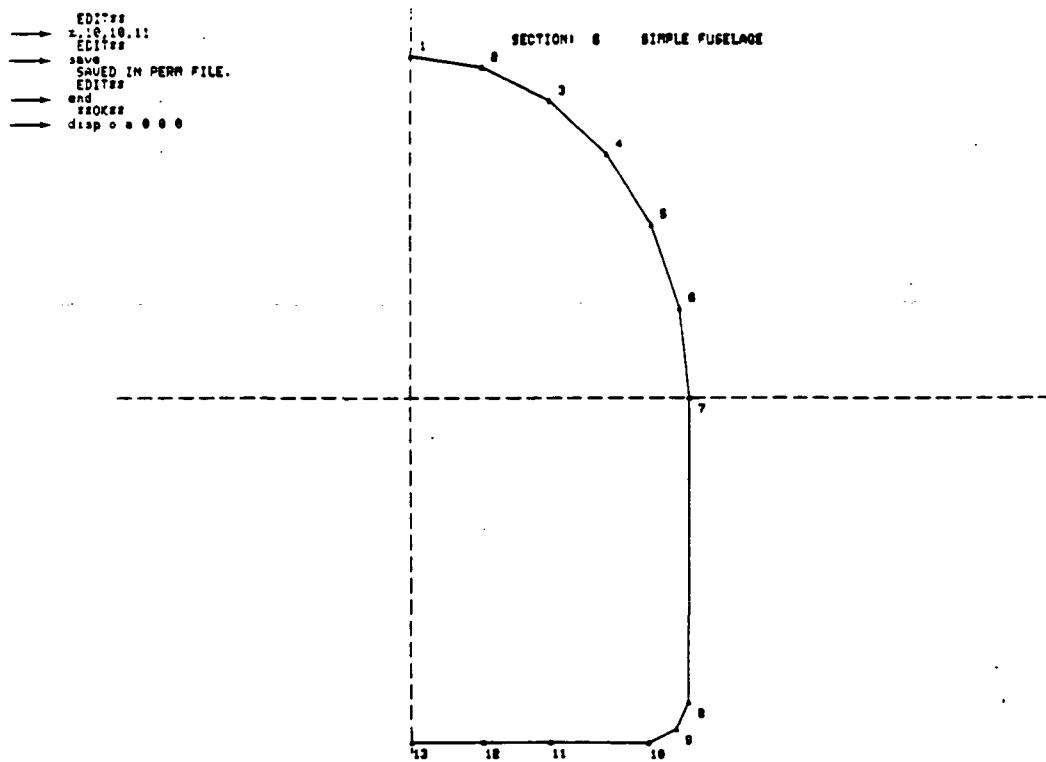
Screen 3-18 List of section 6 modifications and saving the fuselage.
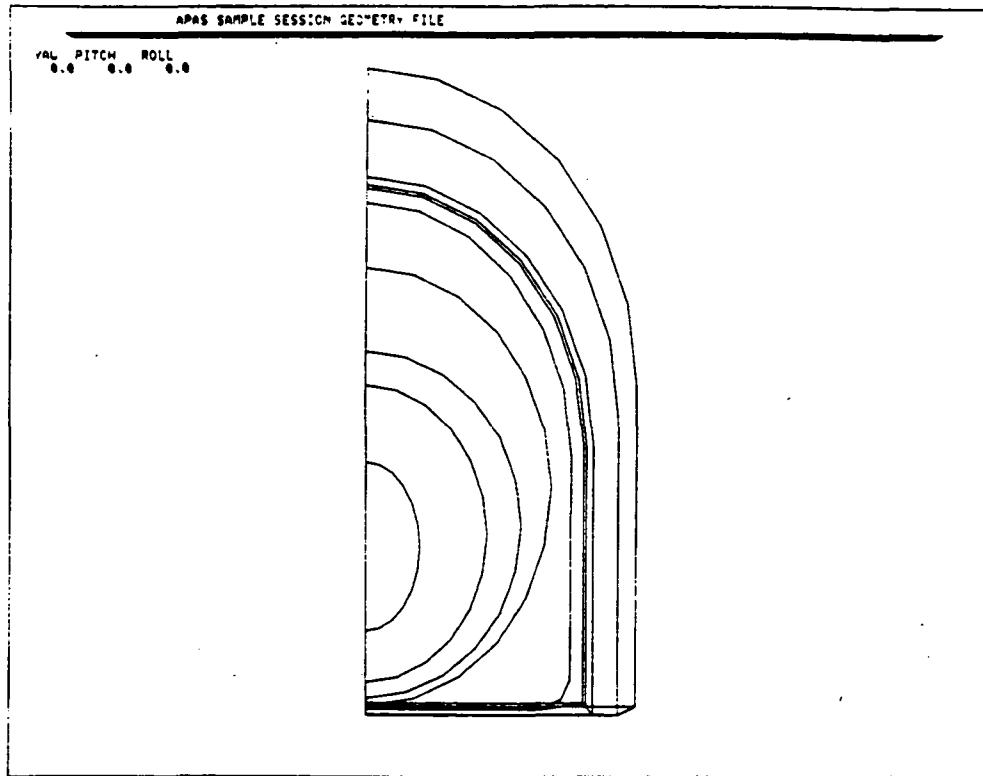
Screen 3-19 Front view of the simple fuselage.
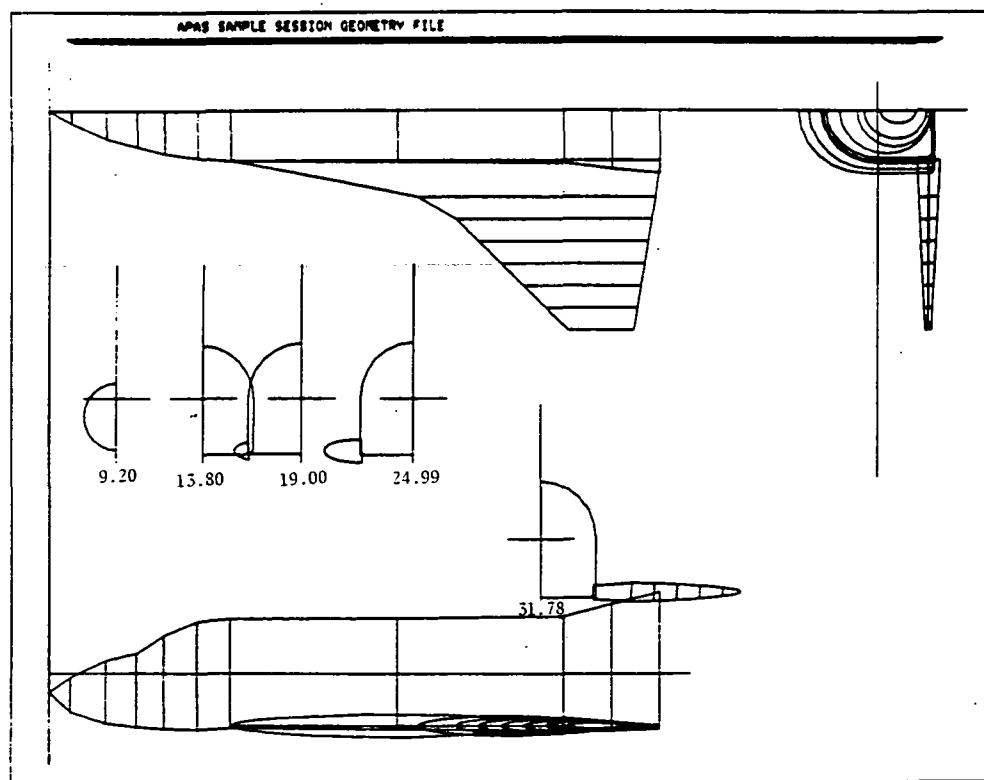
Screen 3-20 Three view of simple wing and fuselage showing
improved wing-body interface.

```
EDIT:=
parameter
       [01.00   SIMPLE WING                    SECTION:  1    SIMPLE WING
  TYPE:  4
  NWET:       1     1
  ENTER TYPE:

ENTER NWET VALUES:

COMPONENT SYMMETRY:      REFLECTIVE AND ASYMMETRIC
ENTER:      1 :  NON-REFLECTIVE
            2 :      REFLECTIVE
   [POSITIVE :      ASYMMETRIC
   [NEGATIVE :      SYMMETRIC
CARRIAGE RETURN : UN-CHANGED

XO:  33.020 YO:     3.302 ZO:   -3.048
ENTER NEW VALUES, PLACE COMMA TO LEAVE VALUE UNCHANGED:
,,-2.362
BET:  0.0  ALP:  0.0  GAM:  0.0
ENTER NEW VALUES, PLACE COMMA TO LEAVE VALUE UNCHANGED:

VORTEX FORCES FOR THIS COMPONENT ARE OFF.
ENTER 'OFF' OR 'ON' OR <CR> TO RETAIN:

EDIT:=
save
SAVED ON PERM FILE.
EDIT:=
end
=====
display
```

1	-17.718	-0.508	0.0	21	-1.760	-0.530	-0.423
2	-17.604	-0.502	0.109	22	-4.039	-0.537	-0.544
3	-17.433	-0.499	0.166	23	-6.319	-0.541	-0.634
4	-17.148	-0.496	0.228	24	-8.599	-0.543	-0.676
5	-16.578	-0.492	0.315	25	-10.879	-0.542	-0.654
6	-15.439	-0.495	0.433	26	-13.159	-0.538	-0.578
7	-13.159	-0.478	0.578	27	-15.439	-0.531	-0.433
8	-10.879	-0.474	0.654	28	-16.578	-0.524	-0.315
9	-8.599	-0.473	0.676	29	-17.148	-0.520	-0.228
10	-6.319	-0.475	0.634	30	-17.433	-0.517	-0.166
11	-4.039	-0.479	0.544	31	-17.604	-0.514	-0.109
12	-1.760	-0.488	0.483	32	-17.718	-0.508	0.000
13	0.520	-0.493	0.284				
14	2.800	-0.500	0.144				
15	3.940	-0.504	0.073				
16	5.080	-0.507	0.028				
17	5.080	-0.509	-0.028				
18	3.940	-0.512	-0.073				
19	2.800	-0.516	-0.144				
20	0.520	-0.523	-0.284				

Screen 3-21 Using the maximum half thickness of wing section 1 to change Zo from -3.048 to -2.362.

APAS SAMPLE SESSION GEOMETRY FILE

8.28   13.44   20.90   28.41   34.23
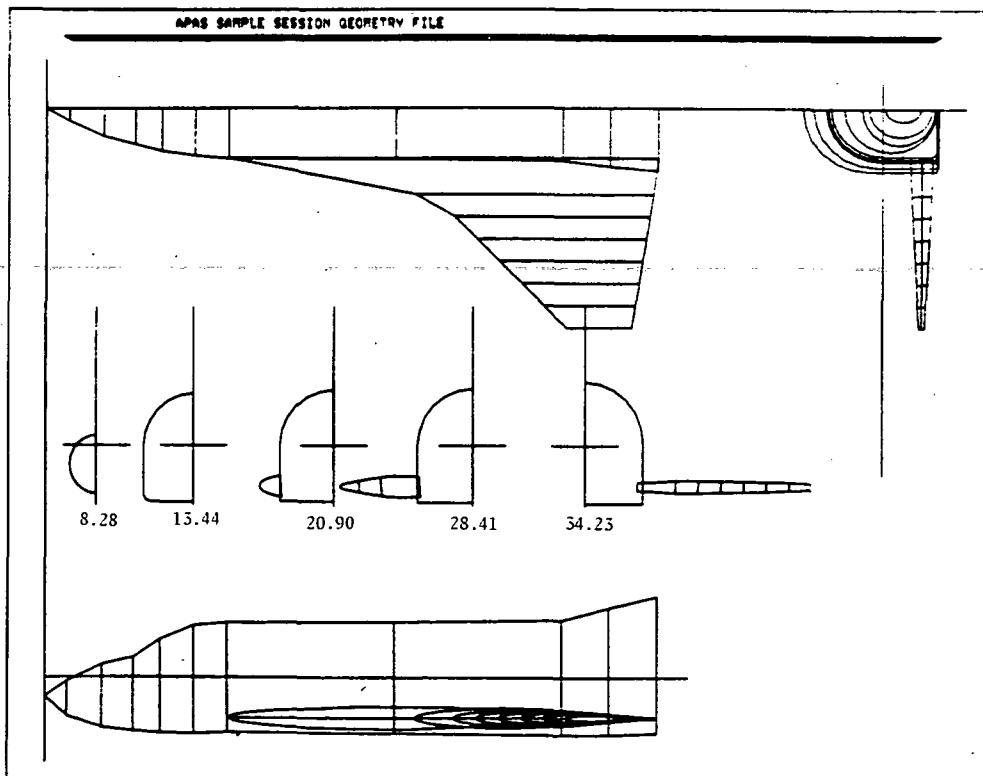
Screen 3-22 Three-view showing wing in its final position on the fuselage.

Vertical Tail Input

Screen 3-23 illustrates the input procedure for the vertical tail using data from table 4. The entries are similar to the wing. The work session continues on screen 3-24 using the VIEW subcommand of EDIT.

```
        IIOKII
  ──▶  term
         I ENTER COMPONENT YAW,PITCH,ROLL :
  ──▶  <CR>
          :0.0    0.0    0.0  DEFAULTS SELECTED

         I  1 FULL SURFACE
         I  2 HALF SURFACE
         I  3 FULL ELLIPSE
         I +4 HALF ELLIPSE UP     -4 HALF ELLIPSE DOWN
         I  5 RECTANGLE
         I +6 TRIANGLE UP         -6 TRIANGLE DOWN
         I  E END
  ──▶  2
         I INPUT COMPONENT NAME:
  ──▶  simple vertical
         I INPUT COMP NUMBER:
  ──▶  201.
         I HALF SURFACE
          XRO,YRO,ZRO (INBOARD LE)
  ──▶ 33.02 0 3.56
         I S,AR,TAPER,SWEEP(DEG),DIH(DEG):
  ──▶ 38.80 1.65 0.4 45 90
         I  1    65 A 0XX
         I  2    64 A 0XX
         I  3    SUPERCRITICAL
         I  4    HEX AIRFOIL
         I  5    BI-CONVEX
         I SELECT AIRFOIL TYPE:
  ──▶  4
         I ENTER : (T/C)1 , (T/C)2 ...., (T/C)N, N(=10
            (DEFAULT VALUES: 0.05,0.05)
  ──▶  .03 .03
        IIOKII
  ──▶  catalog
        IIOKII
  ──▶  edit 201 1
        EDITII
  ──▶  vi
```

Screen 3-23 Vertical tail TERMINAL input

The W key is used to widen the tail-fuselage viewing space (screen 3-24) and the M key is used on screen 3-25 to move the vertical into position relative to the fuselage (steps 1 and 2). The view mode is ended (e, step 3), the vertical is saved, and a full configuration display is requested. The resulting three view is shown on screen 3-26.
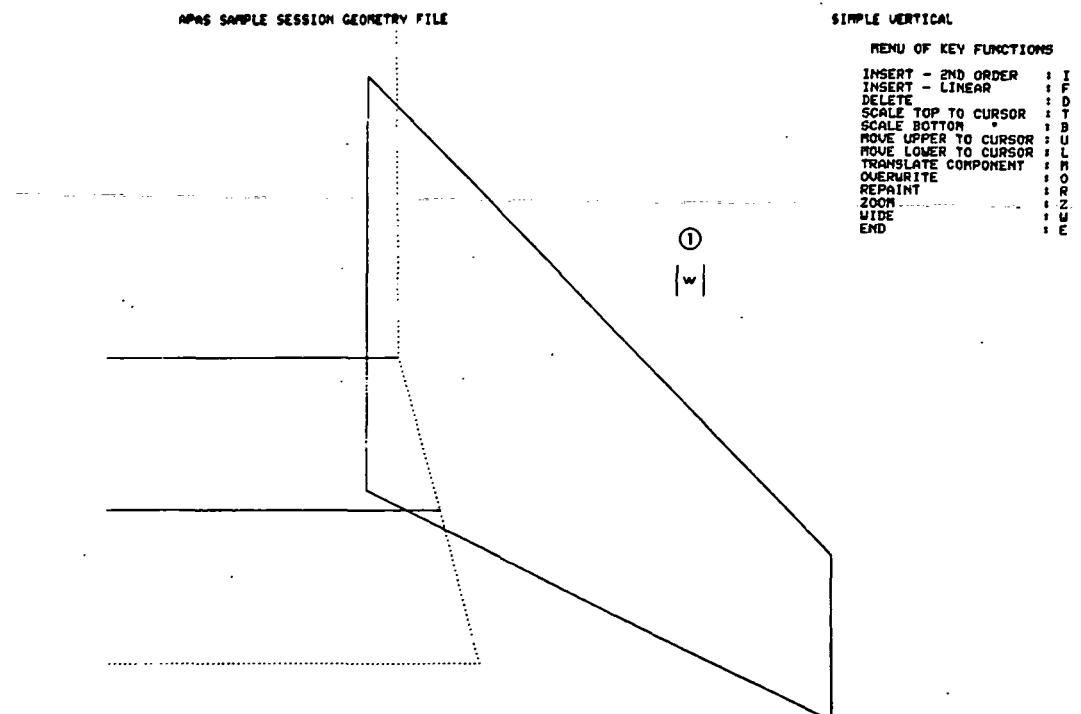
Screen 3-24 Viewing the vertical and widening the viewing space

44

MENU OF KEY FUNCTIONS

```
INSERT - 2ND ORDER    : I
INSERT - LINEAR       : F
DELETE                : D
SCALE TOP TO CURSOR   : T
SCALE BOTTOM    *     : B
MOVE UPPER TO CURSOR  : U
MOVE LOWER TO CURSOR  : L
TRANSLATE COMPONENT   : M
OVERWRITE             : O
REPAINT               : R
ZOOM                  : Z
WIDE                  : W
END                   : E
```

```
EDIT##
save
  SAVED IN PERM FILE.
EDIT##
end
##OK##
disp all
```
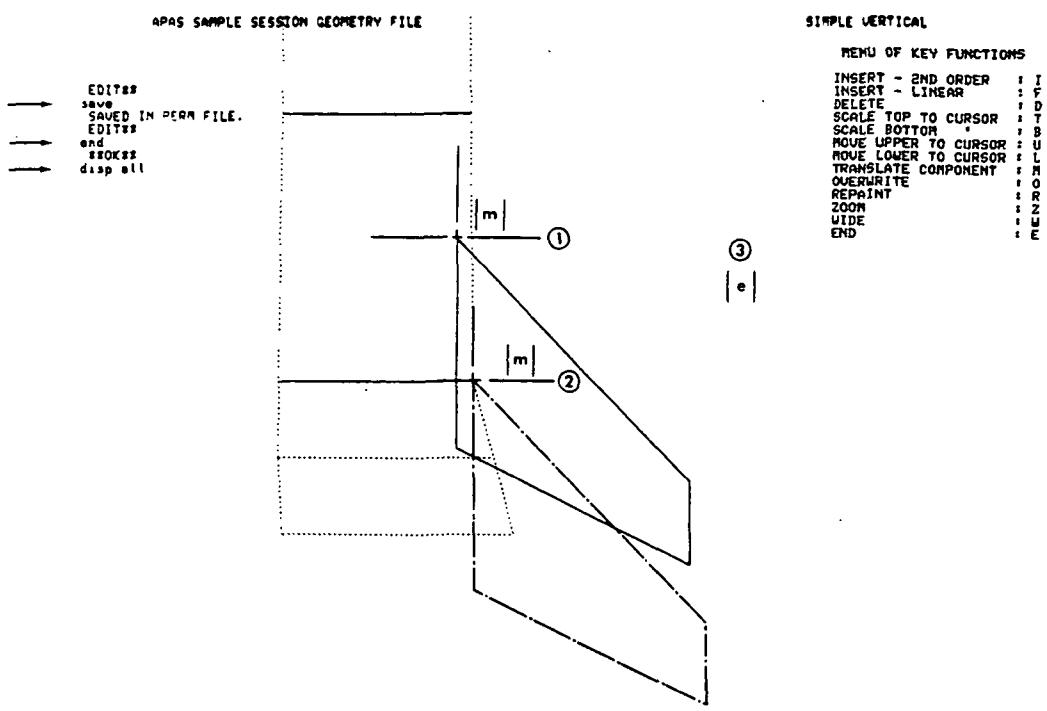
Screen 3-25 The vertical tail translation

Development of the slender body and interference shell analysis components and wing, vertical and shell paneling will be deferred to the arbitrary configuation session to eliminate redundant discussion.
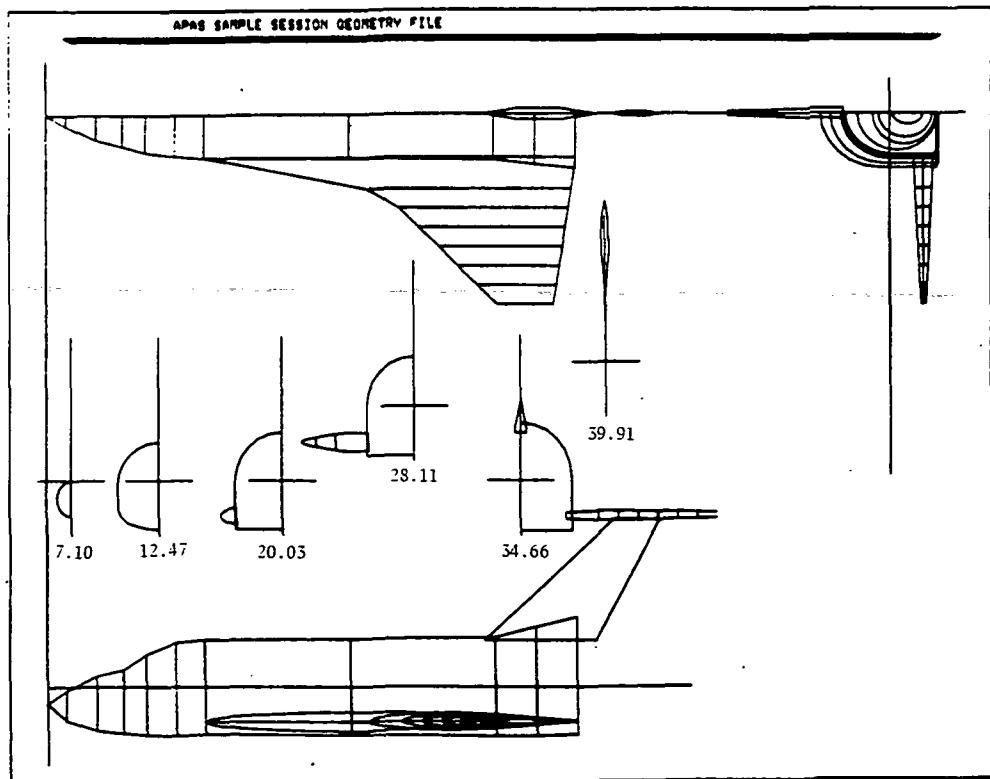
Screen 3-26 Configuration three-view

A typical drawing required for digitizing is presented on figure 3-16. Auxiliary contour data can be used if it is all to the same scale. A configuration input plan should be developed prior to logging on the system. This effort can markedly reduce input geometry session time and increase analysis flexibility on APAS.

The first planning step is to partition the configuration into body and surface components in order to properly apply the system aerodynamic analysis algorithms. These elements can be further partitioned as indicated on figure 3-17 to facilitate digitizing , aerodynamic buildup analysis, etc. Decisions concerning which of the configuration elements will be digitized using the DIGIT command, keyboard input using the TERMINAL command, or card input using the CARD command are made at this time. In the present case, it was elected to digitize the entire vehicle.

The fuselage is examined to locate canopy lines, contour corners, and wing, vertical tail, and pod attachment lines. This information is used to established fuselage defining segments. To eliminate carrying a zero segment the length of the body for the wing and pods (figure 3-18), the fuselage is split into three components. Each is reviewed to establish segment definitions as indicated on figure 3-19. The use of double and triple points to preserve the same number of segments for a particular component is illustrated. For example, the point at which two segments meet is entered twice (double point).

The input process for the pod is similar to the fuselage and will not be repeated.

The wing is now examined. The planform is squared off at the root and tip to provide streamwise edges as indicated on figure 3-20. Chord lines are defined on the top view for the available section cuts. The leading edges of these chord lines are next located along the wing leading edge in the side view. Airfoils can be digitized using one, two, or three segments. The first and last define the upper and lower surface respectively. The second segment (of a three segment definition) provides for a blunt trailing edge. A single segment surface can be used for "camber plane" linear analysis. Various default airfoil options are also provided.

The vertical tail leading and trailing edge points of the root and tip are transferred from the side view to the top view as indicated on figure 3-21. The root chord is digitized by entering the leading-edge point in the side view, moving up the transfer line to the centerline in the top view and entering a point and then moving along the centerline to the trailing edge point to complete the chord line definition. The process is repeated for the tip. Airfoils are defined in the same manner as for the wing.

The configuration is now ready for input to APAS.

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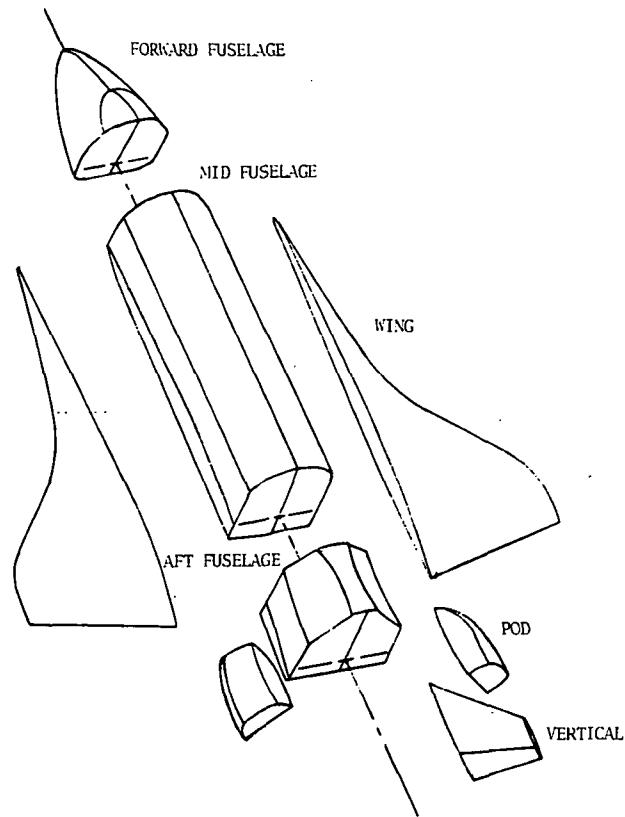
Figure 3-17. Space shuttle orbiter components
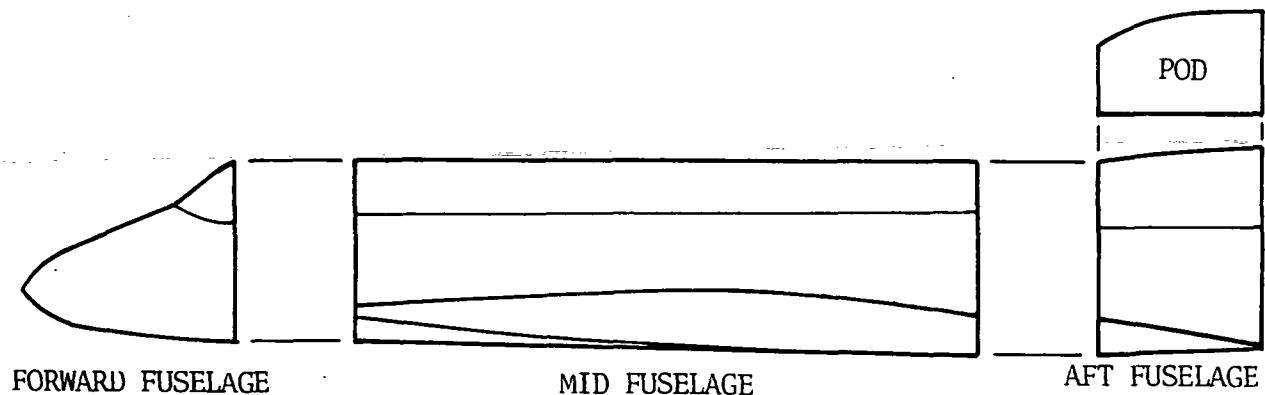
Figure 3-18 Fuselage partitioning for digitizing

Single Point ●   Triple Point □

Double Point ○   Triple point at nose ⊗
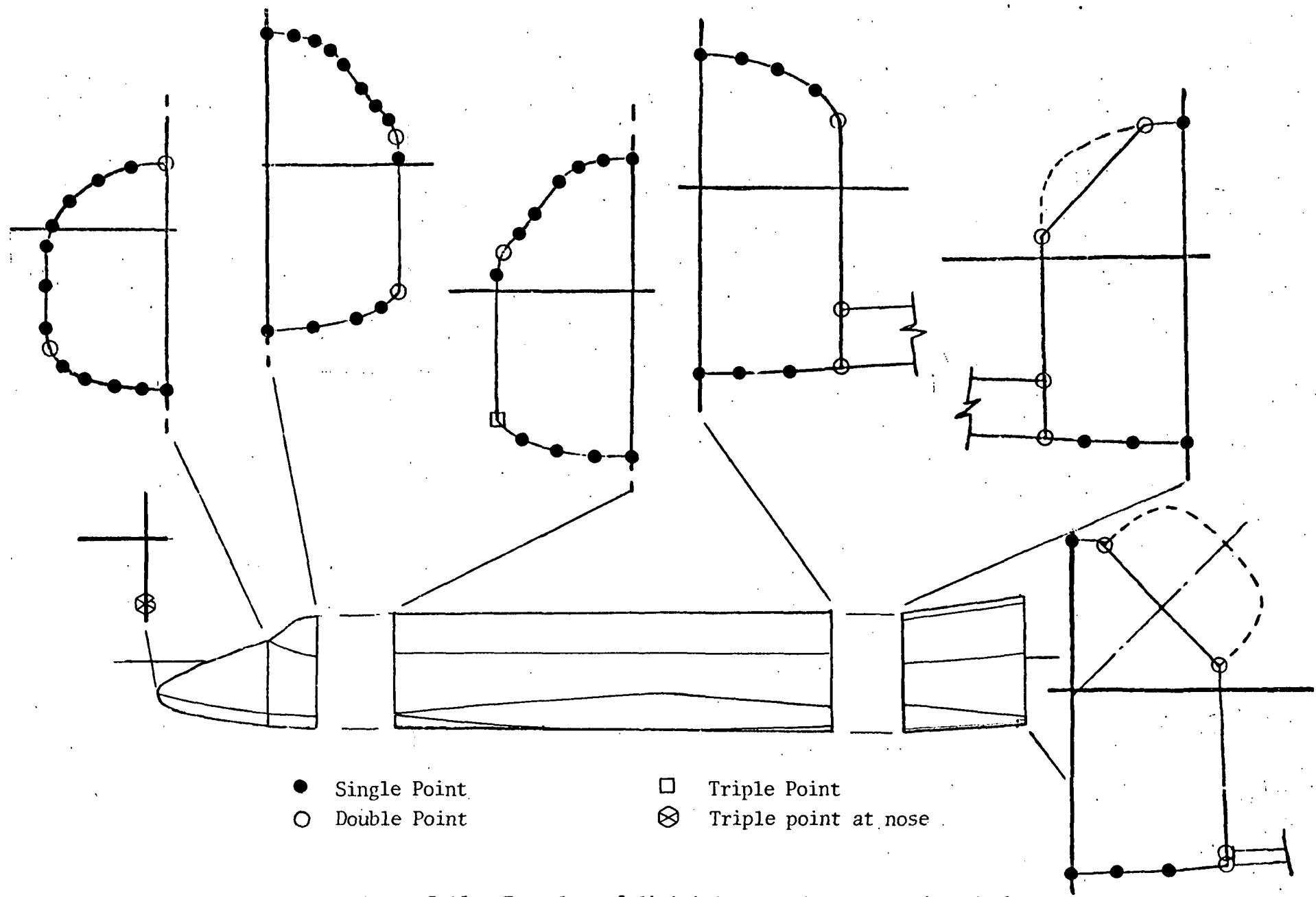
Figure 3-19. Examples of digitizing sections on various body components
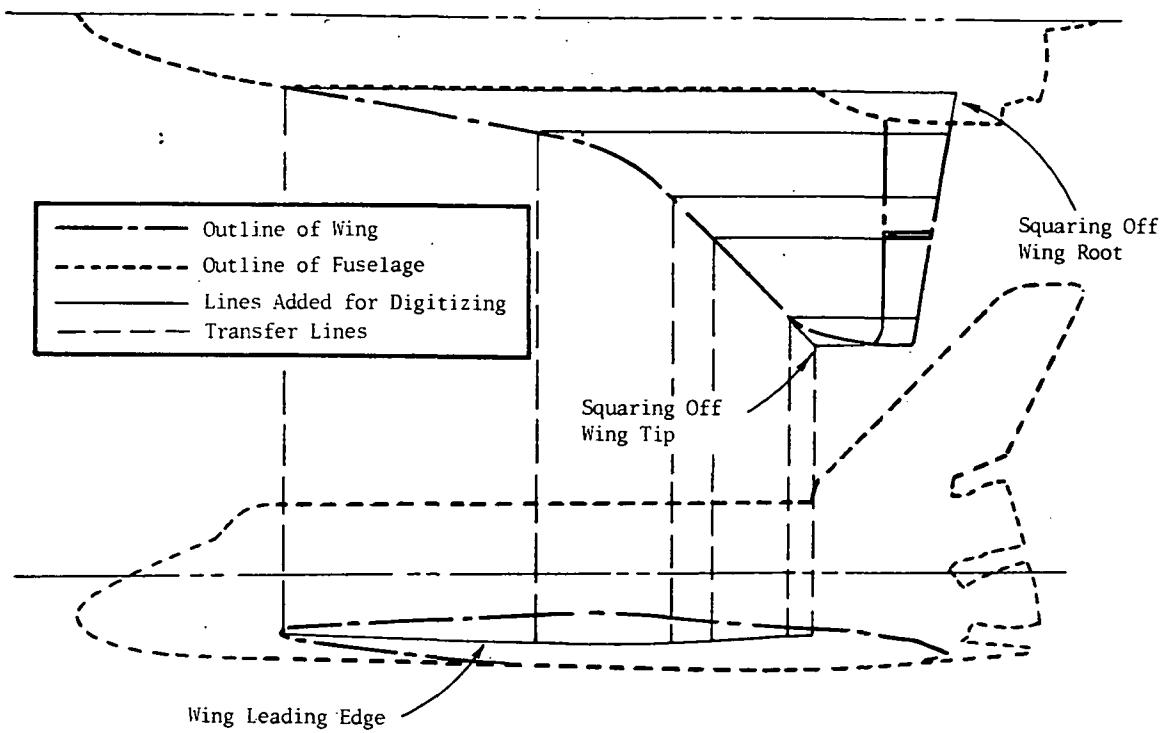
Figure 3-20. Previewing wing surface, adding guide lines
and transfer lines for digitizing

Legend (Figure 3-20):
- —— · —— Outline of Wing
- ———— · Outline of Fuselage
- ————— Lines Added for Digitizing
- — — — Transfer Lines

Labels: Squaring Off Wing Root, Squaring Off Wing Tip, Wing Leading Edge
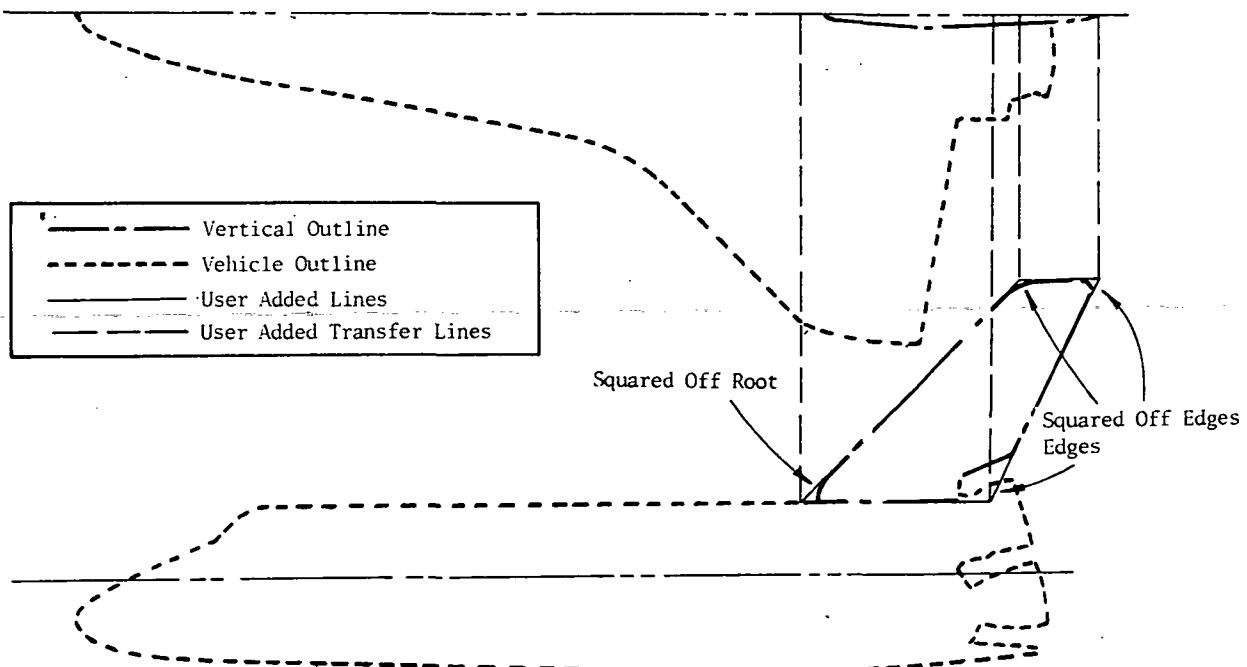
Figure 3-21. Previewing vertical tail, adding guide lines and
transfer lines for digitizing

Legend (Figure 3-21):
- —— · —— Vertical Outline
- ———— Vehicle Outline
- ————— User Added Lines
- — — — User Added Transfer Lines

Labels: Squared Off Root, Squared Off Edges, Edges

51

<u>Digitizing</u>

   The drawing of figure 3-16 is taped to the graphics tablet such that the areas
being digitized sit on the active surface. Log into APAS using the same geometry
file as the simple geometry case. Review the components in the permanent file using
the FILES command.

   Enter DIGITIZE and refer to screen 3-27 for the inputs to initiate digitizing.
In this session, the forward fuselage and wing input will be defined. The first
entry (xo, Xmax) is the x-station values of the selected origin and another point
providing a reasonable distance for scaling the drawing. Xmax is usually taken as
the largest x-station on the active tablet surface. The second entry is (Xo, Yo) top
view, (Xo, Zo) side view, and (Xmax, Zo) side view. Three rectangles are displayed on the
screen to verify these entries, followed by the question "AXIS OK * 1 YES * 2 NO." It is
accepted if the points are near orthogonal. The next entry is the basic component
parameters: the type of component, the number of segments per cross-section, and the
status of each segment; 1 for a wetted (exposed) and -1 for an unwetted. This is
followed by the component number, name, and symmetry. The forward fuselage, component
11.00, will be a type 1 body with three wetted segments.

```
          * KEY * XO,XMAX   *
——▶  0   30.683
          PEN * PLANFORM XO. PROFILE XO. PROFILE XMAX  *

          AXIS OK * 1 YES * 2 NO  ◀——————————————  ③
                                                    |1|
          COMPONENT PARAMETERS
          KEY*TYPE(1,2,3 OR 4), NSEG, NWET(1)....NWET(NSEG)
——▶  1  3  1  1  1
          INPUT COMPONENT NUMBER:
——▶  11
          INPUT COMPONENT NAME:
——▶  forward fuselage
          ENTER SYMMETRY PARAMETER:
          1   :  NON - REFLECTING
          2   :      REFLECTING
          +   :      ASYMMETRIC
          -   :      SYMMETRIC
——▶  2                              (Xo, Yo)

                                        ▢

                 (Xo,Zo)         (Xmax, Zo)

                   ▢                 ▢
```

Screen 3-27   Forward fuselage general digitizing input

   Screens 3-28 through 3-33 illustrate the steps for pen digitizing each of the
forward fuselage sections. Symbols on each cross-section display have been added
to show the contour points digitized. The x return indicates the completion of the
pen input and displays the section origin to allow modification if desired. In these
screens the user changes the Xo value only. If it is desired to change Zo only, then
the input would be:,, and new Zo value.   The commas indicate no change to Xo and Yo
Two other options are available to signal the end of pen input. The s (save) return
indicates pen input is complete and requests the data be saved. The r (repeat) return
option is used to terminate pen input when the user has made a digitizing error and
desires to start over. These latter two options have not been used in the present
set of screens. Once Xo has been input through the keyboard the section data are
printed in the upper right corner of the screen and a prompt message is printed in
the lower left. The user enters a one until end of component is achieved.

PEN * FUSELAGE REF.
    * SEGMENTS FROM TOP OF SECTION   ①

x

②

INPUT XO,YO,ZO FOR SECTION, DEFAULTS:
XO: -0.001 YO: 0.0   ZO: -1.459
0.

③

* 1 NEXT SECTION * 2 REPEAT SECTION * 3 END COMP.

.1   ④
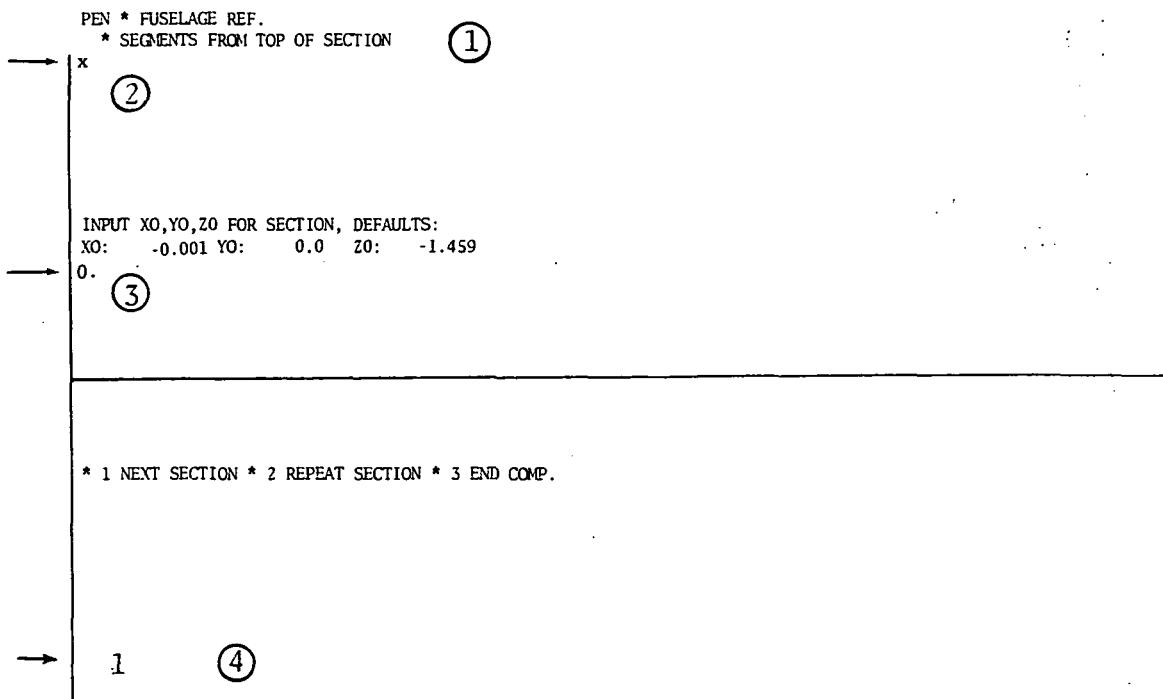
Screen 3-28 Digitizing forward fuselage section 1.

PEN * FUSELAGE REF.
    * SEGMENTS FROM TOP OF SECTION   ①

x

②

INPUT XO,YO,ZO FOR SECTION, DEFAULTS:
XO: 0.672 YO: 0.0   ZO: -0.754
0.559

③

* 1 NEXT SECTION * 2 REPEAT SECTION * 3 END COMP.

1   ④
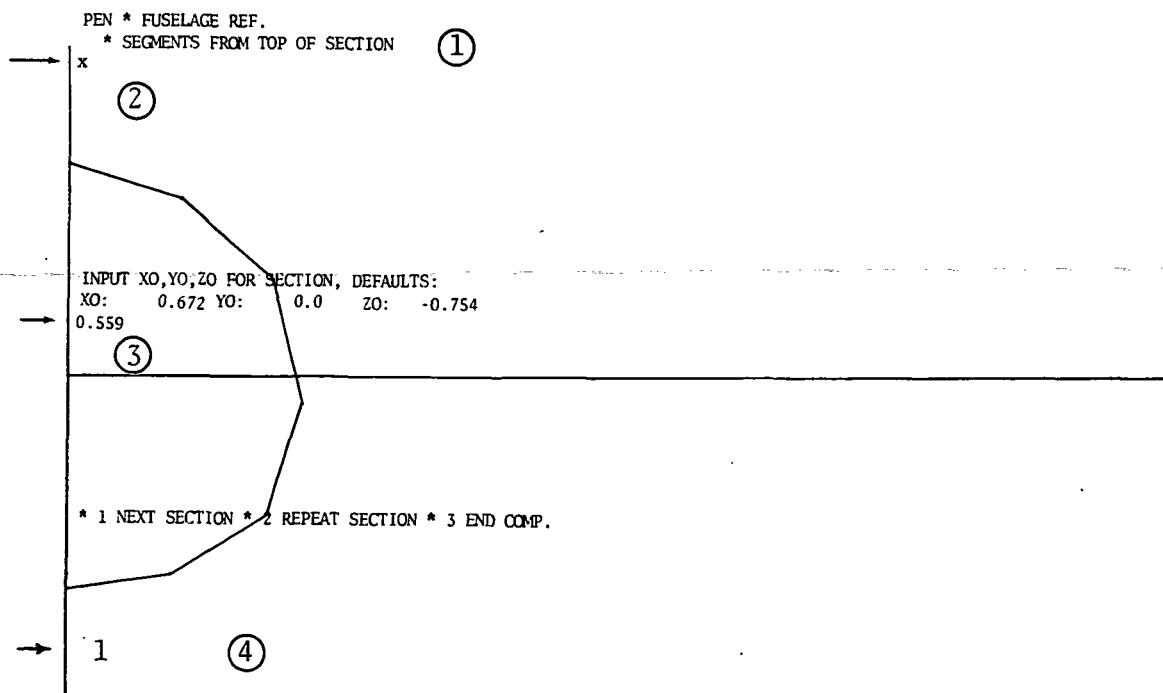
Screen 3-29 Digitizing forward fuselage section 2.

53

PEN * FUSELAGE REF.
  * SEGMENTS FROM TOP OF SECTION
x

INPUT XO,YO,ZO FOR SECTION, DEFAULTS:
XO: 1.699 YO: 0.0   ZO: -0.201
1.524

*1 NEXT SECTION * 2 REPEAT SECTION * 3 END COMP.

1
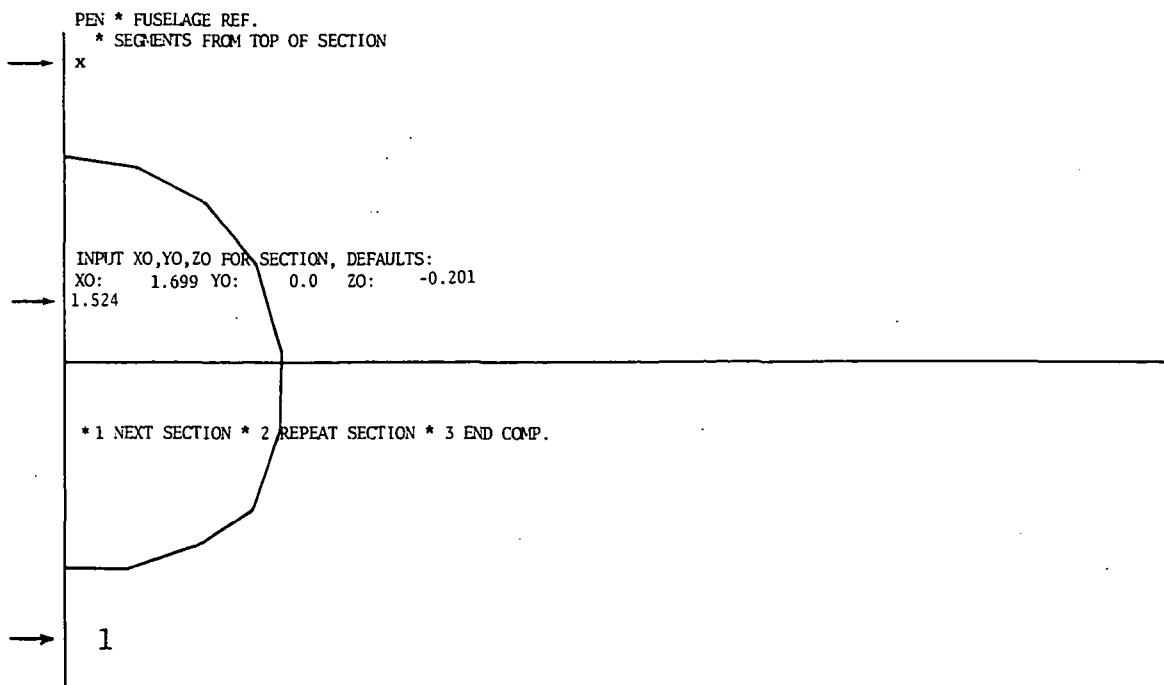
Screen 3-30 Digitizing forward fuselage section 3.

* SECTION S NO. SEG.:   3. PTS / SEG.:   1   9   5
XO =   4.953 YO =   0.0   ZO =   1.207

PEN * FUSELAGE REF.
  * SEGMENTS FROM TOP OF SECTION
x

INPUT XO,YO,ZO FOR SECTION, DEFAULTS:
XO: 5.097 YO: 0.0   ZO: 1.207
4.953

1 NEXT SECTION * 2 REPEAT SECTION * 3 END COMP.

1
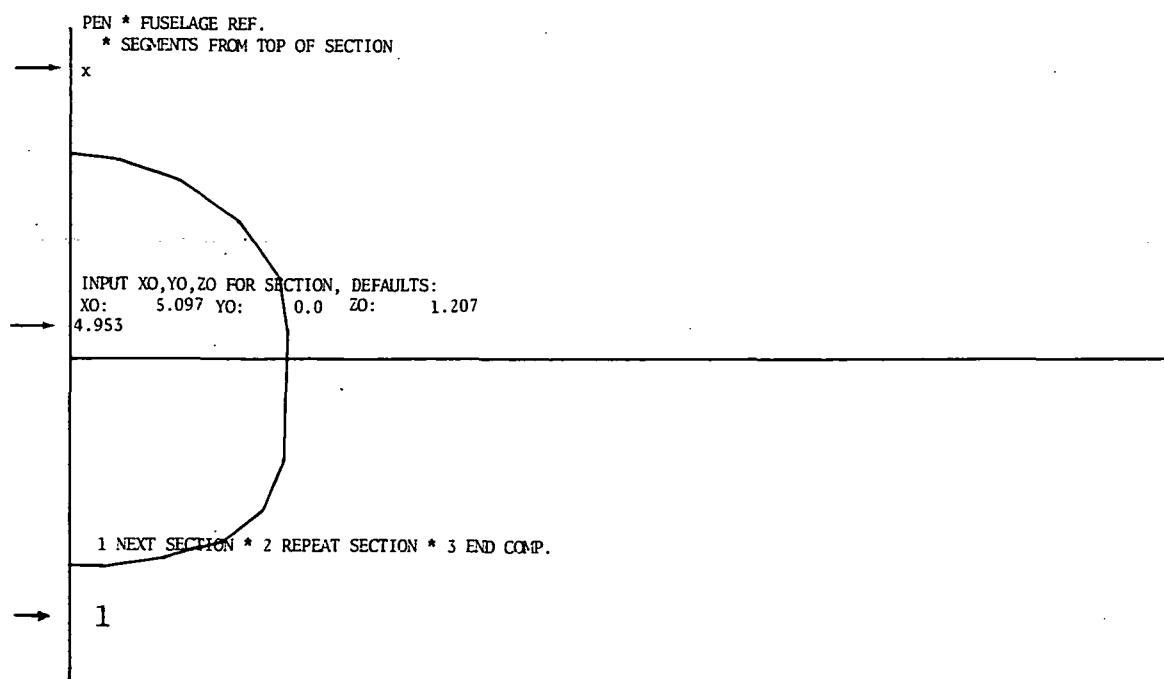
Screen 3-31 Digitizing forward fuselage section 5

* SECTION: 6 NO. SEG.:   3. PTS / SEG.:   7   3   5
XO =   6.324 YO =   0.0 ZO =   2.263

PEN * FUSELAGE REF.
  * SEGMENTS FROM TOP OF SECTION
x

INPUT XO,YO,ZO FOR SECTION, DEFAULTS:
XO: 6.324 YO: 0.0 ZO: 2.263

* 1 NEXT SECTION * 2 REPEAT SECTION * 3 END COMP.

1
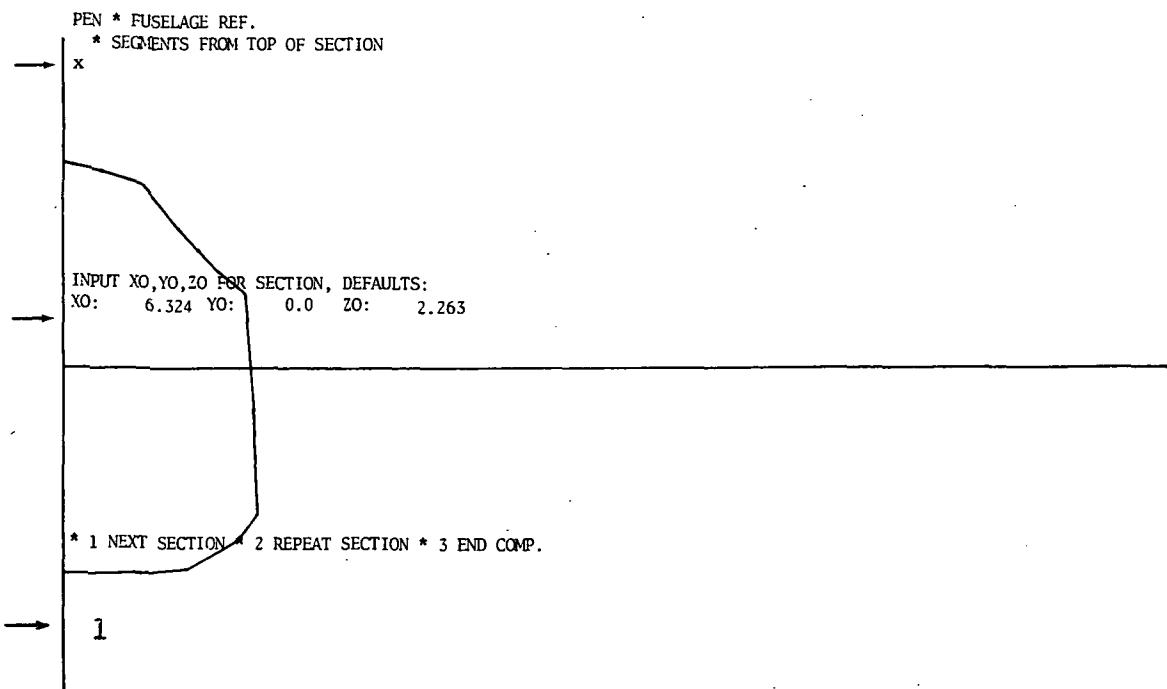
Screen 3-32 Digitizing forward fuselage section 6.

* SECTION: 7 NO. SEG.:   3. PTS / SEG.:   7   5   5
XO =   6.858 YO =   0.0 ZO =   2.465

PEN * FUSELAGE REF.
  * SEGMENTS FROM TOP OF SECTION
x

INPUT XO,YO,ZO FOR SECTION, DEFAULTS:
XO: 7.069 YO: 0.0 ZO: 2.465
6.858

* 1 NEXT SECTION * 2 REPEAT SECTION * 3 END COMP.

3
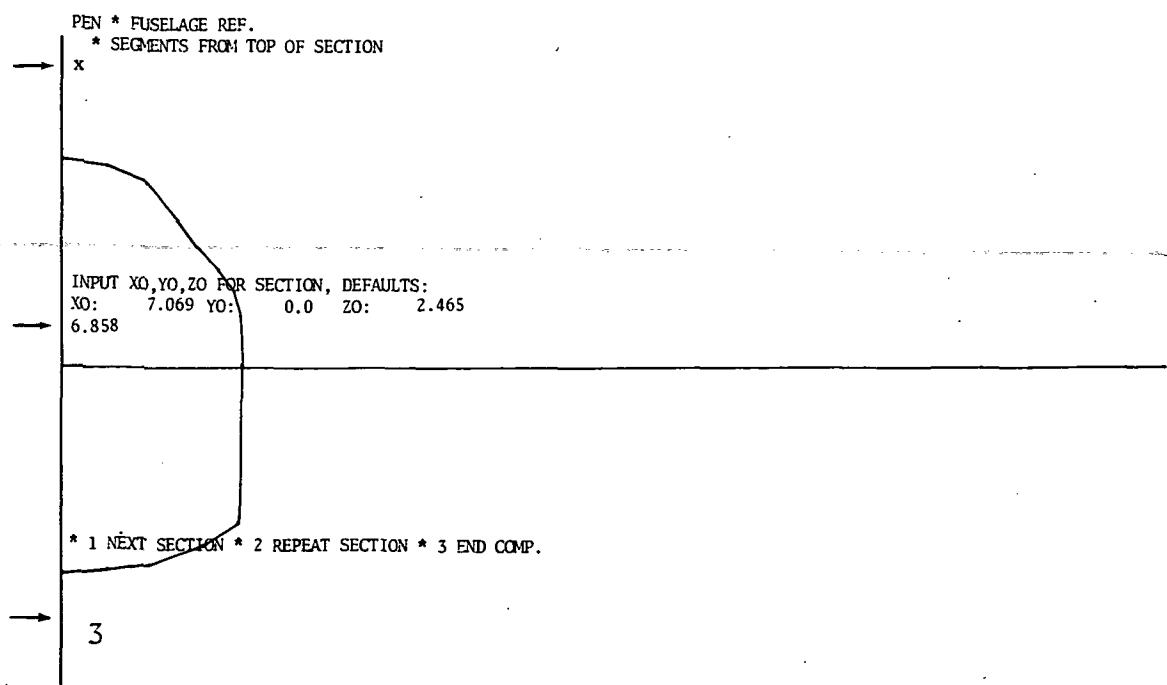
Screen 3-33 Digitizing forward fuselage section 7 and ending
component digitizing.

Screen 3-34 illustrates the entries for processing and storing the geometry.
The smoothing option will be illustrated for wing digitizing where irregularities
in geometry are more important. The user is also given the opportunity to change
the number of segment points by interpolation (bodies only). In the present case,
the default values are accepted and represent the maximum number of points used for
each segment as determined from all 7 input sections. An EDIT/LIST of each section
will display a total of 21 points with the number of points in each segment as shown.
The component is cataloged and a three view is displayed on screen 3-35.

```
                    * SMOOTH OPTION: ENTER ORDER OR
                    * CARRIAGE RETURN FOR SPLINE FIT ONLY.
    ━━▶
                    POINTS/SEGMENT ENRICHMENT.
                    ENTER NEW VALUES OR CARRIAGE RETURN TO RETAIN.
                    PRESENT VALUES :   7   9   5
    ━━▶
                    **OK**
    ━━▶  cata
                    **OK**
    ━━▶  disp
```

Screen 3-34   Body contour processing
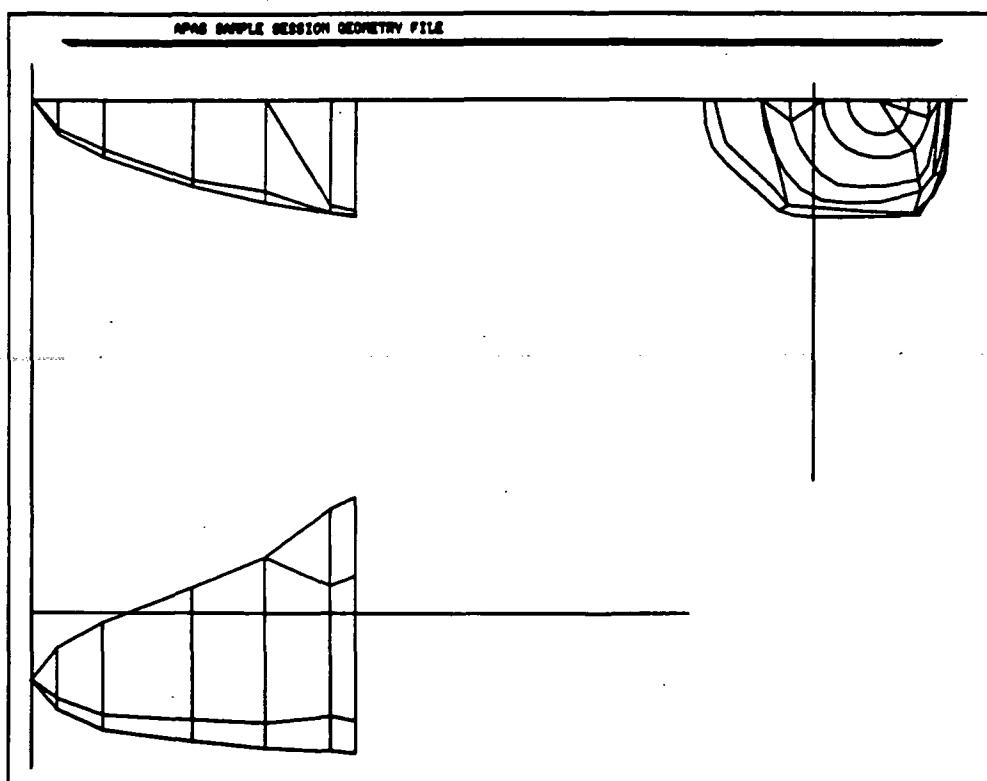
Screen 3-35 Three view of digitized forward fuselage

The mid and aft fuselage and pod are input similarly. The initial data for
these components is shown in screens 3-36, 3-37, 3-38 respectively.   Since the pod is
a type 2 component the cross-sections are digitized to closure as indicated on screen
3-39.

```
          * KEY * XO,XMAX  *
   ──► 0 30.531
          PEN * PLANFORM XO, PROFILE XO, PROFILE XMAX  *

          AXIS OK * 1 YES * 2 NO   ◄─────────────────────  ③
                                                            {1}
          COMPONENT PARAMETERS
          KEY*TYPE(1.2.3 OR 4).NSEG,NWET(1).....NWET(NSEG)
   ──► 1 4 1 1 -1 1
          INPUT COMP NUMBER:
   ──► 12.
          INPUT COMPONENT NAME:
   ──► mid fuselage
          ENTER SYMMETRY PARAMETER:
          1    :   NON - REFLECTING
          2    :        REFLECTING
          +    :        ASYMMETRIC
          -    :        SYMMETRIC
   ──► 2
```

□

□   □

Screen 3-36 Mid fuselage general digitizing input.

```
          * KEY * XO,XMAX  *
   ──► 0 30.531
          PEN * PLANFORM XO, PROFILE XO, PROFILE XMAX  *

          AXIS OK * 1 YES * 2 NO  ◄─────────────────────  ③
                                                           {1}
          COMPONENT PARAMETERS
          KEY*TYPE(1,2,3 OR 4), NSEG,NWET(1)....NWET(NSEG)
   ──► 1 5 1 -1 1 -1 1
          INPUT COMP NUMBER:
   ──► 13
          INPUT COMPONENT NAME:
   ──► aft fuselage
          ENTER SYMMETRY PARAMETER:
          1    :   NOW - REFLECTING
          2    :        REFLECTING
          +    :        ASYMMETRIC
          -    :        SYMMETRIC
   ──► 2
```

□

□   □

Screen 3-37 Aft fuselage general digitizing input

```
                 * KEY * XO,XMAX  *
——→ 0 30.531
                 PEN * PLANFORM XO, PROFILE XO, PROFILE XMAX  *

                 AXIS OK * 1 YES * 2 NO  ←————————————————  ③

                                                           |1|
                 COMPONENT PARAMETERS
                 KEY*TYPE(1.2.3 or 4),·NSEG,NWET(1)....NWET(NSEG).
——→ 2 2 1 -1
                 INPUT COMP NUMBER:
——→ 14
                 INPUT COMPONENT NAME:
——→ pod
                 ENTRY SYMMETRY PARAMETER:
                 1  :   NON - REFLECTING
                 2  :        REFLECTING
                 +  :        ASYMMETRIC
                 -  :         SYMMETRIC
——→ 2


                                             ▫


                            ▫              ▫
```

Screen 3-38 Pod general digitizing input.

```
                                      * SECTION: 4 NO. SEG.:  2. PTS / SEG.:  13     2
                                      XO =   31.750· YO =     0.763 ZO =    2.907
```



```
PEN * FUSELAGE REF.
  * SEGMENTS FROM TOP OF SECTION
——→ x





INPUT XO,YO,ZO FOR SECTION, DEFAULTS:
XO:    30.521 YO:     0.763 ZO:      2.907·
——→ 31.750




* 1 NEXT SECTION * 2 REPEAT SECTION * 3 END COMP.

            ④
            |1|
```
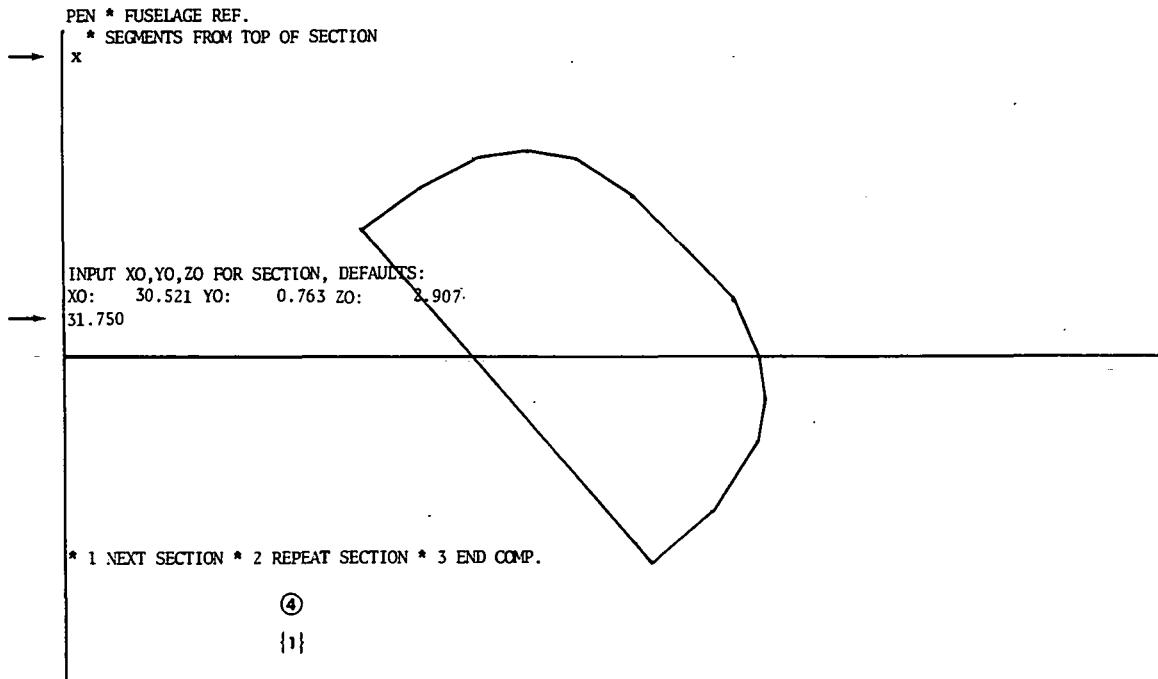
Screen 3-39 Digitized pod contour

When the four components have been digitized, a three view of the complete fuselage is produced (screen 3-40) using the DISPLAY command.

58
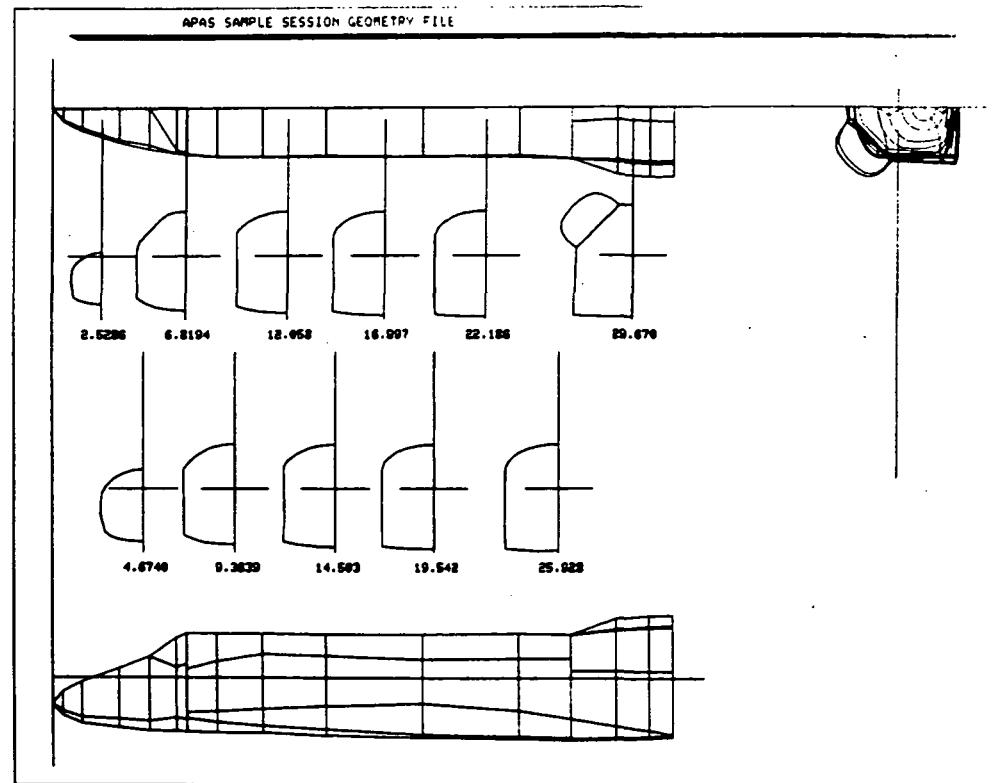
Screen 3-40 Fuselage three view

The general input for the wing (type 4) is shown on screen 3-41. The indicated key and pen input are required to establish scale and location data. Screens of the digitized sections are shown on screens 3-42 through 3-44 for airfoils 1, 2 and the tip. Note the negative thickness input to indicate section digitizing, the chord line location points (rectangles on screen) and the section definition. After defining the origin and chord, the user can now pen in the airfoil cross-section. A s (save) return terminates digitizing and causes the section data to be printed at upper right. APAS then prompts the user on how to proceed as shown in the last line. In screen 3-43 the user indicated input is complete by keying in a s return. However, the number of segments input was wrong. APAS prints out the nature of the error, i.e., number of segments input is incorrect (3 is correct number) and requests user to re-enter pen input. The user does this and enters s a second time. APAS indicates acceptance by printing out the section data at upper right and then the prompt message shown below the airfoil section.

```
                * KEY * XO,XMAX  *
        ⟶   0  30.531
                PEN * PLANFORM XO, PRFILE XO, PROFILE XMAX  *


            AXIS OK * 1 YES * 2 NO ⟵─────────────────  ②

                                                            |1|
            COMPONENT PARAMETERS
            KEY*TYPE(1,2,3 OR 4),NSEG,NWET(1)....NWET(NSEG)
        ⟶ 4  3  1  1  1
            INPUT COMP NUMBER:              ⊡
        ⟶ 111
            INPUT COMPONENT NAME:                  (Xo, Yo)
        ⟶ wing
            ENTER SYMMETRY PARAMETER:
            1  :  NON - REFLECTING       (Xo, Zo)
            2  :       REFLECTING                    (Xmax, Zo)
            +  :       ASYMMETRIC
            -  :       SYMMETRIC           ⊡            ⊡
        ⟶ 2
```

Screen 3-41 General input for wing digitizing

59

KEY * TOC: SET NEGATIVE TO INPUT AIRFOIL
          SET POSITIVE TO SCALE LAST INPUT AIRFOIL
          DEFAULT IS REFERENCE AIRFOIL T / C
PEN * LE(PROFILE), LE AND TE (PLANFORM CHORD LENGTH)
          IF TOC<0. , SECTION LE AND TE REFERENCE
                          (IF DIFFERENT)
          AIRFOIL SECTION FROM TOP L.E.

-.105

s
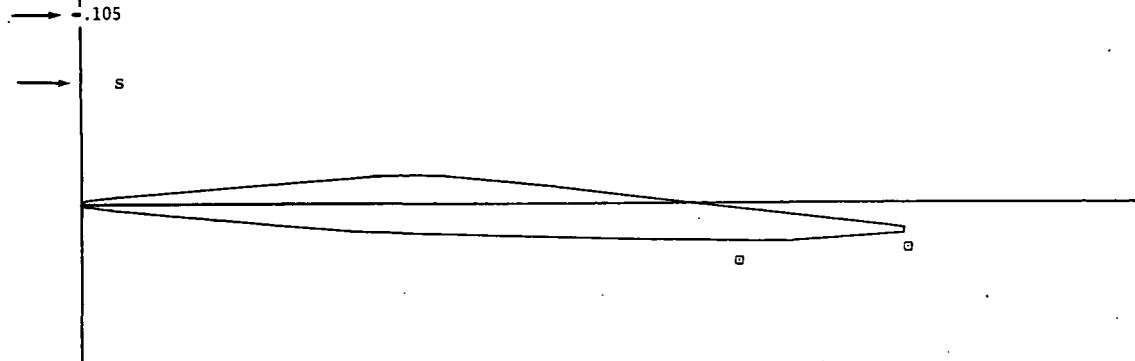
* 1 NEXT SECTION * 2 REPEAT SECTION * 3 END COMP.

③

{1}

Screen 3-42 Digitizing wing section 1

KEY * TOC: SET NEGATIVE TO INPUT AIRFOIL
          SET POSITIVE TO SCALE LAST INPUT AIRFOIL
          DEFAULT IS REFERENCE AIRFOIL T / C
PEN * LE(PROFILE), LE AND TE (PLANFORM CHORD LENGTH)
          IF TOC<0. , SECTION LE AND TE REFERENCE
                          (IF DIFFERENT)
          AIRFOIL SECTION FROM TOP L.E.

-0.1

  * NUMBER OF SEG. INPUT: 2 IS INCORRECT RE - ENTER.

s

s
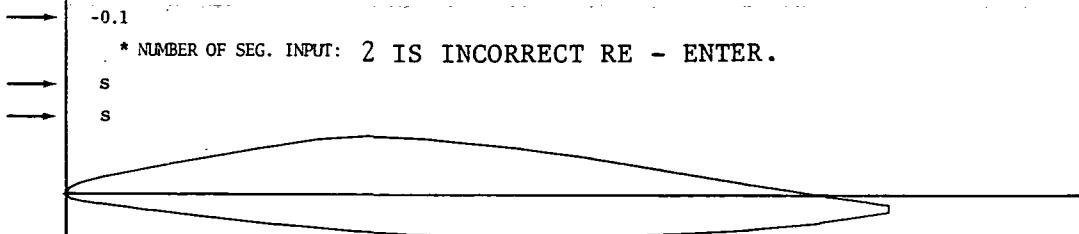
* 1 NEXT SECTION * 2 REPEAT SECTION * 3 END COMP.

④

{1}

Screen 3-43 Digitizing wing section 2.

KEY * TOC: SET NEGATIVE TO INPUT AIRFOIL
           SET POSITIVE TO SCALE LAST INPUT AIRFOIL
           DEFAULT IS REFERENCE AIRFOIL T / C
PEN * LE(PROFILE). LE AND TE (PLANFORM CHORD LENGTH)
        IF TOC<. . SECTION LE AND TE REFERENCE
                        (IF DIFFERENT)
        AIRFOIL SECTION FROM TOP L.E.

* SECTION: 5 NO. SEG.:   3. PTS / SEG.:   5   2   5
XO =   26.795 YO =   11.585 ZO =   -2.121

-.1

s

* 1 NEXT SECTION * 2 REPEAT SECTION *3 END COMP.

③

{3}
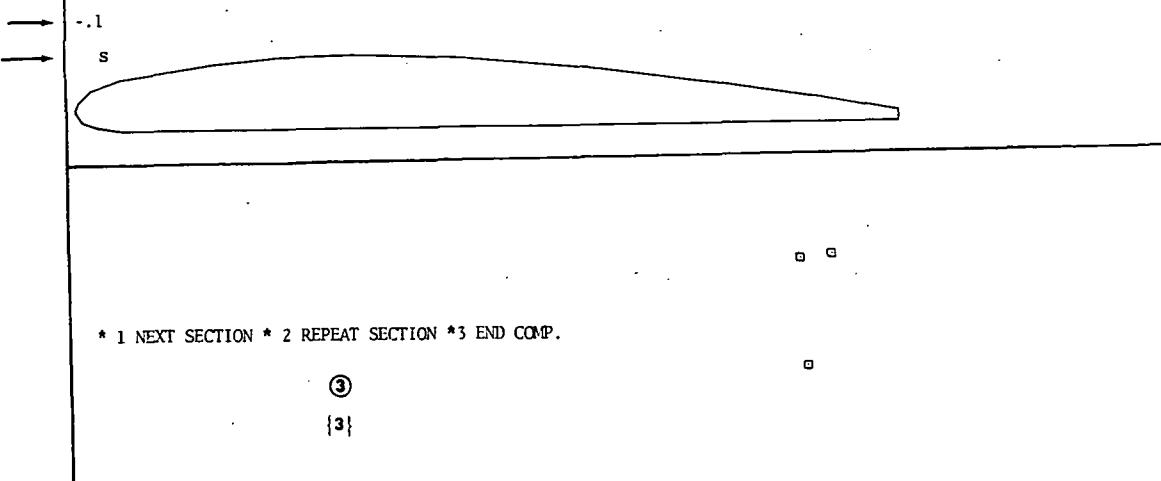
Screen 3-44   Digitizing tip and ending the wing input.

Digitized wing sections may be refined using polynomial smoothing in conjunction with a leading edge algorithm. Three options are available; a default sharp edge, a radius based on the detailed section, or NACA four and five DIGIT airfoil values given by $r/c = 1.10919 (t/c)^2$. The second option was selected here and input in response to prompts of the smoothing function. Screens 3-45 through 3-47 illustrate the resulting airfoil modifications. The vertical scale for these displays has been expanded by a factor of 2.5 for clarity. Each segment of greater than n+1 points (n being the order of the smoothing polynomial) is displayed and the user selects or rejects the refinement. In screen 3-45 for example, the smoothing was rejected in favor of the spline default definition.

The component is then cataloged. Due to the small drawing used, some planform editing may be required.

——SPLINE (DEFAULT)
---SMOOTHED

* ACCEPT SPLINE: 0, SMOOTH: 1, CHANGE ORDER: ENTER ORDER   *

0
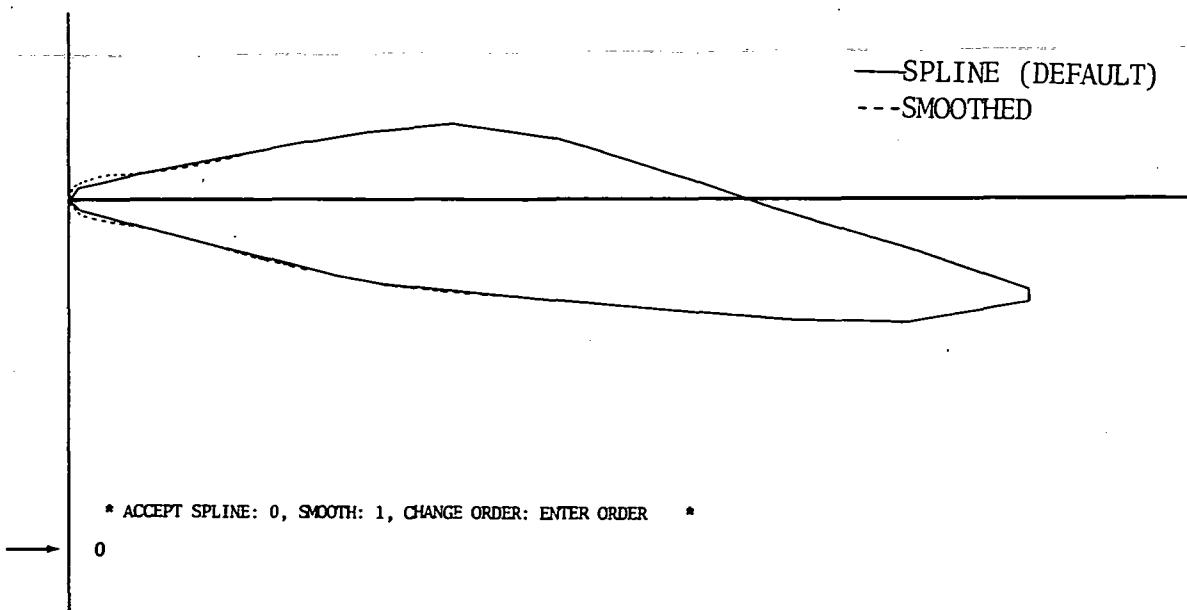
Screen 3-45   Processing wing section 1

61

─SPLINE (DEFAULT)
---SMOOTH

* ACCEPT SPLINE: 0, SMOOTH: 1, CHANGE ORDER: ENTER ORDER   *
1
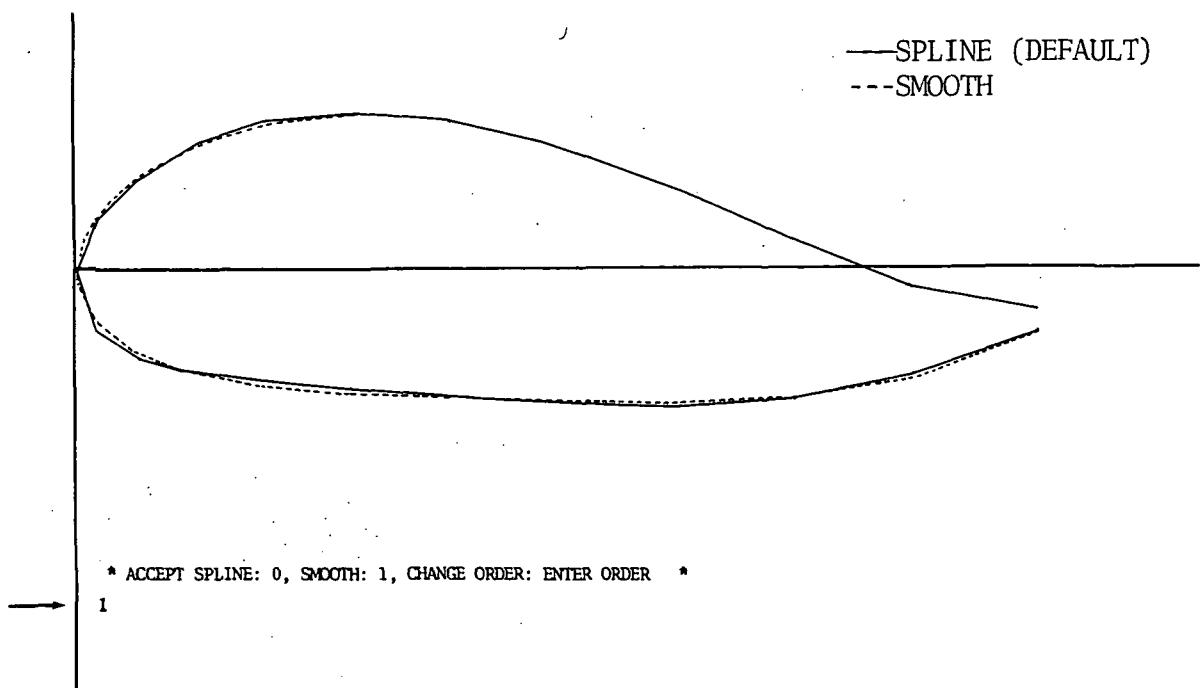
Screen 3-46   Processing wing section 2.

─SPLINE (DEFAULT)
---SMOOTH

* ACCEPT SPLINE: 0, SMOOTH: 1, CHANGE ORDER: ENTER ORDER   *
1
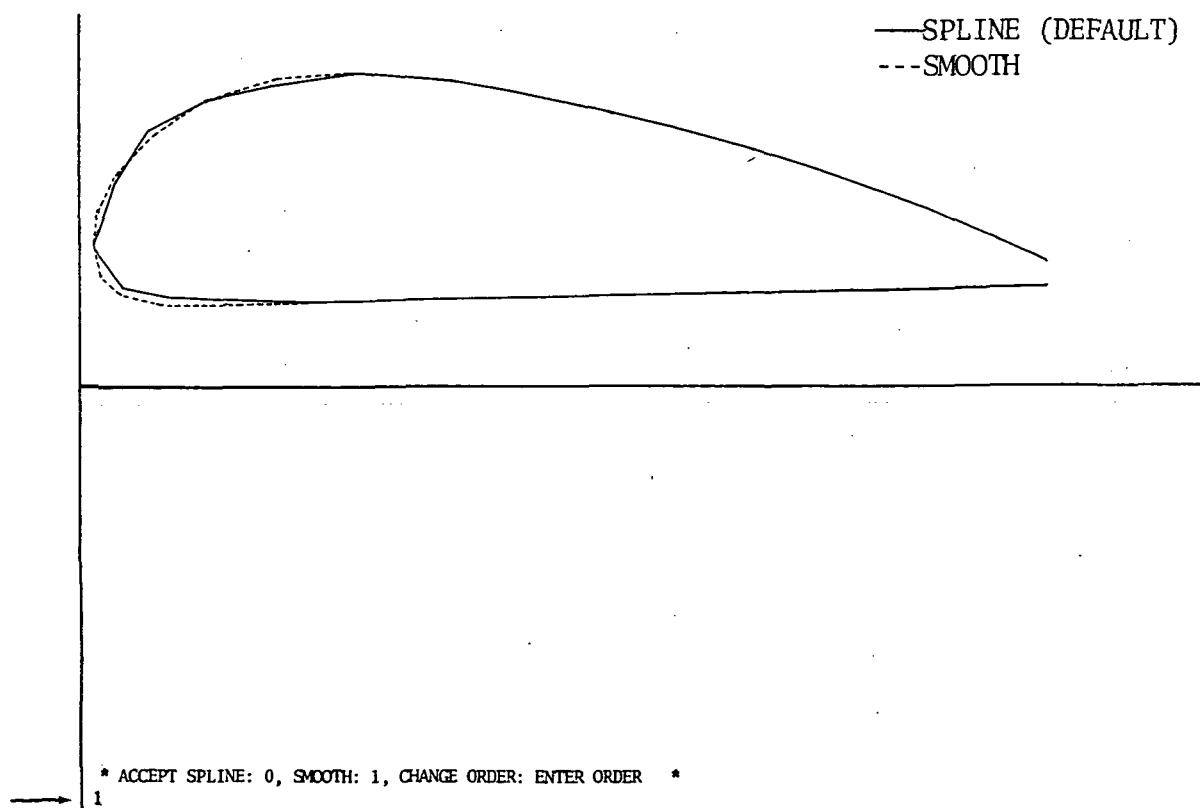
Screen 3-47   Processing wing tip

The vertical tail is digitized using figure 3-16. The input procedure is similar to the wing and will not be shown.

A three-view display of the final configuration is presented on screen 3-48 and completes the input of the geometric components. The aerodynamic analysis requires that slender body and an interference shell components be developed and the wing, vertical tail and shell paneling defined using the PANEL subcommand of EDIT.
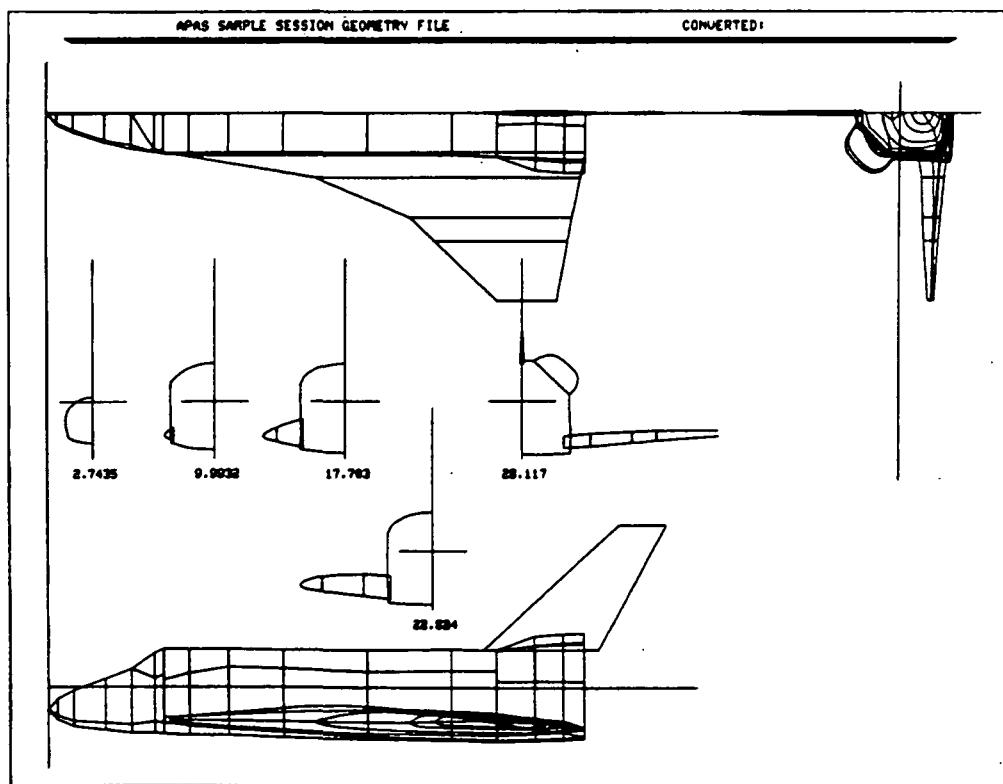
Screen 3-48 Complete configuration three view

Analysis Components

Subsonic-supersonic aerodynamic evaluation requires development of a slender body and interference shell pair for each body. In the sample configuration the fuselage of screen 3-40 is simulated by a slender body. The associated interference shell is constructed to approximate wing-body and tail-body intersections.

Slender Body

A list of the components in the permanent file is displayed on screen 3-49. The user selects components 11 through 14 for slender body generation.

In the sample shown in figure 3-22, a fuselage and nacelle are linked to form one component. At each point along the fuselage contour (starting at the top centerline) a check is made to determine if there are any contour points from other components located in the vicinity. The radius for this check is determined by the parameter FACTOR which is the fraction of the segment length to the next point on the fuselage contour. At point 6 on the fuselage, the first point of the nacelle contour falls within the radius (.7R) and thus the revised contour transitions to the nacelle. To prevent premature returning to the fuselage, additional nacelle contour points must be skipped before initiating the checking process. The number of points skipped is determined by NPASS. At point 10 of the nacelle, the revised contour transitions back to the fuselage to complete the linking.
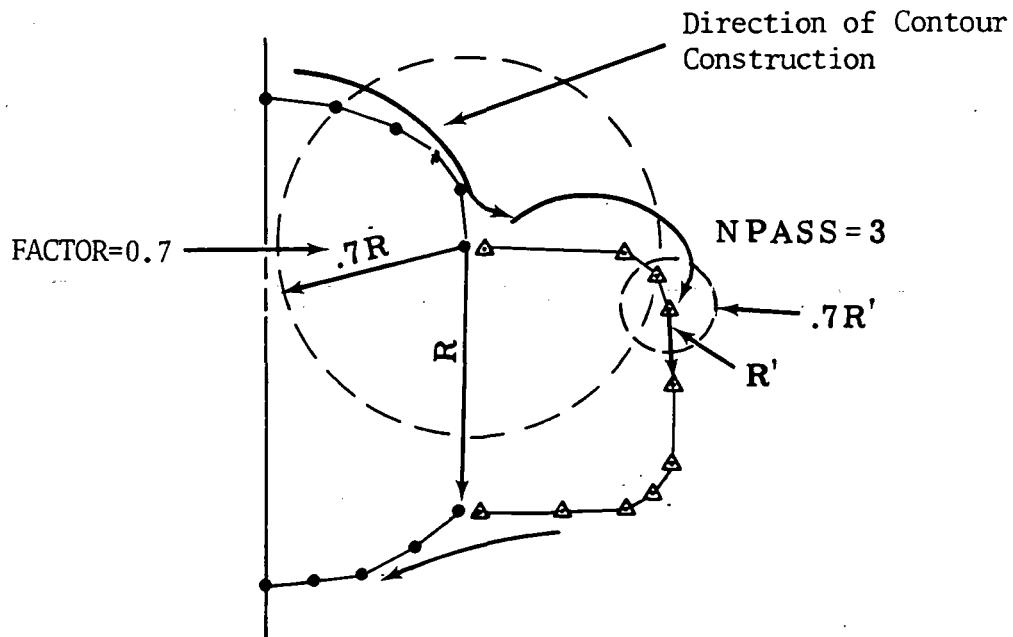
Figure 3-22 SLENDER component linking

When the slender body is generated, the component is catalogued to save it and displayed to verify that the contours are correct, screen 3-51.

Screen 3-49 Selecting body components for generating the slender body.

```
             : SLENDER BODY SIMULATION :
             : ENTER COMPONENT NAME :
      ───→   slender body
             : INPUT COMP NUMBER :
      ───→   611.
             : COMPONENT PARAMETERS FOR SLENDER BODY COMBINATION :
             : ENTER FACTOR, NPASS (DEFAULTS: 0.7,3) :
      ───→
             ::OK::
      ───→   catclog
               INVALID COMMAND CATCLOG
               RE-ENTER INPUT
      ───→   catalog
             ::OK::
      ───→   disp 611. o a 60 -30 30
```

Screen 3-50 Entries required to generate a slender body
from several fuselage components.


```
NPAS SAMPLE SESSION GEOMETRY FILE

YAW  PITCH  ROLL
60.0 -30.0  30.0
```
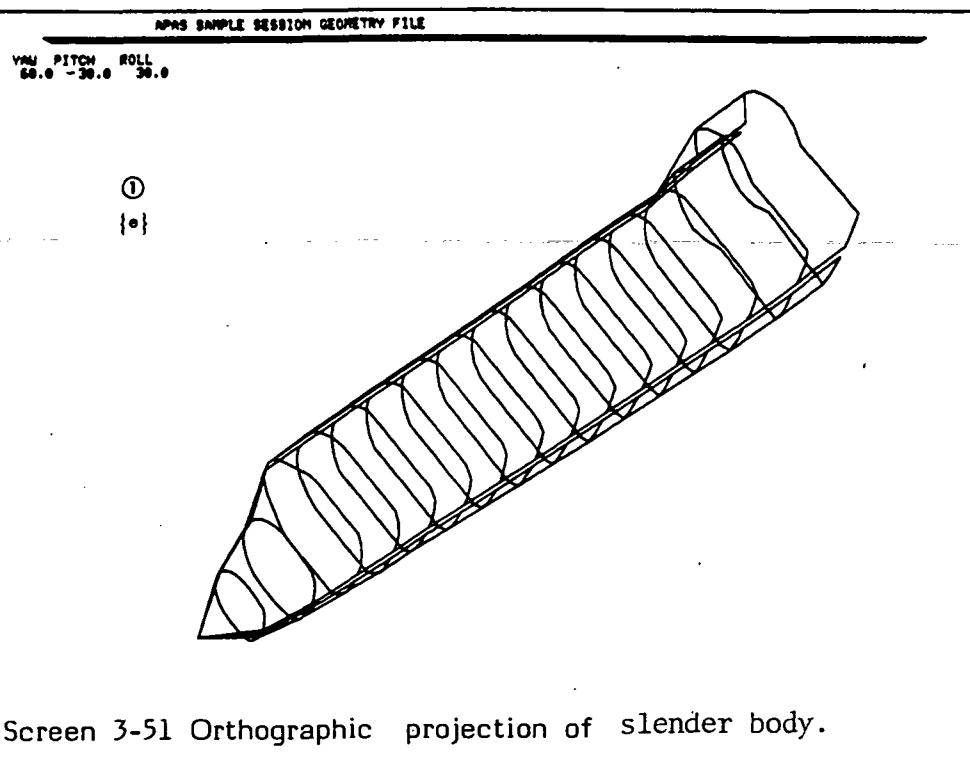
Screen 3-51 Orthographic   projection of slender body.

The slender body simulation for the fuselage requires a series of editing steps as outlined on screens 3-52 through 3-60. The effort is similar to that performed on the simple fuselage (see screen 3-4) and will not be repeated here.

Fuselage sectional forces and moments are governed by the axial rate of change of cross-section area. Consequently denser definition is required in such regions. When a single component is used to generate the slender body, input contours can be appropriately concentrated and editing is generally not necessary. When more than one component is used, the sections are evenly spaced between components, and some longitudinal definition can be lost. By editing in the presence of the forward fuselage (screens 3-52 and 3-53) and zooming in on the forebody (screen 3-54), the nose of the slender body is modified by adding sections and scaling them into place (screens 3-54 through 3-56). After displaying the body (screen 3-57), it is noted that improved definition is required in the crew area and pods. Reduced mid fuselage definition is permissable as a result of small area changes.

Screen 3-52   The slender body editing using forward fuselage
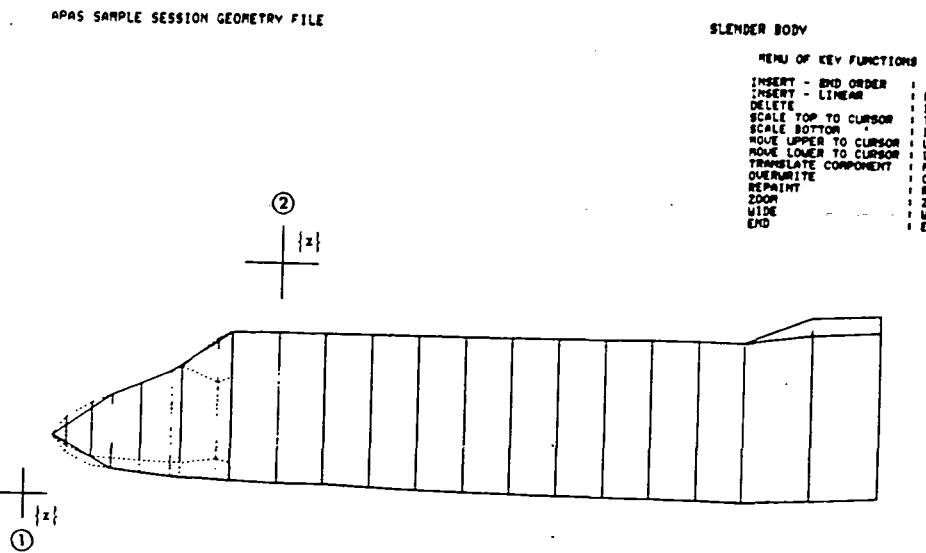
Screen 3-53 Viewing slender body with the forward fuselage
(dashed line) as an underlay.
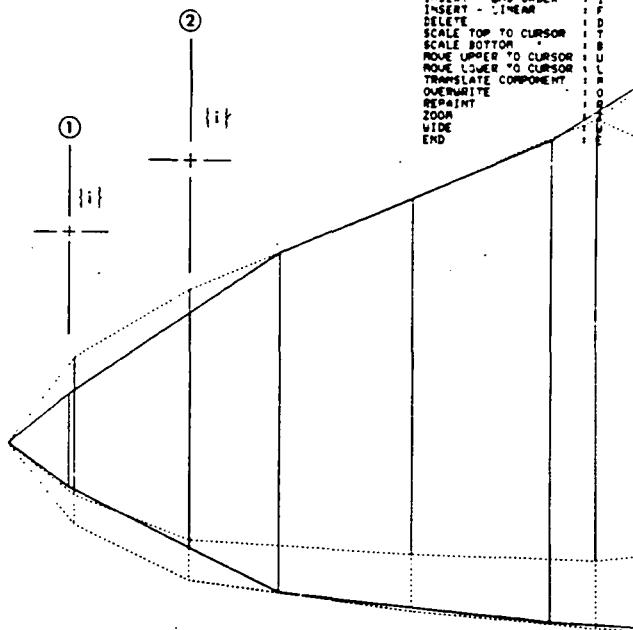
Screen 3-54 Adding sections to the nose of the slender body
using the forward fuselage as reference.
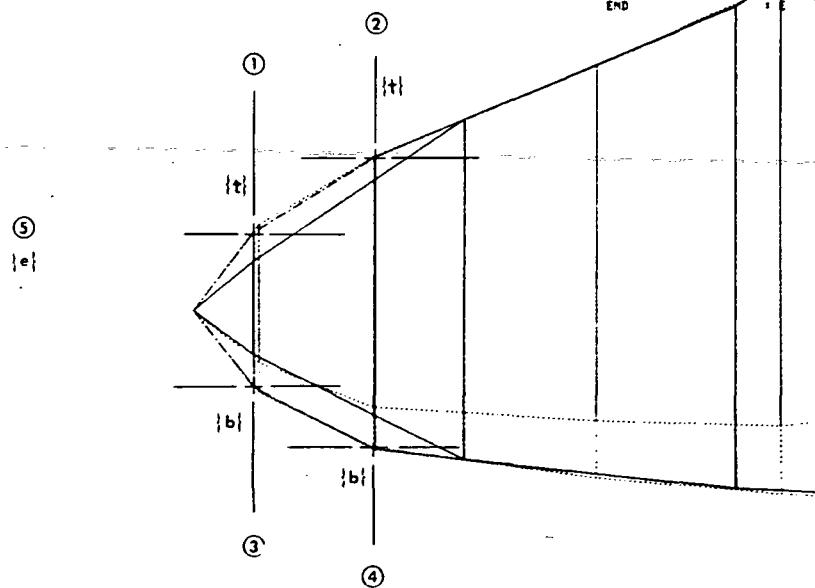
Screen 3-55 Scaling the new sections to match the forward fuselage contours.

```
MENU OF KEY FUNCTIONS

INSERT - END ORDER   : I
INSERT - LINEAR      : F
DELETE               : D
SCALE TOP TO CURSOR  : T
SCALE BOTTOM         : B
MOVE UPPER TO CURSOR : U
MOVE LOWER TO CURSOR : L
TRANSLATE COMPONENT  : R
OVERWRITE            : O
REPAINT              : R
ZOOM                 : Z
WIDE                 : W
END                  : E
```

```
   EDIT##
④  ,
   SAVED IN PERM FILE.
   EDIT##
→  end
   ##OK##
→  disp 611
```

Screen 3-56 Plan view corrections to match forward fuselage.

```
APAS SAMPLE SESSION GEOMETRY FILE

##OK##
→ edit 1611 11 14
  EDIT##
→ w1
```
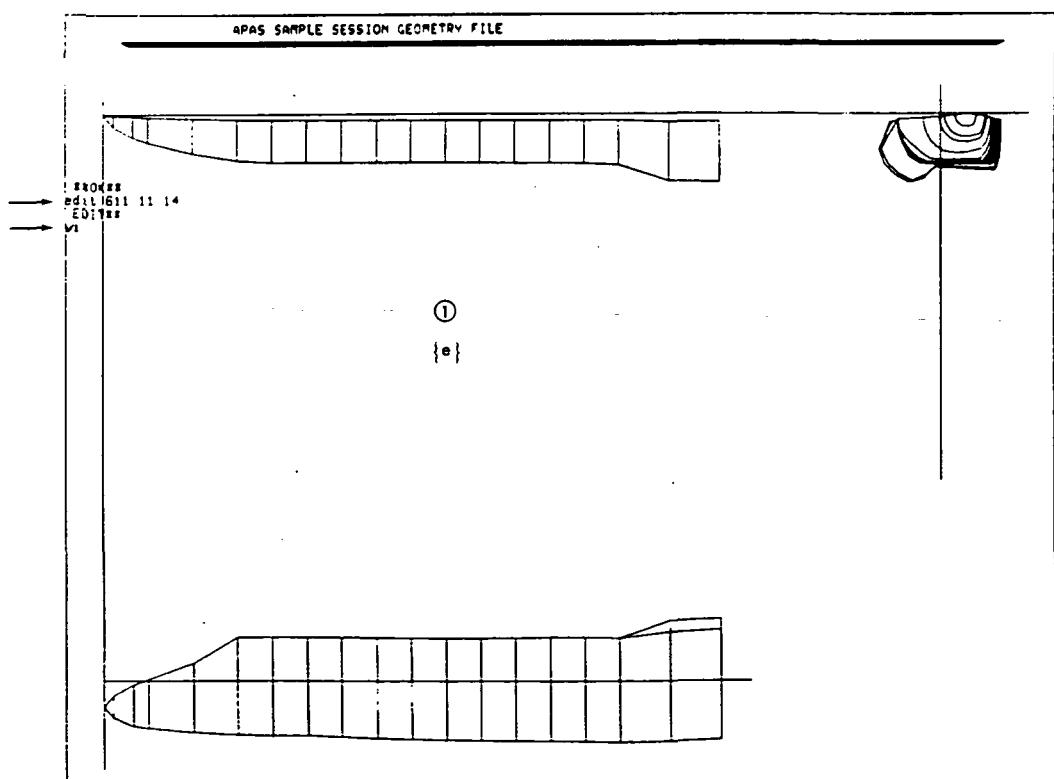
Figure 3-57 Three-view display of slender body modifications.

On screen 3-58, seven sections have been deleted from the cargo area. The fuselage is enlarged with the zoom option and section definition is improved on screen 3-59. Finally, a close-up of the forebody aids in the enhancement of the crew station area in screen 3-60. The last entry on this screen lists the components in the permanent file to select those to be used for generating the interference shell.

SLENDER BODY

MENU OF KEY FUNCTIONS

INSERT - 2ND ORDER   I
INSERT - LINEAR   F
DELETE   D
SCALE TOP TO CURSOR   T
SCALE BOTTOM   B
MOVE UPPER TO CURSOR U
MOVE LOWER TO CURSOR L
TRANSLATE COMPONENT   R
OVERWRITE   O
REPAINT   R
ZOOM   Z
WIDE   W
END   E
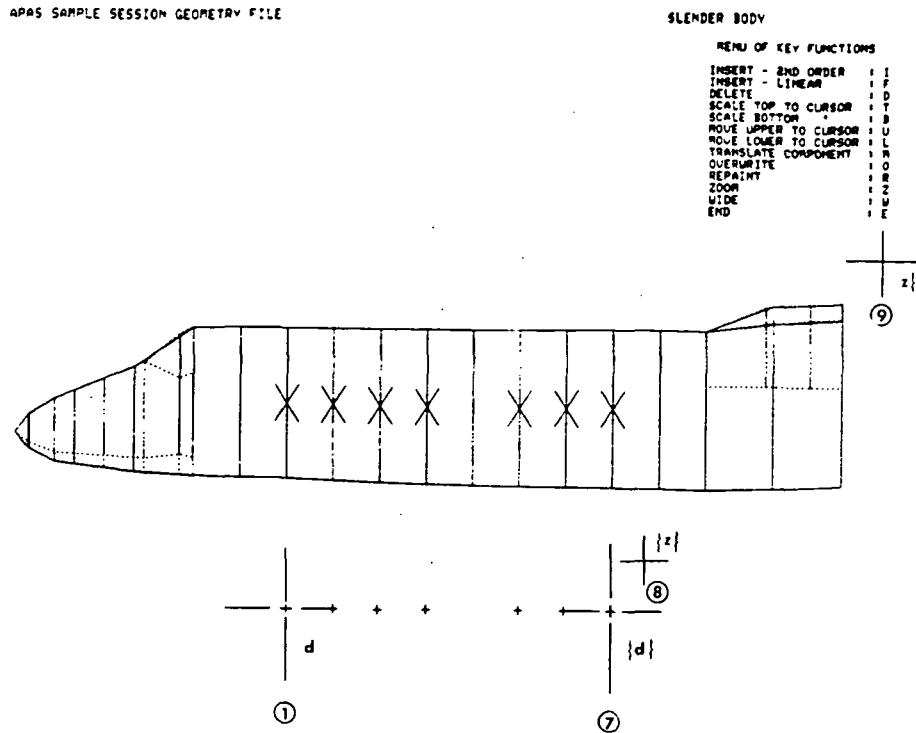
Screen 3-58 Thinning slender body sections.

69
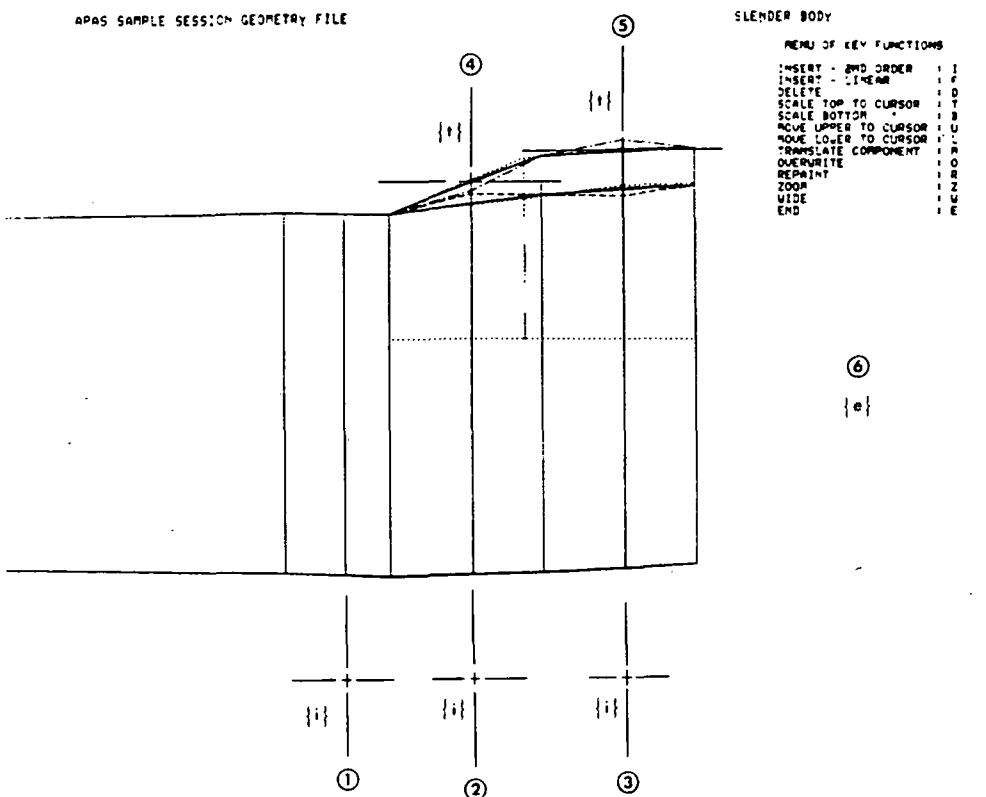
Screen 3-59   Inserting and adjusting sections in aft fuselage
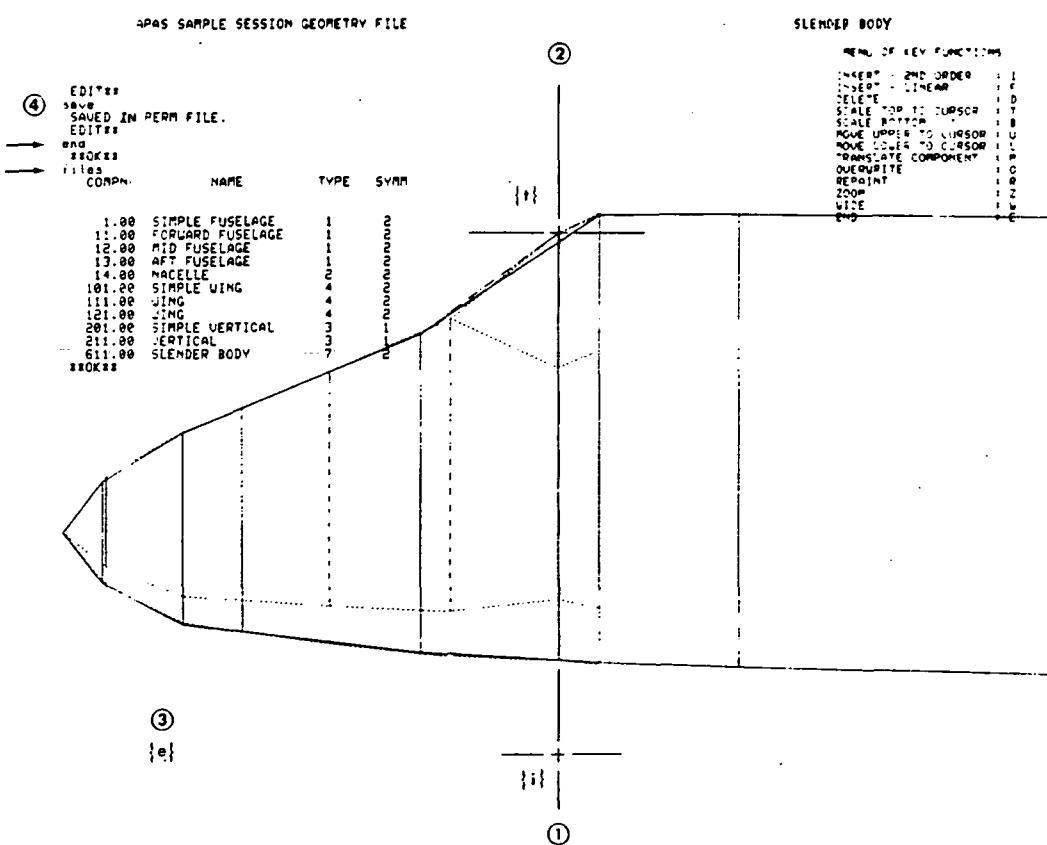
Screen 3-60 Rounding off the slender body crew station

Interference Shell

The INTERFERENCE command is used to construct an interference shell using the slender body (611.00), wing (121.00), and vertical tail (211.00) auxiliary components as indicated on screen 3-61. The number and name are entered in accordance with the rules of page 14.

```
**OK**
inte 611 121 211
ENTER COMPONENT NUMBER:
612.
ENTER COMPONENT NAME:
interf shell
```

Screen 3-61 INTERFERENCE command general input

On screen 3-62, the shell is defined using the graphics cursor to input specific locations following the menu in the lower right hand side of the screen. The construction proceeds as follows.
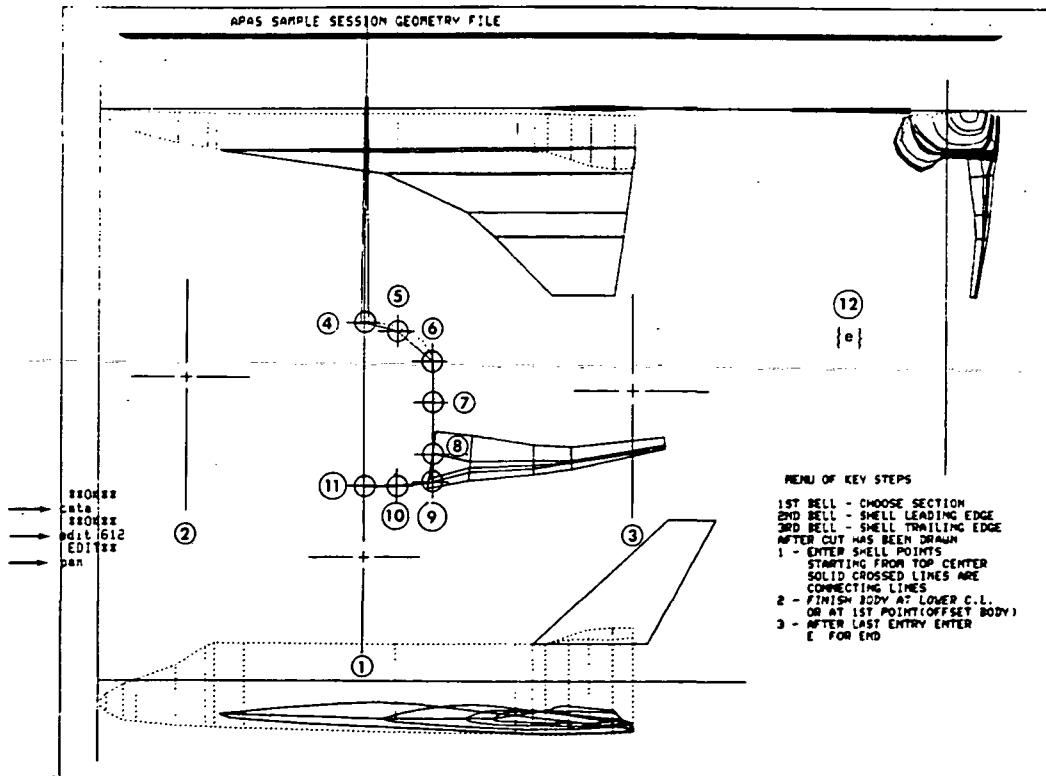
Screen 3-62 Interference shell construction

Select a cross section which is representative of the body the shell is being constructed about. For this step through step 11, the key used to enter points on the screen is arbitrary as long as it's not an "e". Step 2, enter the forward most point for the shell; step three, enter the most aft.

Following step 3, the section selected in step 1 is drawn on the screen in an increased scale to facilitate the next steps. The zoom option (Z-key) can be used to further enlarge the section if desired. Using the graphics cursor, points are entered (steps 4 through 11) defining the shape of the interference shell "tube". Starting from the top of the section, a point is entered to match the vertical root chord. INTERFERENCE automatically matches y and/or z values of points that are entered in proximity to any surface leading edge points. Point 5 is a free point; 6, 7 and 9 have free z values but will be matched to the y value of the wing root chord. Point 8 will be matched exactly to the wing root point. The y value of point 10 will match point 5, and point 11 will be matched to y = 0.0.

Step 12 ends the construction with the entry of an "e". The shell is cataloged to save it.

Paneling

The shell is paneled using the PANEL subcommand of EDIT. The keyboard and graphics entries are shown on screen 3-63. The shell regions are numbered from 1 to 7. Keyboard entries are labeled by step on the outside of the picture border and graphics entries are shown inside. Steps 2 through 8 enter the number of span-wise panels in each region. Entries 9 through 15 describe the chordwise paneling and control surfaces of each region. The interference shell cannot have control surfaces, so only the first two values in each entry (NCHRD-number of chordwise panels and NSPACE-chordwise spacing: 1-even, 2-half cosine and 3-cosine spacing) are used. These have default values of 10 and 1, respectively. The axial paneling of the shell should be geometrically similar to the wing and vertical, NCHRD=15 was selected to improve the simulation. When 15 is entered in step 9, it replaces NCHRD=10 as the default, and a carriage return is all that is required in entries 10 through 15 to set regions 2 through 7 at similar even chordwise spacing. A copy can be made for record purposes before executing step 16.

The wing and vertical tail are paneled on screens 3-64 and 3-65. A control surface line is defined in steps 1(1') and 2(2') using the "c" key to indicate a x/c value will be input for each selected chord from the keyboard. Since the control surface line is straight, the root and tip chord are used for construction. Notice that the chord selected will be the one closest to the graphics cursor, indicated by the offset locations shown in steps 1 and 2 on the screen. Steps 1' and 2' are entered immediately following their respective graphics steps. The spanwise entries (steps 5 through 8) are the same as previously discussed for the shell. Notice in steps 9 through 16 of screen 3-64 that the PANEL subcommand scans through the leading edge regions first (regions 1, 3, 5 and 7), then the trailing edge (flap regions 2, 4, 6 and 8). This allows the user to set up two sets of defaults, one for the forward regions (steps 9 through 12) and one for the flap regions (steps 13 through 16). NCHRD and NSPACE have already been discussed. NFLAP is the flap number (1 through 6) of the region, and SFLAP is the flap symmetry indicator (1 for symmetric, -1 antisymmetric, or 0 for both). The wing control surface (labeled flap 1) is a symmetric flap, and the vertical tail rudder (labeled flap 2) is anti-symmetric.
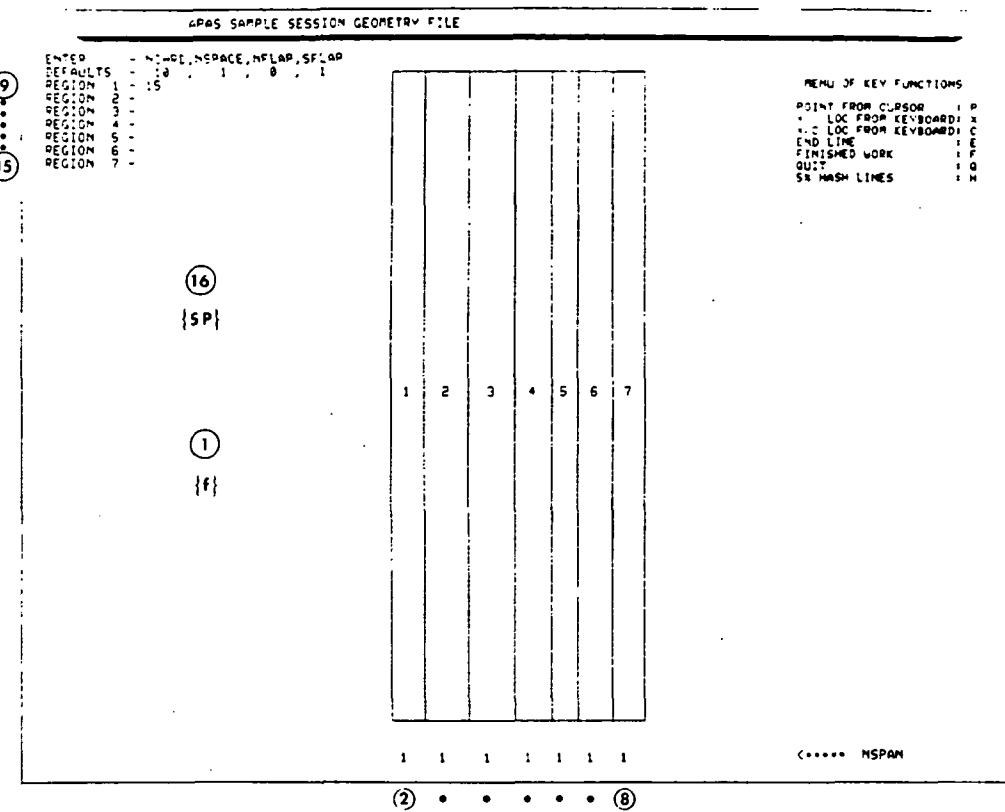
Screen 3-63   Interference shell paneling
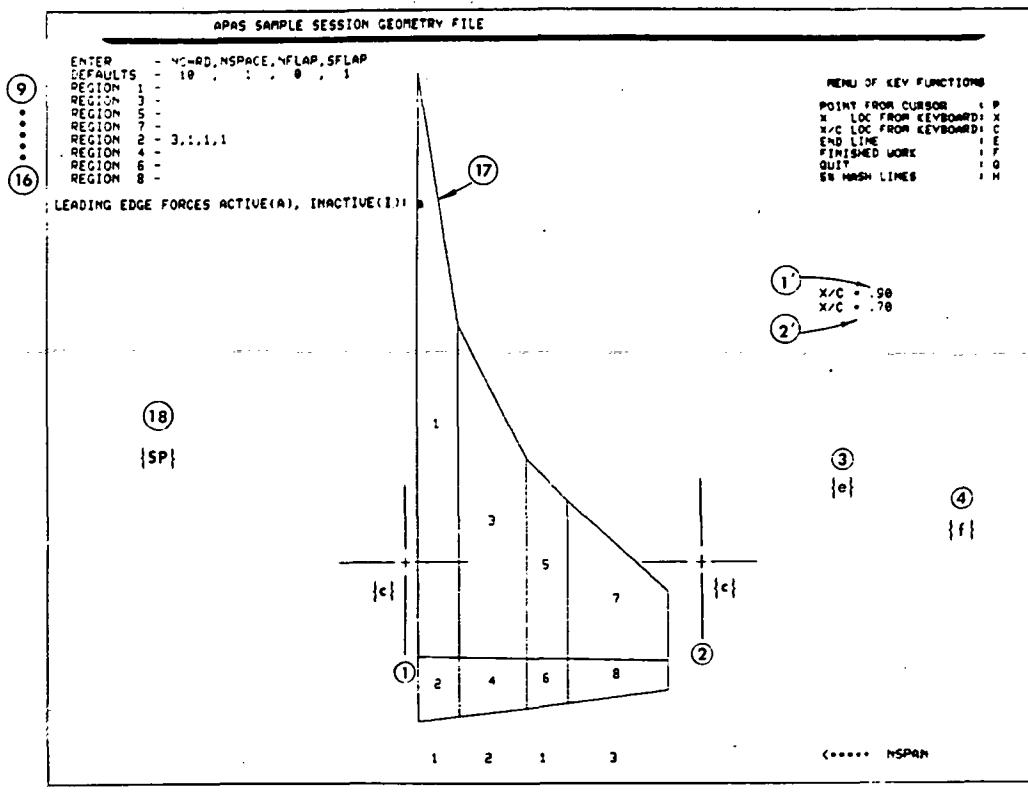
Screen 3-64   Wing-flap paneling

Construction of a partial span flap is accomplished by first positioning the cross hairs near the pertinent inboard section and entering a {c} and then repeating the process near the appropriate outboard section. For a case without flaps, the cross hairs is placed behind the trailing edge of the root and tip and a {p} entered each time. Termination of either case is the same as full span flap of screen 3-64 (i.e. steps 3 and 4).

A constant source panel default is used for calculating thickness effects. If it is changed to a linear axial variation in the SET command, the flap hinge line must be on a constant fractional chord line.

The declaration of leading and side edge vortex forces at subsonic-supersonic speeds is defined for the wing and vertical tail by step 17 of screen 3-64 and step 8 of screen 3-65 respectively.
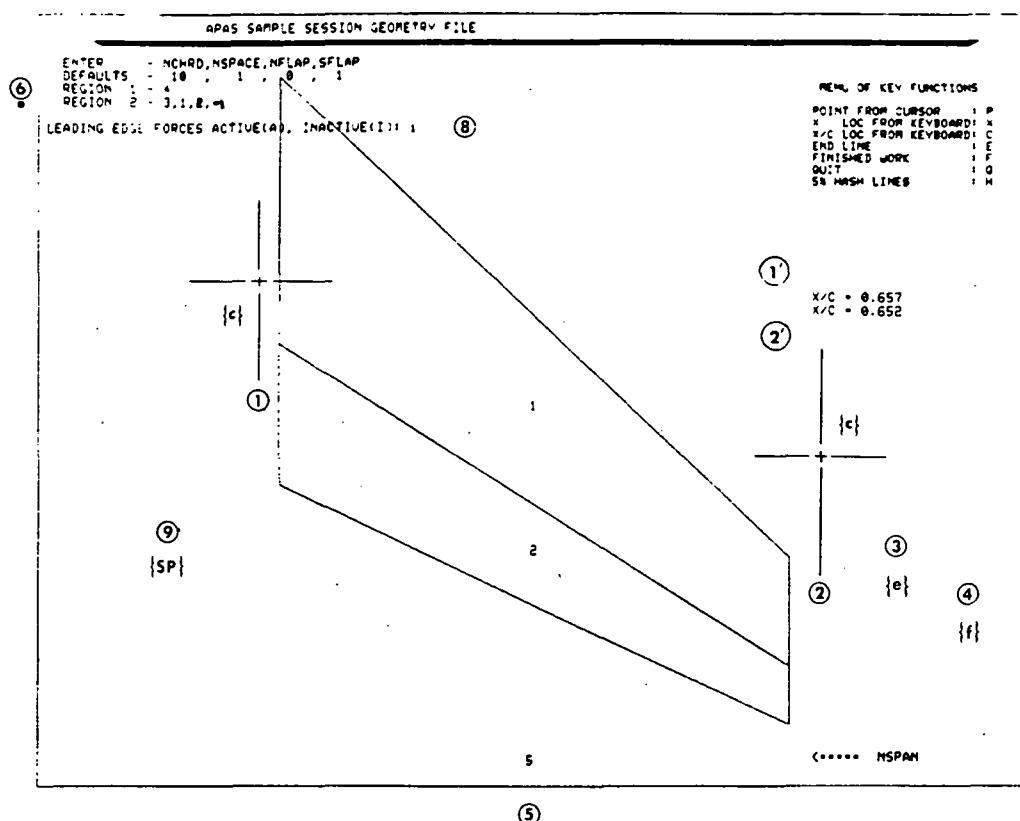
Screen 3-65 Vertical tail-flap paneling

The permanent geometry file now contains all the components necessary to assemble a complete configuration for analysis. The beginning user will find it beneficial to take some of the components that have been generated and manipulate and modify them using the command dictionary for options not explicitly covered in this session. These practice components can be subsequently discarded.

74

SECTION IV

ANALYSIS

Aerodynamic analysis is based on the theory described in Part I. The configuration existing in the <u>local</u> (work) file is evaluated for a user defined series of runs. Configuration assembly from the permanent and component files and run schedule definition is interactively developed for subsequent batch (background) processing to compute results.

Subsonic-supersonic and/or hypersonic evaluation may be conducted in a given analysis. Calculations are automatically processed in an manner which minimizes computational cost and is independent of the run schedule order.

Foreground drag analysis is available for precursor configuration screening purposes and will be discussed initially. The procedures for developing a background set up are then defined. Finally, a set of sample sessions is presented to familarize the user with the various analysis activities of the system.

FOREGROUND

Skin friction and wave drag evaluation can be conducted interactively to facilitate vehicle/major component screening prior to full background analysis.

The VISCOUS command defines vehicle distributions of perimeter and cross-section area as well as component and total vehicle surface area and volume. Evaluation of the skin friction for specified flight conditions is then performed.

The WAVEDRAG command evaluates the wave drag due to volume at supersonic speeds using the area rule. This information is used to determine if vehicle or component reconfiguration should be pursued prior to batch analysis.

The first sample session (pages 77 through 83) illustrates typical input directives and output results for the interactive drag analysis.

BACKGROUND SETUP

The SET command is used to define a schedule of runs to be analyzed. It also processes requests to display the aerodynamic models for verification, define required constants, and select hypersonic panel algorithms prior to dispatching the background input file for processing.

The SET subcommand of SET permits the user to store up to twelve (12) lists that are commonly used for analysis runs. A list in this context is a set of parameters describing flight or wind-tunnel conditions, initial attitudes for static and rotary derivatives, and variable values of angle of attack or sideslip.

The batch input file accommodates thirty-two separate runs or 292 data points. The maximum number of data points per run is 20. The choice of independent variables has been limited to two, angle of attack and sideslip.

The LIST subcommand provides the user with a list of runs in the batch input file attached to the system, giving all non-zero initial conditions and the status (whether analysis has taken place or not) of each run. If a run is to be recomputed, the RESET subcommand is used to return that run to analysis status.

Aerodynamic model verification and hypersonic panel algorithm selections have been built into SET and follow after using the END subcommand. The user can temporarily skip this portion of SET if he is not ready for analysis or simply reviewing the run schedule. The logic must however be processed prior to analysis.

The selected hypersonic panel methods are stored as part of the component geometry and can not be changed from run to run or configuration to configuration. They can be parameterically varied by making several analysis passes adding new runs each time and changing the analysis methods prior to each batch submittal. Analysis print provides a record of the methods used.

The standard print from analysis provides summary type data. If a hypersonic run is questionable, it can be reactived with the PRINT operand specified in the RESET subcommand, and detailed print will result. This will increase the number of output lines for that run by a factor of almost ten and is only recommended for diagnostic purposes.

The second sample session (pages 84 through 93) illustrates configuration assembly, run schedule definition and aerodynamic model validation for background analysis.

SAMPLE SESSIONS

        Precursor drag analysis and setup for background submittal are presented to
familiarize the analyst with these system activities.

FOREGROUND (SESSION 4-1)

        Review the VISCOUS and WAVEDRAG commands of section six prior to beginning
this session.

        A configuration is selected from the permanent file listing on screen 4-1 and
attached to the local file. Note the use of the "g" key to attach all components in
family 11.00 (i.e. 11.00-20.00). A list of the local file verifies the configuration
and the VISCOUS command is entered, fourth entry. Option 3 (the default) is used
to evaluate the surface area and volume using 51 equally spaced axial section cuts.
Screens 4-2 and 4-3 present the resulting perimeter and cross-section area
distribution. Component and total areas and volumes are also tabulated.

        The following message is then presented on the screen:

                0 EXIT
                1 SF DRAG
                2 EDIT

        Selecting option 1, the skin friction setup is completed as shown in screen
4-4. A surface roughness of 0.00000634 meters corresponding to carefully applied
mate paint (table 9) has been entered. For the altitudes of 0.0, 3048, and
6096 meters the user requests detailed print at sea level, M = 0.6 and h = 3048
meters, M = 1.2 and no printout at M = 1.6. The viscous-drag default parameters are
accepted for each component.

        Screens 4-5 and 4-6 present the output requested at M = 0.6 and 1.2, respectively.
Surface wetted areas are calculated in the viscous drag analysis using a component
strip integration as opposed to the total configuration axial section integration
of screens 4-2 and 4.3. The component wetted areas may differ slightly from those
of screen 4-7, since the later is based on screen 4-2. Screen 4-7 presents a
summary of the drag, surface area, and volume for the configuration in the local
file. The user ends the VISCOUS command with a "0" on screen 4-8.

```
             eeQeee
        fi'es
            :CMPN          NAME          TYPE    SYMM

             1.00   SIMPLE FUSELAGE       1       2
            11.00   FORWARD FUSELAGE      1       2
            12.00   MID FUSELAGE          1       2
            13.00   AFT FUSELAGE          1       2
            14.00   POD                   2       2
           101.00   SIMPLE WING           4       2
           121.00   WING                  4       2
           201.00   SIMPLE VERTICAL       3       1
           211.00   VERTICAL              3       1
           611.00   SLENDER BODY          7       2
           612.00   INTERF SHELL          5       2
        ssOKss
        attach 11g 121 211
        ssOKss
        file,l
            COMPN          NAME          TYPE    SYMM

            11.00   FORWARD FUSELAGE      1       2
            12.00   MID FUSELAGE          1       2
            13.00   AFT FUSELAGE          1       2
            14.00   POD                   2       2
           121.00   WING                  4       2
           211.00   VERTICAL              3       1
        ssOKss
        visc
        KEY = 1,2 OR 3
          1   = PLOT = NX,X(1),...,X(NX)
          2   = PLOT = NX,XB,XE
          3   = NO PLOT = NX=51 (ALL SURFACE FLAGED)
        3
```

Screen 4-1   Assembling work file configuration and initiating the
VISCOUS command
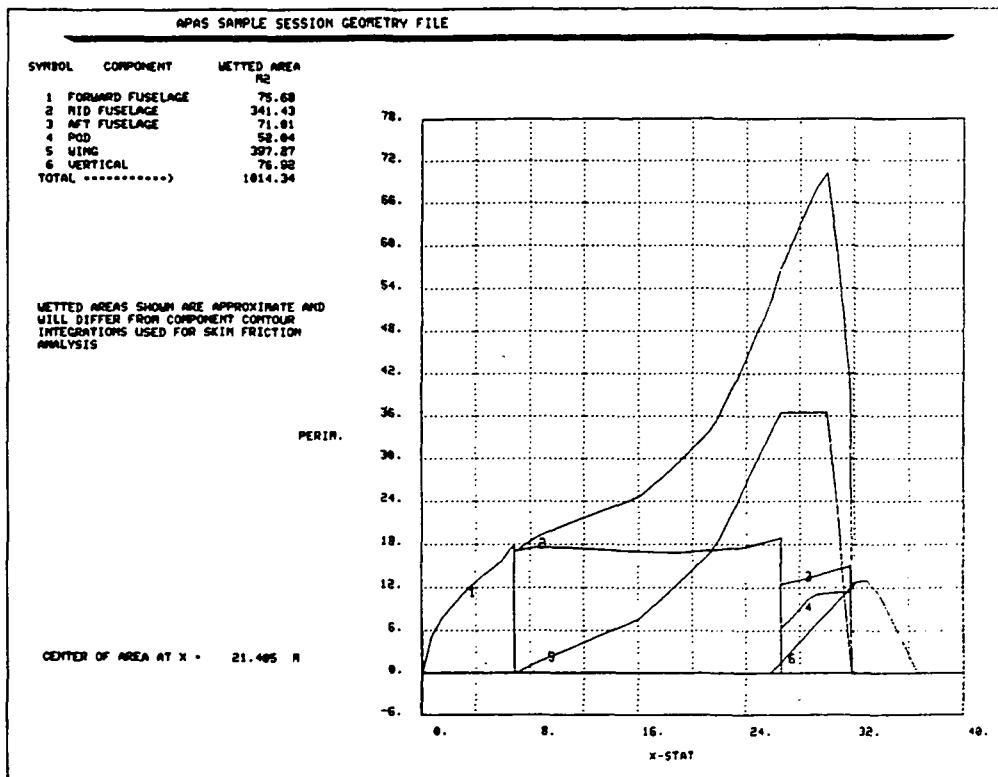
Screen 4-2   Perimeter distribution and wetted area

APAS SAMPLE SESSION GEOMETRY FILE

SYMBOL	COMPONENT	VOLUME M3
1	FORWARD FUSELAGE	73.79
2	MID FUSELAGE	555.10
3	AFT FUSELAGE	157.78
4	POD	40.78
5	WING	157.61
6	VERTICAL	5.10
TOTAL ···········)		990.16

52.

48.

44.

40.

36.

32.

28.

24.

X-AREA   20.

16.

12.

8.

4.

0.

-4.

CENTER OF VOLUME AT X =   19.603 M

0.   8.   16.   24.   32.   40.

X-STAT
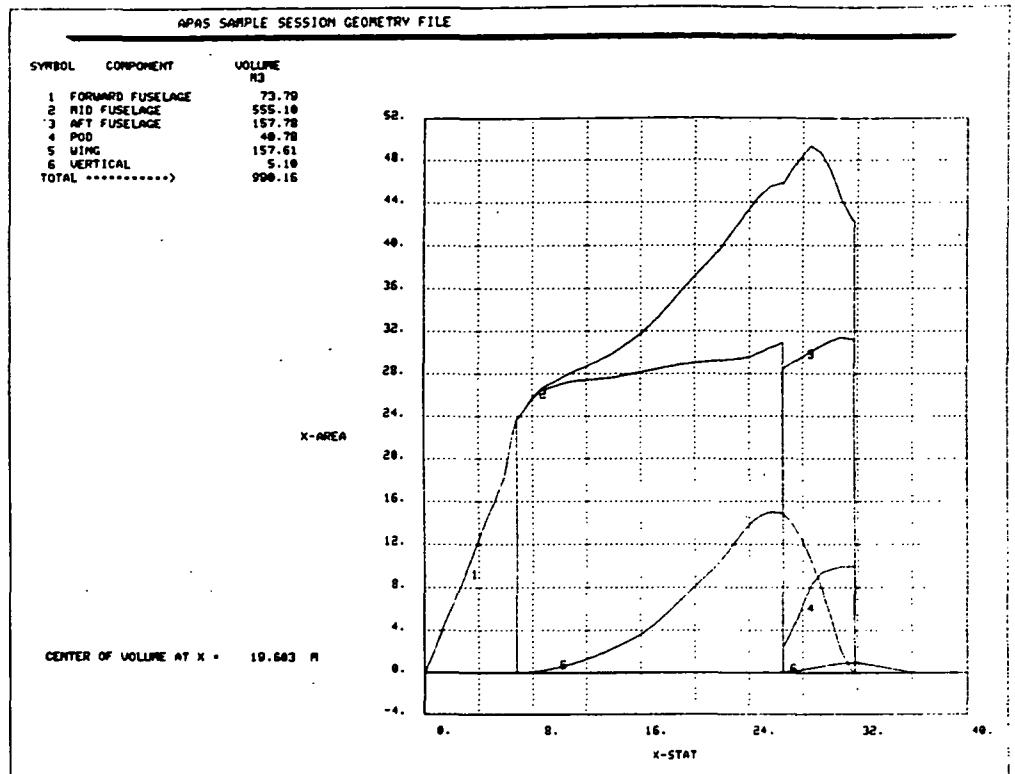
Screen 4-3 Area distribution and volume

APAS SAMPLE SESSION GEOMETRY FILE

SKIN FRICTION DRAG INPUT
INPUT MACH NUMBERS:
.6 1.2 1.6
INPUT SREF(M2):
249.91
ENTER SAND GRAIN HEIGHT (KS(M)) DEFAULT: 0.0
0.00000634
ENTER PRESS(NT/M2),TEMP(K),LISTING MACH NUMBER(0.0 FOR ALL) (DEFAULT IS NONE)
OR ENTER ALTITUDE(M),LISTING MACH NUMBER
ENTER CARRIAGE RETURN TO END
ENTER DATA FOR CASE 1
0 0.6
ENTER DATA FOR CASE 2
3048 1.2
ENTER DATA FOR CASE 3
6096
ENTER DATA FOR CASE 4

FORWARD FUSELAGE ENTER: XTRANS/LENG, FLAT PLATE 1 # AXIS-BODY 2 :
DEFAULTS : 0.01,2

            BODY FORM FACTOR   :   1.07688
            BODY T/C RATIO   :   0.12223
WING   ENTER: XTRANS/LENG, CK, FLAT PLATE 1 # AIRFOIL 2 :
DEFAULTS : 0.01,1.2,2

VERTICAL   ENTER: XTRANS/LENG, CK, FLAT PLATE 1 # AIRFOIL 2 :
DEFAULTS : 0.01,1.2,2

Screen 4-4 VISCOUS calculation input parameters

79

APAS SAMPLE SESSION GEOMETRY FILE

MACH: 0.600   ALT: 0. M   PRESS:101324.125 NT/M2   TEMP: 288.149 K   SREF: 249.910 M2   KS: 0.00000634 M

COMPONENT	WET SURF AREA M2	COMP LENGTH M	FF	X/L TRANS.	REYNOLDS NO.	CDF SMOOTH	CDF ROUGH	CDF USED
FORWARD FUSELAGE	540.2	31.750	1.077	0.010	4.43729E+08	0.00380	0.00375	0.00380
WING	126.4	20.100	1.100	0.010	2.80909E+08	0.00097	0.00096	0.00097
WING	123.6	12.573	1.129	0.010	1.75723E+08	0.00103	0.00103	0.00103
WING	50.0	8.695	1.146	0.010	1.21519E+08	0.00045	0.00044	0.00045
WING	83.0	5.707	1.137	0.010	7.97581E+07	0.00078	0.00078	0.00078
VERTICAL	77.2	4.808	1.048	0.010	6.71999E+07	0.00068	0.00069	0.00069

** TOTAL WET SURFACE AREA   =   1000.45 M2
** TOTAL SKIN FRICTION DRAG =   0.00771

Screen 4-5 VISCOUS detailed print at M=0.6

APAS SAMPLE SESSION GEOMETRY FILE

MACH: 1.200   ALT: 3048. M   PRESS: 69692.562 NT/M2   TEMP: 268.347 K   SREF: 249.910 M2   KS: 0.00000634 M

COMPONENT	WET SURF AREA M2	COMP LENGTH M	FF	X/L TRANS.	REYNOLDS NO.	CDF SMOOTH	CDF ROUGH	CDF USED
FORWARD FUSELAGE	540.2	31.750	1.077	0.010	6.68847E+08	0.00331	0.00318	0.00331
WING	126.4	20.100	1.100	0.010	4.23424E+08	0.00084	0.00081	0.00084
WING	123.6	12.573	1.129	0.010	2.64873E+08	0.00090	0.00087	0.00090
WING	50.0	8.695	1.146	0.010	1.83170E+08	0.00039	0.00038	0.00039
WING	83.0	5.707	1.137	0.010	1.20222E+08	0.00068	0.00066	0.00068
VERTICAL	77.2	4.808	1.048	0.010	1.01293E+08	0.00060	0.00058	0.00060

** TOTAL WET SURFACE AREA   =   1000.45 M2
** TOTAL SKIN FRICTION DRAG =   0.00671

Screen 4-6 VISCOUS detailed print at M=1.2

VISCOUS DRAG

			MACH NUMBERS		
ALTITUDE	TEMPERATURE	PRESSURE	0.60	1.20	1.60
0.0	288.149	.1013E+06	0.00771	0.00650	0.00577
3048.0	268.347	.6963E+05	0.00801	0.00671	0.00599
6096.0	248.564	.4660E+05	0.00835	0.00699	0.00624

NUMBER	NAME	SWET M2	VOLUME M3
11.00	FORWARD FUSELAGE	75.679	73.791
12.00	MID FUSELAGE	341.426	555.096
13.00	AFT FUSELAGE	71.009	157.785
14.00	POD	52.037	40.785
121.00	WING	383.077	157.611
211.00	VERTICAL	77.220	5.097
	TOTALS:	1000.448	990.163

SAND GRAIN HEIGHT: 0.00000634 M

REFERENCE AREA: 249.91 M2

Screen 4-7   VISCOUS summary print

Entering the WAVEDRAG command, second entry, a request is made for the supersonic Mach numbers to be calculated and the reference area, last two entries on screen 4-8. Screens 4-9 and 4-10 present WAVEDRAG output for the specified Mach numbers. Twenty five roll angles are calculated and the drag for each and the total drag are printed on the upper left. Area plots as a function of x are presented for 45 degree roll angle increments. Following the last Mach number, the WAVEDRAG command returns control to the **OK** mode, and the user is ready to exit or continue into analysis session 2. To initiate this effort either clear the work file using the CLEAR command and start at the top of screen 4-11 or attach only components 611.00 and 612.00 and start with the third entry (file,1) on screen 4-11. Note that the configuration including 611.00 and 612.00 could have been attached at the beginning of this session since VISCOUS and WAVEDRAG ignore analysis components.

81

```
                     X 0 EXIT
                     X 1 SF DRAG
                     X 2 EDIT
         ───►    0
                     XXOKXX
         ───►   wave
                     INPUT MACH NUMBERS:
         ──►  1.2 1.6
                     INPUT SREF(M2 ):
         ──►  249.91
```

Screen 4-8 Exiting VISCOUS and entering WAVEDRAG command

Screen 4-9 WAVEDRAG output at M=1.2
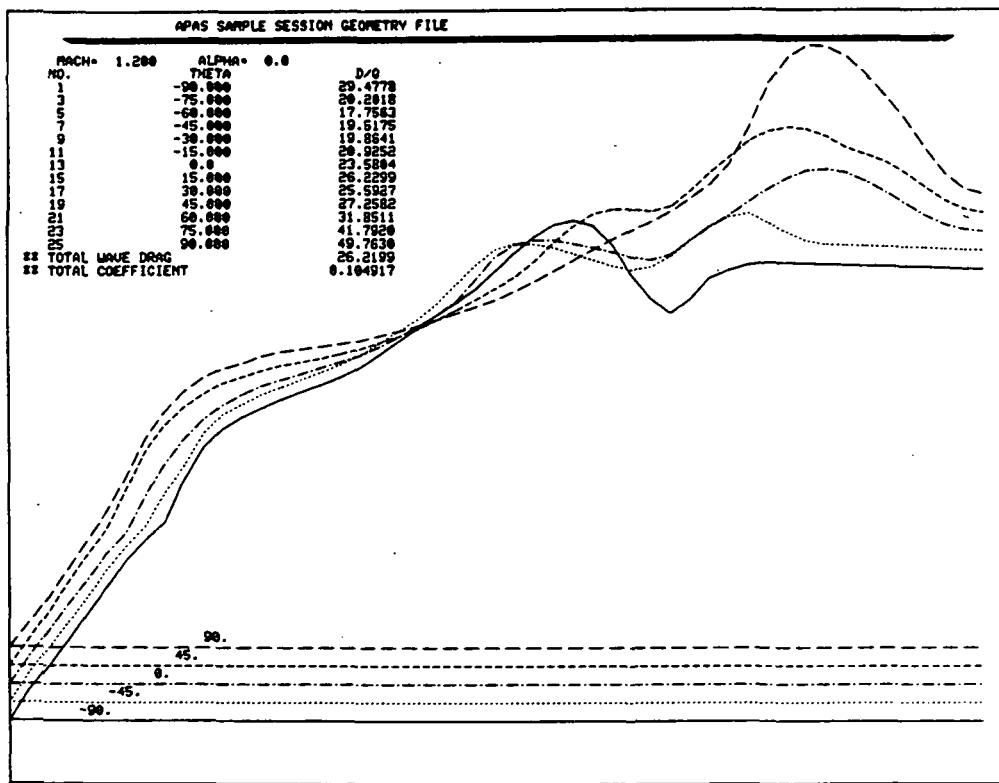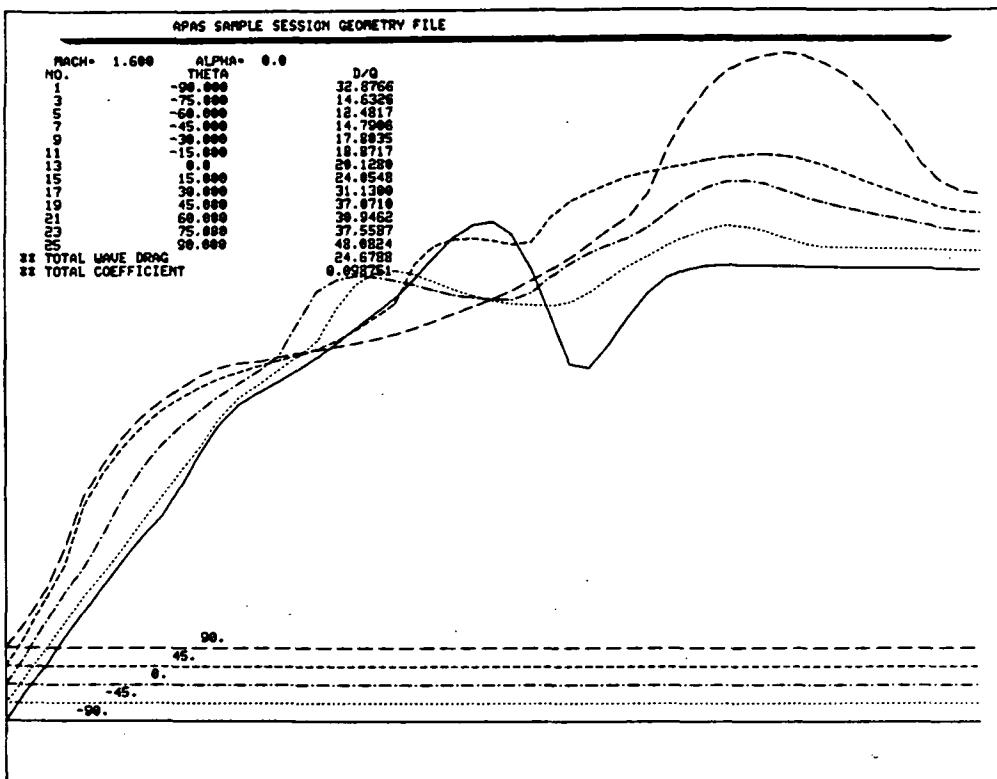
Screen 4-10   WAVEDRAG output at M=1.6

Review the SET command of section six prior to beginning this work session.

Subsonic-Supersonic Configuration

During this effort the user assembles a configuration in the local (work) file and then uses the SET command to define an analysis run schedule. Several of the subcommands of SET are demonstrated to familiarize the analyst with this activity.

In screen 4-11 the user attaches the digitized configuration developed in geometric input session 3-2 to the local file. The SET command of the system recognizes this as configuration 1 and requests the reference quantities to be used for aerodynamic coefficients.

To simplify run schedule preparation, the SET subcommand of SET allows the user to store up to twelve commonly used lists of run variables. Upon entering the SET subcommand (screen 4-11) the system requests the data to be stored in location one. The conditions typically entered are those that will be repetitively used. The analyst then proceeds to define additional sets two through four by calling them out directly as SET2, etc.

Set four is modified in screen 4-12 by defining input for three runs using the ADD subcommand of SET. A set may be deleted using the DELETE subcommand of SET, i.e. DEL,SET2 for example.

```
        ::OK::
    ─► files
        CORPN            NAME            TYPE    SYMM

          1.00   SIMPLE FUSELAGE          1       2
         11.00   FORWARD FUSELAGE         1       2
         12.00   MID FUSELAGE             1       2
         13.00   AFT FUSELAGE             1       2
         14.00   POD                      2       2
        101.00   SIMPLE WING              4       2
        121.00   WING                     4       2
        201.00   SIMPLE VERTICAL          3       1
        211.00   VERTICAL                 3       1
        611.00   SLENDER BODY             7       2
        612.00   INTERF SHELL             5       2
        ::OK::
    ─► attach 11 12 13 14 121 211 611g
        ::OK::
    ─► file,l
        CORPN            NAME            TYPE    SYMM

         11.00   FORWARD FUSELAGE         1       2
         12.00   MID FUSELAGE             1       2
         13.00   AFT FUSELAGE             1       2
         14.00   POD                      2       2
        121.00   WING                     4       2
        211.00   VERTICAL                 3       1
        611.00   SLENDER BODY             7       2
        612.00   INTERF SHELL             5       2
        ::OK::
    ─► set
        CONFIGURATION IN WORK FILE IS CONFIGURATION NUMBER:  1
        ENTER SREF,CBAR,SPAN:
    ─► 249.91,12.060,23.791
        ENTER XCG ,YCG ,ZCG :
    ─► 21.354,0.0,-0.635
        DEFAULT CONFIGURATION IS :  1

        ENTER THE FOLLOWING PARAMETERS IN THE INDICATED UNITS:
                 ALTITUDE(ALT)   :    METERS
        OR STAG PRESSURE(PR)     :    MT/M2
        & STAG TEMPERATURE(TEMP) :    KELVIN
                 ROUGHNESS (KS)  :    METERS
        :: SET ::
    ─► set
        ENTER LIST OF RUN VARIABLES FOR SET1
    ─► m(0.6),ks(0.00000634),alt(0),a(0 5 10 20)
        :: SET ::
    ─► set2 m(1.2) alt(6000) ks(0.00000634) a(0 5 10 20 30)
        :: SET ::
    ─► set3 m(20) alt(30480) a(0 5 10 20 30)
        :: SET ::
    ─► set4 mach(0.8) alt(30480) a(0 5 10 20)
        :: SET ::
```

Screen 4-11 Assembling a configuration and initiating
the SET command and subcommand

The subcommand ADD4 presents most of the parameters required for run 1. The 4 immediately after the word ADD refers to set4 of screen 4-11. The parameters in the run 1 ADD4 statement are in addition to set4 data and will override any redundant parameters. The sand grain height (ks) was input (table 9 under VISCOUS command description) by ADD since it is missing in set4. The second ADD4 statement creates run 2 and modifies the set4 Mach number from 0.8 to 1.6. Since roughness was not specified, the system request this information in the next entry. A run number will also be requested if one is not provided and will not allow duplicates.

```
** SET **
add4 run(1) ks(0.000000634)
RUN:    1 REFERENCE VALUES:
  MACH    •    0.800  PRESSURE•  69683.687  TEMP   •   268.340  ALTITUDE•   3049.000
  BETA    •    0.0     P       •     0.0     Q      •    0.0     R        •    0.0
  D1      •    0.0     D2      •     0.0     D3     •    0.0     D4       •    0.0
  D5      •    0.0     D6      •     0.0     KS     •    0.0000
  INDEPENDANT VARIABLE: ALPHA           4 POINTS
           0.0          5.000     10.000    20.000
** SET **
add4 run(2) mach(1.6)
  ENTER VALUE FOR KS          :
0.00000634
RUN:    2 REFERENCE VALUES:
  MACH    •    1.600  PRESSURE•  69683.687  TEMP   •   268.340  ALTITUDE•   3049.000
  BETA    •    0.0     P       •     0.0     Q      •    0.0     R        •    0.0
  D1      •    0.0     D2      •     0.0     D3     •    0.0     D4       •    0.0
  D5      •    0.0     D6      •     0.0     KS     •    0.0000
  INDEPENDANT VARIABLE: ALPHA           4 POINTS
           0.0          5.000     10.000    20.000
** SET **
```

Screen 4-12   Creating a run schedule using the ADD subcommand

In the first entry of screen 4-13, the RESET subcommand of SET is used to modify run 1 by changing the Mach number to 1.6 (to match run 2) and deflecting the flap 10 degrees. This change reduces the computation costs for this analysis case, since only one Mach solution will be required in the subsonic-supersonic evaluation.

```
** SET **
reset run(1) m(1.6) d1(10)
RUN:    1 REFERENCE VALUES:
  MACH    :    1.600  PRESSURE•  69683.687  TEMP   •   268.340  ALTITUDE•   3049.000
  BETA    :    0.0     P       :    0.0     Q      :    0.0     R        :    0.0
  D1      :   10.0000  D2      :    0.0     D3     :    0.0     D4       :    0.0
  D5      :    0.0     D6      :    0.0     KS     :    0.0000
  INDEPENDANT VARIABLE: ALPHA           4 POINTS
           0.0          5.000     10.000    20.000
** SET **
l
RUN:  1          SET        LINEAR        SOURCES
  MACH   :  1.6000      PRESSURE:  69684.     TEMP   :  268.34     ALTITUDE:  3049.0
  CONFIG :  1    IND. VAR.: ALPHA
           .0          5.0000     10.000    20.000
INITIAL CONDITIONS:
  D1     :  10.000      KS     :  .63400E-05

RUN:  2          SET        LINEAR        SOURCES
  MACH   :  1.6000      PRESSURE:  69684.     TEMP   :  268.34     ALTITUDE:  3049.0
  CONFIG :  1    IND. VAR.: ALPHA
           .0          5.0000     10.000    20.000
INITIAL CONDITIONS:
  KS     :  .63400E-05
** SET **
l,c
CONFIGURATION : 1
   11.00  FORWARD FUSELAGE    BODY
   12.00  MID FUSELAGE        BODY
   13.00  AFT FUSELAGE        BODY
   14.00  POD                 OFF BODY
  121.00  WING                SURFACE
          SYMBOL    FLAP       TYPE
          D1          1        SYM
  211.00  VERTICAL            SURFACE
          D2          2        ANTISYM
  611.00  SLENDER BODY        SLN BODY
  612.00  INTERF SHELL        SHELL
** SET **
```

Screen 4-13   Modifying an existing run and listing the
run schedule and configuration

In the next two entries on screen 4-13, a list of the runs and configurations in the file are displayed. Note that the system assigns flap designations to the user-defined flap numbers.

On screen 4-14, the entry "end" initiates the conversational mode of the SET command. The user is now given the opportunity to examine the aerodynamic model. Only questions that are pertinent to the Mach numbers of the run schedule are asked. Configuration verification must be performed prior to initial analysis in order to fix component parameters for viscous drag. Subsequent analysis using these components does not require model revalidation. The answer to the first question of screen 4-14 is then "no" instead of "yes".

```
           ** SET **
   ───►  end
        ?  CHECK CONFIGURATION MODELS: YES OR NO
   ───►  yes

        ***** CONFIGURATION  1 LIFTING SOLUTION *****
                ENTER "Y" FOR DISPLAYS  , "N" TO SKIP


   ───►  yes
             DISPLAY PANEL MODEL FOR CONFIGURATION  1
             YES OR NO :
   ───►  yes
```

Screen 4-14 Ending SET and initiating analysis
model verification

The reference quantities and paneling, and the wing camber, thickness and twist are displayed or screens 4-15 through 4-18 respectively for review. In the present case they are accepted as satisfactory. On screen 4-19 the viscous-drag parameters for each component are entered by using carriage returns to accept the default values shown. The boundary layer transition point, the airfoil thickness correction factor of table 10 and the type of estimation (flat plate, axisymmetric body or airfoil) are specified. The default values are selected for full scale analysis here. For wind-tunnel evaluation, the transition point is usually fixed at the model grit line or natural transition point if known.

The input file for configuration 1 is now ready for background processing as discussed in section 5.
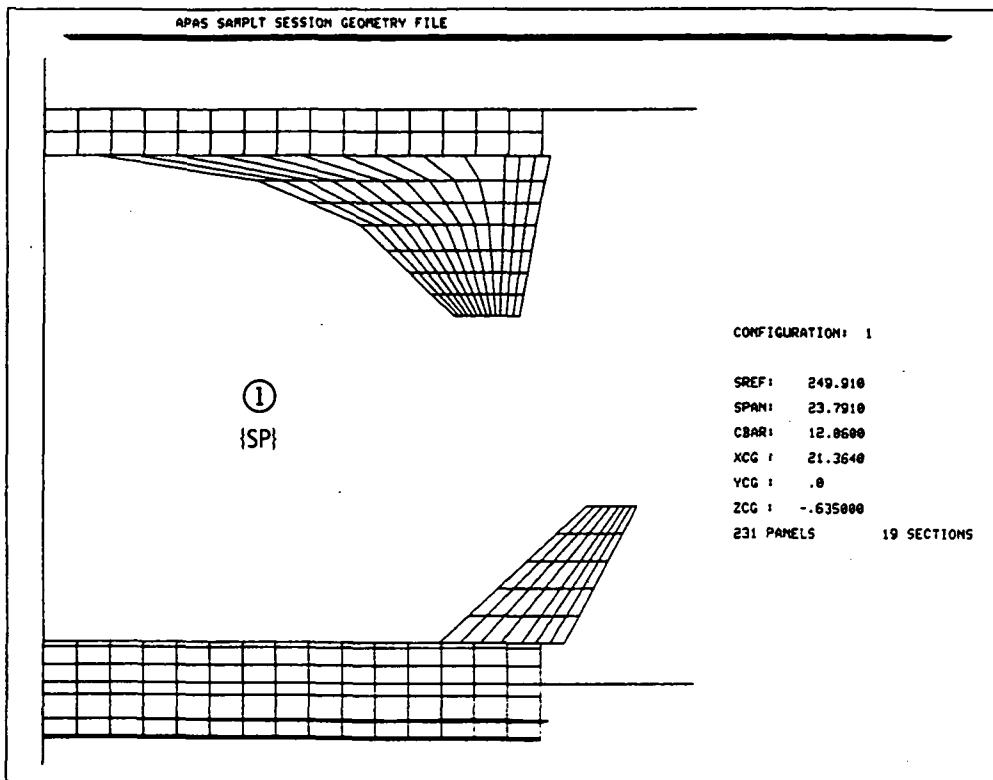
Screen 4-15   Subsonic-supersonic analysis paneling
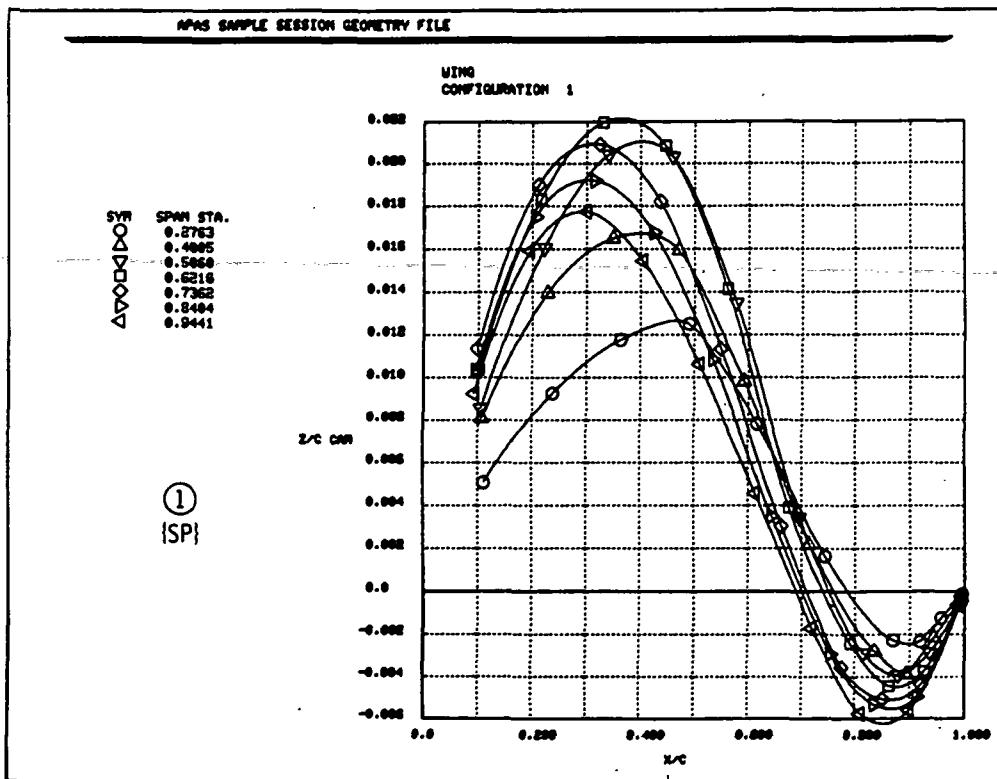
Screen 4-16   Wing camber distribution
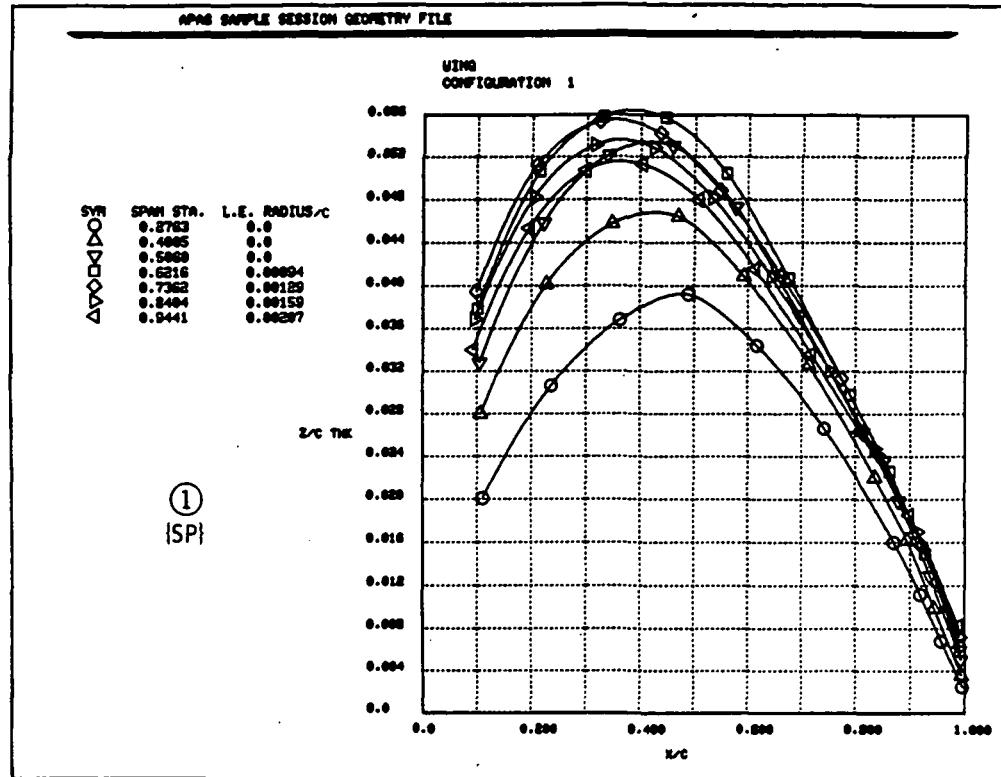
Screen 4-17 Wing thickness distribution
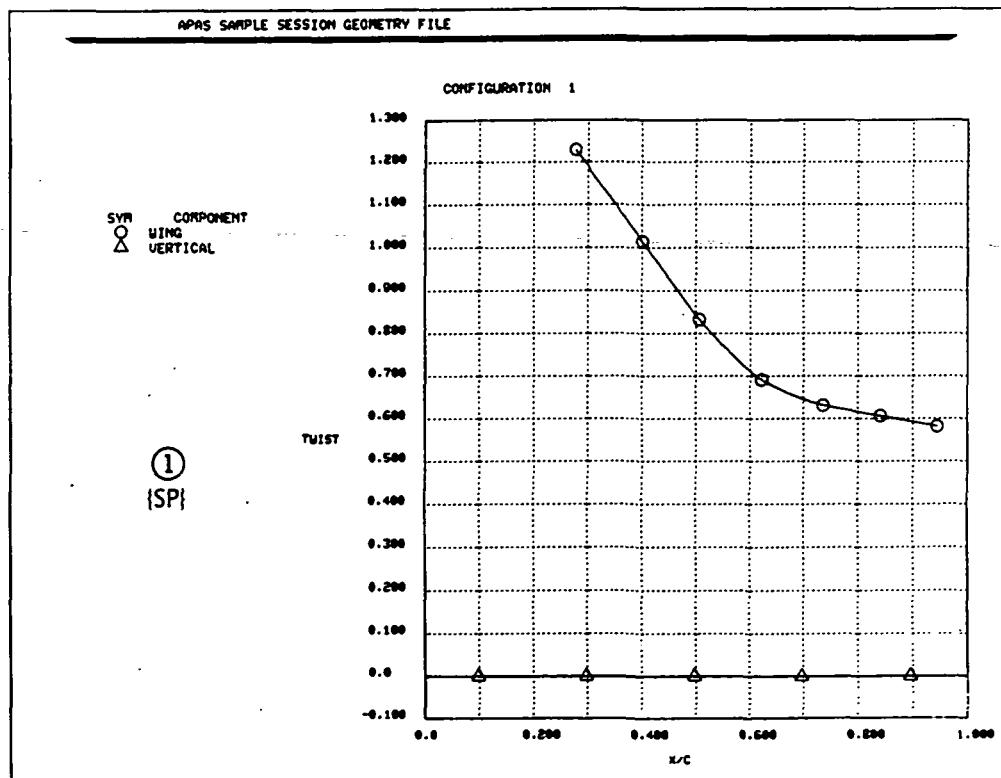
Screen 4-18 Surface twist distribution

```
***** CONFIGURATION  1 VISCOUS DRAG PARAMETERS *****

     FORWARD FUSELAGE ENTER: XTRANS/LENG, FLAT PLATE 1 % AXIS-BODY 2 :
     DEFAULTS : 0.01, 2

     WING            ENTER: XTRANS/LENG, CK, FLAT PLATE 1 % AIRFOIL 2 :
     DEFAULTS : 0.010,1.20, 2

     VERTICAL        ENTER: XTRANS/LENG, CK, FLAT PLATE 1 % AIRFOIL 2 :
     DEFAULTS : 0.010,1.20, 2

     **OK**
```

Screen 4-19 Defining viscous drag parameters

Hypersonic Configuration:

The same configuration is commonly used for both subsonic-supersonic and
hypersonic analysis. In the present case however, a body flap can only be simulated
for the latter case. A second configuration which includes this component is thus
attached to the local as shown on Screen 4-20.

```
file,1
     COMPN             NAME          TYPE    SYMM

      11.00   FORWARD FUSELAGE        1       2
      12.00   MID FUSELAGE            1       2
      13.00   AFT FUSELAGE            1       2
      14.00   POD                     2       2
     121.00   WING                    4       2
     211.00   VERTICAL                3       1
     400.00   BODY FLAP               1       2
     **OK**
```

Figure 4-20 Hypersonic configuration

A run schedule is created in a similar way to the subsonic-supersonic example.
Mach number of 10.0 is selected and automatically flags the run as hypersonic.
A sand grain height is not required.

APAS next interrogates the user concerning hypersonic panel algorithm assignments and aerodynamic model acceptance. The response must be affirmative since this is the initial examination for configuration 2.

Screen 4-21 indicates the analysis method selection for the fuselage and pod components. Starting with the nose, the "1" response to the first question supplies a list of the available compression analysis methods. The user selects the default. The associated Newtonian correlation factor, k, is then requested and the default value of 1.8* is accepted.

```
FORWARD FUSELAGE  NOSE         :
RECOMMENDED IMPACT METHOD: MODIFIED NEWTONIAN
ENTER : NUMBER : OF DIFFERENT METHOD
        RETURN : FOR RECOMMENDED METHOD
        L      : TO LIST METHODS
METHODS FOR IMPACT ANALYSIS:

         1 :  MODIFIED NEWTONIAN
         2 :  MODIFIED NEWTONIAN  +PRANDTL-MEYER
         3 :  TANGENT WEDGE
         4 :  TANGENT WEDGE EMP.
         5 :  TANGENT CONE EMP.
         6 :  OSU BLUNT-BODY EMP.
         7 :  VAN DYKE UNIFIED METHOD
         8 :  BLUNT BODY SKIN FRICTION
         9 :  SHOCK EXPANSION METHOD
        10 :  FREE MOLECULAR FLOW
        11 :  INPUT PRESSURE COEF.
        12 :  HANKEY FLAT-SURFACE EMP.
        13 :  DELTA WING EMP.
        14 :  DAHLEN-BUCK EMP.
        15 :  BLAST-WAVE PRESSURE INCREMENTS
        16 :  MODIFIED TANGENT WEDGE
ENTER ANALYSIS METHOD NUMBER:

IMPACT ANALYSIS METHOD:MODIFIED NEWTONIAN
ENTER VALUE FOR K (DEFAULT:   1.8000) :

FORWARD FUSELAGE  NOSE         :
RECOMMENDED SHADOW METHOD: PRANDTL-MEYER EMP.
ENTER : NUMBER : OF DIFFERENT METHOD
        RETURN : FOR RECOMMENDED METHOD
        L      : TO LIST METHODS
METHODS FOR SHADOW ANALYSIS:

         1 :  NEWTONIAN
         2 :  MODIFIED NEWTONIAN  +PRANDTL-MEYER
         3 :  PRANDTL-MEYER EMP.
         4 :  OSU BLUNT-BODY EMP.
         5 :  VAN DYKE UNIFIED METHOD
         6 :  HIGH MACH NUMBER BASE PRESSURE
         7 :  SHOCK EXPANSION METHOD
         8 :  INPUT PRESSURE COEF.
         9 :  FREE MOLECULAR FLOW
ENTER ANALYSIS METHOD NUMBER:

ENTER VALUE OF Q/QINF (DEFAULT:    1.0000) :

FORWARD FUSELAGE  BODY         :
RECOMMENDED IMPACT METHOD: TANGENT CONE EMP
ENTER : NUMBER : OF DIFFERENT METHOD
        RETURN : FOR RECOMMENDED METHOD
        L      : TO LIST METHODS

FORWARD FUSELAGE  BODY         :
RECOMMENDED SHADOW METHOD: PRANDTL-MEYER EMP.
ENTER : NUMBER : OF DIFFERENT METHOD
        RETURN : FOR RECOMMENDED METHOD
        L      : TO LIST METHODS

ENTER VALUE OF Q/QINF (DEFAULT:    1.0000) :


MID FUSELAGE      BODY         :
RECOMMENDED IMPACT METHOD: TANGENT CONE EMP
ENTER : NUMBER : OF DIFFERENT METHOD
        RETURN : FOR RECOMMENDED METHOD
        L      : TO LIST METHODS

MID FUSELAGE      BODY         :
RECOMMENDED SHADOW METHOD: PRANDTL-MEYER EMP.
ENTER : NUMBER : OF DIFFERENT METHOD
        RETURN : FOR RECOMMENDED METHOD
        L      : TO LIST METHODS

ENTER VALUE OF Q/QINF (DEFAULT:    1.0000) :

AFT FUSELAGE      BODY         :
RECOMMENDED IMPACT METHOD: TANGENT CONE EMP
ENTER : NUMBER : OF DIFFERENT METHOD
        RETURN : FOR RECOMMENDED METHOD
        L      : TO LIST METHODS

AFT FUSELAGE      BODY         :
RECOMMENDED SHADOW METHOD: PRANDTL-MEYER EMP.
ENTER : NUMBER : OF DIFFERENT METHOD
        RETURN : FOR RECOMMENDED METHOD
        L      : TO LIST METHODS

ENTER VALUE OF Q/QINF (DEFAULT:    1.0000) :

AFT FUSELAGE      BLUNT END     :
RECOMMENDED IMPACT METHOD: MODIFIED NEWTONIAN
ENTER : NUMBER : OF DIFFERENT METHOD
        RETURN : FOR RECOMMENDED METHOD
        L      : TO LIST METHODS

IMPACT ANALYSIS METHOD:MODIFIED NEWTONIAN
ENTER VALUE FOR K (DEFAULT:   1.2000) :

AFT FUSELAGE      BLUNT END     :
RECOMMENDED SHADOW METHOD: HIGH MACH NUMBER BASE PRESSURE
ENTER : NUMBER : OF DIFFERENT METHOD
        RETURN : FOR RECOMMENDED METHOD
        L      : TO LIST METHODS

ENTER VALUE OF Q/QINF (DEFAULT:    1.0000) :


POD               BODY         :
RECOMMENDED IMPACT METHOD: TANGENT CONE EMP
ENTER : NUMBER : OF DIFFERENT METHOD
        RETURN : FOR RECOMMENDED METHOD
        L      : TO LIST METHODS

POD               BODY         :
RECOMMENDED SHADOW METHOD: PRANDTL-MEYER EMP.
ENTER : NUMBER : OF DIFFERENT METHOD
        RETURN : FOR RECOMMENDED METHOD
        L      : TO LIST METHODS

ENTER VALUE OF Q/QINF (DEFAULT:    1.0000) :

POD               BLUNT END     :
RECOMMENDED IMPACT METHOD: MODIFIED NEWTONIAN
ENTER : NUMBER : OF DIFFERENT METHOD
        RETURN : FOR RECOMMENDED METHOD
        L      : TO LIST METHODS

IMPACT ANALYSIS METHOD:MODIFIED NEWTONIAN
ENTER VALUE FOR K (DEFAULT:   1.2000) :

POD               BLUNT END     :
RECOMMENDED SHADOW METHOD: HIGH MACH NUMBER BASE PRESSURE
ENTER : NUMBER : OF DIFFERENT METHOD
        RETURN : FOR RECOMMENDED METHOD
        L      : TO LIST METHODS

ENTER VALUE OF Q/QINF (DEFAULT:    1.0000) :
```

Screen 4-21 Hypersonic analysis methods for the fuselage and pod

*Part I, page 102

90

Again, using the "1" response for the expansion analysis, a list of available shadow methods is displayed. The empirical Prandtl-Meyer expansion default is accepted. There are no other input parameters required for this method. The default value of 1.0 is selected for the ratio of local to free stream dynamic pressure and the setup goes on to the main part of the forward fuselage.

In the remainder of the panel algorithm assignments shown on screens 4-21 and 4-22, each body and surface is broken down, and analysis methods for each piece are selected. Note that since the fuselage components were consecutively numbered, a blunt base was not constructed until the aft fuselage and pod were set. The default methods for a surface with a flap are the ones shown here. If the SHKEP operand is used when setting up a given run they will be superseded by shock-expansion analysis at the time of analysis. After defining the hypersonic panel methods for each component, the user examines the finite element model, using the last two entries on screen 4-22. Typical views are presented on screens 4-23 and 4-24.

The input file for configuration 2 is now ready for background analysis.

```
WING              LEADING EDGE:
RECOMMENDED IMPACT METHOD: MODIFIED NEWTONIAN
ENTER : NUMBER : OF DIFFERENT METHOD
         RETURN : FOR RECOMMENDED METHOD
         L      : TO LIST METHODS

IMPACT ANALYSIS METHOD:MODIFIED NEWTONIAN
ENTER VALUE FOR K (DEFAULT:   1.8000) :

WING              LEADING EDGE:
RECOMMENDED SHADOW METHOD: PRANDTL-MEYER EXP.
ENTER : NUMBER : OF DIFFERENT METHOD
         RETURN : FOR RECOMMENDED METHOD
         L      : TO LIST METHODS

ENTER VALUE OF Q/QINF (DEFAULT:    1.0000) :

WING              SURFACE   :
RECOMMENDED IMPACT METHOD: TANGENT WEDGE EXP.
ENTER : NUMBER : OF DIFFERENT METHOD
         RETURN : FOR RECOMMENDED METHOD
         L      : TO LIST METHODS

WING              SURFACE   :
RECOMMENDED SHADOW METHOD: PRANDTL-MEYER EXP.
ENTER : NUMBER : OF DIFFERENT METHOD
         RETURN : FOR RECOMMENDED METHOD
         L      : TO LIST METHODS

ENTER VALUE OF Q/QINF (DEFAULT:    1.0000) :

WING              BLUNT T.E. :
RECOMMENDED IMPACT METHOD: MODIFIED NEWTONIAN
ENTER : NUMBER : OF DIFFERENT METHOD
         RETURN : FOR RECOMMENDED METHOD
         L      : TO LIST METHODS

IMPACT ANALYSIS METHOD:MODIFIED NEWTONIAN
ENTER VALUE FOR K (DEFAULT:   1.8000) :

WING              BLUNT T.E. :
RECOMMENDED SHADOW METHOD: HIGH MACH NUMBER BASE PRESSURE
ENTER : NUMBER : OF DIFFERENT METHOD
         RETURN : FOR RECOMMENDED METHOD
         L      : TO LIST METHODS

ENTER VALUE OF Q/QINF (DEFAULT:    1.0000) :
```

```
VERTICAL          SURFACE    :
RECOMMENDED IMPACT METHOD: MODIFIED NEWTONIAN
ENTER : NUMBER : OF DIFFERENT METHOD
         RETURN : FOR RECOMMENDED METHOD
         L      : TO LIST METHODS

IMPACT ANALYSIS METHOD:MODIFIED NEWTONIAN
ENTER VALUE FOR K (DEFAULT:   1.8000) :

VERTICAL          SURFACE    :
RECOMMENDED SHADOW METHOD: PRANDTL-MEYER EXP.
ENTER : NUMBER : OF DIFFERENT METHOD
         RETURN : FOR RECOMMENDED METHOD
         L      : TO LIST METHODS

ENTER VALUE OF Q/QINF (DEFAULT:    1.0000) :

BODY FLAP         SURFACE    :
RECOMMENDED IMPACT METHOD: TANGENT WEDGE EXP.
ENTER : NUMBER : OF DIFFERENT METHOD
         RETURN : FOR RECOMMENDED METHOD
         L      : TO LIST METHODS
4
BODY FLAP         SURFACE    :
RECOMMENDED SHADOW METHOD: PRANDTL-MEYER EXP.
ENTER : NUMBER : OF DIFFERENT METHOD
         RETURN : FOR RECOMMENDED METHOD
         L      : TO LIST METHODS
3
ENTER VALUE OF Q/QINF (DEFAULT:    1.0000) :

DO YOU WISH TO SEE CONFIGURATION  2
YES OR NO :
yes
INPUT YAW,PITCH,ROLL ANGLES FOR DISPLAY:
60-30 30
```

Screen 4-22 Hypersonic methods for the wing, vertical tail and body flap


```
APAS SAMPLE SESSION GEOMETRY FILE

YAW  PITCH  ROLL
60.0  -30.0  30.0




: 1 VIEW     :
: E END      :
: ENTER COMMAND:
INPUT YAW,PITCH,ROLL ANGLES FOR DISPLAY:
60 0 90


          ①

         |SP|
```
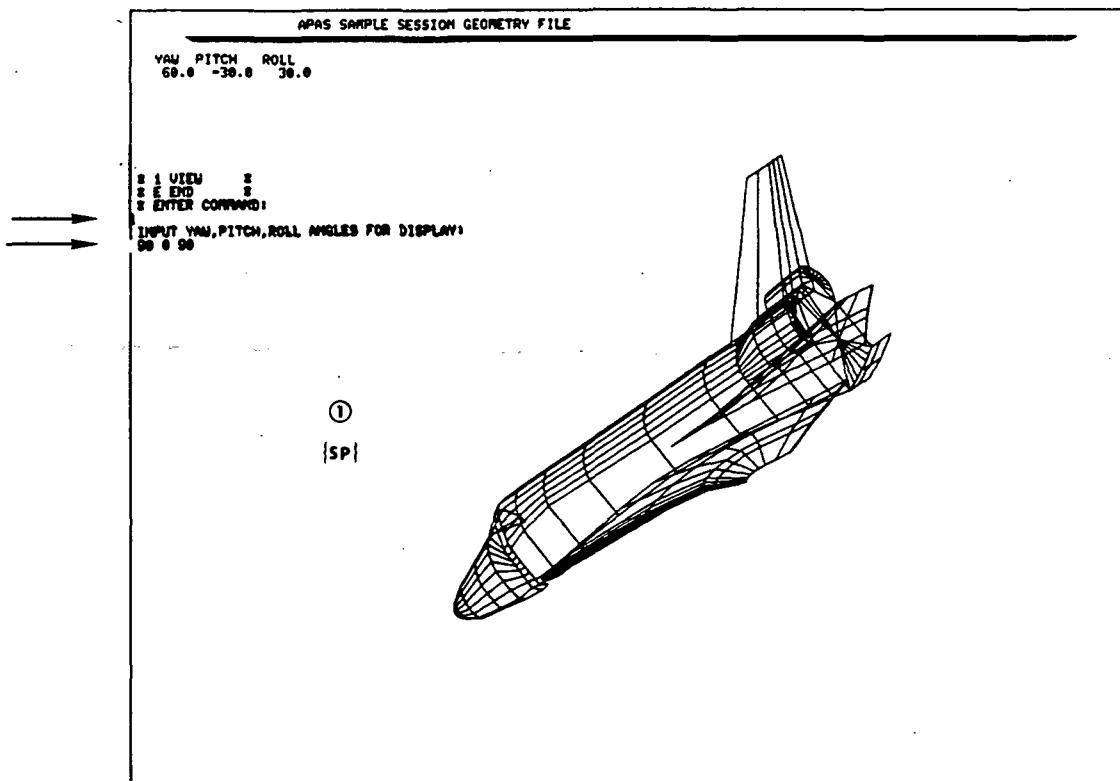
Screen 4-23 Orthographic projection of the hypersonic geometry model
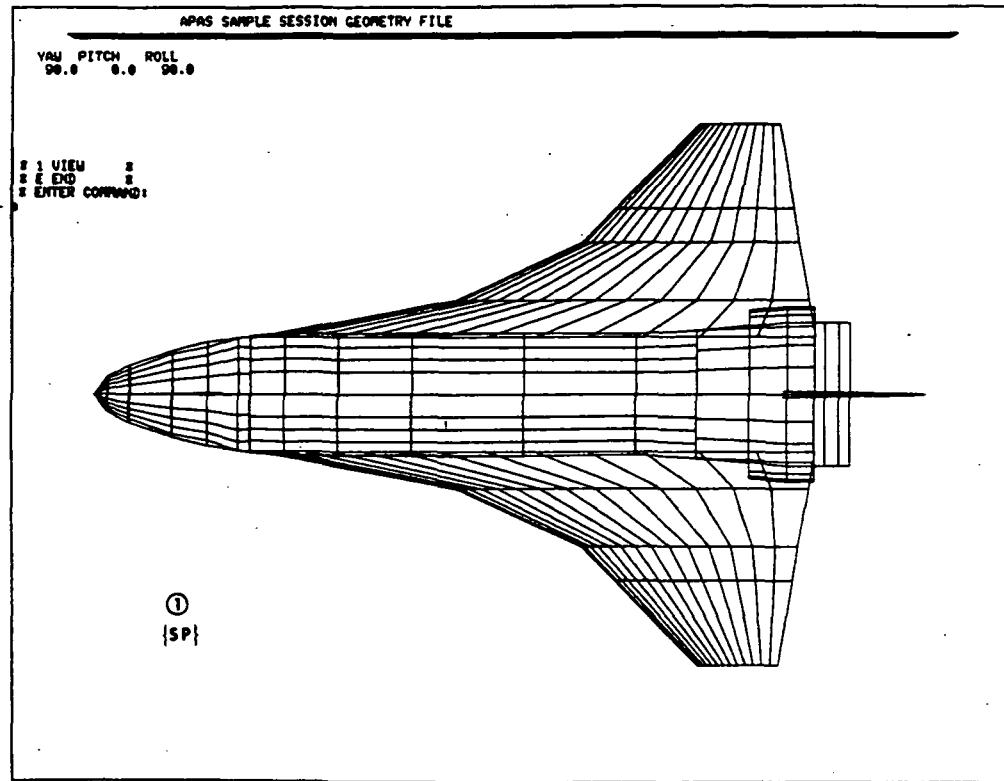
Screen 4-24 Top view of the hypersonic geometry model

Section 5

ANALYSIS OUTPUT

Foreground (interactive) analysis results are discussed in section 4 in order to correlate them with directives to prompts and will not be repeated.

Background analysis results are available in two forms: detailed print data and output file storage of forces, moments, and pressures of each specified vehicle condition for interactive display.

The most commonly used printed results are discussed initially. More specialized information which can be used to uncover problems is subsequently considered. The output display command PLOT, and its subcommands are then described to introduce the user to their capabilities. Sample sessions illustrating various PLOT subcommands is provided to familiarize the user with generating displays of the analysis results.

PRINT

APAS analysis is structured to minimize repetitive calculations. Processing and printout are in the same order and as follows.

Configuration C_i

    Mach number independent

        1) Slender body solutions
        2) Wetted areas

    Place runs in numerical order Mach number

        Run UDP solution for Mach number M_j
        Run wave drag due to volume for M_j

        Calculate force & pressure for run R_k at M_j

            Run wave drag due to lift for R_k
            Run viscous drag for R_k
            Calculate & store total forces and moments for R_k

        Cycle on runs until a new Mach number comes up (cycle on k)

    Cycle on Mach numbers until all runs for configuration are done (cycle on j)

Cycle on configuration (cycle on i)

A detailed output variable glossary is presented in appendix C for decoding printed results. Figure 5-1 presents slender body solution results. Each slender body of the configuration has similar output. A cursory examination of the force coefficients should be made to identify obvious problems such as negative lift, positive side force, etc.

A component summary of the configuration surface area and volume obtained from a cutting plane analysis is presented on figure 5-2. These results are similar to those from foreground analysis and will differ slightly from the contour integration skin friction results of figure 5-7.

General output of the subsonic-supersonic panel solution is shown in figure 5-3. The reference data should correspond to SET input data. The symmetry codes should be one (1) except for the centerline vertical and antisymmetric surfaces such as skewed wings which are zero (0). Surface lateral extent and the number of spanwise panels should be verified.

Users typically scan subsonic-supersonic analysis for the complete configuration forces and moments (figure 5-4). Unit solutions for symmetrical (longitudinal) characteristics are printed first followed by antisymmetrical (lateral-directional) results.

Supersonic wave drag due to volume is then printed (figure 5-5). These results should be the same as the WAVEDRAG command interactive analysis. The next three pages present the lifting wave drag for three angles of attack. Figure 5-6 present the results of one calculation.

The evaluation is then followed by the viscous-drag solution (figure 5-7). The results will be the same as those from the VISCOUS command interactive analysis.

Figure 5-8 presents a six component data summary of the subsonic-supersonic analysis as a function of angle of attack or sideslip. Results are presented for the aerodynamic characteristics with and without edge (leading and tip) vortex consideratons. The drag results do not include friction or wave drag due to volume and correspond to zero (CD0), one hundred percent (CD100), or attainable suction (CDL) drag due to lift.

Typical hypersonic analysis results are presented on figures 5-9 through 5-12. Six component aerodynamic characteristics are evaluated in a component buildup format. An initial page, (figure 5-9) presents the breakdown of the configuration and the flap symbols (if any) applied to the control surfaces.

The analysis is processed component by conponent for each run. The output is similar to that used in the hypersonic arbitrary body program, reference 3. Surface area and volume characteristics and panel compression/expansion algorithms are presented for each component followed by its forces and moments (figure 5-11). Complete configuration characteristics are then summarized (figure 5-12). Note that the results are for air and the flap has been calculated without shock expansion algorithms.

APAS SAMPLE SESSION GEOMETRY FILE

SREF (M2)	SPAN (M)	CBAR (M)	X-CG (M)	Y-CG (M)	Z-CG (M)
249.9100	23.7910	12.0600	21.3540	0.0	-0.6350

BC	DESC	CY	CL	CLL	CM	CN
1	AL=0	-0.00000	0.02825	-0.00000	0.05555	-0.00000
2	AL=1	0.00000	0.00792	0.00000	0.00535	0.00000
3	JB=1	-0.00002	0.79243	0.00000	-0.78205	-0.00001
4	BE=1	-0.00707	0.00000	0.00000	-0.00000	-0.00291
5	PB=1	-0.04479	0.00923	-0.00275	-0.00450	0.00176
6	RB=1	0.30131	-0.01009	0.01052	-0.00706	-0.22640

X	S	SPX	SFPX	WXL	CNB1	CNB2	SPPXR
0.000	0.00000	0.0	11.09628	0.00003	0.0	0.0	11.09628
0.510	0.00143	0.05538	4.73393	0.04349	-0.01259	0.00285	1.01427
1.527	0.00489	0.09778	-0.89088	0.07807	-0.04246	0.00401	-0.59902
2.286	0.00705	0.09231	-1.68680	0.09615	-0.05459	0.00381	0.10348
4.572	0.01417	0.11941	-0.02370	0.13441	-0.05852	0.00389	0.47133
6.323	0.02162	0.11944	-0.10122	0.15292	0.08098	0.00348	-0.89094
6.858	0.02355	0.09954	-0.42057	0.15857	0.12691	0.00328	-1.94629
8.647	0.02631	0.04191	-1.64928	0.16600	0.07996	0.00222	-0.31245
17.595	0.02829	0.00653	0.87715	0.16643	0.00322	0.00030	0.00291
24.753	0.02967	0.01579	0.23818	0.16958	0.00391	0.00079	0.03410
25.768	0.03022	0.01719	1.04351	0.17212	-0.13447	0.00090	0.20076
26.542	0.03064	0.05716	1.44867	0.17434	-0.22401	0.00258	3.83406
27.947	0.03637	0.10831	1.07900	0.20365	-0.05327	0.00602	-0.98409
29.146	0.03978	0.06172	-0.32064	0.22971	0.13513	0.00476	-1.53435
30.538	0.04104	0.01357	-2.17424	0.24116	-0.03887	0.00070	-0.66423
31.750	0.04105	-0.01285	0.04297	0.23471	-0.05333	-0.00164	0.09318

SLENDER BODY SOLUTION HAS BEEN CALCULATED - COMPUTATION TIME 13.938 SEC.

Figure 5-1 Slender body solution

VISCOUS DRAG PROGRAM

APAS SAMPLE SESSION GEOMETRY FILE

NUMBER	COMPONENT	WETTED AREA (M2)	VOLUME (M3)
11.00	FORWARD FUSELAGE	75.68	73.79
12.00	MID FUSELAGE	341.42	555.09
13.00	AFT FUSELAGE	71.01	157.79
14.00	FOD	52.04	40.79
121.00	WING	397.27	157.61
211.00	VERTICAL	76.92	5.10
	TOTAL:	1014.34	990.16

Figure 5-2 Viscous solution wetted area and volume summary

UNIFIED DISTRIBUTED PANEL PROGRAM
APAS SAMPLE SESSION GEOMETRY FILE

SREF (M2)	SPAN (M)	CBAR (M)	X-CG (M)	Y-CG (M)	Z-CG (M)
249.9100	23.7910	12.0600	21.3540	0.0	-0.6350

COMPONENT NAME	TYPE	SYMMETRY	SEMI-SPAN	INCIDENCE	SPANWISE PANELS	ACTIVE
INTERF SHELL	5	1	9.9575	0.0	7	1
WING	4	1	11.5764	0.0	7	1
VERTICAL	3	0	8.0299	0.0	5	1

COMPONENT: INTERF SHELL   WILL BE CALCULATED WITH VORTEX LIFT OFF
COMPONENT: WING   WILL BE CALCULATED WITH VORTEX LIFT ON
COMPONENT: VERTICAL   WILL BE CALCULATED WITH VORTEX LIFT OFF

Figure 5-3 Lifting surface solution header page

ETA	CHORD	TWIST(DEG)	CN	CN*C/CAVG	CL*C/CAVG	X/C C.P.
0.27625	20.46275	0.0	0.02702	0.05122	0.05105	0.53887
0.40049	14.14536	0.0	0.03765	0.04934	0.04934	0.45133
0.50597	11.13342	0.0	0.04689	0.04837	0.04837	0.41852
0.62157	8.72438	0.0	0.05752	0.04649	0.04643	0.38419
0.73625	7.16045	0.0	0.06608	0.04384	0.04383	0.38441
0.84042	5.74060	0.0	0.07206	0.03832	0.03831	0.36881
0.94414	4.32683	0.0	0.06552	0.02626	0.02626	0.29645

NORMAL/SIDE	LIFT	SIDE	RCLL	PITCH	YAW
0.01723	0.03443	0.0	0.0	-0.00995	0.0

COMPONENT 3 VERTICAL   CAVG= 31.12254

ETA	CHORD	TWIST(DEG)	CN	CN*C/CAVG	CL*C/CAVG	X/C C.P.
0.09789	6.43027	0.0	0.00000	0.00000	0.0	0.0
0.29759	5.62477	0.0	-0.00000	-0.00000	0.0	0.0
0.49718	4.81967	0.0	-0.00000	-0.00000	0.0	0.0
0.69661	4.01526	0.0	-0.00000	-0.00000	0.0	0.0
0.89574	3.21202	0.0	-0.00000	-0.00000	0.0	0.0

NORMAL/SIDE	LIFT	SIDE	RCLL	PITCH	YAW
-0.00000	0.0	0.00000	0.00000	0.0	-0.00000

TOTAL FORCES AND MOMENTS FOR THE COMPLETE CONFIGURATION

FORCE		MOMENT			CENTER OF PRESSURE X STATION
LIFT	SIDE	RCLL	PITCH	YAW	
0.04743	0.00000	0.00000	-0.00590	0.00000	22.85327

Figure 5-4   Subsonic-supersonic panel solution forces and moments

WAVE DRAG PROGRAM

APAS SAMPLE SESSION GEOMETRY FILE

MACH= 1.600   VOLUME DRAG

NO.	THETA	D/Q
1	-90.000	32.8766
2	-82.500	22.4307
3	-75.000	14.6326
4	-67.500	12.1368
5	-60.000	12.4817
6	-52.500	13.3022
7	-45.000	14.7906
8	-37.500	18.6805
9	-30.000	17.8035
10	-22.500	17.3735
11	-15.000	18.8717
12	-7.500	18.9401
13	0.0	20.1280
14	7.500	20.9426
15	15.000	24.0547
16	22.500	27.3976
17	30.000	31.1302
18	37.500	29.2453
19	45.000	37.0710
20	52.500	37.4960
21	60.000	30.9462
22	67.500	32.7350
23	75.000	37.5587
24	82.500	42.7536
25	90.000	48.0824

** TOTAL WAVE DRAG   24.6787

** TOTAL COEFFICIENT   0.098750

Figure 5-5   Volume wave drag solution

97

WAVE DRAG PROGRAM

APAS SAMPLE SESSICN GECPETRY FILE

```
        MACH=  1.600      ALPHA=  3.0
        NO.              THETA            D/Q
         1              -90.000          35.8427
         2              -82.500          29.6606
         3              -75.000          23.8080
         4              -67.500          19.4547
         5              -60.000          16.4867
         6              -52.500          14.4289
         7              -45.000          13.9046
         8              -37.500          17.2065
         9              -30.000          15.4639
        10              -22.500          15.1732
        11              -15.000          17.2207
        12               -7.500          17.8595
        13                0.0            19.9613
        14                7.500          21.9959
        15               15.000          26.6143
        16               22.500          31.5220
        17               30.000          36.9408
        18               37.500          38.8132
        19               45.000          48.1823
        20               52.500          48.3128
        21               60.000          42.9049
        22               67.500          49.1249
        23               75.000          59.0378
        24               82.500          73.4263
        25               90.000          93.9657


  ** TOTAL WAVE DRAG              31.6825 VOLUME + LIFT

  ** TOTAL COEFFICIENT            0.126776
```

Figure 5-6   Lifting wave drag solution

VISCOUS DRAG PROGRAM

APAS SAMPLE SESSICN GECPETRY FILE

MACH: 1.600 ALT: 3049. M PRESS: 69683.687 NT/M2 TEMP: 268.340 K SREF: 249.910 M2 KS: 0.00000634 M

COMPONENT	WET SURF AREA M2	CCMP LENGTH M	FF	X/L TRANS.	REYNOLDS NO.	CDF SMOOTH	CDF ROUGH	CDF USED
FORWARD FUSELAGE	540.1	31.750	1.144	0.010	8.91710E+08	0.00314	0.00292	0.00314
WING	126.4	20.100	1.100	0.010	5.64510E+08	0.00075	0.00070	0.00075
WING	123.6	12.573	1.129	0.010	3.53129E+08	0.00080	0.00075	0.00080
WING	50.02	8.695	1.146	0.010	2.44203E+08	0.00035	0.00033	0.00035
WING	83.04	5.707	1.137	0.010	1.60281E+08	0.00060	0.00057	0.00060
VERTICAL	77.22	4.808	1.048	0.010	1.35044E+08	0.00053	0.00050	0.00053

```
  ** TOTAL WET SURFACE AREA  =   1000.45  M2
  ** TOTAL SKIN FRICTION DRAG =  C.00618

  ** TOTAL VEHICLE BASE DRAG  =  C.04427
```

Figure 5-7   Viscous drag solution

SCHEDULE FOR RUN 1

MACH	CT	P	Q	R	D1	D2
1.60	0.0	0.0	0.0	0.0	10.00	0.0

ALPHA	BETA	LIFT	SIDE	RCLL	PTCH	YAW						
0.0	0.0	0.10497	0.0	0.0	0.00746	0.0	CDO:	0.013302	CD100:	0.029840	LINEAR	
0.0	0.0	0.10497	0.0	0.0	0.00746	0.0	CDL:	0.029840	SUCTION:	1.000	W/LE	VTX
0.0	0.0	0.10543	0.0	0.0	0.00718	0.0	CDL:	0.029866	SUCTION:	0.235	W/TIP	VTX
5.00	0.0	0.34212	0.0	0.0	-0.02203	0.0	CDO:	0.042796	CD100:	0.046496	LINEAR	
5.00	0.0	0.34212	0.0	0.0	-0.02203	0.0	CDL:	0.046496	SUCTION:	1.000	W/LE	VTX
5.00	0.0	0.34634	0.0	0.00002	-0.02483	0.0	CDL:	0.047179	SUCTION:	0.058	W/TIP	VTX
10.00	0.0	0.57927	0.0	0.0	-0.05151	0.0	CDO:	0.110192	CD100:	0.092922	LINEAR	
10.00	0.0	0.57927	0.0	0.0	-0.05151	0.0	CDL:	0.092923	SUCTION:	0.994	W/LE	VTX
10.00	0.0	0.59400	0.0	0.00009	-0.06103	0.0	CDL:	0.096490	SUCTION:	0.031	W/TIP	VTX
20.00	0.0	1.05356	0.0	0.0	-0.11047	0.0	CDO:	0.358332	CD100:	0.275087	LINEAR	
20.00	0.0	1.05375	0.0	0.0	-0.11038	0.0	CDL:	0.275260	SUCTION:	0.601	W/LE	VTX
20.00	0.0	1.10786	0.0	0.00049	-0.14468	0.0	CDL:	0.298494	SUCTION:	0.011	W/TIP	VTX

Figure 5-8 Subsonic-supersonic analysis summary

HYPERSONIC ARBITRARY-BODY PROGRAM, MARK III MCD 3

APAS SAMPLE SESSION GEOMETRY FILE
CONFIGURATION: 2

COMPONENT	NAME	SYMBOL	FLAP	TYPE
11.00	FORWARD FUSELAGE			
12.00	MID FUSELAGE			
13.00	AFT FUSELAGE			
14.00	POD			
121.00	WING			
211.00	VERTICAL	D1	1	SYMM
400.00	BODY FLAP	D2	2	ANTISYMM

Figure 5-9 Hypersonic analysis configuration

```
HYPERSONIC ARBITRARY-BODY PROGRAM, MARK III MOD 3
   RUN    3

APAS SAMPLE SESSION GEOMETRY FILE

FORWARD FUSELAGE BODY NOSE            TOTAL AREA OF INPUT ELEMENTS   M2 =      1.124   TOTAL NUMBER OF ELEMENTS =   40
                                      TOTAL VOLUME OF INPUT ELEMENTS M3=      0.218

   IMPACT:  1      ISHAD:  3     IMPACI:  0    ISHADI:  0    CPSTAG:  1.20    QQINF:  1.00    ENPN:   0.0    ETAC:  1.00
                ********                     ********                   ********

FORWARD FUSELAGE MAIN BODY, SEGMENT:  3    TOTAL AREA OF INPUT ELEMENTS   M2 =     11.513   TOTAL NUMBER OF ELEMENTS =   10
                                           TOTAL VOLUME OF INPUT ELEMENTS M3=      3.977

   IMPACT:  5      ISHAD:  3     IMPACI:  0    ISHADI:  0    CPSTAG:  1.20    QQINF:  1.00    ENPN:   0.0    ETAC:  1.00
                ********                     ********                   ********

FORWARD FUSELAGE MAIN BODY, SEGMENT:  2    TOTAL AREA OF INPUT ELEMENTS   M2 =     23.493   TOTAL NUMBER OF ELEMENTS =   35
                                           TOTAL VOLUME OF INPUT ELEMENTS M3=     29.939

   IMPACT:  5      ISHAD:  3     IMPACI:  0    ISHADI:  0    CPSTAG:  1.20    QQINF:  1.00    ENPN:   0.0    ETAC:  1.00
                ********                     ********                   ********

FORWARD FUSELAGE MAIN BODY, SEGMENT:  1    TOTAL AREA OF INPUT ELEMENTS   M2 =      4.349   TOTAL NUMBER OF ELEMENTS =    4
                                           TOTAL VOLUME OF INPUT ELEMENTS M3=      2.381

   IMPACT:  5      ISHAD:  3     IMPACI:  0    ISHADI:  0    CPSTAG:  1.20    QQINF:  1.00    ENPN:   0.0    ETAC:  1.00
                ********                     ********                   ********
```

Figure 5-10   Hypersonic analysis panel summary

```
HYPERSONIC ARBITRARY-BODY PROGRAM, MARK III MOD 3
   RUN    3

APAS SAMPLE SESSION GEOMETRY FILE
                 FORWARD FUSELAGEAIR

   MACH=  10.000  VEL=   3366.9 M/SEC   RE/M =  0.19887E+08
   ALT =   3049. M

   S REF =   249.91 M2  SPAN =   23.79 M  MAC  =   12.06 M
   X CG =    -21.35 M   Y CG =    0.0  M  Z CG =   -0.63 M

FORCE DATA
   ALPHA   C D       C L       C A       C Y      C N
   BETA    L/D       C M       C LL      C LN     C F

   0.0    0.03425  -0.02732  0.03425   0.0     -0.02732
   0.0   -0.79761  -0.03521  0.0       0.0      0.0

   5.00   0.02862  -0.01561  0.02587   0.0     -0.01306
   0.0   -0.54560  -0.01532  0.0       0.0      0.0

  10.00   0.02622  -0.00264  0.02628   0.0      0.00195
   0.0   -0.10087   0.00559  0.0       0.0      0.0

  20.00   0.03169   0.02321  0.02184   0.0      0.03265
   0.0    0.73233   0.04830  0.0       0.0      0.0
```

Figure 5-11   Hypersonic analysis component summary

```
HYPERSONIC ARBITRARY-BODY PROGRAM, MARK III MOC 3
  RUN    3

APAS SAMPLE SESSION GEOMETRY FILE
                 TOTAL MOMENTS AND FORCES FOR COMPLETE CONFIGURATION          AIR
                 FLAP DATA DOES NOT INCLUDE SHOCK EXPANSION ALGORITHMS

  MACH=  10.000  VEL=   3366.9 M/SEC    RE/M =  0.19887E+08
  ALT =   3049. M


  S REF =    249.91 M2  SPAN =   23.79 M  MAC  =   12.06 M
  X CG  =   -21.35 M   Y CG =    0.0 M  Z CG =   -0.63 M

FORCE DATA
  ALPHA    C D        C L        C A        C Y        C N
  BETA     L/D        C M        C LL       C LN       C F


   0.0    0.06270   -0.04588   0.06270   -0.00000   -0.04588
   0.0   -0.73173   -0.02647  -0.00000    0.00000    0.0


   5.00   0.05780    0.02464   0.05543   -0.00000    0.02958
   0.0    0.42628   -0.00993  -0.00000    0.00000    0.0


  10.00   0.07259    0.12054   0.05055   -0.00000    0.13132
   0.0    1.66063    0.00449  -0.00000    0.00000    0.0


  20.00   0.19409    0.39557   0.04710   -0.00000    0.43810
   0.0    2.03804    0.01625  -0.00000    0.00000    0.0
```

Figure 5-12   Hypersonic analysis total configuration summary

WAVE DRAG PROGRAM

```
                 APAS SAMPLE SESSION GEOMETRY FILE



            MACH=   1.600       VOLUME DRAG
            NO.              THETA              D/Q
             1              -90.000            32.8766
             2              -82.500            22.4307
             3              -75.000            14.6326
             4              -67.500            12.1368
             5              -60.000            12.4817
             6              -52.500            13.3022
             7              -45.000            14.7906
             8              -37.500            18.6805
             9              -30.000            17.8035
            10              -22.500            17.3735
            11              -15.000            18.8717
            12               -7.500            18.9401
            13                0.0              20.1280
            14                7.500            20.9426
            15               15.000            24.0547
            16               22.500            27.3976
            17               30.000            31.1392
            18               37.500            29.2453
            19               45.000            37.0710
            20               52.500            37.4960
            21               60.000            30.9462
            22               67.500            32.7350
            23               75.000            37.5587
            24               82.500            42.7536
            25               90.000            48.0824


        ** TOTAL WAVE DRAG                     24.6787

        ** TOTAL COEFFICIENT                   0.098750
```

Figure 5-13   Volume wave drag

Analysis detailed print should be reviewed to identify any obvious difficulties prior to interactive display of the data. A diagnostic effort will be presented to illustrate this activity.

Suppose the following problem occurs. Examination of the wave drag solution indicates unreasonable increases with angle of attack (figures 5-13 and 5-14). Reviewing the symmetrical net pressure coefficient (figure 5-15) it is found that the vertical tail pressures are erroneous. Examining the summary of panel control points, figure 5-16, it is discovered that the centerline vertical incorrectly had an image indicated in the last column by the word YES. This also could have been uncovered by reviewing the summary page (figure 5-17) where the symmetry of the vertical is erroneously indicated to be 1. The solution is to change the symmetry of the vertical in APAS, and reprocess the analysis.

APAS SAMPLE SESSION GEOMETRY FILE

```
        MACH=  1.600     ALPHA=  0.0
        NO.           THETA              D/Q
         1           -90.000          31.6082
         2           -75.000         100.6105
         3           -60.000         354.1449
         4           -45.000         887.5928
         5           -30.000        1879.0591
         6           -15.000        3930.6814
         7             0.0          9449.7313
         8            15.000       17424.1396
         9            30.000       13461.3821
        10            45.000        2809.7827
        11            60.000        2928.0473
        12            75.000         507.6590
        13            90.000          65.0841


   ** TOTAL WAVE DRAG                    4484.69  VOLUME + LIFT

   ** TOTAL COEFFICIENT                 17.897537
```

Figure 5-14   Erroneous lifting-wave drag

UNIFIED DISTRIBUTED PANEL PROGRAM
APAS SAMPLE SESSION GEOMETRY FILE

SYMMETRICAL SOLUTION C_p - NET

```
BASIC
 -0.00000  -0.00000  -0.00001  -0.00032  -0.00228   0.00115   0.00045   0.06622   0.05251  -0.01585
 -0.05205   0.01462  -0.04315  -0.02185   0.04794   0.00000  -0.00000  -0.00005  -0.00145   0.00019
 -0.01821   0.04349   0.01624   0.02542   0.00797  -0.04860  -0.01599   0.07252   0.00268   0.03644
 -0.00000  -0.00000  -0.00042  -0.00919  -0.04580  -0.03079   0.06602   0.01036  -0.03386   0.02846
 -0.01472   0.04577   0.17412  -0.03919   0.12880  -0.00001  -0.00000  -0.00721  -0.07654  -0.05151
  0.03363   0.03871   0.00295  -0.07647   0.10613   0.00696   0.18395   0.04540   0.00349   0.09364
 -0.00001  -0.00000  -0.02032  -0.06879  -0.04920   0.04800   0.00457  -0.06149  -0.03256   0.01619
  0.00645   0.13437   0.09373   0.06870   0.18721  -0.00000  -0.00000  -0.00826   0.03497  -0.02601
 -0.00162  -0.01557  -0.02322  -0.01023  -0.02699   0.01581   0.00052   0.05444  -0.03004   0.10100
 -0.00000   0.00000  -0.00145   0.00567   0.00605  -0.01758   0.00492  -0.00301  -0.03398   0.00348
 -0.02498   0.02939  -0.00797  -0.01954   0.03901  -0.01266   0.01428   0.03596   0.03805   0.07444
 -0.00438  -0.13034  -0.08148  -0.11711  -0.12707  -0.07503   0.03958   0.06608   0.14769   0.11188
 -0.08893  -0.10298  -0.07797  -0.11550  -0.23493  -0.16852   0.08580   0.09893   0.21381   0.12565
 -0.05696  -0.05042  -0.08167  -0.18535  -0.25946  -0.35827   0.09389   0.22889   0.26761   0.19783
  0.03646  -0.04178  -0.10355  -0.17243  -0.29360  -0.38977  -0.02042   0.22670   0.25642   0.23704
  0.19555   0.07312  -0.05923  -0.19104  -0.32645  -0.44050  -0.08525   0.11448   0.24033   0.26411
  0.25841   0.18923   0.10593  -0.02046  -0.20635  -0.47072  -0.17497   0.01685   0.12803   0.26044
  0.56325   0.32307   0.18180  -0.00654  -0.22441  -0.57752   0.41205  -36.25014  -25.66489   11.48055
-11.67812 -29.43752 -28.00427 -19.26134 -30.92506 -22.23326   1.35866   11.81686   56.57005  -52.28316
 -5.90812 -58.02379 -45.82957  14.68507  23.10925  35.91295 -48.71996 -29.45729  -27.13666  -33.16554
  2.01506  51.33102 -35.90993 -24.71251 -29.91002  30.48864  86.93475  73.04482    2.06686  -17.45102
```

```
UNIT ALPHA
  0.00000  -0.00000   0.00000   0.00004   0.00035   0.00034   0.00032   0.00015   0.00010   0.00168
  0.00376   0.00459   0.00785   0.00869   0.01096  -0.00000   0.00000   0.00001   0.00017   0.00025
  0.00099   0.00078   0.00061   0.00136   0.00287   0.00605   0.00728   0.00821   0.01095   0.01491
 -0.00000  -0.00000   0.00008   0.00089   0.00224   0.00279   0.00334   0.00510   0.00729   0.00912
  0.01040   0.01131   0.01403   0.01798   0.01735  -0.00000  -0.00000   0.00141   0.00456   0.00588
  0.00603   0.00692   0.00997   0.01133   0.01130   0.01232   0.01371   0.01685   0.01841   0.02290
 -0.00000  -0.00000  -0.00271  -0.00788  -0.00942  -0.00930  -0.00929  -0.01032  -0.01049  -0.01022
 -0.01103  -0.01334  -0.01294  -0.01231  -0.01777  -0.00000  -0.00000  -0.00091  -0.00157  -0.00318
 -0.00413  -0.00479  -0.00566  -0.00693  -0.00832  -0.00993  -0.01114  -0.01104  -0.01111  -0.01213
 -0.00000   0.00000  -0.00016  -0.00102  -0.00271  -0.00336  -0.00434  -0.00500  -0.00506  -0.00795
 -0.00994  -0.01030  -0.01045  -0.00938  -0.01183   0.03058   0.02137   0.02113   0.02225   0.02293
  0.02741   0.03084   0.04332   0.04493   0.04368   0.07446   0.03210   0.02957   0.02791   0.03194
  0.03364   0.03294   0.03626   0.03804   0.04097   0.10163   0.04167   0.04479   0.04096   0.03800
  0.03672   0.03603   0.03947   0.03965   0.03913   0.13112   0.07187   0.05473   0.04850   0.04390
  0.04113   0.04023   0.04039   0.03974   0.03933   0.13346   0.09687   0.06789   0.05830   0.05360
```

Figure 5-15   Erroneous vertical-tail pressure coefficients

UNIFIED DISTRIBUTED PANEL PROGRAM
APAS SAMPLE SESSION GEOMETRY FILE

SUMMARY OF PANEL CONTROL POINTS

	XBAR	YBAR	ZBAR	XC	AREA	SIN(THETA)	COS(THETA)	IMAGE
1	206.51910	25.06512	90.89946	233.07768	3661.74609	-0.24450	0.96965	YES
2	277.34180	25.06512	90.89946	303.90039	3661.74414	-0.24450	0.96965	YES
3	348.16479	25.06512	90.89946	374.72314	3661.73828	-0.24450	0.96965	YES
4	418.98755	25.06512	90.89946	445.54614	3661.75000	-0.24450	0.96965	YES
5	489.81055	25.06512	90.89946	516.36890	3661.73828	-0.24450	0.96965	•
6	560.63330	25.06512	90.89946	587.19189	3661.75000	-0.24450	0.96965	•
7	631.45630	25.06512	90.89946	658.01489	3661.75000	-0.24450	0.••	•
8	702.27930	25.06512	90.89946	728.83765	3661.73828	•	•	•ES
9	773.10205	25.06512	90.89946	799.66064	3661.••	•	•	YES
10	843.92505	25.06512	90.89946	870.46340	••	•	•	YES
11	914.74780	25.06512	90.89946	941.30••	•	•••	0.99974	YES
12	985.57080	25.06512	•	•	•	0.02272	0.99974	YES
13	1056.39355	25.•	•	•	•••.032	0.02272	0.99974	YES
14	1127.21655	•	•	•	••.23804	0.02272	0.99974	YES
15	1198.03••	•	•	•	838.23218	0.02272	0.99974	YES
•	•	•	•	•••.01177	838.23218	0.02272	0.99974	YES
•	•	•	•••.19473	1108.60474	838.23218	0.02272	0.99974	YES
•	•	•	-84.19473	1126.39771	838.23804	0.02272	0.99974	YES
•	•	••248	-84.19473	1144.19067	838.22632	0.02272	0.99974	YES
173	1153.9940•	431.29492	-84.17220	1159.70552	725.11938	0.02272	0.99974	YES
174	1169.21655	431.29492	-84.17220	1174.92310	725.13110	0.02272	0.99974	YES
175	1184.43408	431.29492	-84.17220	1190.14062	725.12524	0.02272	0.99974	YES
176	1067.90137	-0.00171	128.15036	1084.01050	2712.31250	1.00000	0.00000	YES
177	1110.95937	-0.00171	128.15036	1126.96851	2712.31250	1.00000	0.00000	YES
178	1153.81738	-0.00171	128.15036	1169.92651	2712.31250	1.00000	0.00000	YES
179	1196.77539	-0.00171	128.15036	1212.88477	2712.32812	1.00000	0.00000	YES
180	1231.85229	-0.00171	128.21807	1242.01807	1712.06055	-1.00000	0.00000	YES
181	1258.96118	-0.00171	128.21730	1269.12695	1712.06836	1.00000	0.00000	YES
182	1286.07007	-0.00171	128.21735	1296.23584	1712.06055	1.00000	0.00000	YES
183	1128.24902	-0.00169	191.27580	1142.27490	2360.50195	1.00000	0.00000	YES
184	1165.65166	-0.00169	191.27580	1179.67773	2360.50195	1.00000	0.00000	YES
185	1203.05444	-0.00169	191.27580	1217.08032	2360.50195	1.00000	0.00000	YES
186	1240.45728	-0.00169	191.27580	1254.46340	2360.51758	1.00000	0.00000	YES
187	1271.18774	-0.00169	191.36292	1280.16699	1511.75122	1.00000	0.00000	YES
188	1295.13257	-0.00169	191.36295	1304.11182	1511.75903	1.00000	0.00000	YES
189	1319.07739	-0.00169	191.36295	1328.05664	1511.75903	1.00000	0.00000	YES
190	1188.56274	-0.00167	254.36548	1200.50659	2008.68921	1.00000	0.00000	YES
191	1220.41333	-0.00167	254.36548	1232.35742	2008.68921	1.00000	0.00000	YES
192	1252.26416	-0.00167	254.36548	1264.20801	2008.68921	1.00000	0.00000	YES
193	1284.11475	-0.00167	254.36545	1296.05859	2008.69702	1.00000	0.00000	YES
194	1310.50757	-0.00167	254.48355	1318.30078	1311.45848	1.00000	0.00000	YES
195	1331.28979	-0.00167	254.48357	1339.08301	1311.45410	1.00000	0.00000	YES
196	1352.07202	-0.00167	254.48357	1359.86523	1311.45410	1.00000	0.00000	YES
197	1248.82056	-0.00165	317.39673	1258.68433	1656.88379	1.00000	0.00000	YES
198	1275.12427	-0.00165	317.39673	1284.90804	1656.88379	1.00000	0.00000	YES
199	1301.42798	-0.00165	317.39673	1311.29175	1656.88379	1.00000	0.00000	YES
200	1327.73169	-0.00165	317.39673	1337.59546	1656.88379	1.00000	0.00000	YES
201	1349.80347	-0.00165	317.56567	1356.41138	1111.13940	1.00000	0.00000	YES
202	1367.42505	-0.00165	317.56567	1374.03296	1111.15479	1.00000	0.00000	YES
203	1385.04639	-0.00165	317.56543	1391.65430	1111.14697	1.00000	0.00000	YES
204	1308.97729	-0.00163	380.32227	1316.76440	1305.06885	1.00000	0.00000	YES
205	1329.74341	-0.00163	380.32227	1337.53052	1305.06885	1.00000	0.00000	YES
206	1350.50928	-0.00163	380.32227	1358.29639	1305.06885	1.00000	0.00000	YES
207	1371.27539	-0.00163	380.32227	1379.06250	1305.06885	1.00000	0.00000	YES
208	1389.05981	-0.00163	380.56398	1394.48364	910.83374	1.00000	0.00000	YES
209	1403.52368	-0.00163	380.56374	1408.94751	910.84131	1.00000	0.00000	YES
210	1417.98755	-0.00163	380.56398	1423.41138	910.83374	1.00000	0.00000	YES

SOURCE INFLUENCE MATRIX HAS BEEN CALCULATED - COMPUTATION TIME 16.682 SEC.
VORTEX INFLUENCE MATRICES HAVE BEEN CALCULATED - COMPUTATION TIME 16.520 SEC.

Figure 5-16   Erroneous vertical-tail image indicator

UNIFIED DISTRIBUTED PANEL PROGRAM
APAS SAMPLE SESSION GEOMETRY FILE

SREF (M2)	SPAN (M)	CBAR (M)	X-CG (M)	Y-CG (M)	Z-CG (M)
249.9100	23.7910	12.0600	21.3640	0.0	-0.6350

COMPONENT NAME	TYPE	SYMMETRY	SEMI-SPAN	INCIDENCE	SPANWISE PANELS	ACTIVE
INTERF SHELL	5	1	9.9575	0.0	7	1
WING	4	1	11.5764	0.0	7	1
VERTICAL	3	1	8.0299	0.0	5	1

COMPONENT: INTERF SHELL   WILL BE CALCULATED WITH VORTEX LIFT OFF
COMPONENT: WING   WILL BE CALCULATED WITH VORTEX LIFT ON
COMPONENT: VERTICAL   WILL BE CALCULATED WITH VORTEX LIFT OFF

Figure 5-17   Erroneous vertical-tail symmetry

DISPLAY

Interactive plotting of aerodynamic results is accomplished using the PLOT command of section six.

There are twenty-five parameters (table 5) available at each analysis point. The first six are standard test or flight reference quantities. Parameters seven through eighteen are force and moment coefficients, and nineteen through twenty-three are force derivatives as a function of angle of attack and sideslip. Upper and lower surface pressure coefficients are stored following the force data for up to five (5) requested analysis points.

The LIST subcommand enables the user to review all the analysis runs in the output file and initial conditions for each run.

The SET subcommand of PLOT minimizes keyboard entries required by pre-setting up to twelve commonly used plot lines. User inputs at the time of display generation will override entries of the set list. Each of the aerodynamic variables can be displayed as a function of angle of attack or sideslip. Multiple runs can be combined to display results as a function of Mach number or one of the flap-deflection angles (D1 to D6) where applicable using the RUN operand of the PLOT subcommand of PLOT. Run lists are also used to simultaneously display more than one run on a single plot for comparison. The RUNM operand permits identification of run list subsets.

An existing run list applies to the current and all subsequent displays until modified by the user. A Mach list applies only to the current display and is replaced by the prior run list for the next display. Initial conditions for each grid should be specified for a Mach list.

There are three display formats and five grids available for plotting aerodynamic results. They are illustrated in figures 5-18 through 5-20. Grid positions do not have to be specified in order on a PLOT or SET list; however grids cannot be skipped, i.e., if grid 2 is filled then grid 1 must also have a plot specified or an error will result. Form 1 contains three narrow grids, figure 5-18, and is typically used to display slope data as a function of Mach number. Form 2 is useful for displaying a force or moment coefficient as a function of the run variable (V_r) on grid 2 and the slope or value at $V_r = 0$ as a function of Mach number on grid 1. Form 3, figure 5-20, is commonly used to display force and moment coefficients as a function of the run variable.

Table 5

AERODYNAMIC PARAMETER STORAGE

Location	Symbol	Description
1	TT	Total Temperature
2	PT	Total Pressure
3	PO	Static Pressure
4	q	$1/2 \rho V^2$
5	RN	Reynolds Number/L
6	M	Mach Number
7	CNR	Normal-Force Coefficient
8	CC	Chord-Force Coefficient
9	CL	Lift Coefficient
10	CM	Pitching-Moment Coefficient
11	CD	Total-Drag Coefficient
12	CDP	Viscous-Drag Coefficient
13	CDM	Wave-Drag Coefficient
14	CD0	Zero Suction Drag Coefficient
15	CD100	100% Suction Drag Coefficient
16	CY	Side-Force Coefficient
17	CN	Yawing-Moment Coefficient
18	CR	Rolling-Moment Coefficient
19	CL_α	Lift Derivative Coefficient
20	CM_α	Pitching-Moment Derivative Coefficient -per deg
21	CY_β	Side-Force Derivative Coefficient -per deg
22	CN_β	Yawing-Moment Derivative Coefficient -per deg
23	CR_β	Rolling-Moment Derivative Coefficient -per deg
24	ALPHA	Angle Of Attack -deg
25	BETA	Angle Of Side-Slip -deg
26-50		Optional Data Locations
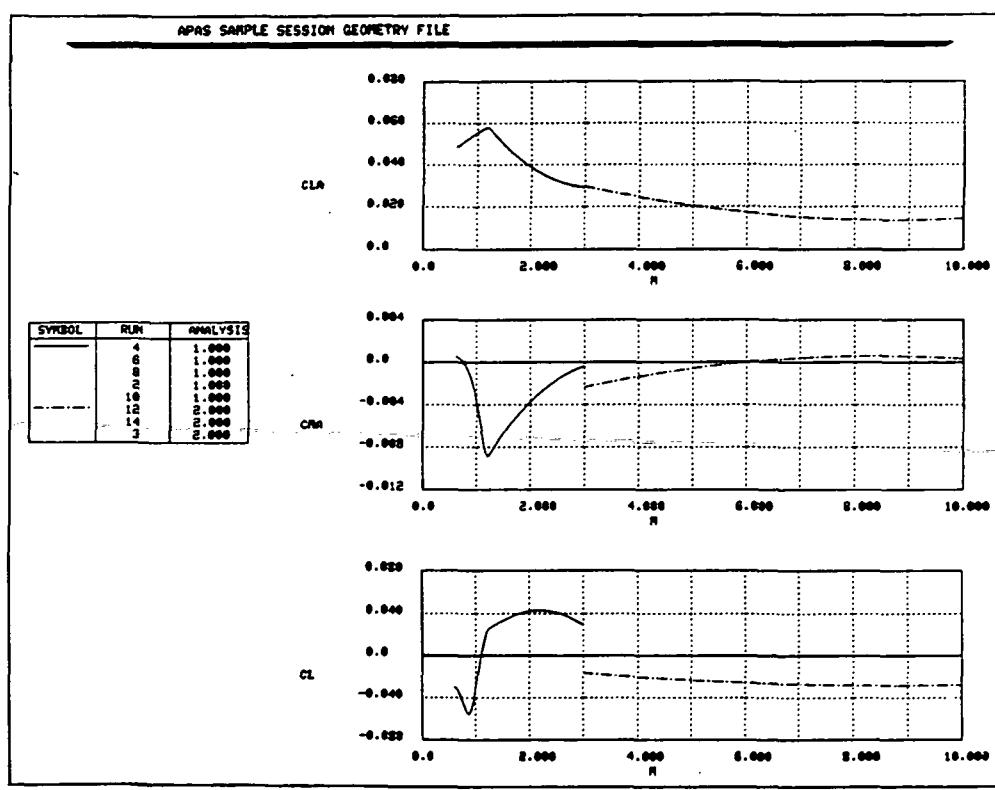
Figure 5-18.   PLOT form 1 display
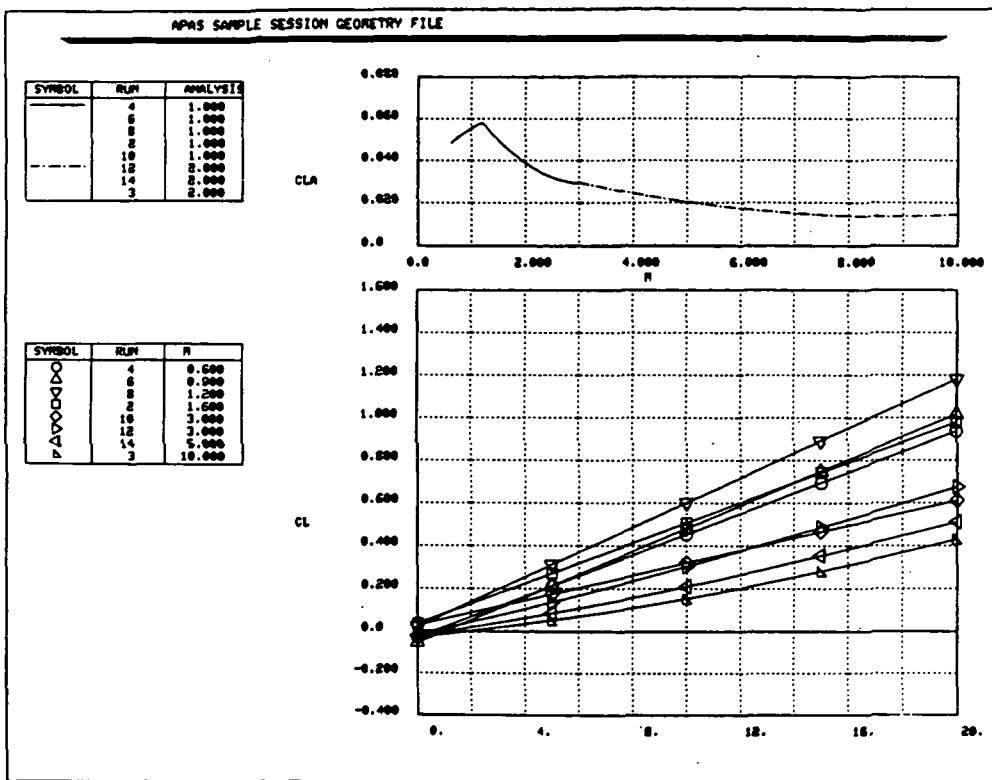
Figure 5-19. PLOT form 2 display
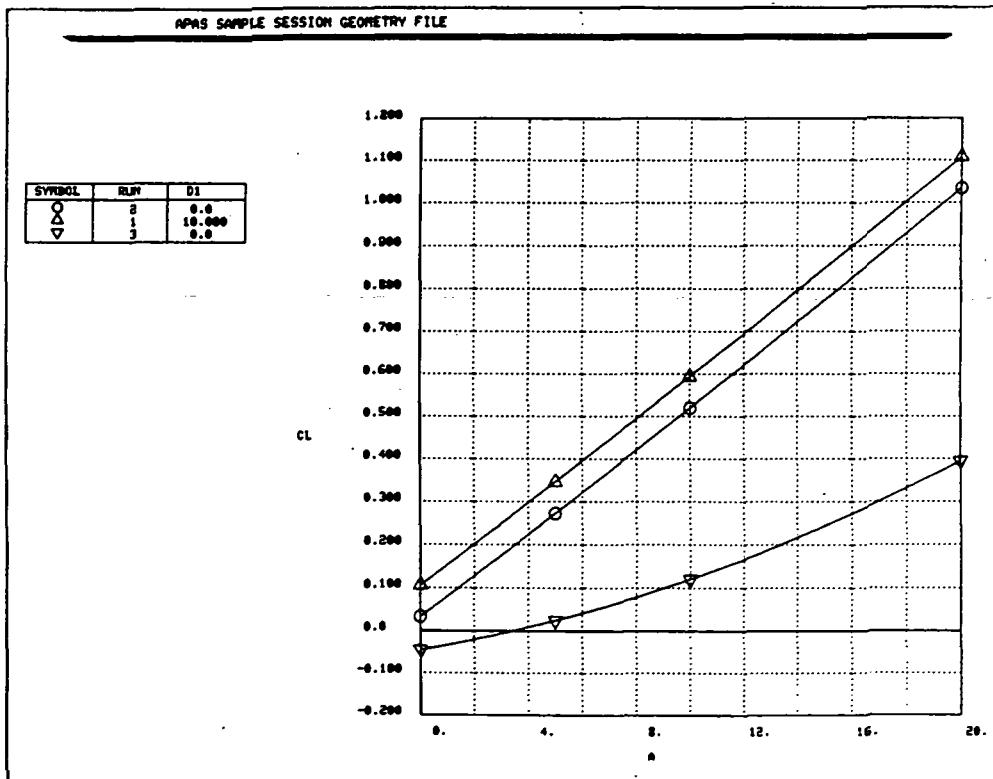
Figure 5-20. PLOT form 3 display

Review the PLOT command of section six prior to initiating this effort. Various subcommands will be demonstrated to familiarize the analyst with the system interactive display activity.

Constant Mach Number (Session 5-1)

Some of the aerodynamic results from the run list created in analysis session 4-2 will be displayed. In screen 5-1, the user enters the PLOT command and lists the runs available in the current output file on screen 5-2.

A plot of C_L versus angle of attack for runs 1, 2 and 3 is requested. The system searches the output file, selects the required data, and displays plotting information on screen 5-3. This screen will be replaced in ten seconds with the requested plot. Unresolved data will result in an error message, and the pre-plot page will remain. The PAGE operand of the PLOT subcommand can be used to set the screen to hold or copy mode instead of the ten second wait mode. The resulting display is shown on screen 5-4.

```
              **OK**
          →  plot
              ***PLOT***
          →  1
```

Screen 5-1   PLOT command entry and listing of runs
currently available in the output file

```
                                        RUN SUMMARY
RUN     M      A      B      P      Q      R     D1     D2     D3     D4     D5     D6    RUN STATUS
  1  1.600   0.0    0.0    0.0    0.0    0.0   10.000  0.0    0.0    0.0    0.0    0.0   ANALYZED
  2  1.600   0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0   ANALYZED
  3 10.000   0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0   ANALYZED
***PLOT***
→ plot cl/a run(2,1,3)
```

Screen 5-2   Listing of runs in current output file and
entering subcommand to display C_L versus α

```
                        PLOT DATA SUMMARY

FORM:  3

GRID:  1                              CL    VS.   A

REFERENCE  :    A      B      P      Q      R     D1     D2     D3     D4     D5     D6
   DATA    :   0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0

         POINT   RUN    MACH     D1
           1      2    1.600    0.0
           2      1    1.600   10.000
           3      3   10.000    0.0

ENTER 'CARRIAGE RETURN' TO START PLOT, OR ENTER A NEW 'PLOT' SUBCOMMAND:

NOTE:  TO CONTROL PAGE STOP ON THIS PREPLOT PAGE USE 'PAGE'  OPERAND

→
```

Screen 5-3   Pre-plot page for lift display
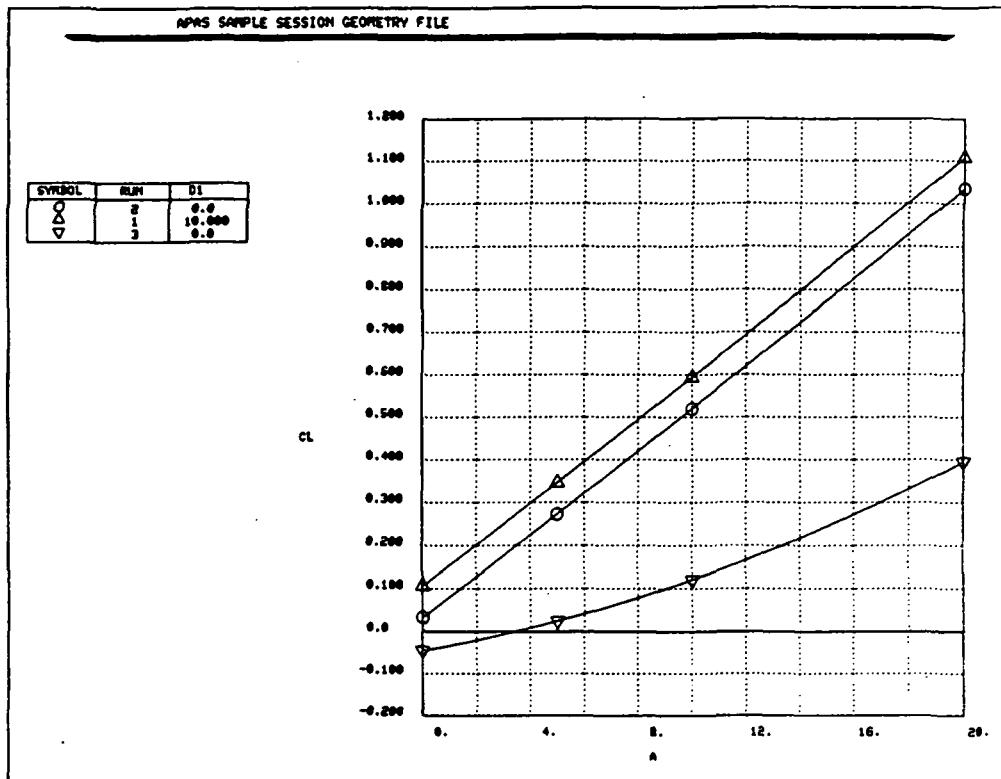
Screen 5-4 Display of C_L versus α

On screen 5-5, the new plot schedules are specified using the SET subcommand. After review a carriage return is keyed in to reactivate the **PLOT** mode. There are seven plot schedules which the user can display. To obtain a drag polar display plot schedule 3 is selected using plot3 entry. Note that it is not necessary to re-enter the run schedule keyed in on screen 5-2. The resulting pre-plot page and display are shown on screens 5-6 and 5-7.

Screen 5-5 Utilizing the SET subcommand to specify new plotlists and plotting the current runlist

110

FORM: 3

GRID: 1   CL   VS.   CD

REFERENCE DATA	:	A 0.0	B 0.0	P 0.0	Q 0.0	R 0.0	D1 0.0	D2 0.0	D3 0.0	D4 0.0	D5 0.0	D6 0.0

POINT	RUN	MACH	D1
1	2	1.600	0.0
2	1	1.600	10.000
3	3	10.000	0.0

ENTER "CARRIAGE RETURN" TO START PLOT, OR ENTER A NEW "PLOT" SUBCOMMAND:

NOTE: TO CONTROL PAGE STOP ON THIS PREPLOT PAGE USE "PAGE" OPERAND

Screen 5-6 Preplot page for drag polar display
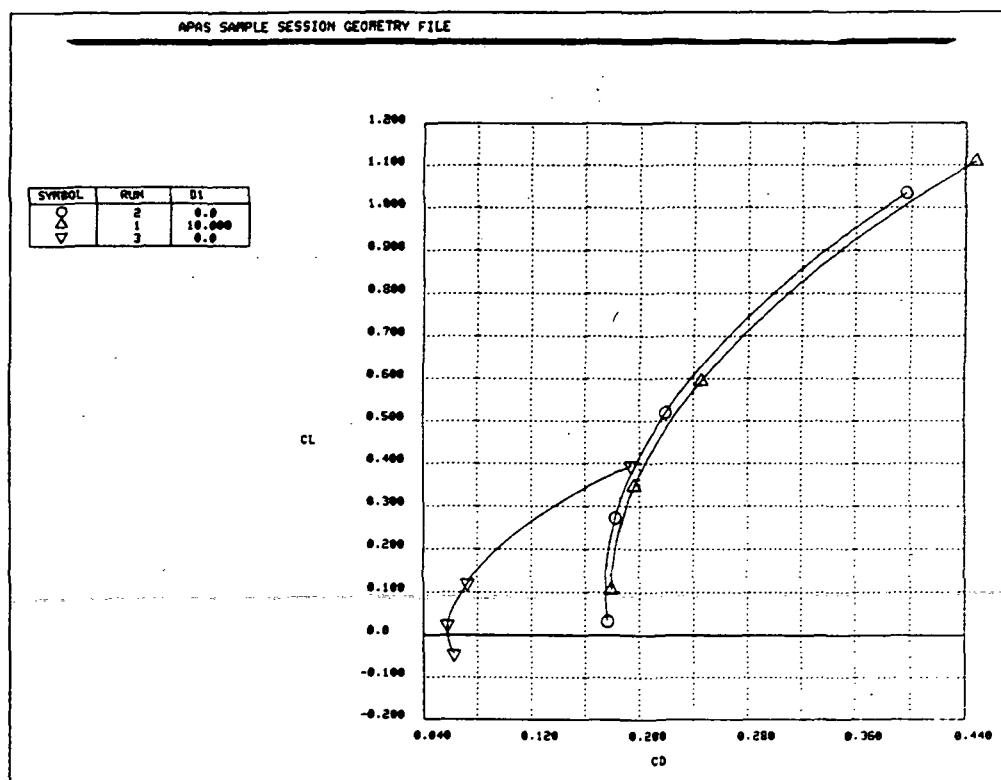
Screen 5-7 Display of lift versus drag

On screen 5-8, the runs available have been relisted for review, and a display of C_L versus C_M has been selected with an absicissa scale (SA1) of 0.1. The rsulting display is shown on screen 5-9.

Screen 5-8 C_L versus C_M display request
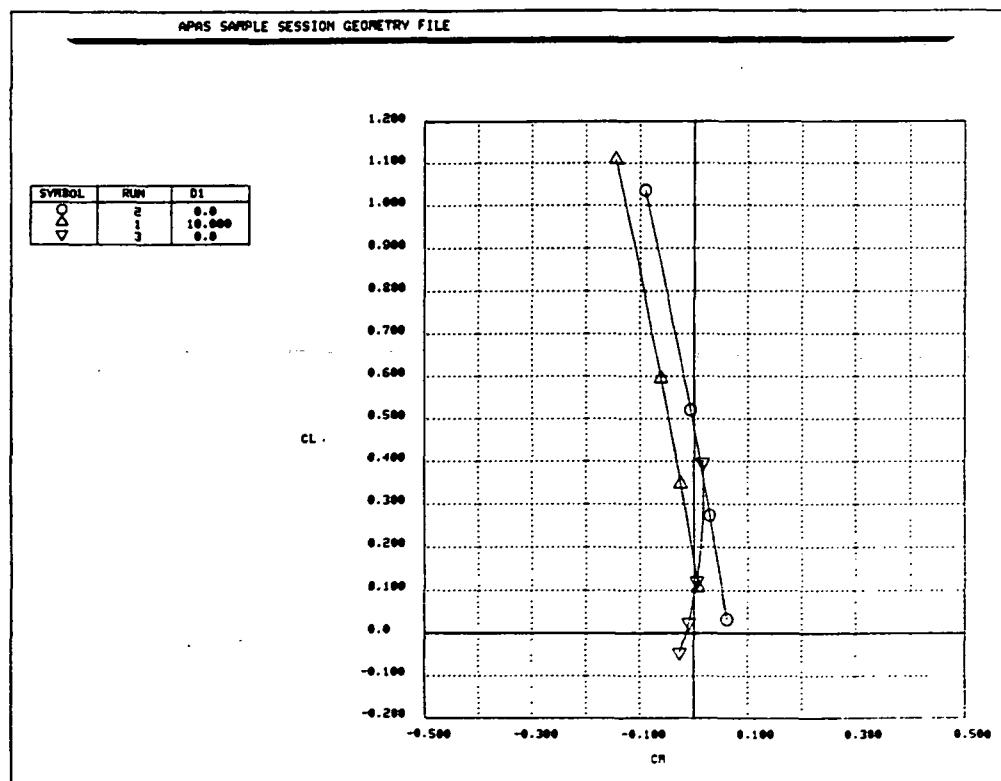
Screen 5-9 C_L versus C_M display

112

The final activity of this session, requests the pitching moment plot for run 3 (screen 5-10), and is displayed on screen 5-11.

ᶻᶻᶻPLOTᶻᶻᶻ
—▶ plot cl/cm run(3) sal=0.1

Screen 5-10 Run 3 C_L versus C_M display request

APAS SAMPLE SESSION GEOMETRY FILE

SYMBOL	RUN	R
O	3	10.000
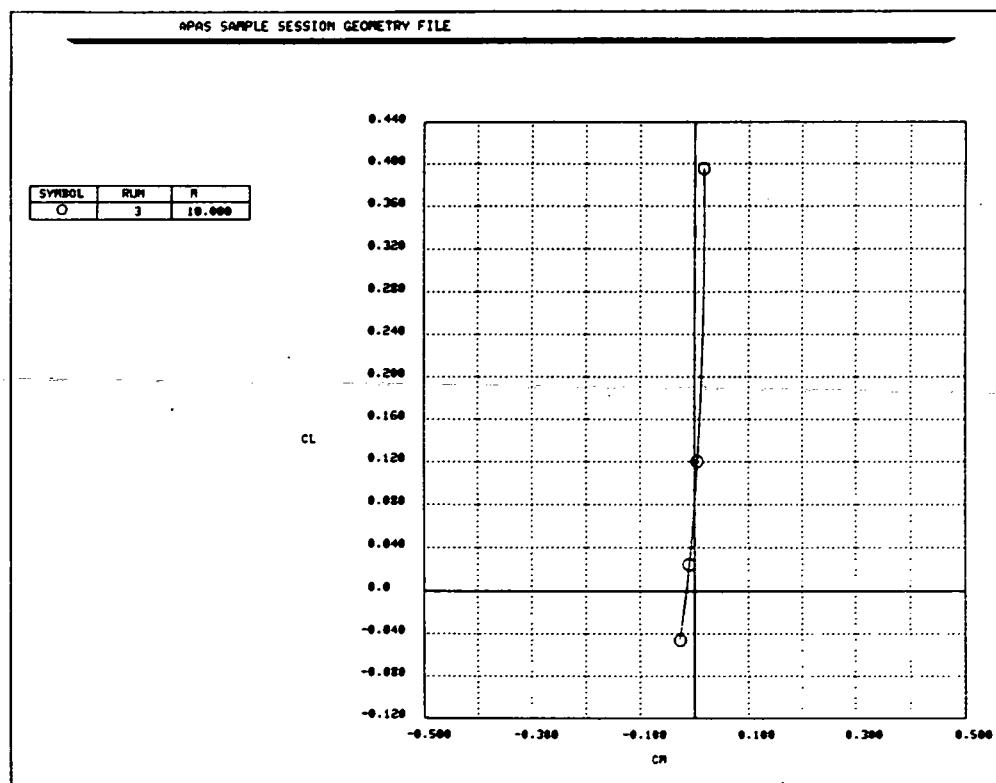
Screen 5-11 Run 3 C_L versus C_M display

A new set of analysis runs was processed and added to the output file for a total of 22. Runs 1 through 14 are pitch analysis with the trailing edge flap undeflected and deflected ten degrees. Runs 15 through 22 are side slip analysis at zero angle of attack. The new runs cover the subsonic, supersonic and hypersonic speed range of the study configuration. Runs 10 and 11 are linear supersonic analysis and runs 12 and 13 hypersonic evaluation for the same Mach numbers. As a result of the increased analysis coverage, a series of aerodynamic displays can be set up to summarize overall vehicle characteristics.

The SET subcommand of PLOT is used to request the longitudinal slope ($dC_L/d\alpha$, $dC_m/d\alpha$, dC_m/dC_L) preset plot list. The PLOT subcommand and RUN operand are then used to display the analysis results as a function of Mach number (screen 5-12). Runs 4, 6, 8, 2, and 10 are the subsonic-supersonic runs and are placed in ascending Mach number order. These are followed by the hypersonic runs 12, 14, and 3 also in ascending order. The RUNM operand partitions the list into 5 subsonic-supersonic cases and 3 hypersonic cases to identify the results by analysis method. The pre-plot page is shown on screen 5-13. The resulting display on screen 5-14.

```
      ***PLOT***
 ——► set6


      CURRENT PLOT SCHEDULE  6 IS:CLA/M(A=0.) CMA/M(A=0.) DCMDCL/M(A=0.)
      ENTER NEW PLOT SCHEDULE  6, OR 'CARRIAGE RETURN' TO RETAIN AS IS
 ——►
      ***PLOT***
 ——► plot6 run(4 6 8 2 10 12 14 3) runm(5 3)
```

Screen 5-12   Input for displaying Mach number variation of
longitudinal aerodynamic derivatives

```
                          PLOT DATA SUMMARY

FORM: 1

GRID: 1                    CLA   VS.   M

REFERENCE :  A     .     P     Q     R    D1    D2    D3    D4    D5    D6
     DATA :  0.0   0.0   0.0   0.0   0.0  0.0   0.0   0.0   0.0   0.0   0.0

          POINT  RUN  MACH    ANALYSIS
            1     4   0.600    1.000
            2     6   0.900    1.000
            3     8   1.200    1.000
            4     2   1.600    1.000
            5    10   3.000    1.000
            6    12   3.000    2.000
            7    14   5.000    2.000
            8     3  10.000    2.000

GRID: 2                    CMA   VS.   M

REFERENCE :  A     .     P     Q     R    D1    D2    D3    D4    D5    D6
     DATA :  0.0   0.0   0.0   0.0   0.0  0.0   0.0   0.0   0.0   0.0   0.0

          POINT  RUN  MACH    ANALYSIS
            1     4   0.600    1.000
            2     6   0.900    1.000
            3     8   1.200    1.000
            4     2   1.600    1.000
            5    10   3.000    1.000
            6    12   3.000    2.000
            7    14   5.000    2.000
            8     3  10.000    2.000

GRID: 3                   DCMDCL  VS.   M

REFERENCE :  A     .     P     Q     R    D1    D2    D3    D4    D5    D6
     DATA :  0.0   0.0   0.0   0.0   0.0  0.0   0.0   0.0   0.0   0.0   0.0

          POINT  RUN  MACH    ANALYSIS
            1     4   0.600    1.000
            2     6   0.900    1.000
            3     8   1.200    1.000
            4     2   1.600    1.000
            5    10   3.000    1.000
            6    12   3.000    2.000
            7    14   5.000    2.000
            8     3  10.000    2.000

ENTER 'CARRIAGE RETURN' TO START PLOT, OR ENTER A NEW 'PLOT' SUBCOMMAND:
NOTE: TO CONTROL PAGE STOP ON THIS PREPLOT PAGE USE 'PAGE'
```

Screen 5-13   Longitudinal display pre-plot page
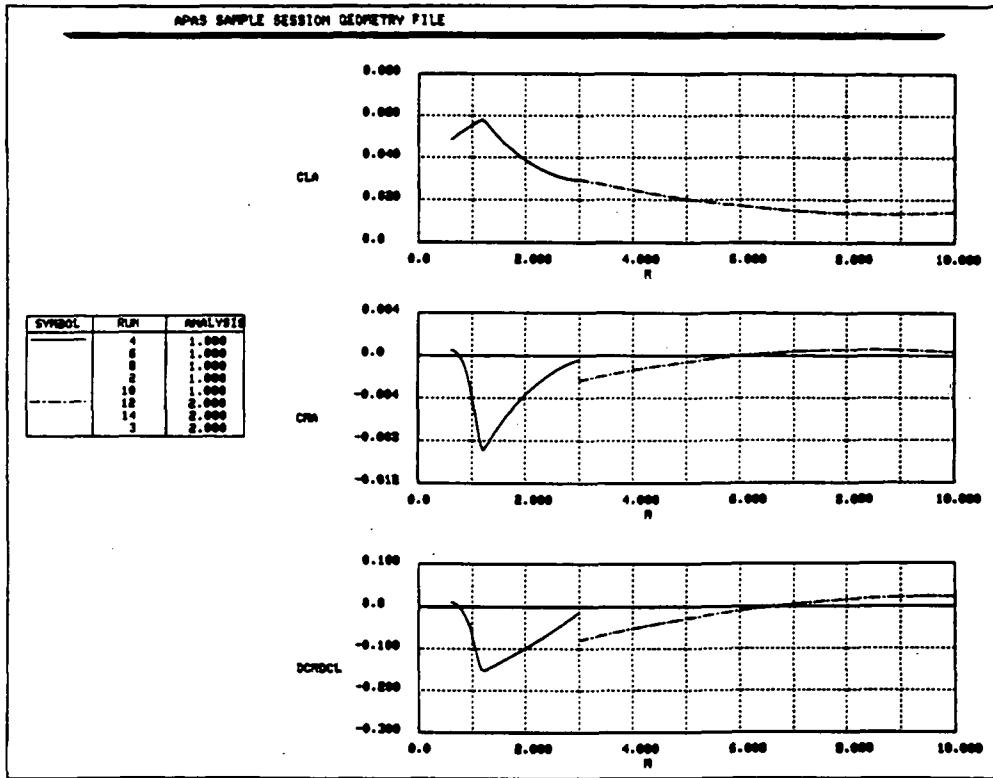
Screen 5-14 Mach number display of longitudinal
characteristics

     Using form 2, a more detailed display can be made of individual characteristics.
Screen 5-15 shows the input for displaying lift curve slope as a function of Mach
number and lift versus angle of attack. The run list is the same as the previous
plot. Similar inputs and displays are shown for longitudinal stability in screens
3-17 and 3-18, and drag in screens 3-19 and 3-20.

          %%%PLOT%%%
       ───➤ plot cla(a=0) cl/a run(4 6 8 2 10 12 14 3) runs(5 3)

Screen 5-15 Input for displaying lift and lift curve slope

115
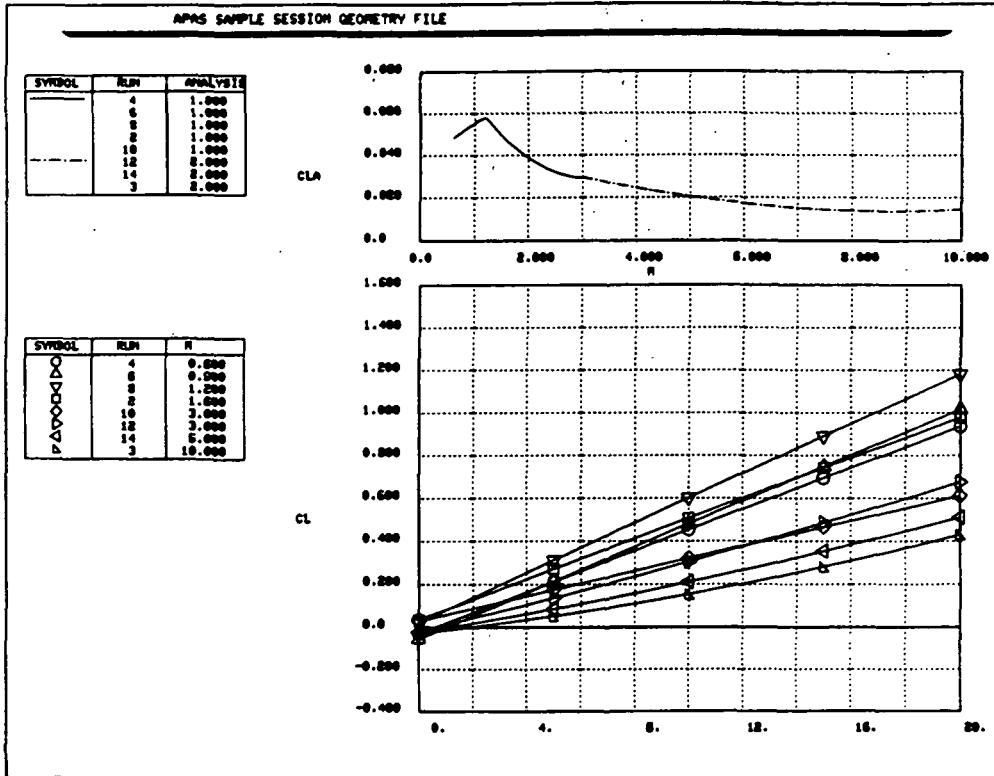
Screen 5-16 Lift characteristics displayed as a function of Mach
number and angle of attack

XXXPLOTXXX
→ plot dcmdcl(a=0) cl/cm runs(5 3)

Screen 5-17   Longitudinal stability and lift versus
pitching moment display request

116
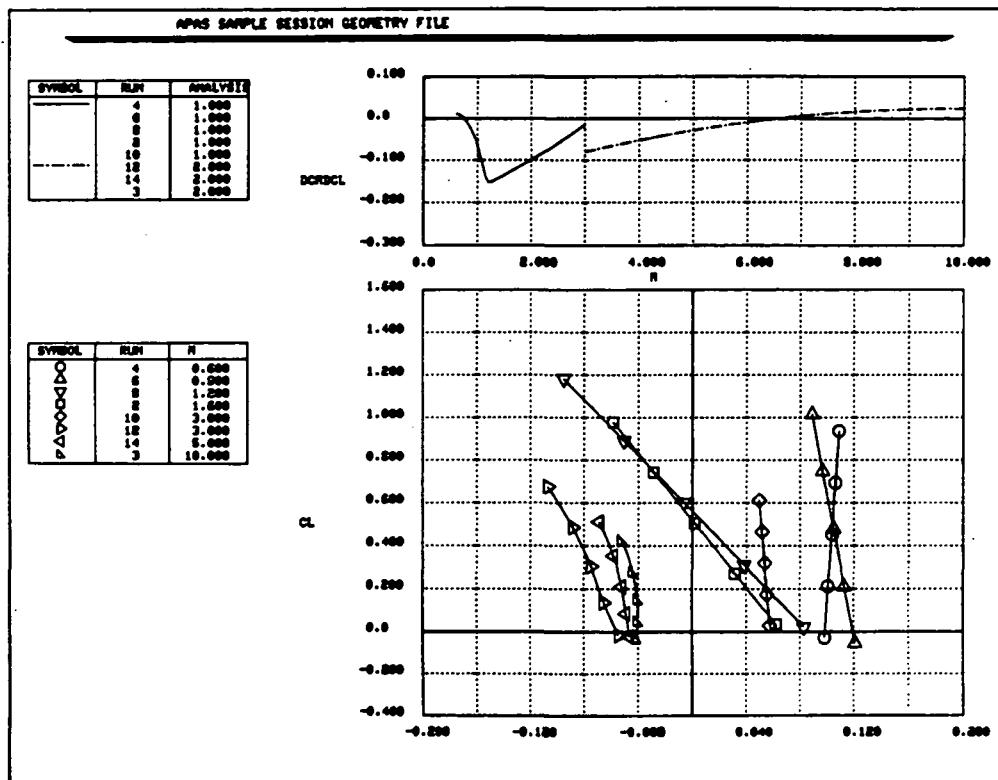
Screen 5-18 Longitudinal stability as a function of Mach number and
lift versus pitching moment

```
            XXXPLOTXXX
——————▶  set

         CURRENT PLOT SCHEDULES:
           1:  CL/A
           2:  CM/A
           3:  CL/CD
           4:  F2 CLA/M CL/A
           5:  CLA CMA CLO
           6:  CL/CM SA1=0.1
           7:  CL/CD0 SA1=0.1 CL/CD100 SA2=0.1 CL/CD SA3=0.1
           8:  CDO/M(A=0.) CL/CD G1


         CURRENT PLOT SCHEDULE   9 IS:
         ENTER NEW PLOT SCHEDULE   9, OR 'CARRIAGE RETURN' TO RETAIN AS IS
——————▶
         XXXPLOTXXX
——————▶ plot8 runs(5 3)
```

Screen 5-19   Drag at α=0 and C_L versus C_D display request

117
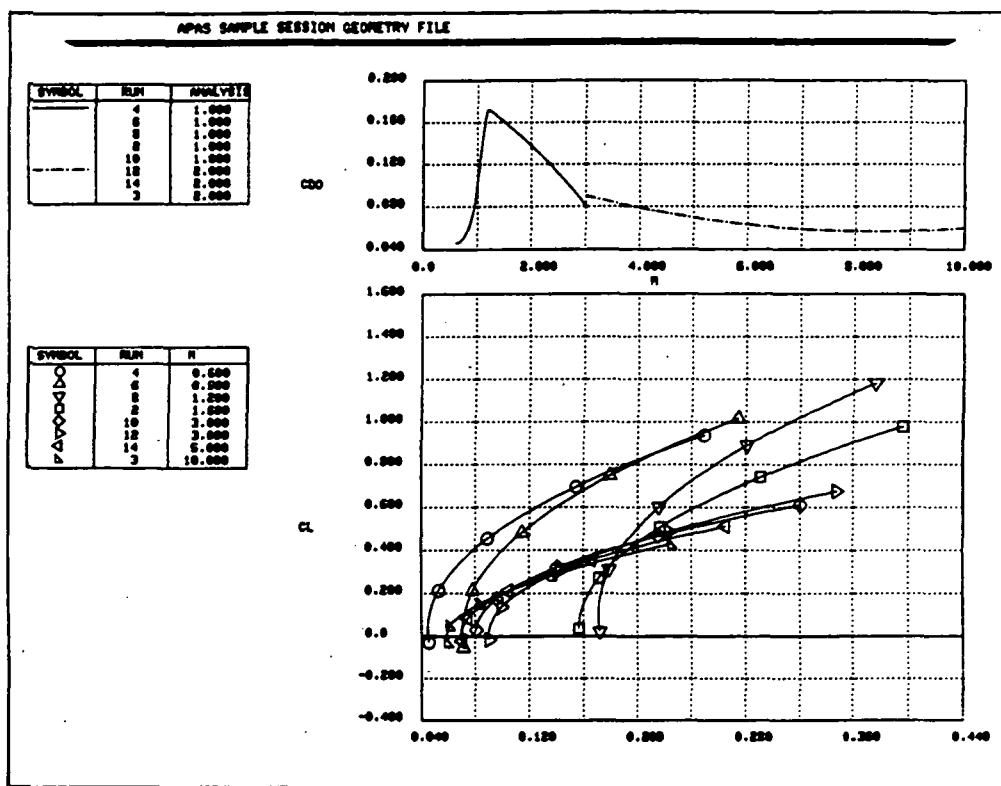
Screen 5-20 Drag characteristics as a function of Mach number and lift

Similarly, the input and display shown on screens 5-21 and 5-22 summarize the lateral-directional chracteristics (C_{y_β}, C_{n_β}, and C_{ℓ_β}) from runs 15 through 22.

PLOT
plot cyb(b=0) cnb(b=0) crb(b=0) run(15 16 17 18 19 20 21 22) runm(5 3)

Screen 5-21 Input for displaying lateral-directional
characteristics as a function of Mach number

118
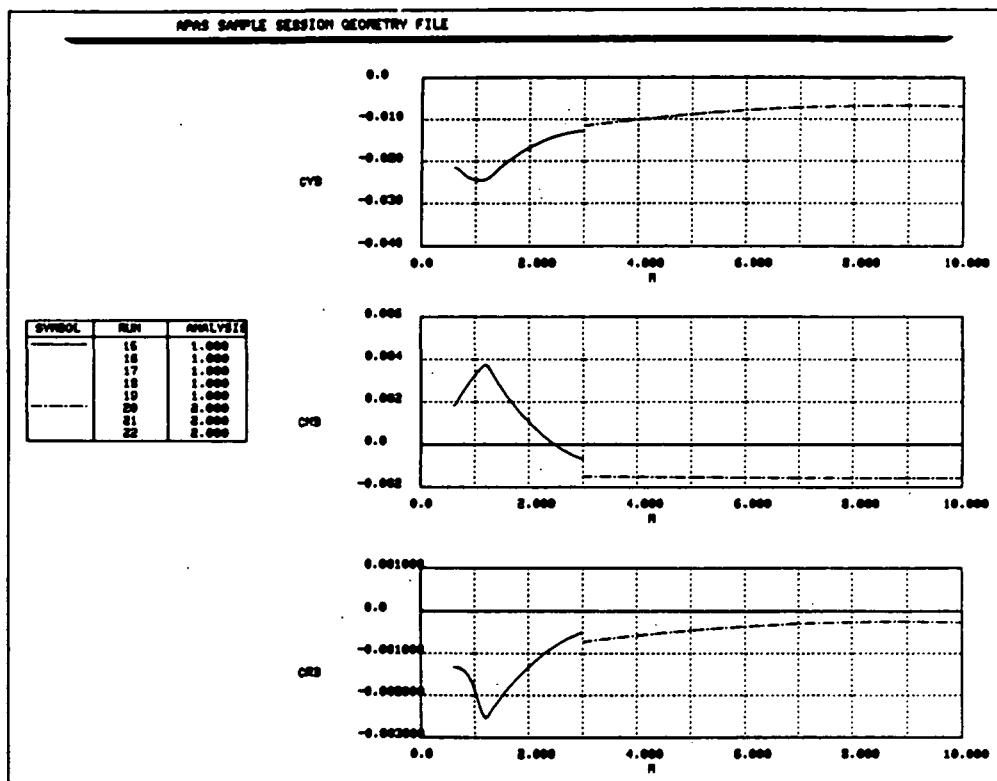
Screen 5-22 Lateral-directional characteristics displayed as a
function of Mach number

Section 6

COMMAND/SUBCOMMAND DICTIONARY

General grouping of commands by system activity is presented on figure 6-1.
A functional index is presented on table 6.

Each command/subcommand begins with a summary description including examples.
Information then follows on its detailed use. This format allows progressively
reduced reading load with increasing experience. Once familiarization with the
command structure is gained, many of the activities only require cursory review to
recall mechanics.

The command summary has been designed to give as much information as possible
on one page. Its format is as follows:

1. Name

2. Type of entree

3. Input format (always contained in a box)

4. List of operands and their function

5. Command/subcommand abbreviation

6. Function

7. Examples

A command and its associated operands are keyed in on one line. A typical
directive is

DISPLAY [,FILE][,VIEW] [,COMP(1),....COMP(N)][,ALL] [,ANGLE,-β, α, γ] <CR>

where DISPLAY identifies the command desired and the square brackets are used to indicate
optional operands which may be entered in any order. Nested brackets are used to separate
the operands into logical groups. Strings of periods ..... indicate to continued as in
one through seven. The comma before each operand is a delimiter and must be entered.
A blank proceeding each entered operand is also adaptable but was not used in order to
explicity indicate this point.

The remainder of this section alphabetically defines system commands and subcommands.
Their use is best learned by reviewing the cited examples and practicing the various
operations.
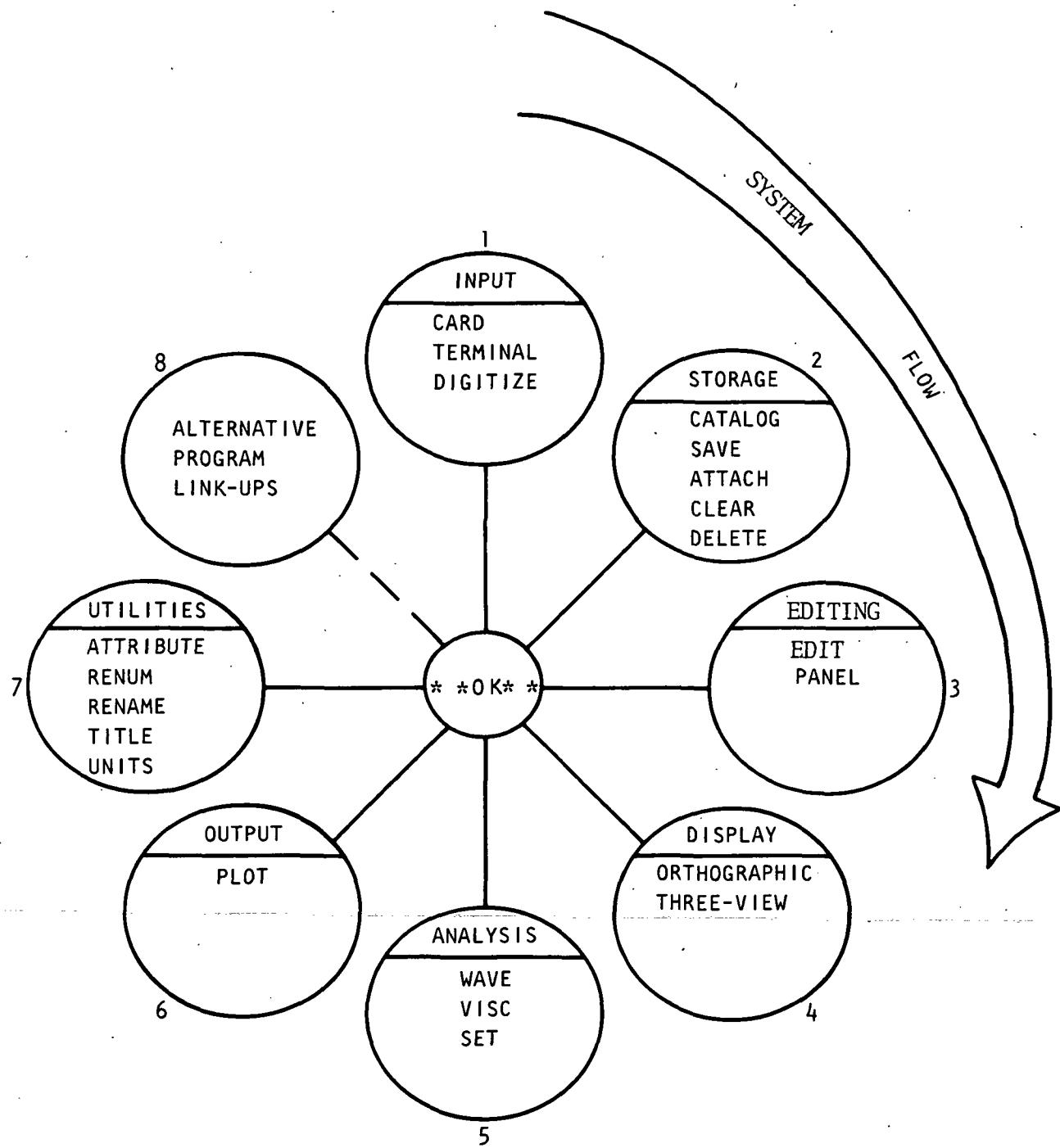
Figure 6-1 Command/Subcommand summary by system activity

TABLE 6   COMMAND INDEX

SYSTEM FUNCTION	SECTION	COMMAND(S)	
SET DEFAULTS (OPTIONAL)	3	ATTRIBUTE	
FILE LABELING	3	TITLE	
UNITS DECLARATION	3	ATTRIBUTE UNITS	
CONFIGURATION DEFINITION	3	CARD DIGITIZE INTERFERENCE SLENDER TERMINAL	
DISPLAY	3	DISPLAY	
COMPONENT EDITING AND PANELING	3	EDIT	
COMPONENT MANAGEMENT	3	ATTACH CATALOG CLEAR COPP COPY DELETE	FILES RENAME RENUMBER SAVE STATUS
FOREGROUND ANALYSIS	4	VISCOUS WAVEDRAG	
BACKGROUND ANALYSIS	4	SET	
ANALYSIS PLOTTING	5	PLOT	
EXIT		EXIT	

COMMAND ATTACH

```
ATTACH,COMP(1)l,COMP(2),...COMP(15)][,ALL] [,FILE]
```

OPERANDS: COMPN - COMPONENT NUMBER

ALL   - ATTACH ALL COMPONENTS FROM [,FILE]

        [P]ERMANENT; DEFAULT
        [C]OMPONENT

ABBREVIATION: ATTA

FUNCTION: COPIES NON-REDUNDANT COMPONENTS FROM [FILE] INTO LOCAL FILE

LIMITS: FIFTEEN (15) COMPONENTS PER CONFIGURATION. ALL COMPONENTS MUST HAVE SAME UNITS

EXAMPLE: SCREEN 4-1, 4-11

COMMAND: ATTRIBUTE

```
┌─────────────────────────────────────┐
│                                      │
│              ATTRIBUTE               │
│                                      │
└─────────────────────────────────────┘
```

OPERANDS: NONE

ABBREVIATION: ATTR

FUNCTION: MODIFICATION OF SYSTEM DEFAULTS

PROMPTS:

```
PRESENT USER DEFAULTS:
    FILE  OPERAND FOR COMMANDS ----------->: PERMANENT
    ANGLE OPERAND FOR DISPLAY COMMAND --->: YAW= 90.00 PITCH=  0.0  ROLL= 90.00
    UNIT  OPTION FOR  UNITS COMMAND ----->: METERS
    VIEW  OPERAND FOR DISPLAY COMMAND --->: THREE VIEW
    LINE -TYPE OPTION FOR DISPLAY COMMAND : STICK
    VIEW  OPERAND FOR EDIT/LIST SUBCOMMAND: FULL DISPLAY

ENTER: 'CR' - NO CHANGE
        1  - FILE  OPERAND
        2  - ANGLE OPERAND FOR DISPLAY COMMAND
        3  - UNIT  OPTION  FOR UNITS   COMMAND
        4  - VIEW  OPERAND FOR DISPLAY COMMAND
        5  - LINE  TYPE OPTION FOR DISPLAY COMMAND
        6  - VIEW  OPERAND FOR EDIT/LIST SUBCOMMAND
```

AVAILABLE OPTIONS WILL BE DISPLAYED FOR NUMBERED USER RESPONSE(S)

-CARD-

COMMAND CARD


```
CARD,COMP(1)[,COMP(2),....COMP(N)][,FILE]
```


OPERANDS: COMP   - COMPONENT NUMBER IN CARD FILE

                 FILE   - [P]ERMANENT; DEFAULT
                           [L]OCAL

ABBREVIATION: NONE

FUNCTION: COPIES COMPONENT PLACED IN CARD FILE INTO [FILE]

EXAMPLE: CARD, 101,L

COMMAND CATALOG

```
┌─────────────────────────────────┐
│                                 │
│                                 │
│         CATALOG[,FILE]          │
│                                 │
│                                 │
│                                 │
└─────────────────────────────────┘
```

OPERANDS: FILE -   [P]ERMANENT; DEFAULT
                          [L]OCAL
                          [B]OTH

ABBREVIATION: CATA

FUNCTION: CATALOG COMPONENT UNDERGOING INPUT OR EDITING INTO REQUESTED FILE.
                 PROTECTS OLD COMPONENTS WITH SAME NUMBER.

EXAMPLE: SCREEN   3-1, 3-6 , 3-50

CLEAR

COMMAND CLEAR

```
┌─────────────────────────┐
│                         │
│         CLEAR           │
│                         │
└─────────────────────────┘
```

OPERANDS: NONE

ABBREVIATION: CL

FUNCTION: PURGES ALL COMPONENTS IN THE LOCAL FILE.

COMMAND COPP

```
COPP, COMP(1)[,COMP(2),....COMP(n)][,ALL] [,FILE]
```

OPERANDS: COMP   - COMPONENT NUMBER

ALL   ATTACH ALL COMPONENTS FROM [,FILE]

FILE   - [C]OMPONENT; DEFAULT

[L]OCAL

ABBREVIATION: NONE

FUNCTION: COPY A COMPONENT FROM [,FILE] INTO PERMANENT FILE.
PROTECTS OLD COMPONENTS WITH SAME NUMBER.

EXAMPLE: COPP, ALL, C

COMMAND COPY

COPY,COMP,COMPN [,FILE]

OPERANDS: COMP - COMPONENT NUMBER

             COMPN - COMPONENT NUMBER TO BE COPIED TO

             FILE - [P]ERMANENT ; DEFAULT
                      [L]OCAL

ABBREVIATION: NONE

FUNCTION: COPY A COMPONENT TO A NEW RECORD IN THE
             SAME FILE

EXAMPLE: COPY, 101, 102, L

COMMAND DELETE

```
DELETE,FILE,COMP(1)[,COMP(2)...,COMP(n)][,ALL]
```

OPERANDS: FILE-   [P]ERMANENT
                          [L]OCAL

                 COMP   COMPONENT NUMBER

                 ALL - DELETE ALL COMPONENTS

ABBREVIATION: DEL

FUNCTION: ELIMINATE COMPONENTS FROM SPECIFIED FILE

EXAMPLE: DEL, L, 121, 211

COMMAND DIGITIZE

DIGITIZE [,COMPN] [,AXIS] [,FILE]

OPERANDS:

COMPN: RE-DIGITIZE COMPONENT COMPN;DEFAULT IS NEW COMPONENT

AXIS: NEW AXIS SYSTEM WILL BE REQUESTED;DEFAULTS TO AXIS ON FIRST CALL TO DIGITIZE. DEFAULTS TO PREVIOUS AXIS ON SUBSEQUENT CALLS.

FILE: [P]ERMANENT; DEFAULT
[L]OCAL

ABBREVIATION: DIGI

FUNCTION: DIGITIZE COMPONENT FROM DRAWING USING GRAPHICS TABLET. A COMMON SET OF UNITS MUST BE USED.

EXAMPLE SCREEN 3-27 THROUGH 3-34, 3-41 THROUGH 3-47

132

SYMBOL	DESCRIPTION
◯	Point input from tablet
{ }	Information in bracket does not appear on screen
⌐	Indicated information is on graphics screen
∧	Tablet input using digitizing pen or puck
< CR >	Carriage return
•	Position of point to be input from tablet

VARIABLE

XO	MINIMUM X VALUE FROM DRAWING
XMAX	MAXIMUM X VALUE FROM DRAWING
TYPE	1 - NON-PLANAR CENTERLINE (EG. FUSELAGE) 2 - NON-PLANAR OFF-SET (EG. ENGINE POD) 3 - HALF PLANAR (EG. VERTICAL TAIL) 4 - FULL PLANAR (EG. WING)
NSEG	NUMBER OF SEGMENTS/SECTION
NWET(1)	WETTED-UNWETTED SEGMENT FLAG
	1 - WETTED
	-1 - UNWETTED
TOC	t/C MAX OF AIRFOIL
	TOC < 0 , INPUT AIRFOIL SECTION
	TOC > 0 LAST INPUT AIRFOIL SECTION SCALED TO NEW CHORD AND TOC

COMPONENT SYMMETRY PARAMETERS

——— Stored boundary

----- Generated by symmetry directive

Codes
1 Non-reflective
2   Reflective
+   Asymmetric
-       Symmetric

Reflective Asymmetric

Code = 2

Example: Fuselage

                 Fuselage-Nacelle

Reflective Symmetric

Code = -2

Example: Missiles

                 Podded Nacelles

Aircraft   Component
$\mathsf{C_L}$ $\mathsf{C_L}$

Aircraft
$\mathsf{C_L}$

Non-reflective Asymmetric

Code = 1

Example: Centerline Vertical

Reflective Asymmetric

Code = 2

Example: Winglets or

                 Twin verticals

Aircraft
$\mathsf{C_L}$
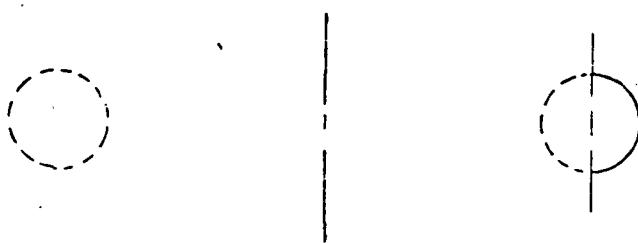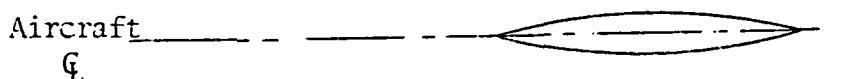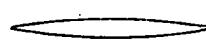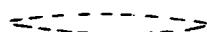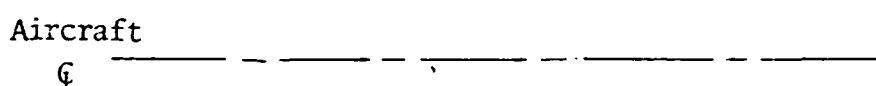
SET UP AXIS SYSTEM
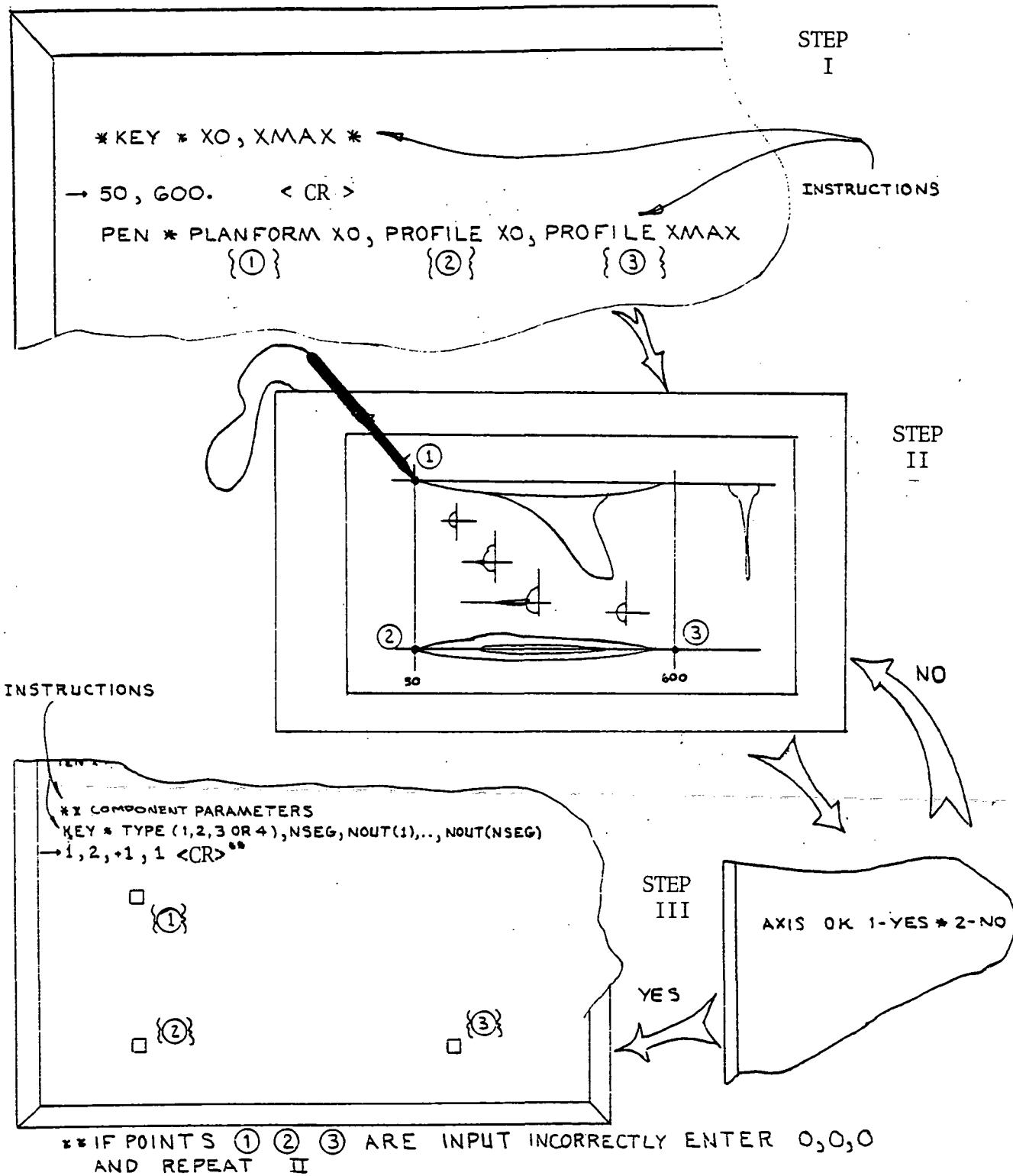
INPUT COMPONENT NUMBER

→ number

INPUT COMPONENT NAME

→ name

ENTER SYMMETRY PARAMETER

1 NON-REFLECTING

2 REFLECTING

+ ASYMMETRIC

- SYMMETRIC

→ symmetry parameter
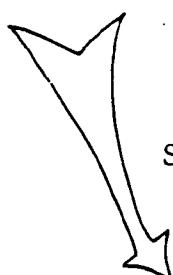
SURFACE

GO TO STEP
IV-A
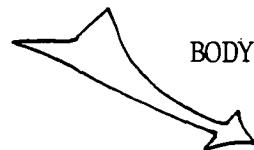
BODY

GO TO STEP
IV-B

SURFACE INPUT

KEY * TOC: SET NEGATIVE TO INPUT AIRFOIL.SET
            POSITIVE TO SCALE LAST INPUT AIRFOIL
            DEFAULT IS REFERENCE AIRFOIL T/C
PEN * LE(PROFILE), LE AND TE (PLANFORM CHORD LENGTH)
            IF TOC <0, SECTION LE AND TE
            REFERENCE (IF DIFFERENT).AIRFOIL
            SECTION FROM TOP L.E.

STEP
IV A

STEP
V-A

TOC ≤ 0

TOC > 0

POINTS ③-⑩   SEGMENT 1
POINTS ⑪-⑱   SEGMENT 2

STEP
VI-A

XO=200.3 YO=31.1 ZO=0.3

IV-A

S <CR>

£ 1 NEXT SECT. £ 2 REPEAT SECT. £ 3 END COMP.
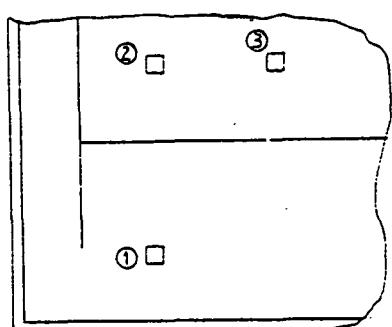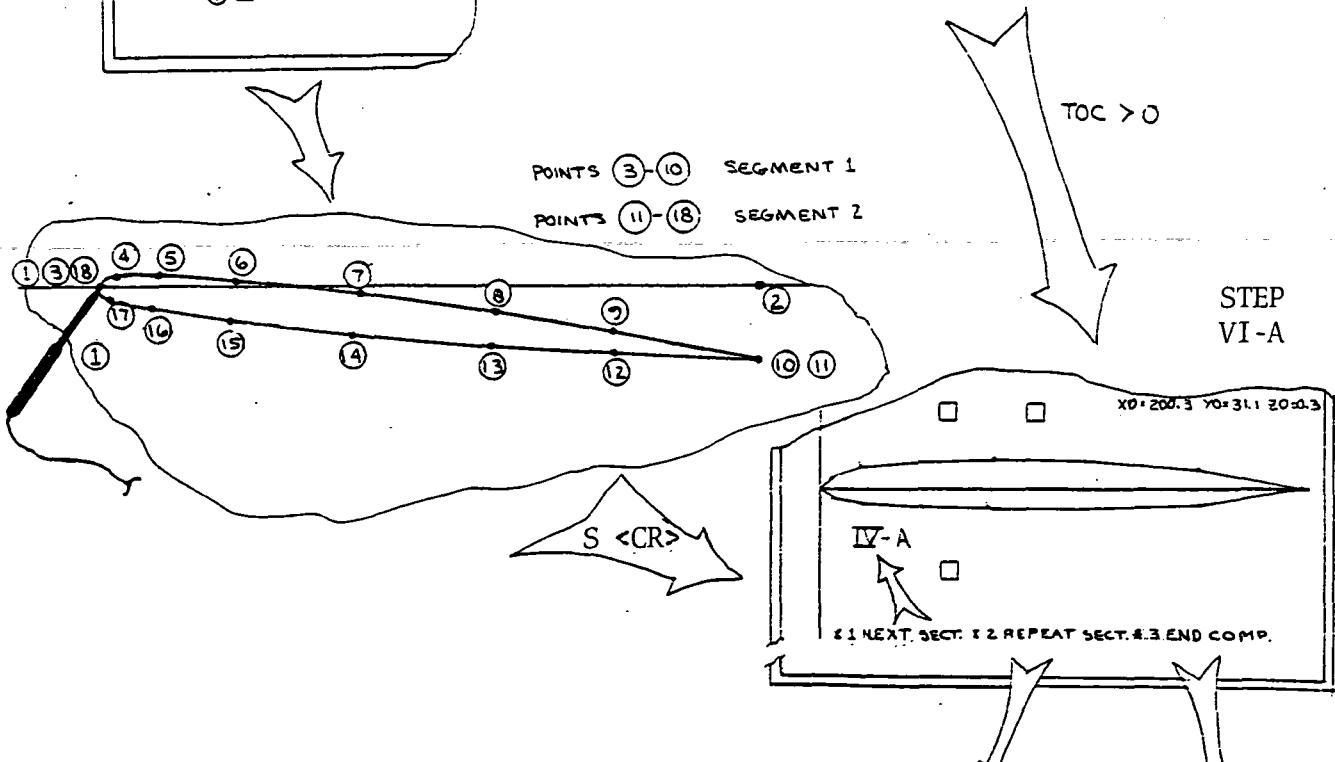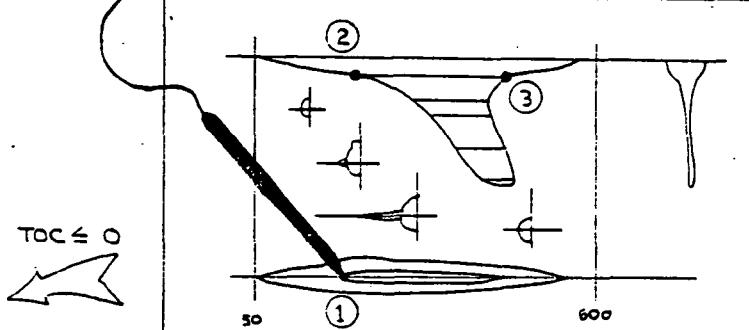
RETURN TO STEP IV-A

GO TO

VII

137

BODY INPUT

PEN * FUSELAGE REF.
    * SEGMENTS FROM TOP (COUNTER-CLOCKWISE)

STEP
IV-B

X<CR>

KEYBOARD REF.
POINT INPUT

STEP
V-A

STEP
V-B

POINTS ②-⑦
    SEGMENT 1

POINTS ⑧-⑬
    SEGMENT 2

* SEGMENT

INPUT XO, YO, ZO FOR SECT. DEFAULTS:
324.0, 0.0, -.12
325.6, 0.0, -.12   <CR>

XO=325.6 YO=0.0 ZO=-0.12
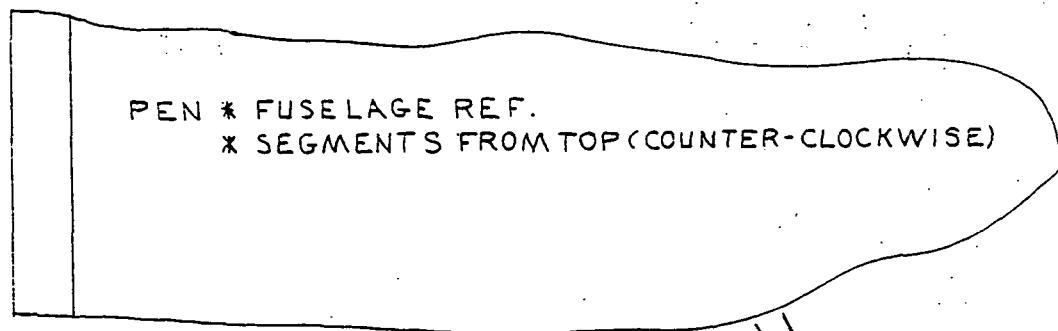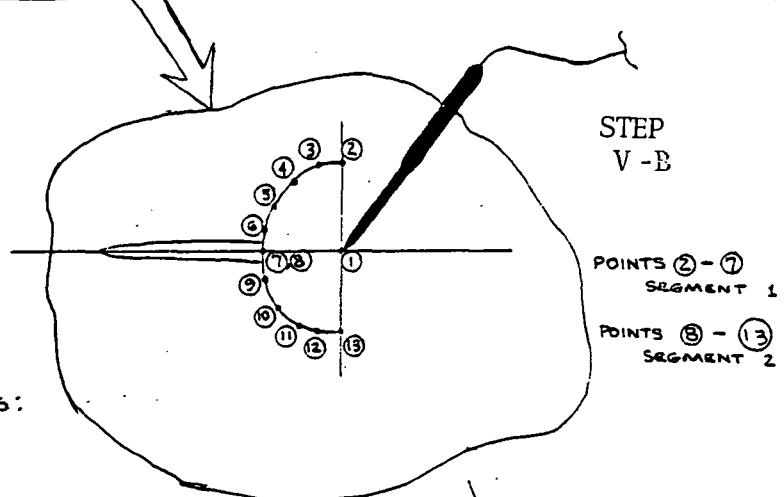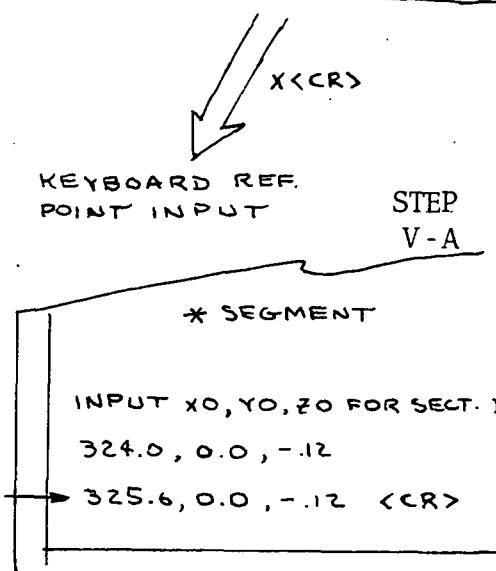
STEP
VI

OPTION WHEN
SECTION IS OFF
DRAWING

S<CR>

Ⅳ   Ⅴ

* 1 NEXT SECT. * 2 REPEAT SECT. * 3 END COMPONENT
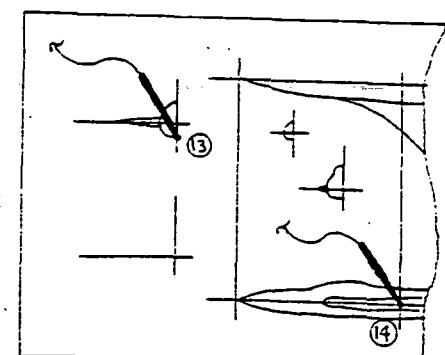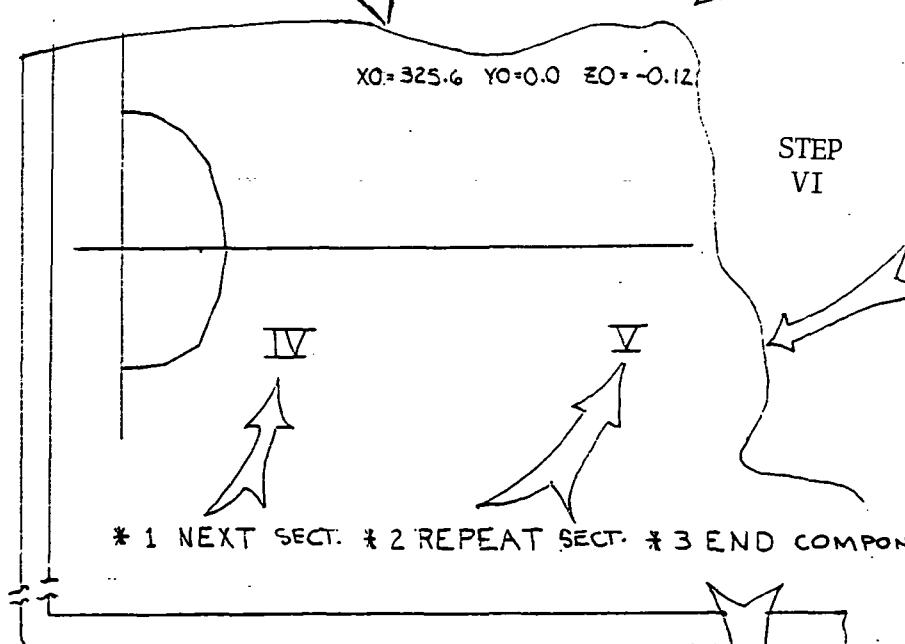
GO TO STEP VII

SEGMENT INTERPOLATION/SMOOTHING

* SMOOTH OPTION: ENTER ORDER OR

* CARRIAGE RETURN FOR SPLINE FIT ONLY

3 < CR >

STEP VII

SURFACE

BODY

STEP VIII

{ SPLINE }

{ LEAST SQUARES }

* L.E. RADIUS: METHOD 1: 1 METHOD 2: 2 OFF: 3

* ACCEPT SPLINE: 0, SMOOTH: 1, CHANGE ORDER: ENTER ORDER

?

0

1

>1

GO TO NEXT SEGMENT

REPEAT SEGMENT
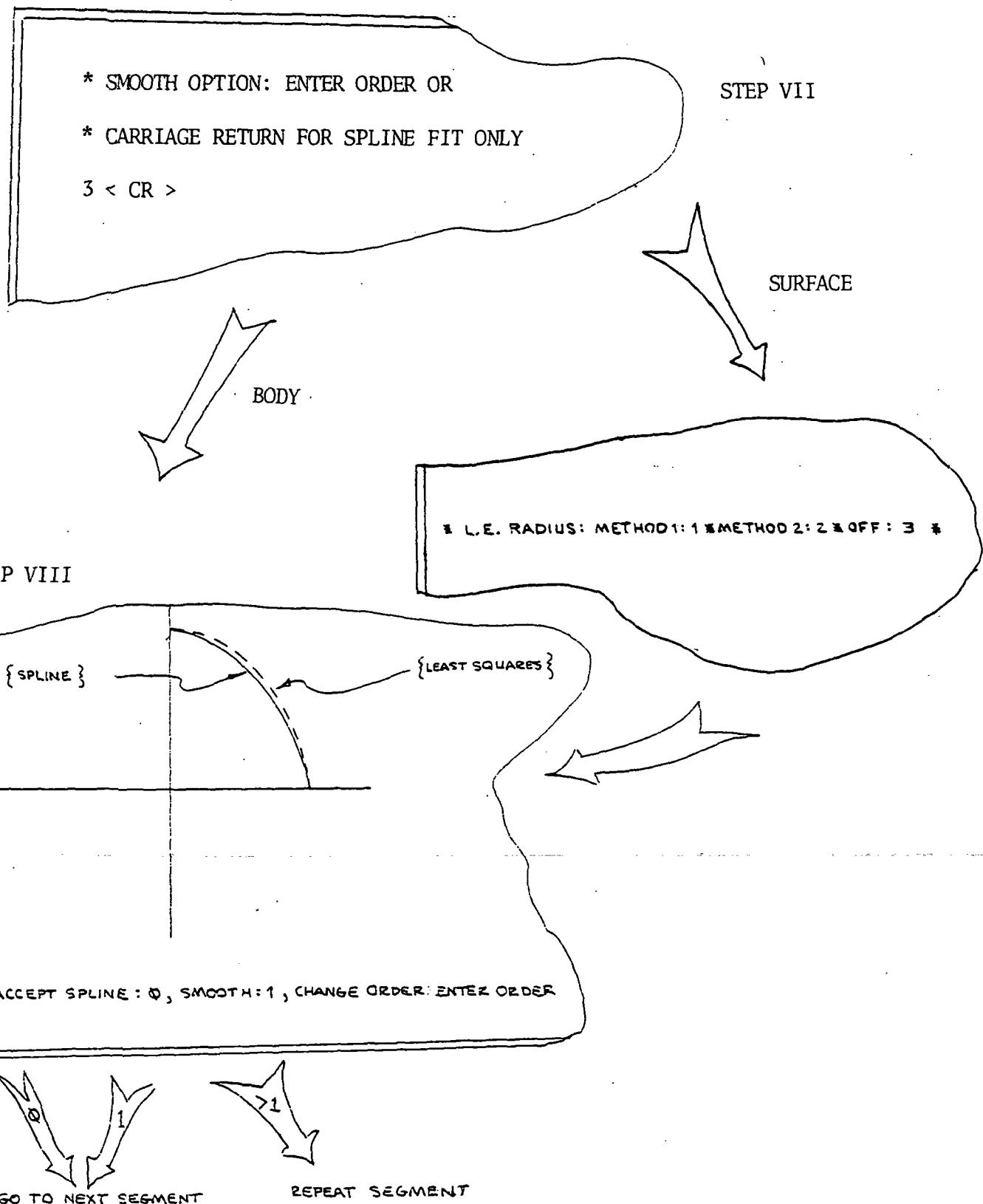
NOTES

1) XO and XMAX do not have to extend the length of the tablet or encompass the entire configuration. They are simply two convenient points on the drawing.

2) The XO in the plan view and profile view must be the same X-station.

3) When a change in segments occurs, the user inputs two points. If two or more segments occur at the same point (i.e. segments of zero length such as would occur on the cross section at the end of a canopy. See below), the user should input a number of identical points equal to the number of segments, i.e. if three segments meet at the same point three points are input.
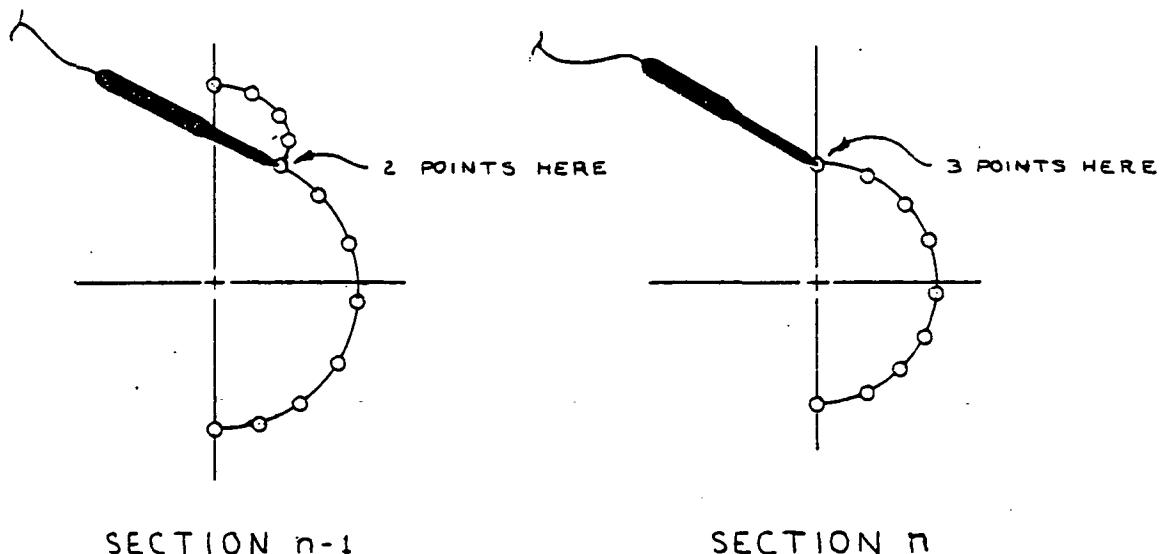
SECTION n-1   SECTION n

The first and last points on a section do not require multiple points unless segments converge or originate there.

4) The latest airfoil is always the reference section. A default
    section can only be used if the plnar component has two segments.

5) Three airfoil nose options are available: a default sharp edge, a
    radius based on the input points ahead of the maximum thickness, or
    NACA four and five digit airfoil values given by

$$R_{LE}/c = 1.1019 \ (t/c)^2$$

6) The multipoint routine used for graphics tablet digitizing has three
    termination options. The S <CR> indicates the cross section is
    completed. R <CR> indicates an error has occurred and input is
    being reinitiated. X <CR> allows keyboard correction of the section
    reference point.

7) The maximum number of input points per cross section is forty including
    reference POINTS such as the center line for a body section or chord
    markers for an airfoil.

COMMAND DISPLAY

DISPLAY[,FILE][,VIEW][,COMP(1),...COMP(N)][,ALL][,ANGLE,YAW,PITCH,ROLL]

OPERANDS: FILE: [P]ERMANENT; DEFAULT

                       [L]OCAL

          VIEW: [T]HREEVIEW STICK; DEFAULT*

                       [O]RTHOGRAPHIC STICK

          COMP: COMPONENT NUMBER; DEFAULT IS [ALL]

          [A]NGLE: YAW,PITCH,ROLL VIEWING ANGLES (ORTHOGRAPHIC ONLY)
                      DEFAULTS* ARE YAW = 90, PITCH = 0, ROLL = 90
                      0,0,0 PROVIDES A HEAD ON VIEW.
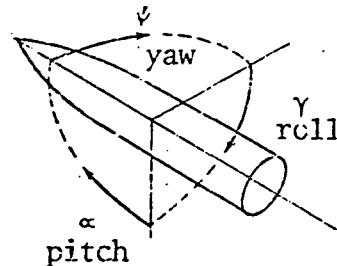
ABBREVIATION: DISP.

FUNCTION: DISPLAY COMPONENT(S) IN ORTHOGRAPHIC PROJECTION OR THREE VIEW.
STICK OR HIDDEN PANEL* LINE TYPE IS AVAILABLE. ORTHOGRAPHIC
HAS THE FOLLOWING OPTION MENU

```
* 1 VIEU     *
* 2 UINDOU   *
* 3 ZOOM OUT *
* 4 PERS ON  *
* 5 PERS OFF *
* E END      *
* ENTER COMMAND:
```

EXAMPLE: FIGURE 3-11 to 3-15; SCREEN 3-18, 3-25, 3-34, 3-51

*SET WITH ATTRIBUTE COMMAND

COMMAND EDIT

$$EDIT[,COMPN][,FILE][,COMPREF_1 \ldots.,COMPREF_n]$$

OPERANDS: COMPN: COMPONENT NUMBER; DEFAULT IS COMPONENT IN CORE

                      FILE: [P]ERMANENT, [L]OCAL, [C]OMPONENT; DEFAULT IS PERMANENT

                      $COMPREF_i$:   REFERENCE COMPONENT USED IN VIEW
                                        SUB-COMMAND

ABBREVIATION: NONE

FUNCTION: SECTION LISTING AND EDITING. SECTIONS CAN BE DISPLAYED,
INSERTED, MODIFIED, OR DELETED. FULL COMPONENT EDITING
IS PERFORMED IN EDIT USING THE VIEW SUBCOMMAND. PANELING
SURFACE COMPONENTS IS PERFORMED USING THE PANEL SUBCOMMAND

EXAMPLE: SCREEN 3-1 THROUGH 3-25, 3-52 THROUGH 3-65

SUBCOMMAND A, B

$$\boxed{\text{[SEC,]} A=VAL \quad \text{[,N1,N2]} \text{[,N3]} \text{[,V]}}$$

OPERANDS:

SEC — SECTION NUMBER; DEFAULT IS CURRENT SECTION

=VAL — VALUE OF ANGLE FOR ROTATION -DEGREES
- COUNTER-CLOCKWISE
+ CLOCKWISE
(MUST HAVE "=" SIGN IN FRONT OR DECIMAL
POINT IN VAL)

N1,N2 — START POINT AND END POINT
IF N1 IS GREATER THAN N2 ROTATION TAKES
PLACE ON POINTS NOT BETWEEN N1 AND N2

N3 — POINT TO ROTATE ABOUT, DEFAULT IS N1. IF N3 IS
SPECIFIED N1, N2 MUST BE ENTERRED

V — VERIFY INPUT VALUE

DEFAULT IF N1,N2,N3 ARE OMITTED
ALL POINTS IN SECTION ARE ROTATED ABOUT
POINT 1.

ABBREVIATION: NONE

FUNCTION: ROTATE BODY OR AIRFOIL SECTIONS.

BODY (TYPE 1 AND 2)

A INCLINE SECTION ABOUT Y-AXIS

B INCLINE SECTION ABOUT Z-AXIS

AIRFOIL   (TYPE 3 AND 4)

A   INCREMENTAL INCIDENCE ANGLE $< \pm 90°$

B   ABSOLUTE DIHEDRAL ANGLE OF AIRFOIL.   ZERO 'IS
PARALLEL TO AIRCRAFT PLANE OF SYMMETRY

EXAMPLE: 1, A = 6.0, V

145
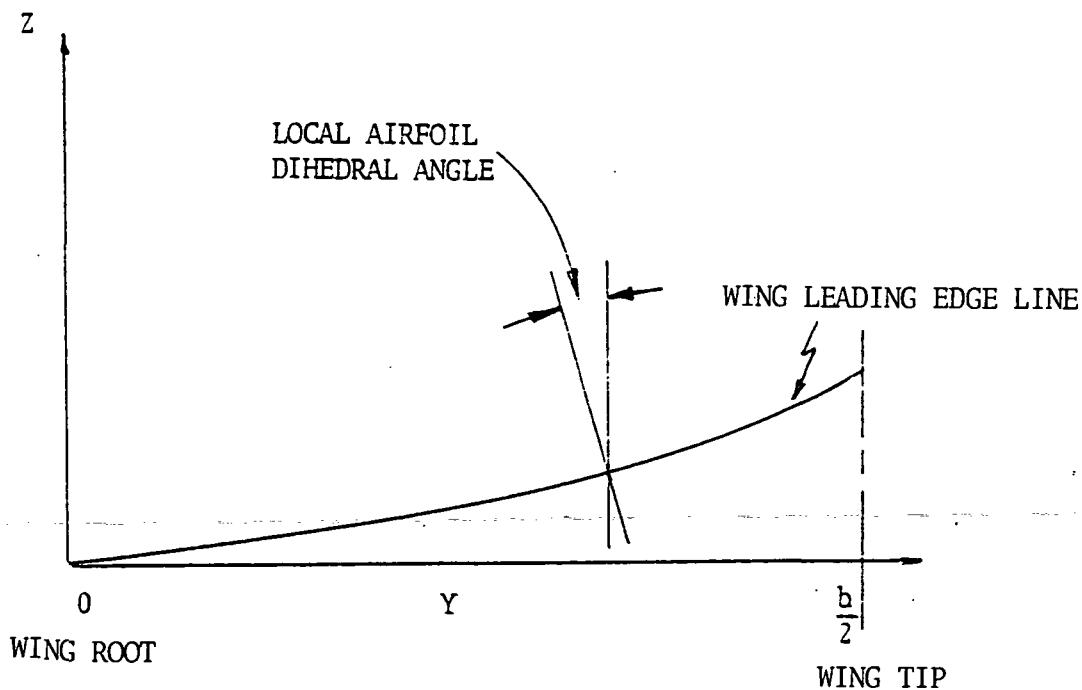
SUBCOMMAND DELETE

$$\text{DELETE,N1} \left[\text{,N2}\right] \left[\text{,V}\right]$$

OPERANDS: N1 - SECTION TO DELETE

                     N2 - DELETE SECTIONS FROM N1 TO N2

                     V   - VERIFY INPUT SECTION

ABBREVIATION: DEL

FUNCTION: DELETE SECTIONS FROM COMPONENT GEOMETRY.

EXAMPLE: DEL, 2, 3, V

SUBCOMMAND DUPLICATE

                        DUPLICATE=VAL,N1[,V]

OPERANDS: =VAL - INTERIOR LOCATION OF NEW SECTION
                          X BODY
                          Y WING, Y > 1.0
                          Y TYPE 3, 4, 5
                          b̄
                  N1   - SECTION TO BE DUPLICATED
                  V   - VERIFY NEW SECTION

ABBREVIATION: DU

FUNCTION: DUPLICATE SECTION N1 AT LOCATION VAL.

EXAMPLE   DU = 9.5, 4, V

SUBCOMMAND DX, DY, DZ

$$[SEC,] DX = VAL \; [,N1][,N2] \; [,V]$$

OPERANDS: SEC   -   SECTION NUMBER; DEFAULT IS CURRENT SECTION

               =VAL -   VALUE TO BE <u>ADDED</u> TO X. (MUST HAVE "="
                         SIGN IN FRONT OR OF VAL DECIMAL POINT IN

               N1   -   POINT TO HAVE INCREMENT ADDED

               N2   -   ALL POINTS FROM N1 TO N2 ARE TO HAVE
                         INCREMENT ADDED

               V   -   VERIFY INPUT VALUE

               DEFAULT WHEN N1, N2 ARE OMITTED IS "ALL"

ABBREVIATIONS: NONE

FUNCTION: ADD INCREMENTAL VALUE TO X, Y, OR Z OF A GIVEN
               SECTION   USING SUB-COMMAND DX, DY, OR DZ,
               RESPECTIVELY

EXAMPLE: SCREEN 3-8, 3-9

SUBCOMMAND INSERT

INSERT=VAL [,V]

OPERANDS: =VAL - INTERIOR LOCATION OF NEW SECTION
                            X   BODY
                            Y   WING, Y > 1.0
                            $\frac{Y}{b}$ TYPE 3, 4, 5

                   V   - VERIFY NEW SECTION

ABBREVIATION: IN

FUNCTION: SPLINE INTERPOLATE A NEW SECTION AT LOCATION VAL
                   ON A SEGMENT BY SEGMENT BASIS.

EXAMPLE: IN = 9.503, V

SUBCOMMAND LIST

```
[SEC,] LIST [,SP] [,SD]
```

OPERANDS: SEC   -   SECTION NUMBER; OMIT FOR CURRENT SECTION.

               SP   -   DISPLAY SECTION BUT SUPPRESS X,Y,Z VALUES

               S.D   LIST X,Y,Z VALUES BUT SUPPRESS DISPLAY OF
                      -   SECTION

                          DEFAULTS LIST DATA AND DISPLAY SECTION. SET
                          WITH ATTRIBUTE COMMAND.

ABBREVIATION: L

FUNCTION: DISPLAY SECTION AND LIST X, Y,Z COORDINATES. MULTIPLE
               POINTS CORRESPOND TO CONCIDENT SEGMENTS.

EXAMPLE: SCREEN 3-7,3-8, 3-13

SUBCOMMAND PANEL

```
┌─────────────────────────────────────┐
│                                       │
│     PANEL [,NOSEC]   [,VERIFY]        │
│                                       │
└─────────────────────────────────────┘
```

OPERANDS: [N]OSEC: SURFACE IS CONSIDERED ONE SPANWISE REGION WITH
                           STRAIGHT ROOT TO TIP LINES; DEFAULT IS ALL
                           SURFACE SPAN STATIONS ARE CONSIDERED REGION
                           BOUNDARIES

                [V]ERIFY: VERIFY REGION, FLAP, AND PANEL SPECIFICATIONS

ABBREVIATION: PAN

FUNCTION: DEFINITION OF SUBSONIC-SUPERSONIC ANALYSIS REGIONS, FLAP
                BOUNDARIES AND PANEL SPECIFICATION BY REGION FOR SURFACE
                COMPONENTS (TYPES 3 THROUGH 5).

OPERATION: A PLANER VIEW OF THE SURFACE COMPONENT IS DISPLAYED WITH
                A MENU OF KEY FUNCTIONS. DATA IS INPUT BY GRAPHICS CURSOR
                AND KEYBOARD.

LIMITS: 350 TOTAL PANELS
                 20 CHORDWISE
                 50 SPANWISE PER CONFIGURATION

EXAMPLE: SCREEN 3-63, 3-64, 3-65, FIGURE E-1, E-2

DESCRIPTION OF KEY FUNCTIONS

P - POINT FROM CURSOR

CHORDWISE AND SPANWISE COORDINATES ARE TAKEN FROM THE CURSOR POSITION. THE
LATTER IS RE-ASSIGNED THE VALUE OF THE NEAREST SECTION ON THE SURFACE.

X - X-LOCATION FROM KEYBOARD. THE SPAN LOCATION IS TAKEN AS THE CLOSEST
SECTION TO THE GRAPHICS CURSOR.

C - X/C LOCATION FROM KEYBOARD. THE SPAN LOCATION IS TAKEN AS THE CLOSEST
SECTION TO THE GRAPHICS CURSOR.

E - END OF FLAP LINE. E IS ENTERED FOLLOWING THE LAST POINT FOR THE FLAP
LINE BEING ENDED.

F - FINISH OF SURFACE LINES. ENTERED FOLLOWING THE ENTRY OF THE ENDPOINT
OF THE LAST FLAP LINE.

Q - TERMINATE REGION/PANELING INSTRUCTION AND EXIT FROM PANEL SUBCOMMAND.

H - FIVE (5) PERCENT CHORD MARKS TO AID FLAP DEFINITION

IF F IS THE ONLY KEY (OTHER THAN AN H) ENTERED THE LEADING AND TRAILING EDGE
AND DISPLAYED SPANWISE SECTIONS WILL BE USED TO DEFINE THE SURFACE REGIONS FOR PANEL-
ING. FLAP BOUNDARIES ARE DEFINED USING THE CURSOR AND P KEY TO ESTABLISH INBOARD/
OUTBOARD SPAN EXTENT AND THE X OR C KEY TO ESTABLISH CHORD EXTENT. THE E KEY
INDICATES THE END OF A PARTIAL SPAN HINGE LINE. THIS PROCESS IS DEMONSTRATED
ON SCREEN 3-64.

EACH REGION IS ASSIGNED A NUMBER FOLLOWING THE F ENTRY AS ILLUSTRATED ON
FIGURE E-1. THE NUMBER OF SPANWISE PANELS, NSPAN, FOR EACH REGION IS DEFINED
ALONG THE LOWER BORDER OF THE SCREEN AND IS INITIATED BY THE APPEARANCE OF AN
ARROW AT THE LOWER RIGHT. THE NUMBER OF CHORDWISE PANELS, SPACING AND FLAP
DATA ARE ENTERED AT THE UPPER LEFT OF THE SCREEN. THE FOLLOWING DATA IS
REQUESTED BY REGION.

NCHRD: NUMBER OF CHORDWISE PANELS FOR THIS REGION

NSPACE: TYPE OF CHORDWISE SPACING:
             1- EVEN
             2- HALF COSINE
             3- FULL COSINE

NFLAP: FLAP NUMBER FOR THIS REGION. A ZERO IS ENTERED FOR
             NO FLAP. THE USER MAY SELECT ANY INTEGER VALUE. REGIONS
             HAVING THE SAME FLAP NUMBER ARE CONSIDERED ONE CONTROL
             SURFACE

SFLAP: TYPE OF FLAP DEFLECTION (NOT USED UNLESS FLAP EXISTS.
             -1- ANTI-SYMMETRIC
              0- BOTH
              1- SYMMETRIC

VERIFICATION OF REGION, FLAP, AND PANEL SPECIFICATION USING THE V OPERAND IS
ILLUSTRATED ON FIGURE E-2.

HYPERSONIC RESEARCH VEHICLE CHECKOUT FOR APAS1

ENTER   - NCHRD,NSPACE,NFLAP,SFLAP
DEFAULTS - 10 ,   1 , 0 , 1
REGION 1 - 3,2,1,
REGION 2 - 5
REGION 3 - 3,1,2
REGION 4 - 3,2,1
REGION 5 - 5
REGION 6 - 3,1,2
REGION 7 - 8,2
REGION 8 - 3,1,2
REGION 9 - 8,2
REGION 10 - 3,1,2

MENU OF KEY FUNCTIONS

POINT FROM CURSOR   : P
X   LOC FROM KEYBOARD: X
X/C LOC FROM KEYBOARD: C
END LINE   : E
FINISHED WORK   : F
QUIT   : Q
5% HASH LINES   : H

1

4

2

5

7

9

3   6   8   10

2   2   2   2

<...... NSPAN

-EDIT/PANEL- (CONTINUED)

153
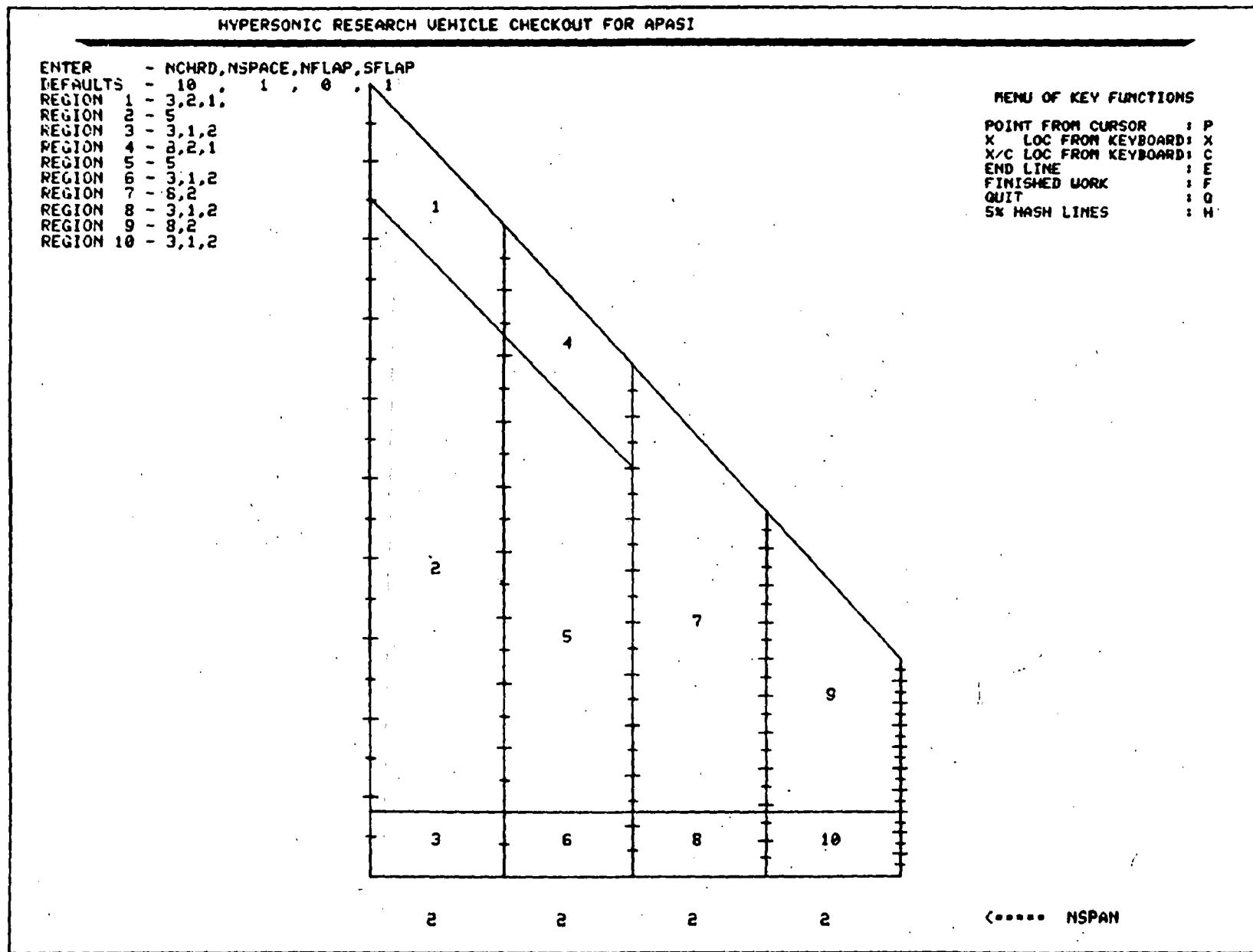
Figure E-1.   Surface Region, Paneling, and
Flap Specification

MENU OF KEY FUNCTIONS

POINT FROM CURSOR   : P
X   LOC FROM KEYBOARD: X
X/C LOC FROM KEYBOARD: C
END LINE   : E
FINISHED WORK   : F
QUIT   : Q
5% HASH LINES   : H

REGION LEGEND

REGION,FLAP(NCHRD,NSPAN)
    SFLAP,SPACING

1,1(3, 3)
BOTH HCOS

4,1(3, 2)
BOTH HCOS

2,0(5, 2)
EVEN

5,0(5, 2)
EVEN

7,0(8, 2)
HCOS

9,0(8, 2)
HCOS

3,2(3, 2)
BOTH EVEN

6,2(3, 2)
BOTH EVEN

8,2(3, 2)
BOTH EVEN

10,2(3, 2)
BOTH EVEN
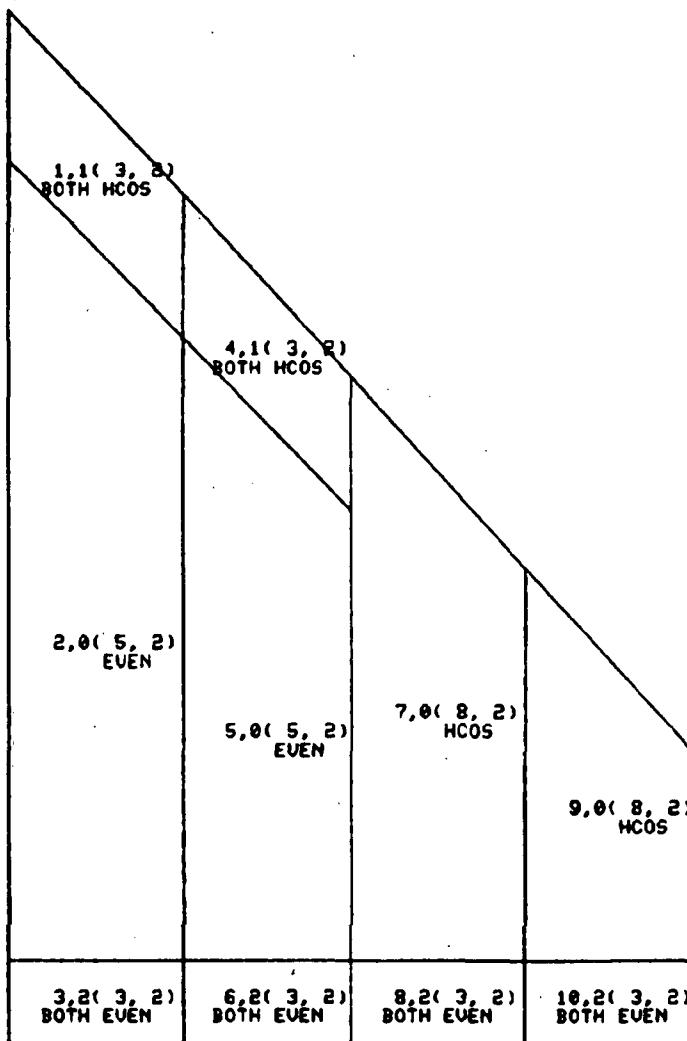
EDIT/PANEL   (CONCLUDED)

154

Figure E-2. Verification of Surface Region,
Paneling, and Flap Specifications

SUBCOMMAND   PARAMETER

```
┌──────────────────────────────────┐
│                                  │
│            PARAMETER             │
│                                  │
└──────────────────────────────────┘
```

OPERANDS: NONE

ABBREVIATIONS: P

FUNCTION: CHANGE COMPONENT PARAMETERS CONTAINED IN THE HEADER AND RECORD
             OF EACH COMPONENT

PROMPTS/RESPONSES:

    100.0   DEMO COMPONENT
    TYPE: 1
    NWET: 1 1 -1 1
    ENTER TYPE:
→2 <CR> (or <CR> to retain)

    ENTER NWET:
→1,-1,-1,1 <CR> [or <CR>]

    COMPONENT SYMMETRY: REFLECTIVE AND   SYMMETRIC
    ENTER: 1 : NON-REFLECTIVE
                    2 : REFLECTIVE
            POSITIVE : ASYMMETRIC
            NEGATIVE : SYMMETRIC
       ᴄᴀRRIAGE RETURN : UN-CHANGED
→1 <CR> (or <CR> to return)

    XO: 0.00 YO: 40.00 ZO -20.00
    ENTER NEW VALUES, PLACE COMMA TO LEAVE VALUE UNCHANGED
→200.0,,-30 <CR> (or <CR> to retain)

    BET: 0.00 ALP: 0.00 GAM: 0.00
    ENTER NEW VALUES, PLACE COMMA TO LEAVE VALUE UNCHANGED
→,,10. <CR> (or <CR> to retain)

    EDIT**

EXAMPLE: Screen 3-21

SUBCOMMAND SAVE

```
┌─────────────────────────────────────┐
│                                      │
│         SAVE [,COMPN] [,FILE]        │
│                                      │
└─────────────────────────────────────┘
```

OPERANDS: COMPN - NEW COMPONENT NUMBER; DEFAULT IS CURRENT
                           NUMBER

                   FILE - [P]ERMANENT

                           [L]OCAL

ABBREVIATION: S

FUNCTION: SAVE WORK PERFORMED ON A COMPONENT IN EDIT

EXAMPLE: SCREENS 3-5, 3-9, 3-18, 3-21, 3-25, 3-57, 3-60

156

SUBCOMMAND SC

```
SC = VAL,1,NS [,V]
```

OPERANDS: = VAL - SCALING VALUE

1 - FIRST COMPONENT SECTION

NS - NUMBER OF COMPONENT SECTIONS

V - VERIFY

ABBREVIATION: NONE

FUNCTION: FULL COMPONENT SCALING RELATIVE TO VEHICLE ORIGIN

CAN BE CONCATENATED WITH SUBCOMMANDS DX,DY AND DZ
TO SCALE AND TRANSLATE ALONG MORE THAN ONE AXIS.

ALSO SEE SUBCOMMANDS SX,SY,SZ,ST FOR SPECIALIZED
COMPONENT SCALING.

EXAMPLE: SC = 0.10, 1, 5, V

SUBCOMMANDS   SX,SY,SZ,ST

$$\left[\text{ SEC,}\right]\text{ SX=VAL }\left[\text{,SEC1,SEC2,ALL}\right]\left[\text{,V}\right]$$

OPERANDS: SEC - SECTION NUMBER . DEFAULT IS CURRENT SECTION

                  VAL - SCALING VALUE

                  SEC1,SEC2, ALL - SCALE ALL SECTIONS FROM SEC1 TO SEC2

                  V - VERIFY WITH PRINTOUT OF SCALED POINTS

ABBREVIATION: NONE

FUNCTION: SINGLE AXIS SCALING FUNCTIONS

                  SX - SCALE   X COORDINATES
                  SY - SCALE   Y COORDINATES
                  SZ - SCALE   Z COORDINATES
                  ST - SCALE WING SECTIONS TO THICKNESS SPECIFIED BY VAL

                  CAN BE CONCATENATED WITH EACH OTHER AND SUB-COMMANDS
                  DX, DY AND DZ TO SCALE AND TRANSLATE ALONG MORE THAN
                  ONE AXIS.

                  ALSO SEE SUBCOMMAND SC FOR FULL COMPONENT SCALING

EXAMPLE: 1, SX = 5.903

158

SUBCOMMAND - SPOFF,SPON,SDOFF,SDON,SOFF

```
┌─────────────────────────────┐
│                             │
│            SPOFF            │
│                             │
└─────────────────────────────┘
```

OPERANDS: NONE

ABBREVIATIONS: NONE

FUNCTION: CHANGE PRINT AND DISPLAY DEFAULTS. CAN ALSO BE USED
                IN CONJUNCTION WITH LIST SUBCOMMAND.

                SPOFF   SUPPRESS PRINT OFF

                SPON   SUPPRESS PRINT ON

                SDOFF   SUPPRSSS DISPLAY OFF

                SDON   SUPPRESS DISPLAY ON

                SOFF   TURN OFF ALL SUPPRESSION

EXAMPLE: SOFF

SUBCOMMAND - T/C

```
┌─────────────────────────────┐
│                             │
│         [SEC,] T/C          │
│                             │
└─────────────────────────────┘
```

OPERAND: SEC - SECTION NUMBER;   DEFAULT IS CURRENT SECTION

ABBREVIATION: T

FUNCTION: EVALUATES AND DISPLAYS MAXIMUM T/C AND ASSOCIATED X/C

EXAMPLE: 1, T

SUBCOMMAND - VON,VOFF

```
┌─────────────────────────────────────┐
│                                       │
│             VON  OR  VOFF             │
│                                       │
└─────────────────────────────────────┘
```
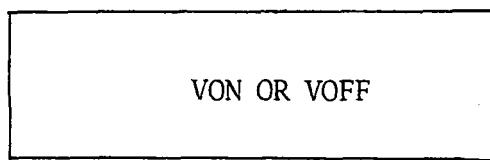
OPERANDS: NONE

ABBREVIATION: NONE

FUNCTION: ACTIVATES VERIFY MODE IN EDIT KEY COMMANDS TO
                 AUTOMATICALLY PRINT CHANGES

EXAMPLE: VON

SUBCOMMAND VIEW

```
┌─────────────────────────────┐
│                             │
│        VIEW [= ROLL]        │
│                             │
└─────────────────────────────┘
```

OPERANDS: ROLL: OPTIONAL ROLL ANGLE, IN DEGREES, FOR TYPE
                          1 AND 2 COMPONENT VISUAL EDITING; DEFAULT
                          IS 0.0

ABBREVIATION: VI

FUNCTION: COMPONENT EDITING USING GRAPHICAL DISPLAY

OPERATION: DISPLAY OF THE EDITING COMPONENTS IS PLACED ON THE SCREEN.
                   USER SPECIFIED SUBSIDIARY COMPONENTS ARE SHOWN AS DASHED LINES.
                   INPUT FOR THIS SUBCOMMAND IS THROUGH THE GRAPHICS CURSOR USING
                   KEYS TO DEFINE THE TYPE OF OPERATION DESIRED.

EXAMPLE: SCREEN 3-1 THROUGH 3-4, 3-6 THROUGH 3-10, 3-24, 3-25,
                   3-52 THROUGH 3-60

DESCRIPTION OF KEY FUNCTIONS:

I - INSERT A SECTION AT THE CURSOR X-LOCATION USING SECOND-ORDER INTERPOLATION.

F - INSERT A SECTION AT THE CURSOR X-LOCATION USING LINEAR INTERPOLATION.

D - DELETE CLOSEST SECTION TO CURSOR X LOCATION

T - SCALE SECTION INDICATED BY GRAPHICS CURSOR SUCH THAT THE TOP OF THE SECTION MATCHES THE Z (VERTICAL) LOCATION OF THE CURSOR. SCALING IS ON Z ONLY. THE BOTTOM OF THE SECTION IS UNCHANGED.

B - SCALE SECTION INDICATED BY GRAPHICS CURSOR SUCH THAT THE BOTTOM OF THE SECTION MATCHES THE Z (VERTICAL) LOCATION OF THE CURSOR. SCALING IS ON Z ONLY. THE TOP OF THE SECTION IS UNCHANGED.

U - MOVE SECTION NEAREST CURSOR VERTICALLY SUCH THAT THE TOP OF THE SECTION MATCHES THE Z (VERTICAL) LOCATION OF THE CURSOR.

L - MOVE SECTION NEAREST CURSOR VERTICALLY SUCH THAT THE BOTTOM OF THE SECTION MATCHES THE Z (VERTICAL) LOCATION OF THE CURSOR.

O - DISPLAY THE EDITED COMPONENT ON THE PRESENT SCREEN

R - REPAINT THE SCREEN.

Z - ZOOM IN ON AN AREA. THIS INPUT LOCATES ONE CORNER OF THE BOX; THE NEXT INPUT FROM THE CURSOR LOCATES THE OPPOSITE CORNER.

W - INCREASES THE VIEWING AREA BY 100%.

E - END

THE VARIOUS KEY OPTIONS ARE ACCOMPLISHED IN ONE OPERATION, ONE SECTION AT A TIME WITH THE EXCEPTION OF ZOOM. KEYS D,T,B,U, AND L OPERATE ON THE SECTION CLOSEST TO THE CURSOR AT THE TIME THE KEY IS ENTERED. KEYS I AND F DO NOT FUNCTION NEAR EXISTING SECTIONS.

SUBCOMMANDS X, Y, AND Z

$$[\text{SEC}] \; X \; [=\text{VAL}] \; [,\text{N1}] \; [,\text{N2}] \; [,\text{N3}] \; [,\text{V}]$$

OPERANDS:

SEC   -   SECTION NUMBER; DEFAULT IS CURRENT SECTION

=VAL   -   REPLACEMENT VALUE OF X. MUST HAVE
"=" SIGN IN FRONT OR DECIMAL POINT IN
VAL

N1   -   POINT TO BE GIVEN NEW VALUE

N2   -   ALL POINTS FROM N1 TO N2 ARE TO BE
SET TO VAL

N3   -   ALL POINTS FROM N1 TO N2 ARE TO BE SET
THE VALUE OF POINT N3

V   -   VERIFY INPUT VALUE. DEFAULT
WHEN N1, N2, N3 ARE OMITTED IS "ALL"

ABBREVIATION: NONE

FUNCTION: REPLACE PRESENT VALUES OF X, Y, OR Z OF A
GIVEN SECTION USING SUBCOMMAND X, Y, OR Z
RESPECTIVELY.

EXAMPLE: SCREENS 3-15, 3-16, 3-18

164

SUBCOMMAND   -   XH

$$XH \left[, N1\right] \left[, N2\right]$$

OPERANDS: N1   -   CHANGE POINT N1 TO Y,Z VALUES INDICATED
                       BY CROSS HAIRS

             N2   -   CHANGE POINTS FROM N1 TO N2 TO Y,Z VALUES
                       INDICATED BY CROSS HAIRS

             DEFAULT - LOCATE POINT TO MODIFY, ENTER NON-ZERO VALUE.
                        MOVE TO DESIRED LOCATION ENTER NON ZERO VALUE
                        TO CONTINUE OR ZERO TO END

ABBREVIATION: NONE

FUNCTION: BODY (TYPES 1, 2, 7, 8) SECTION MODIFICATION USING
                 GRAPHICS CURSOR

EXAMPLE: Screen 3-12

COMMAND EXIT

```
┌─────────────────────────────┐
│                             │
│           EXIT              │
│                             │
└─────────────────────────────┘
```
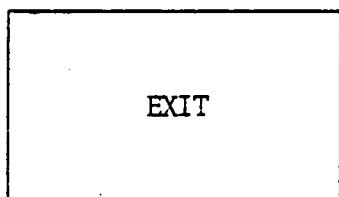
OPERANDS: NONE

ABBREVIATION: NONE

FUNCTION: CLOSE FILES AND EXIT FROM SYSTEM

EXAMPLE: **OK**
                 →EXIT

COMMAND FILES

```
┌─────────────────────────────┐
│                             │
│        FILES [,FILE]        │
│                             │
└─────────────────────────────┘
```

OPERANDS: FILE - [P]ERMANENT; DEFAULT
                          [L]OCAL
                          [C]OMPONENT

ABBREVIATION: FILE

FUNCTION: LIST COMPONENTS STORED IN EITHER PERMANENT
                 OR INDICATED FILE

EXAMPLE: SCREENS 3-49, 3-52, 3-60, 4-1, 4-11

COMMAND INTERFERENCE

```
INTERFERENCE,COMP(1)[,COMP(2),...COMP(N)] [,FILE]
```

OPERANDS: COMP: COMPONENT NUMBERS TO BE USED FOR REFERENCE. AT
                           LEAST ONE MUST BE SPECIFIED.

                    FILE - [P]ERMANENT; DEFAULT
                           [L]OCAL
                           [B]OTH

ABBREVIATION: INTE

FUNCTION: SLENDER BODY INTERFERENCE SHELL CONSTRUCTION FOR
                    SUBSONIC/SUPERSONIC ANALYSIS

EXAMPLE: SCREEN 3-61

COMMAND - PLOT

```
┌─────────────────────────────────────────┐
│                                           │
│                                           │
│                   PLOT                     │
│                                           │
│                                           │
└─────────────────────────────────────────┘
```
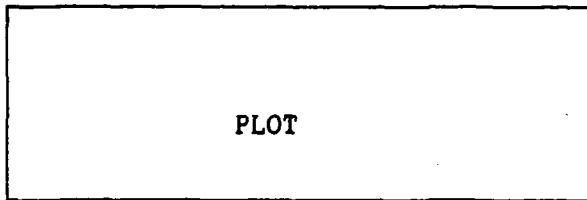
OPERANDS   :   NONE

ABBREVIATION: NONE

FUNCTION   :   ANALYSIS DISPLAY. THE AVAILABLE VARIABLES ARE PRESENTED
                   ON TABLE 7.

EXAMPLE: SCREEN 5-1 THROUGH 5-22

TABLE 7

ANALYSIS PLOT VARIABLES

A	ANGLE OF ATTACK α - DEGREES
B	SIDE-SLIP ANGLE β - DEGREES
CD	TOTAL DRAG COEFFICIENT C_D
CDo	DRAG COEFFICIENT AT $C_L = 0.0, C_{D_o}$
CDO	ZERO SUCTION DRAG COEFFICIENT $C_{D_{0\%}}$
CDM	WAVE DRAG COEFFICIENT C_{D_W}
CDP	VISCOUS DRAG COEFFICIENT C_{D_P}
CD100	100% SUCTION DRAG COEFFICIENT $C_{D_{100\%}}$
CL	LIFT COEFFICIENT C_L
CLA	LIFT CURVE SLOPE C_{L_α} - DEG^{-1}
CLO	LIFT COEFFICIENT AT ZERO ANGLE OF ATTACK C_{L_O}
CM	PITCHING-MOMENT COEFFICIENT C_M
CMA	PITCHING-MOMENT SLOPE C_{M_α} - DEG^{-1}
CN	YAWING-MOMENT COEFFICIENT C_n
CNA	NORMAL FORCE SLOPE C_{N_α} - DEG^{-1}
CNB	YAWING MOMENT SLOPE C_{n_β} - DEG^{-1}
CNR	NORMAL-FORCE COEFFICIENT C_N
CR	ROLLING-MOMENT COEFFICIENT C_ℓ
CRB	ROLLING MOMENT SLOPE C_{ℓ_β} - DEG^{-1}
CY	SIDE-FORCE COEFFICIENT C_Y
CYB	SIDE FORCE SLOPE C_{Y_β} - DEG^{-1}

DCMDCL   PITCH STABILITY dC_M/dC_L

D1,....,D6   FLAP DEFLECTION ANGLE δ_i - DEGREES

M   MACH NUMBER

P   ROLL RATE-RAD/SEC

Q   PITCH RATE-RAD/SEC

R   YAW RATE-RAD/SEC

SUBCOMMAND LIST

```
┌─────────────────────┐
│                     │
│       LIST          │
│                     │
└─────────────────────┘
```

OPERANDS: NONE

ABBREVIATIONS: L

FUNCTION: PROVIDES LIST OF RUNS CURRENTLY AVAILABLE IN THE
                     OUTPUT FILE

EXAMPLE: SCREEN 5-1

SUBCOMMAND - PLOT

```
PLOT [n]  [Gg₁] [[,FUNCTION₁[(IC₁=val,..,ICₙ=val)]]],...

   [[Gg₃] [,FUNCTION₃[(IC₁=val,..,ICₙ=val)]]] [,FORMf]

   [[,RUN(R₁,R₂,....Rₖ)] [,MACH (M₁,M₂,...Mₖ)]]

   [[,SOg=VAL] [,SAg=VAL] [,TOL=VAL]]

   [,RUNM (N₁,N₂,...N₁)] [,PAGE=p]

   [,LVFIX=VNAME] [,RVFIX=VNAME]
```

OPERANDS:

n   : SET NUMBER TO CONCATENATE ONTO PLOT LIST (n ≤ 12).

Gg   : ALLOWS DATA TO BE ARBITRARY PLACED ON DIFFERENT
                 GRIDS OF A PLOT FORM, WHERE "g" DEFINES THE GRID THE
                 FUNCTION THAT FOLLOWS IS TO BE PLACED. THE DEFAULT IS
                 TO FILL THE TOP GRID WITH THE FIRST FUNCTION AND LOWER
                 GRIDS IN SUCCESSION

FUNCTION   : PARAMETERS TO DISPLAY. FOR EXAMPLE CL/A i.e. LIFT
                 COEFFICIENT VERSUS ANGLE OF ATTACK. / IS USED TO
                 SEPARATE THE ORDINATE (LEFT SIDE) FROM THE
                 ABSCISSA. IF NO ABSCISSA IS INDICATED MACH
                 NUMBER IS ASSUMED.

                 IC_1=VAL,...INITIAL CONDITIONS. FOR EXAMPLE CLA/M(A=0)
                 i.e. LIFT CURVE SLOPE AT ZERO ANGLE OF ATTACK VERSUS
                 MACH NUMBER. SEE TABLE 7

FORMf [Ff] : PLOT FORM

173
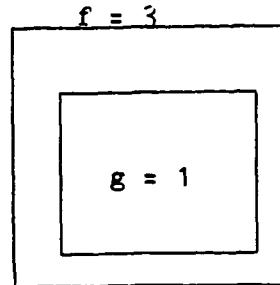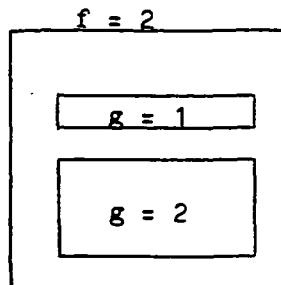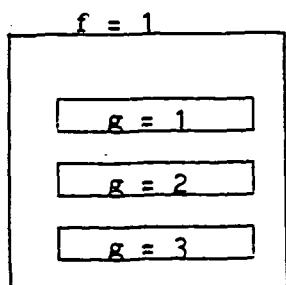
RUN($R_1,R_2,...R_k$) : RUN NUMBER LIST TO BE USED FOR THIS PLOT
($k \leq 32$). IF A LIST IS NOT SUPPLIED, THE CURRENT
RUN LIST AT THE TIME OF EXECUTION WILL BE USED OR
MAY BE ADDED IN THE PLOT SUBCOMMAND TO OVERRIDE
THE SET RUN LIST. A RUN LIST SUPERSEDES A
MACH LIST.

MACH[($M_1,M_2,...M_k$)] : MACH LIST TO BE USED FOR THIS PLOT (k $\leq$ 32).
ENTERING THE MACH NUMBER ALONE WILL OVERRIDE
THE CURRENT RUN LIST FOR THE CURRENT MACH LIST.
ADDING A MACH LIST IN THE PLOT SUBCOMMAND WILL
OVERRIDE LISTINGS IN SET.

SOg=VAL : ORDINATE GRID SCALE WHERE g INDICATES THE
GRID NUMBER AND VAL IS THE NUMERICAL VALUE
OF THE SCALING. DEFAULT (VAL = 0.0 FOR
AUTO MATIC SCALING).

SAg=VA : ABSCISSA GRID SCALE WHERE g INDICATES
GRID NUMBER AND VAL IS THE AXIS
NUMERICAL INCREMENT. DEFAULT (VAL =
0.0 FOR AUTO MATIC SCALING).

TOL=VAL : COMPARISON TOLERANCE. WHERE "VAL" EQUALS THE
INCREMENT TO BE USED WHEN COMPARING INITIAL
CONDITIONS OF ONE RUN AGAINST ANOTHER FOR
DISPLAY CONSISTENCY. DEFAULT (VAL = 0.50).

RUNM($N_1,N_2,...N_n$) : RUN LIST PARTITIONING FOR PLOTTING
IDENTIFICATION. SEE SCREEN 5-12,
5-14.

$$N_1 + N_2 + ...N_n = k \qquad (n \leq 8)$$

WHERE k IS THE TOTAL NUMBER OF RUNS IN THE
CURRENT RUNLIST. IT IS RECOMMENDED THAT
LVFIX BE SPECIFIED. RUNM MUST BE SET FOR
EACH NEW PLOT

PAGE=p : PRE-PLOT SUMMARY PAGE CONTROL

p = -1 DON'T STOP BEFORE PLOTTING: DEFAULT
0 ALWAYS STOP BEFORE PLOTTING
1 STOP ONLY IN CASE OF ERROR
2 STOP AND TAKE A HARD COPY

LVFIX=VNAME   : INDEPENDENT VARIABLE "VNAME" TO DISPLAY IN
                             PLOT SYMBOL TABLE. IF UNSPECIFIED THE FIRST
                             TWO RUNS ARE COMPARED AND THE FIRST UNEQUAL
                             INDEPENDENT VARIABLE FOUND WILL BE USED. MACH
                             NUMBER IS DISPLAYED WHEN NO DIFFERANCES ARE
                             FOUND. SEE SCREENS 5-4 AND 5-16.

RVFIX=VNAME   : FOR PLOTS USING A MACH LIST ONLY. ONLY RUNS
                             WITH VARIABLE NAME "VNAME" AS THE INDEPENDENT
                             VARIABLE WILL BE SELECTED FOR PLOTTING.

FUNCTION: DISPLAY ANALYSIS RESULTS IN GRAPHICAL FORM. EACH
                             PLOT IS CONSTRUCTED INDEPENDENTLY USING RUN LISTS
                             OR MACH LISTS SUPPLIED BY THE USER. EACH GRID IN
                             A DISPLAY CAN HAVE DIFFERENT INITIAL CONDITIONS.

                             THE REQUIRED INPUT CAN BE REDUCED BY PRE-ENTERING
                             COMMON SETS OF DISPLAY PARAMETERS USING THE SET
                             SUBCOMMAND

ABBREVIATION: PL

EXAMPLE: SCREEN 5-3

175

SUBCOMMAND - SET

```
SET[n]   [Gg₁] [[,FUNCTION₁[(IC₁=val,..,ICₙ=val)]]],...

   [[Gg₃] [,FUNCTION₃[(IC₁=val,..,ICₙ=val)]]] [,FORMf]

   [[,RUN(R₁,R₂,....Rₖ)] [,MACH (M₁,M₂,...Mₖ)]]

   [[,SOg=VAL] [,SAg=VAL] [,TOL=VAL]]

   [,RUNM (N₁,N₂,...N₁)] [,PAGE=p]

   [,LVFIX=VNAME] [,RVFIX=VNAME]
```

OPERANDS:

n   : SET NUMBER ASSIGNED TO THIS INPUT LINE (n ≤ 12)

.
.   SAME AS SUBCOMMAND PLOT
.

FUNCTION: USED TO DEFINE AND DISPLAY PLOT LISTS (SCHEDULES) WHICH ARE USED
                   ON A REGULAR BASIS. A SCHEDULE IS ACCESSED FROM THE
                   PLOT SUBCOMMAND BY CONCATENATING IT. SEE SCREEN 5-12.

                   SET IS A CONVENIENCE FUNCTION IN APAS. RUN LISTS ARE NOT
                   USUALLY PLACED ON PLOT LISTS SINCE THEY ARE THE MOST VARIED
                   OPERAND ENTERED IN THE PLOT STATEMENT.

EXAMPLE: SCREEN 5-5, 5-12

COMMAND RENAME

RENAME,COMP[,FILE]

OPERANDS: COMP - COMPONENT NUMBER OR RECORD NUMBER

                 FILE - [P]ERMANENT; DEFAULT
                        [L]OCAL

ABBREVIATION: RENA

FUNCTION: CHANGE COMPONENT NAME

EXAMPLE: rename, 121
                 ENTER NEW COMPONENT NAME

              → wing

COMMAND RENUMBER

```
┌─────────────────────────────────────────────────────┐
│                                                       │
│                                                       │
│         RENUMBER,OLDCOMPN,NEWCOMPN[,FILE]             │
│                                                       │
│                                                       │
└─────────────────────────────────────────────────────┘
```

OPERANDS: OLDCOMPN: OLD COMPONENT NUMBER,

                 NEWCOMPN: NEW COMPONENT NUMBER

                 FILE - [P]ERMANENT; DEFUALT
                        [L]OCAL

ABBREVIATION: RENU

FUNCTION: CHANGE COMPONENT NUMBER

EXAMPLE: RENU, 101, 121

COMMAND SAVE

```
┌─────────────────────────────────┐
│                                 │
│                                 │
│          SAVE[,FILE]            │
│                                 │
│                                 │
└─────────────────────────────────┘
```

OPERANDS: FILE - [P]ERMANENT ; DEFAULT
                    [L]OCAL

ABBREVIATION: S

FUNCTION: PLACE COMPONENT IN REQUESTED FILE. IT WILL BE
                CATALOGED IF NEW.

COMMAND SET

```
┌─────────────────────┐
│         SET         │
└─────────────────────┘
```

OPERANDS: NONE

ABBREVIATION: NONE

FUNCTION: BACKGROUND ANALYSIS INPUT FILE DEFINITION

                      TO ENTER A NEW CONFIGURATION, PERTINENT COMPONENTS
                      ARE ATTACHED TO THE LOCAL FILE AND PROMPTED REFERENCE
                      QUANTITIES ARE SPECIFIED. ONLY A LIST OF COMPONENTS
                      (AS APPOSED TO GEOMETRY) IS STORED. A CONFIGURATION
                      DOES NOT HAVE TO BE ENTERED IF IT ALREADY EXISTS.

                      RUNS CAN BE ADDED, DELETED, OR RESET USING SET SUBCOMMANDS.

LIMITS: 10 CONFIGURATIONS

                      292 DATA POINTS *

                      32 RUNS

                      20 POINTS/RUN

EXAMPLE: SCREEN 4-11

        *ANALYSIS INDEPENDENT VARIABLE COMBINATIONS

SUBCOMMAND ADD

```
ADD[n] [,RUN(r)] [,[ALPHA(a_1,...,a_n)] [BETA(b_1,...,b_n)]]

   [,MACH(m)] [,ICOND_1(ic_1),......,ICOND_n(ic_n)] [,CONFIG(c)]

   [,[AIR][HELIUM]] [,[NOPRINT][PRINT]] [,[SHKOFF][SHKEXP]]

   [,[HYPOFF][HYPER]] [,[LINEAR][FIXED]] [,PROTECT(p)]
```

OPERANDS:

n
: SET NUMBER TO CONCATENATE ONTO ADDLIST (n < 12). (SEE SET SUBCOMMAND OF SET)

RUN(r)
: RUN NUMBER (r). ANY VALUE BETWEEN 1 AND 9999 CAN BE USED IN ANY ORDER

ALPHA(a_1-a_n)
: [A] ANGLE-OF-ATTACK LIST. EITHER ALPHA OR BETA LIST SHOULD BE SPECIFIED OR A RUN WITH ONLY ONE DATA POINT WILL RESULT.

BETA(b_1-b_n)
: [B] ANGLE-OF-SIDE-SLIP LIST.

MACH (m)
: [M] MACH NUMBER (m)

$ICOND_i(ic_i)$
: INITIAL CONDITION (ic) FOR ANALYSIS CALCAULATIONS. SEE TABLE 8

CONFIG(c)
: [C] CONFIGURATION TO USE FOR ANALYSIS. DEFAULT IS THE HIGHEST OR MOST RECENT.

AIR
HELIUM
: ATMOSPHERE FOR HYPERSONIC ANALYSIS. DEFAULT IS AIR

NOPRINT
PRINT
: DIAGNOSTIC PRINT FOR HYPERSONIC RUNS. INCREASES OUTPUT BY A FACTOR OF TEN. DEFAULT IS NOPRINT.

181

SHKOFF   : SHOCK EXPANSION INDICATOR FOR HYPERSONIC FLAP DEFLECTION
SHEXP   CALCULATIONS. DEFAULT IS SHKOFF.

HYPOFF   : HYPERSONIC ANALYSIS INDICATOR. MACH NUMBERS LESS THEN
HYPER   4.0 DEFAULT TO THE SUBSONIC-SUPERSONIC ANALYSIS   UNLESS
                  THE HYPER KEYWORD IS INVOKED. DEFAULT IS HYPOFF.

LINEAR   : SUBSONIC-SUPERSONIC SOURCE (THICKNESS) SOLUTION INDICATOR
FIXED   DEFAULT IS LINEAR.

PROTECT(p)   : [PROT] PROTECTION KEY TO PREVENT OTHER USERS FROM
                  ALTERING OR DELETING A RUN.

FUNCTION: ENTER A NEW RUN INTO THE INPUT FILE INDEX. WHEN USED WITH A SETLIST,
           THE AMOUNT OF INPUT REQUIRED AND POSSIBLE ERRORS ARE CONSIDERABLY
           REDUCED. REQUIRED INFORMATION WILL BE REQUESTED BY THE SYSTEM IF
           NOT PROVIDED IN THE ADD STATEMENT.

EXAMPLE: SCREEN 4-12

TABLE 8

Analysis Initial Conditions

ALPHA(a)   : [A] INITIAL ANGLE OF ATTACK -DEGREES

BETA(b)   : [B] INITIAL SIDE-SLIP ANGLE -DEGREES

P(p)   : ROLL RATE -RADIANS/SEC

Q(q)   : PITCH RATE -RADIANS/SEC

R(r)   : YAW RATE -RADIANS/SEC

D1(d_1),..,D6(d_6) : FLAP DEFLECTION ANGLES -DEGREES

ALTITUDE(alt)   : [ALT] ALTITUDE -METERS OR FEET

KS(ks)   : EQUIVALENT SAND GRAIN HEIGHT -METERS, INCHES OR CM
                    FOR VISCOUS DRAG (SEE TABLE 9). ONLY REQUIRED
                    FOR SUBSONIC-SUPERSONIC ANALYSIS.

PRESSURE(pr)   : [PRESS] STAGNATION PRESSURE - Nt/m2 OR lb/ft^2.
                    NOT REQUIRED WHEN ALTITUDE IS SPECIFIED.

TEMPERATURE(t)   : [TEMP] STAGNATION TEMPERATURE -KELVIN OR RANKINE.
                    NOT REQUIRED WHEN ALTITUDE IS SPECIFIED.

INITIAL CONDITIONS ARE THE PARAMETRIC VALUES WHICH DEFINE THE CON-
FIGURATION ATTITUDE AND ATMOSPHERIC CONDITIONS AT WHICH A GIVEN RUN
IS TO BE ANALYZED. A STRING OF THESE CONDITIONS ARE INPUT WITH
THE ADD OR RESET SUBCOMMANDS WHICH WILL THEN DEFINE THE ATTRIBUTES
UTILIZED AT THE TIME EACH RUN IN THE ANALYSIS FILE IS EXECUTED.
THE SET SUBCOMMAND IS A CONVENIENT WAY TO MAINTAIN A GROUP OF PRESET
LISTS OF INITIAL CONDITION STRINGS WHICH ARE USED REPEATEDLY.

MACH NUMBER, ALTITUDE OR TEMPERATURE AND PRESSURE, AND SAND GRAIN
HEIGHT (FOR NON-HYPERSONIC RUNS)   INITIAL CONDITIONS WILL BE
REQUESTED BY THE SYSTEM IF THE USER FAILS TO INPUT THEM WHEN ADDING
A RUN TO THE ANALYSIS FILE.

ANGLE OF ATTACK OR SIDE-SLIP MAY BE SPECIFIED TO HAVE FROM 1 TO 20
VALUES IN A GIVEN RUN. THEY ARE THE INDEPENDENT VARIABLES
IN THE SAME SENSE AS A WIND TUNNEL TEST.

SUBCOMMAND   DELETE

```
DELETE,r(1)[,r(2),...r(n)]
```

OPERANDS:

    r   : RUN NUMBER(S) TO DELETE FROM INPUT FILE.

ABBREVIATION: DEL

FUNCTION: DELETE ANALYSIS RUNS FROM THE INPUT FILE.

EXAMPLE: DEL, r3

SUBCOMMAND END
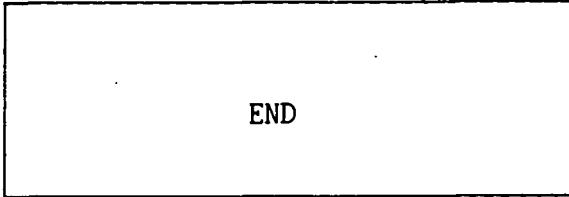
```
+-------------------------------------------------+
|                                                 |
|                                                 |
|                      END                        |
|                                                 |
|                                                 |
+-------------------------------------------------+
```

OPERANDS: NONE

ABBREVIATION: E

FUNCTION: ENDS RUN LIST DEFINITION ACTIVITY OF SET AND INITIATES
             THE AERODYNAMIC MODEL VALIDATION AND HYPERSONIC ALGORITHM
             ASSIGNMENT PHASE.

EXAMPLE: SCREEN 4-14 THROUGH 4-24

SET / LIST

- SET / LIST -

SUBCOMMAND   LIST

```
┌─────────────────────────────────────┐
│                                     │
│          LIST[,CONFIG][,r]          │
│                                     │
└─────────────────────────────────────┘
```

OPERANDS:

      CONFIG   : [C] LIST CONFIGURATION

      r   : LIST SPECIFIC RUN (CONFIGURATION) NUMBER. DEFAULT IS ALL

ABBREVIATION: L

FUNCTION: DISPLAYS RUN OR CONFIGURATION DATA. THE FORMER PROVIDES
               THE RUN CONDITIONS THAT ARE NON-ZERO AND SPECIFIES
               WHETHER IT IS TO BE ANALYZED (DESIGNATED BY THE
               WORD SET) OR HAS BEEN ANALYZED.

EXAMPLE: SCREEN 4-13

SUBCOMMAND   REFERENCE

REFERENCE[,c]

OPERANDS:

c   : CONFIGURATION NUMBER

ABBREVIATION: REF

FUNCTION: USED TO VERIFY OR RESET REFERENCE DATA BY
             CONFIGURATION. REFERENCE DATA CHANGED FOR
             RUNS ALREADY ANALYZED WILL RESULT IN INCORRECT
             OUTPUT DATA.

PROMPT/RESPONSE:

    CONFIGURATION: c
    SREF:sref   CBAR:cbar   SPAN:span
    ENTER NEW VALUES OR CARRIAGE RETURN:
    → $sref_{new}, cbar_{new}, span_{new}$ <CR>

    XCG: xcg   YCG: ycg   ZCG: zcg
    ENTER NEW VALUES OR CARRIAGE RETURN:
    → $xcg_{new}, ycg_{new}, zcg_{new}$ <CR>

    ***WARNING *** DATA FROM RUNS USING THESE UPDATED ***
    ***   REFERENCE QUANTITIES MAY NOW BE IN ERROR   ***

SUBCOMMAND - RESET

```
RESET,RUN(r) [,[ALPHA(a_1,...,a_n)] [BETA(b_1,...,b_n)]]

   [,MACH(m)] [,ICOND_1(ic_1),......,ICOND_n(ic_n)] [,CONFIG(c)]

   [,[AIR] [HELIUM]] [,[NOPRINT] [PRINT]] [,[SHKOFF] [SHKEXP]]

   [,[HYPOFF] [HYPER]] [,[LINEAR] [FIXED]] [,PROTECT(p)]
```

OPERANDS:

RUN(r)   : RUN NUMBER (r) TO BE REANALYZED. RUN NUMBERS
                     CAN HAVE ANY VALUE BETWEEN 1 AND 999 AND DO NOT
                     HAVE TO BE IN ORDER

ALPHA(a_1-a_n) : [A] ANGLE-OF-ATTACK LIST. EITHER ALPHA OR BETA LIST
                     SHOULD BE SPECIFIED OR A RUN WITH ONLY ONE DATA
                     POINT WILL RESULT. NUMBER OF VALUES MUST BE LESS
                     THAN OR EQUAL TO THE ORIGINAL NUMBER

BETA(b_1-b_n)   : [B] ANGLE OF SIDE SLIP LIST

MACH(m)   : [M] MACH NUMBER (m)

ICOND$_i$(ic_i)   : INITIAL CONDITION (ic) FOR ANALYSIS CALCULATIONS. SEE
                     TABLE 8

CONFIG(c)   : [C] CONFIGURATION TO USE FOR ANALYSIS. DEFAULT IS THE
                     HIGHEST OR MOST RECENT.

AIR   : ATMOSPHERE FOR HYPERSONIC ANALYSIS. DEFAULT IS AIR
HELIUM

NOPRINT   : DIAGNOSTIC PRINT FOR HYPERSONIC RUNS. INCREASES OUT -
PRINT   PUT BY A FACTOR OF TEN. DEFAULT IS NOPRINT

SHKOFF   : SHOCK EXPANSION INDICATOR FOR HYPERSONIC FLAP DEFLECTION
SHKEXP   CALCULATIONS. DEFAULT IS SHKOFF

HYPOFF   :   HYPERSONIC ANALYSIS INDICATOR. MACH NUMBERS LESS THAN
HYPER   4.0 DEFAULT TO THE SUBSONIC-SUPERSONIC ANALYSIS UNLESS
                THE HYPER KEYWORD IS INVOKED. DEFAULT IS HYPOFF.

LINEAR   :   SUBSONIC-SUPERSONIC SOURCE (THICKNESS) SOLUTION INDICATOR.
FIXED   DEFAULT IS LINEAR.

PROTEST(p) :   [PROT] PROTECTION KEY TO PREVENT OTHER USERS FROM
                ALTERING OR DELETING A RUN.

FUNCTION: MODIFICATION OF AN EXISTING RUN OR RETURN OF A RUN FROM ANALYZED TO
            ANALYSIS STATUS. ONLY UPDATES NEED BE PROVIDED.

EXAMPLE: SCREEN 4-13

SUBCOMMAND - SET

```
SET[n] [,[ALPHA(a_1,...,a_n)] [BETA(b_1,...,b_n)]]

   [,MACH(m)] [,ICOND_1(ic_i),......,ICOND_n(ic_n)] [,CONFIG(c)]

   [,[AIR] [HELIUM]] [,[NOPRINT] [PRINT]] [,[SHKOFF] [SHKEXP]]

   [,[HYPOFF] [HYPER]] [,[LINEAR] [FIXED]] [,PROTECT(p)]
```

OPERANDS:

n   : SET NUMBER OF THIS VARIABLE LIST.

ALPHA(a_1-a_n) : [A] ANGLE-OF-ATTACK LIST. EITHER ALPHA OR BETA LIST
                    SHOULD BE SPECIFIED OR A RUN WITH ONLY ONE DATA POINT
                    WILL RESULT.

BETA(b_1-b_n) : [B] ANGLE OF SIDE SLIP LIST

MACH(m)   : [M] MACH NUMBER (m)

ICOND$_i$(ic_i) : INITIAL CONDITION (ic) FOR ANALYSIS CALCULATIONS. SEE
                    TABLE 8

CONFIG(c)   : [C] CONFIGURATION TO USE FOR ANALYSIS. DEFAULT IS THE
                    HIGHEST OR MOST RECENT.

AIR   : ATMOSPHERE FOR RUN HYPERSONIC ANALYSIS. DEFAULT IS AIR.
HELIUM

NOPRINT   : DIAGNOSTIC PRINT FOR HYPERSONIC RUNS. INCREASES OUTPUT
PRINT   BY A FACTOR OF TEN. DEFAULT IS NOPRINT.

SHKOFF   : USE SHOCK EXPANSION INDICATOR FOR HYPERSONIC FLAP
SHKEXP   DEFLECTION CALCULATIONS. DEFAULT IS SHKOFF.

HYPOFF   : HYPERSONIC ANALYSIS INDICATOR. MACH NUMBERS LESS THAN
HYPER   4.0 WILL DEFAULT TO THE SUBSONIC-SUPERSONIC ANALYSIS.
              UNLESS THE HYPER KEYWORD IS INVOKED. DEFAULT IS HYPOFF.

LINEAR   : SUBSONIC-SUPERSONIC SOURCE (THICKNESS) SOLUTION INDICATOR.
FIXED   DEFAULT IS LINEAR.

PROTECT(p) : [PROT] PROTECTION KEY TO PREVENT OTHER USERS FROM ALTERING
              OR DELETING A RUN.

FUNCTION: DEVELOPMENT OF COMMONLY USED ANALYSIS VARIABLE LISTS. UP TO TWELVE (12).
           CAN BE STORED IN THE USER FILE. SET ENTRY WITH NO OPERANDS PROVIDES
           STATUS DISPLAY AND THE OPPORTUNITY TO FILL THE NEXT AVAILABLE LOCATION.

EXAMPLE: SCREEN 4-11

COMMAND SLENDER

SLENDER, COMP(1) [,COMP(2),...COMP(6)]

OPERANDS: COMP: COMPONENTS TO BE LINKED TO FORM A SLENDER BODY.
                       LIMIT IS SIX (6).

               FILE - [P]ERMANENT ; DEFAULT
                       [L]OCAL
                       [C]OMPONENT

ABBREVIATION: SLEN

FUNCTION: SLENDER BODY CONSTRUCTION . LIMIT IS FIVE (5).
               AN OFFSET COMPONENT COUNTS AS ONE .

PROMPT/RESPONSE:

        SLENDER-BODY SIMULATION
        ENTRY COMPONENT NAME
    →   slender body
        INPUT COMPONENT NUMBER
    →   700.0
        COMPONENT PARAMETERS FOR SLENDER-BODY COMBINATION
        ENTER FACTOR,NPASS
    →   0.7, 3

FACTOR: FRACTION OF THE SEGMENT LENGTH TO THE NEXT POINT ON THE CURRENT
          SECTION TO USE IN FINDING THE NEAREST SURROUNDING POINT. CONTROLS
          TRANSITION TO AN ADJACENT COMPONENT AS INDICATED IN FIGURE 3-22.
          DEFAULT IS 0.7

NPASS: NUMBER OF POINTS TO PROCESS ON THE NEW CONTOUR BEFORE STARTING
          THE PASSING CHECK AGAIN. IT IS USED TO PREVENT ERRONEOUS BACK
          LINKING. DEFAULT IS 3.

EXAMPLE: SCREENS 3-49, 3-50

COMMAND STATUS

```
┌─────────────────────────────────┐
│                                 │
│                                 │
│            STATUS               │
│                                 │
│                                 │
└─────────────────────────────────┘
```
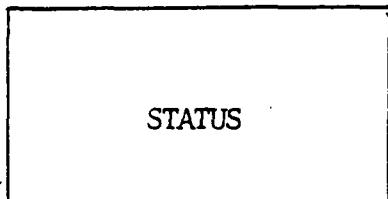
OPERANDS: NONE

ABBREVIATION: ST

FUNCTION: IDENTIFIES THE COMPONENT NUMBER AND NAME IN CORE

COMMAND TERMINAL

```
┌─────────────────────────┐
│                         │
│        TERMINAL         │
│                         │
└─────────────────────────┘
```
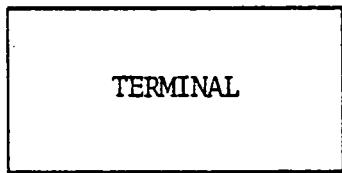
OPERANDS: NONE

ABBREVIATION: TERM

FUNCTION: SIMPLE COMPONENT GEOMETRY INPUT USING KEYBOARD. A
                 COMMON SET OF UNITS MUST BE USED.

EXAMPLE: SCREENS 3-1, 3-6 , 3-23

GEOMETRY OPTION   GEOMETRY

$$S = \frac{c_R + c_T}{2} b$$

$$AR = \frac{b^2}{S}$$

1

$$\lambda = \frac{c_T}{c_R}$$

$$\Gamma = 0$$

c_R c_T $(Y0, Z0)$ x y $x z/4$ b

$$S = \frac{c_R + c_T}{2} b$$

$$AR = \frac{b^2}{S}$$

2

$$\lambda = \frac{c_T}{c_R}$$

$(X0, Y0, Z0)$ c_T c_R b
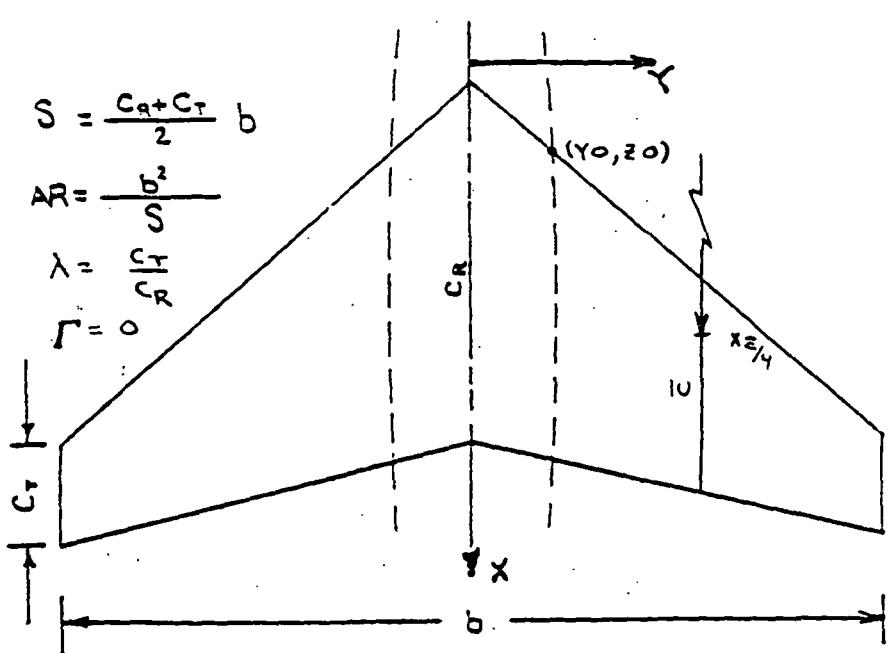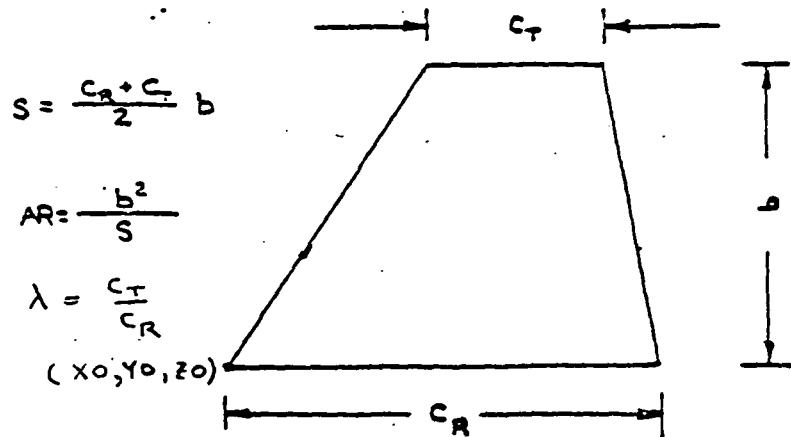
GEOMETRY OPTION   GEOMETRY

— STORED BOUNDARY
-- GENERATED BY SYMMETRY

3

4

-4

5

6

-6
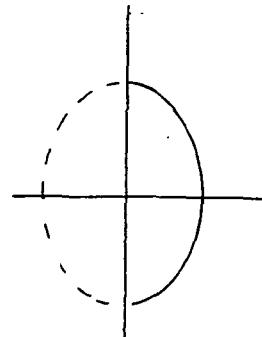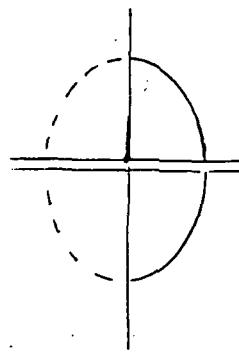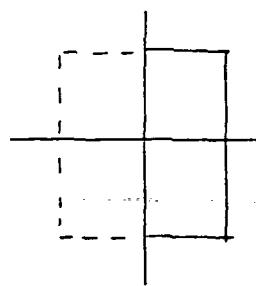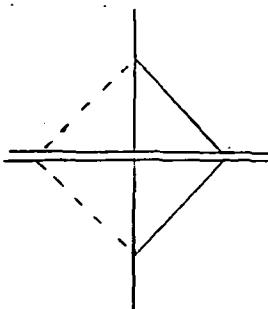
PROMPTS:

      ENTER COMPONENT YAW,PITCH,ROLL :
→ 0.0,0.0,0.0 <CR> [or <CR>]

   * 1 FULL SURFACE
   * 2 HALF SURFACE
   * 3 FULL ELLIPSE
   * +4 HALF ELLIPSE UP   -4 HALF ELLIPSE DOWN
   * 5 RECTANGLE
   * +6 TRIANGLE UP   -6 TRIANGLE DOWN
   * E END

FULL SURFACE INPUT:

→ 1 <CR>
     INPUT COMPONENT NAME:
   simple wing <CR>
     INPUT COMPONENT NUMBER:
→ 101. <CR>

     FULL SURFACE   : X(CBAR/4),YO(ROOT),ZO(ROOT)
→ 33.02,3.30,-3.05 <CR>
     S,AR,TAPER,SWEEP(DEG),DIH(DEG): S-IN^2,C$_m^2$, or m^2
→ 249.91.,2.3,.2,45 3 <CR>
   * 1 65 A 0XX
   * 2 64 A 0XX
   * 3 SUPERCRITICAL
   * 4 HEX AIRFOIL
   * 5 BI-CONVEX
   * SELECT AIRFOIL TYPE:
→ 1 <CR>
     ENTER : (T/C)1,...,(T/C)N, N<=10
     (DEFAULT VALUES: 0.05,0.05)
→ 0.04 0.03 <CR> [or <CR>]
   OK

HALF SURFACE INPUT

→ 2 <CR>
     INPUT COMPONENT NAME:
→ simple vertical <CR>
     INPUT COMPONENT NUMBER:
→ 301. <CR>

   HALF SURFACE   :XO(ROOT),YO(ROOT),ZO(ROOT)
   ETC.

197

BODY INPUT

→ 3 <CR>
    INPUT COMPONENT NAME
→ simple fuselage <CR>
    INPUT COMPONENT NUMBER
→ 10.<CR>

    BODY COMPONENT
  XRO,YRO,ZRO   (origin of body)
→0.0,0.0,0.0 <CR> [or <CR>]
    NUMBER OF CROSS SECTIONS OR
    X(1),A(1),W/H(1).,.,.,X(NCS),A(NCS),W/H(NCS)

→ 5 <CR>
    ENTER SETS OF (X,A,W/H) FOR 5 CROSS SECTIONS
→ 5.59 0.0 0.88 <CR>
  ?
→ 11.68 20.65 0.88 15.24 28.39 0.88 <CR>
  ?
→ 33.02 30.97 0.88 <CR>
  ?
→ 38.10 43.87 0.88 <CR>

  MAXIMUM HEIGHT ABOVE COMP. REF. LINE: 3.9836

  MAXIMUM HALF WIDTH OF COMPNENT   :   3.5055
  OK

COMMAND TITLE

```
┌─────────────────────────────────┐
│                                 │
│          TITLE [,FILE]          │
│                                 │
└─────────────────────────────────┘
```

OPERANDS: FILE   - [P]ERMANENT ; DEFAULT
                                  [L]OCAL

ABBREVIATION: TITL

FUNCTION: INPUT OR CHANGE TITLE OF SPECIFIED FILE

EXAMPLE: → title,L

                    PRESENT TITLE IS: APAS SAMPLE SESSION
                    ENTER: NEW TITLE OR 'CR'

                    → <CR>

COMMAND UNITS

```
┌─────────────────────────────┐
│                             │
│                             │
│        UNITS [,FILE]        │
│                             │
│                             │
└─────────────────────────────┘
```

OPERANDS: FILE - [P]ERMANENT ;DEFAULT
                                 [L]OCAL

ABBREVIATION: UNIT

EXAMPLE:
                          → unit
                             PRESENT UNITS ARE: INCHES
                             ENTER: 1 - METERS, 2 - INCHES; OR 3 - CENTIMETERS
                          → 1
                             USER DEFAULT UNITS UPDATED TO MATCH FILE UNITS
                             (THIS SESSION ONLY)

COMMAND   VISCOUS

```
+-------------------------------------------+
|                                           |
|                                           |
|               .VISCOUS                    |
|                                           |
|                                           |
+-------------------------------------------+
```
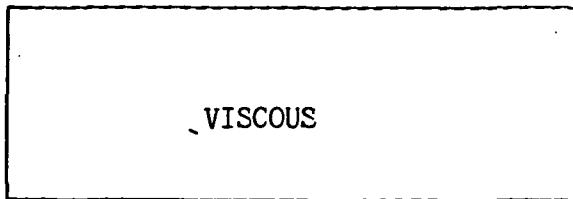
OPERANDS: NONE

ABBREVIATIONS: VISC

FUNCTION: INTERACTIVE VISCOUS DRAG ANALYSIS. PERIMETER AND CROSS-
            SECTIONAL AREA DISTRIBUTIONS ARE GENERATED FOR THE
            CONFIGURATION IN THE LOCAL FILE WITH THE OPTION TO
            CALCULATE VISCOUS DRAG AT SPECIFIED CONDITIONS.

PROMPTS:

        KEY * 1,2 OR 3
          1 * PLOT * NX,X(1),...,X(NX)
          2 * PLOT * NX,XB,XE
          3 * NOPLOT * NX=51 (ALL SURFACES FLAGGED)

     →3<CR>

            OPTIONS 1 AND 2 ARE SPECIALIZED FEATURES FOR CONFIGURATIONS
            WHICH DO NOT HAVE CLOSE CONTROL ON WETTED SURFACE SEGMENTS.
            NO EQUIVALENT PROCEDURE EXISTS IN THE BACKGROUND ANALYSIS.

            OPTION 3 SIMULATES THE BACKGROUND VISCOUS DRAG ANALYSIS.
            SURFACE AREA IS EVALUATED USING 51 CUTTING PLANES IN THE
            INTERACTIVE ANALYSIS AND COMPONENT CONTOUR INTEGRATION IN
            THE BATCH EVALUATION.

OPTION 1:

```
DEMONSTRATICN
SCALE=20.0
NX,X(1),...,X(NX)
2,200,300
```
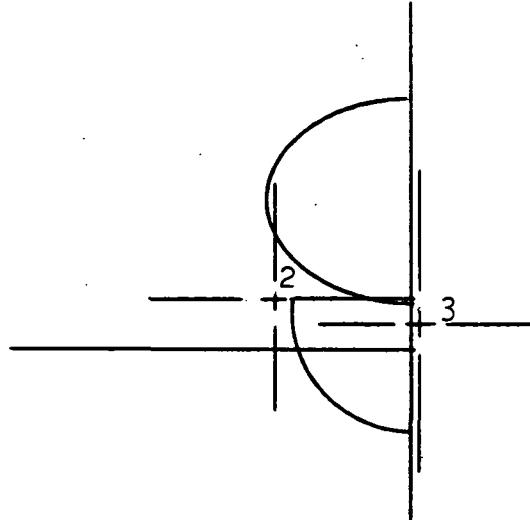
THE SYSTEM ASKS FOR THE NUMBER OF SECTION CUTS ,NX, TO MAKE AND THE
X-STATICN VALUES. THE CURSOR (+   ) APPEARS ON THE SCREEN
AFTER EACH CROSS SECTION SPECIFIED IS DISPLAYED. WETTED LINE SEGMENTS
OF THE CUT WILL APPEAR SOLID, UNWETTED SEGMENTS WILL APPEAR DASHED. TO
ELIMINATE (MAKE UNWETTED) UNWANTED LINE SEGMENTS LOCATE ONE END CF THE ,
LINE SEGMENT AND ENTER THE NUMERICAL VALUE CORRESPONDING TO THE LOCATION
OF THE DESIRED COMPONENT IN THE LOCAL FILE. MOVE THE CURSOR TO THE OTHER
END OF THE SEGMENT AND ENTER THE NUMERICAL VALUE CORRESPONDING TO THE
OTHER COMPONENT AT THIS INTERSECTION. IF NONE EXISTS OR THE OTHER COMP-
ONENT ALREADY HAS AN UNWETTED LINE INDICATED ENTER A 0. WHEN FINISHED
OR IF NO SEGMENTS NEED TO BE FLAGGED, ENTER 0. EACH PAIR' CF NUMBERED
ENTREES ELIMINATES A SEGMENT EQUIVALENT TO THAT LENGTH FROM EACH IN-
DICATED COMPONENT. IT IS RECOMMENDED THAT NX $\leq$ 5 BE USED TO KEEP THE
SCREEN UNCONGESTED. WHEN CROSS-SECTION WETTED PERIMETER CORRECTIONS ARE
COMPLETED ENTER 0,0 IN RESPONSE TO THE "NX,X(1),...,X(NX)" QUESTION.

OPTION 2:

INSTEAD OF ANSWERING: "NX,X(1),...,X(NX)", THE QUESTION: "NX,XB,XE"
WHERE:

             NX: IS THE NUMBER OF CROSS SECTION CUTS TO MAKE BETWEEN
             XB: THE BEGINNING X-STATION AND
             XE: THE ENDING X-STATION.

- VISCOUS - (CONTINUED)

OPTION 3:

PLOTS OF PERIMETER AND CROSS-SECTIONAL AREA ARE DISPLAYED
USING THE CROSS-HAIRS TO SEPARATE PAGES. THE SYSTEM THEN
RESPONDES WITH THE FOLLOWING QUESTION:

```
   0 EXIT
   1 SF DRAG
   2 EDIT
```

→1<CR>   ; DEFALUT IS 0

FOR THE EDIT OPTION REFER TO OPTION 1 DESCRIBED PREVIOUSLY. THE
RESPONSES FOR THE SKIN FRICTION DRAG ANALYSIS FOR A BODY
AND SURFACE ARE SHOWN BELOW.

```
   SKIN FRICTION DRAG INPUT
   INPUT MACH NUMBERS:
```

→0.6 1.2 1.6<CR>

```
   INPUT SREF(M2)
```

→1250.<CR>

```
   ENTER SAND GRAIN HEIGHT (KS(M))(DEFAULT:0.0)
```

→0.000021<CR>

```
   ENTER PRESS NT/M2,TEMP(K),LISTING MACH NUMBER
                             (0.0 FOR ALL) (DEFAULT IS NONE)
   CR ENTER ALTITUDE,LISTING MACH NUMBER
   ENTER CARRIAGE RETURN TO END:
```

→ 1221.,551.,0.6<CR>

→ 10000,1.2<CR>

→ <CR>

```
SAMPLE BODY
ENTER: XTRANS/LENG, FLAT PLATE 1 * AXIS-BODY 2 :
DEFAULT : 0.01,2


→ <CR>


SAMPLE SURFACE
ENTER: XTRANS/LENG, CK, FLAT PLATE 1 * AIRFOIL 2 :
DEFAULT : 0.01,1.2,2


→ 0.05,1.3,2<CR>
```

THE SAND GRAIN HEIGHT, KS, IN METERS IS THE EQUIVALENT ROUGHNESS OF THE CONFIGURATION SEE TABLE 9.

PFS IF THE STATIC PRESSURE IN NEWTONS/SQUARE METER, TFS IS THE STATIC TEMPERATURE IN KELVIN. ALTITUDE IS IN METER ABOVE SEE LEVEL THE LISTING MACH NUMBER IS ONE OF THE INPUT MACH NUMBERS AT WHICH A COMPONENT BRAKE-DOWN OF VISCOUS DRAG IS DESIRED.

XTRANS/LENG IS THE LAMINAR TRANSITION POINT AS A FRACTION OF COMPONENT LENGTH. CK IS THE AIRFOIL LINEAR THICKNESS CORRECTION COEFFICIENT AND ACCOUNTS FOR SURFACE CURVATURE EFFECTS.SEE TABLE 10.

THE SYSTEM NOW BLOCKS IN AND TITLES THIS PAGE FOR COPYING. A PAGE FOR EACH REQUESTED MACH NUMBER IS DISPLAYED FOLLOWED BY A SUMMARY PAGE CONTAINING ALL THE CONDITIONS RUN AND TABULATIONS OF COMPONENT WETTED AREA AND VOLUMES.

EXAMPLE: SCREEN 4-4

TABLE 9

Equivalent Sand Grain Roughness

TYPE OF SURFACE	EQUIVALENT SAND GRAIN HEIGHT		
	METERS	INCHES	CENTIMETERS
AERODYNAMICALLY SMOOTH	0.0	0.0	0.0
POLISHED WOOD OR METAL	5.09×10^{-4} - 2.03×10^{-6}	0.02004- 0.00008004	0.0509- 0.000203
NATURAL SHEET METAL	3.96×10^{-6}	0.000156	0.000396
SMOOTH MATTE PAINT, CAREFULLY APPLIED	6.34×10^{-6}	0.000249	0.000634
STANDARD CAMOUFLAGE PAINT, AVERAGE APPLICATION	1.00×10^{-5}	0.0003996	0.000100
CAMOUFLAGE PAINT, MASS PRODUCTION SPRAY	3.05×10^{-5}	0.0012	0.00305
DIP-GALVANIZED METAL SURFACE	1.52×10^{-4}	0.0060	0.0152
NATURAL SURFACE OF CAST IRON	2.54×10^{-4}	0.009996	0.0254

TABLE 10

Airfoil Thickness Correction Factors

AIRFOIL	THICKNESS CORRECTION (CK)
AIRFOIL t/cmax AT 30% CHORD	2.0
NACA 64 OR 65 SERIES AIRFOIL	1.2

COMMAND   WAVEDRAG

```
┌─────────────────────────────────────┐
│                                      │
│                                      │
│              WAVEDRAG                │
│                                      │
│                                      │
└─────────────────────────────────────┘
```
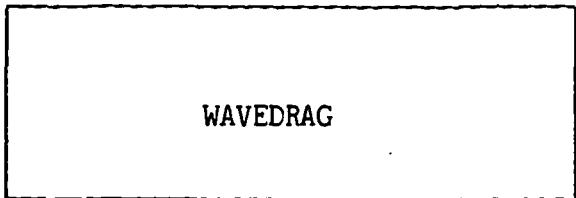
OPERANDS: NONE

ABBREVIATIONS: WAVE

FUNCTION: INTERACTIVE WAVE DRAG ANALYSIS. SUPERSONIC THICKNESS DRAG
            IS CALCULATED FOR COMPONENTS CURRENTLY ATTACHED IN THE
            LOCAL FILE

PROMPTS:

        ENTER SREF (M2):

    → 1255.0<CR>

        ENTER MACH NUMBERS:

    → 1.2,1.6,2.0,2.2<CR>

        A DISPLAY OF NORMAL OBLIQUE PROJECTED CROSS-SECTIONAL AREA AS
        A FUNCTION OF X-STATION AND ROLL ANGLE IS DISPLAYED   ALONG
        WITH A TABULATION OF WAVEDRAG AS A FUNCTION OF ROLL ANGLE
        AND THE TOTAL DRAG.   THE CROSS-HAIRS APPEAR ON THE SCREEN WHEN
        A CASE IS COMPLETED. PRESSING ANY KEY WILL INITIATE ANALYSIS
        OF THE NEXT CASE.

EXAMPLE: SCREEN 4-8, 4-9, 4-10

206

APPENDIX A

DATA DESCRIPTION
FOR CARD INPUT GEOMETRY

Vehicle body, surface, and field point data can be entered in card image form using the input format described in this appendix.

Data set access and transfer to the local or permament file is accomplished using the CARD command of section 6.

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	TITLE OF GE		TITLE (72 Characters)
13	OMETRY FILE		
25			
37			
49		73 80	
61			
1	20		
13	3.0		NC - No. of Components (< 50)
25	100.0		COMPONENT NUMBER 1
37	300.0		
49		73 80	
61			
1	– 70		
13			COMPONENT NUMBER 50
25			
37			(Last card before first component data must have a minus sign
49		73 80	in column 1
61			
1			
13			(Last card of each component must have a minus sign in column 1)
25			
37			
49		73 80	
61			

208

115

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	100.00		COMPONENT NUMBER (> 50.0)
13	FUSELAGE		COMPONENT NAME (16 Characters)
25			
37			BODY COMPONENTS
49		73 ... 80	
61			
1	100		
13	18.0		NCS Number of cross section (≤18)
25			X_0 ⎫
37 (116)			Y_0 ⎬ Relative origin of component
49			Z_0 ⎭
61	3.0	73 ... 80	CTYPE 3.0 Full Ellipse, ± 4.0 Half Ellipse ⎱ see 5.0 Rectangle, ± 6.0 Triangle ⎰ page 196
1	105		RLC (Locations 105-199 are for section data)
13	0.0		A_1 cross sectional area
25	0.0		D_1 h/2 (full height of $\triangle$ and $\bigcirc$)
37			X_R ⎫
49			Y_R ⎬ Section origin relative to X0,Y0,Z0
61		73 ... 80	Z_R ⎭
1	− 190		RLC + NCS*5
13	500.0		A_{NCS}
25	12.62		D_{NCS}
37	741.0		X_R
49	0.0	73 ... 80	Y_R
61	−6.2		Z_R

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
[1] 3 0 0 . 0 0		COMPONENT NUMBER (> 50.0)
[13] W I N G		COMPONENT NAME (16 Characters)
[25]		
[37]		SURFACE COMPONENTS
[49]	73 80	
[61]		
[1] 1 0 0		
[13] 2 . 0		NCS Number of cross sections $\leq$ 17 sections
[25] 0 . 0		X_0
[37] 0 . 0		Y_0 Relative origin of component
[49] 0 . 0	73 80	Z_0
[61] 1 . 0		CTYPE 1.0 Full Surface, 2.0 Half Surface; see page 195
[1] 1 0 5		1.0-65A; 2.0-64A; 3.0-supercritical
[13] 2 . 0		AIRFOIL TYPE 4.0-HEX; 5.0 BI-CONVEX; 0.0-USER INPUT Z/C'S
[25] 0 . 0		UPPER SURFACE Flag; if (DA(105) = 0.0 set = 1.0
[37] 0 . 0		LOWER SURFACE Flag; if symmetric leave 0.0
[49]	73 80	NO. X/C'S INPUT if DA(105) = 0.0
[61]		
[1] 1 1 0		
[13] 4 . 0		AR OPTIONAL DATA (SEE TERMINAL COMMAND)
[25] 3 5 0 . 0		S
[37] 0 . 3 4		TAPER
[49] 5 5 . 0	73 80	SWEEP
[61]		DIHEDRAL

210

117

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH	
[1] 115		RLC 115 - 199 are for section data	
[13] 0.60		T/C_{MAX} x 10.0	
[25] 210.0		CHORD	(CONSECUTIVELY, ONE
[37] 165.0		X_R	CARD PER CROSS SECTION
[49] 23.0	73 80	Y_R Coord. of L.E. relative to $X_0, Y_0 Z_0$	2ND SECTION IS CARD
[61] 0.0		Z_R	120, 3RD 125, ETC.)
[1] 200		RLC 200 - 219 are for x/c's	
[13] 0.0		X/C_1	
[25] 0.1		X/C_2 (fill in only if UPPER SURFACE flag is > 0.0)	
[37] ⁞		⁞	
[49] ⁞	73 80	⁞	
[61] ⁞		⁞	
[1] 215			
[13] ⁞		⁞	
[25] ⁞		⁞	
[37] ⁞		⁞	
[49] ⁞	73 80	⁞	
[61] 1.0		X/C_{20}	
[1] 220		DA(220-399) Are for upper and lower surface Z/C's. The upper	
[13] 0.0		Z/C's of one section are followed directly by the Z/C's for the	
[25] 0.002		lower surface.	
[37] 0.008			
[49] ⁞	73 80	(fill in only if UPPER SURFACE flag is >0.0)	
[61] .⁞			

(left margin, rotated: 118)

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1200.00		COMPONENT NUMBER (>0.0)
FIELD POINTS		COMPONENT NAME (16 CHARACTERS)
	73 ... 80	
100		
20.0		NPOINTS = NUMBER OF FIELD POINTS ($\leq 40.$)
	73 ... 80	
9.0		CTYPE
110		
200.0		X_1
.		X_2
.		.
.	73 ... 80	.
.		.
115		105 + NPOINTS
400.0		.
.		.
.		.
.	73 ... 80	X NPOINTS

FORM 114-C-17 REV. 7-58

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	150		RLC (LOCATIONS 150-199 FOR Y VALUES)
13	40.0		Y_1
25	45.0		Y_2
37	50.0		Y_3
49	.	73 80	.
61	.		.
1	165		145 + NPOINTS
13	40.0		.
25	45.0		.
37	50.0		.
49		73 80	.
61			Y NPOINTS
1	200		RLC (LOCATIONS 200-249 FOR Z VALUES)
13	10.0		Z_1
25	0.0		Z_2
37	-10.0		Z_3
49		73 80	.
61			.
1	-215		195 + NPOINTS
13	10.0		.
25	0.0		.
37	-10.0		.
49		73 80	.
61			Z NPOINTS

FORM 114-C-17 REV. 7-68

20	3.00	100.0	300.0	1200.0	
100.0FORWARD FUSELAGE					
100	8.00				3.00
105	0.00	0.00	0.00	0.00	0.00
110	78.00	5.00	15.00	0.00	4.00
115	210.00	8.25	30.00	0.00	8.00
120	386.00	11.10	50.00	0.00	11.00
125	490.00	13.00	78.00	0.00	13.00
130	1020.00	25.00	95.00	0.00	7.00
135	1758.00	28.00	115.00	0.00	8.50
140	1900.00	29.00	130.00	0.00	9.00
300.0INBOARD WING					
100	5.00	0.00	18.00	-8.00	1.00
105	0.00	1.00	1.00	11.00	0.00
110	1.00	100.00	0.00	70.00	0.00
115	0.11	800.00	0.00	0.00	0.00
120	0.12	726.00	74.00	12.00	0.00
125	0.13	633.00	167.00	24.00	0.00
130	0.14	500.00	300.00	36.00	0.00
135	0.17	400.00	400.00	48.00	0.00
200	0.00	0.10	0.20	0.30	0.40
205	0.50	0.60	0.70	0.80	0.90
210	1.00				
220	0.0000	0.0219	0.0563	0.0588	0.0569
225	0.0550	0.0538	0.0544	0.0569	0.0606
230	0.0625	0.0000	0.0094	0.0156	0.0213
235	0.0275	0.0338	0.0400	0.0463	0.0525
240	0.0325	0.0031	0.0062	0.0372	0.0606
245	0.0592	0.0585	0.0572	0.0565	0.0572
250	0.0599	0.0620	0.0640	-0.0062	0.0110
255	0.0193	0.0262	0.0331	0.0393	0.0455
260	0.0517	0.0585	0.0324	0.0021	0.0174
265	0.0521	0.0553	0.0553	0.0545	0.0557
270	0.0550	0.0537	0.0585	0.0569	0.0557
275	-0.0174	0.0126	0.0237	0.0316	0.0395
280	0.0458	0.0521	0.0585	0.0585	0.0284
285	0.0000	-0.0080	0.0140	0.0240	0.0360
290	0.0480	0.0590	0.0640	0.0660	0.0650
295	0.0620	0.0570	0.0800	0.0280	0.0370
300	0.0460	0.0520	0.0590	0.0660	0.0720

Sample Listing of a Card Image Data File

305	0.0500	0.0210	-0.0070	-0.0075	0.0313
310	0.0438	0.0563	0.0663	0.0800	0.0825
315	0.0825	0.0800	0.0750	0.0713	0.0075
320	0.0425	0.0488	0.0550	0.0613	0.0825
325	0.0875	0.0775	0.0488	0.0188	0.0100
1200.0FIELD	POINTS				
100	10.00				9.00
105	-100.00	-50.00	50.00	100.00	150.00
110	200.00	400.00	600.00	800.00	1000.00
150	100.00	100.00	100.00	100.00	100.00
155	100.00	100.00	100.00	100.00	100.00
200	50.00	50.00	50.00	50.00	50.00
205	50.00	50.00	50.00	50.00	50.00

Sample Listing of a Card Image Data File (Concluded)

POINT SPACING, INTERPOLATION, AND GEOMETRY TRANSFORMATIONS

Point spacing and data interpolation procedures are defined. A summary of the transformations used to position and display geometry are presented.

POINT SPACING

Given a set of ordered input points in three space, the angle between two consecutive vectors $\bar{a}$ and $\bar{b}$ can be determined as follows:
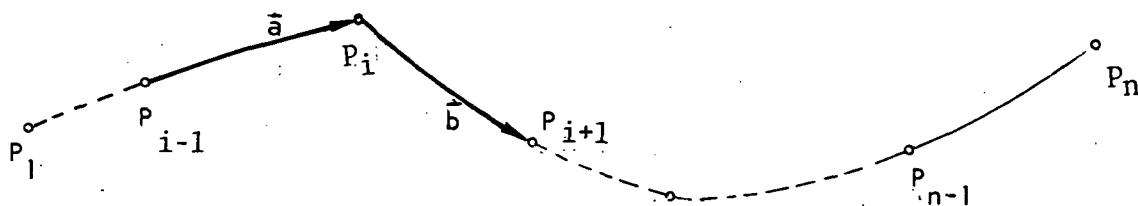
$$\cos \theta_i = \frac{\bar{a} \cdot \bar{b}}{|a| \, |b|} \qquad 2 \leq i \leq n-1$$

where

$$\bar{a} = a_1 \, \bar{i} + a_2 \, \bar{j} + a_3 \, \bar{k}$$

$$\bar{b} = b_1 \, \bar{i} + b_2 \, \bar{j} + b_3 \, \bar{k}$$

Thus

$$\theta_i = \cos^{-1} \left[\frac{a_1 b_1 + a_2 b_2 + a_3 b_3}{\sqrt{(a_1^2 + a_2^2 + a_3^2)(b_1^2 + b_2^2 + b_3^2)}} \right]$$

The end points are arbitrarily defined as $\theta_1=0$ and, $\theta_n=\theta_{n-1}$. A rule for spacing points based on the total angular displacement can be developed such that the angular change between any two vectors is a constant. That is:

$$\Delta\theta = \text{constant}$$

$$\theta = \sum_1^n |\theta_i|$$

Alternatively, a constant incremental arc length rule can be considered

$$\Delta S/S = \text{constant}$$

$$S_1 = 0$$
$$S = \sum_2^n \sqrt{(x_i - x_{i-1})^2 + (y_i - y_{i-1})^2 + (z_i - z_{i-1})^2}$$

A spacing algorithm (SPCTOL) was designed considering either or both properties. It is used with a 0.5 property bias to space points on digitized body cross sections and during hypersonic model generation.

INTERPOLATION

There are three methods of curve fitting geometry data and one method for curve fitting analysis display data. They are linear, second order and least squares smoothing. The second order routine is also used for analysis data.

The linear curve fit solves the equation.

$$Y = Y_n + \frac{(Y_{n+1} - Y_n)(X - X_n)}{X_{n+1} - X_n}$$

$$\text{where } X_n \leq X \leq X_{n+1}.$$

217

The second order curve fit solves the equation

$$Y = \frac{(X - X_n)(X - X_{n+1})}{(X_{n-1} - X_n)(X_{n-1} - X_{n+1})} \, Y_{n-1}$$

$$+ \frac{(X - X_{n-1})(X - X_{n+1})}{(X_n - X_{n-1})(X_n - X_{n+1})} \, Y_n$$

$$+ \frac{(X - X_{n-1})(X - X_n)}{(X_{n-1} - X_{n-1})(X_{n+1} - X_n)} \, Y_{n+1}$$

for the value y. The evaluation is performed first for a left triplet, then the right triplet. The two resulting y's are averaged.
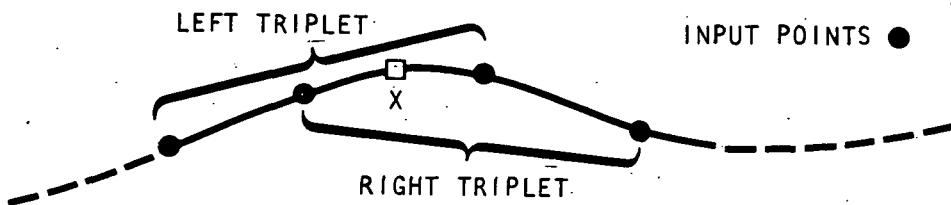
A least-squares curve fit solves for the coefficients a_1, a_2, ... a_n in the equation

$$Z = \sqrt{2rx(1-x)} + X(1-X)[\, a_1 + a_2 X + \ldots \ldots a_{n-1} X^{n-2}] + XZ_t \qquad 0 \le x \le 1$$

such that the error $\sum_{i=1}^{n} (z - z_i)^2$ is a minimuum in the least squares sense under the condition that the curve passes exactly through the first and last points. r is taken as the initial normalized radius of curvature and z_t is the normalized maximum half thickness. The input data is prepared such that the first point passes through z=0, and the last point passes through $z=z_t$. The value of r can be input or can be solved for as an additional unknown coefficient a_n

$$r = \frac{a_n^2}{2}$$

When r and z_t are set to zero, a standard least squares fit, results. This form is used for digitized body sections.

The principle purpose of this routine, is to smooth airfoil data being input through the digitizer.

GEOMETRY TRANSFORMATIONS

Consider two orthogonal reference systems μ and ν. The transformation from μ to ν is defined by

$$
[x \quad y \quad z \quad h]_\nu = [x \quad y \quad z \quad h]_\mu
\begin{bmatrix}
A & E & I & M \\
B & F & J & N \\
C & G & K & O \\
D & H & L & P
\end{bmatrix}
$$

The specific APAS applications are

COMPONENT POSITION

$$
[C] = \begin{bmatrix}
A & E & I & O \\
B & F & J & O \\
C & G & K & O \\
X_o & Y_o & Z_o & 1/s*
\end{bmatrix}
$$

*S = SCALING FACTOR

SCALING INDIVIDUAL AXIS DIRECTIONS

$$
[S] = \begin{bmatrix}
S_x & O & O & O \\
O & S_y & O & O \\
O & O & S_z & O \\
O & O & O & 1
\end{bmatrix}
$$

PERSPECTIVE VIEWING

$$
[P] = \begin{bmatrix}
1 & O & O & 1/D* \\
O & 1 & O & 1/D* \\
O & O & 1 & O \\
O & O & O & 1
\end{bmatrix}
$$

*D = VIEWING DISTANCE

DISPLAY POSITION

$$
[D] = \begin{bmatrix}
A & E & I & O \\
B & F & J & O \\
C & G & K & O \\
O & O & O & 1
\end{bmatrix}
$$

To rotate a component with position [C] into viewing space [D], the transformation

$$[T] = [C] \times [D]$$

will define the position in one operation. The sub matrix

$$\begin{bmatrix} A & E & I \\ B & F & J \\ C & G & K \end{bmatrix}$$

due to sideslip (β), pitch (α), and roll (γ) can be determined from a standard axis rotation and are as follows
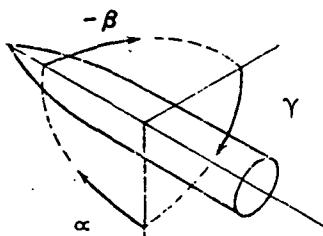
$$
\begin{aligned}
A &= \cos\alpha \; \cos\beta \\
B &= \sin\beta \; \cos\gamma - \sin\alpha \; \cos\beta \; \sin\gamma \\
C &= -(\sin\alpha \; \cos\beta \; \cos\gamma + \sin\beta \; \sin\gamma) \\
E &= -\cos\alpha \; \sin\beta \\
F &= \sin\alpha \; \sin\beta \; \sin\gamma + \cos\beta \; \cos\gamma \\
G &= \sin\alpha \; \sin\beta\cos\gamma - \cos\beta \; \sin\gamma \\
I &= \sin\alpha \\
J &= \cos\alpha \; \sin\gamma \\
K &= \cos\alpha \; \cos\gamma
\end{aligned}
$$

APPENDIX C. OUTPUT VARIABLE DESCRIPTIONS*

INTERACTIVE

A, ALPHA	Angle of attack, $\alpha°$
ALTITUDE, ALT	Altitude, m or ft
B, BETA	Angle of Side Slip, $\beta°$
CONFIG.	Configuration
D1,...,D6	Flap Deflection Angle, $\delta°_1$, $\delta°_2$...
KS	Sand Grain Height, K_S - m or ft
M, MACH	Mach Number, M
P	Non-Dimensional Rolling Velocity, $\hat{p}$
PRESSURE, PR	Static Pressure, P_∞ - Nt/m^2 or lb/ft^2
Q	Non-Dimensional Pitching Velocity, $\hat{q}$
R	Non-Dimensional Yawing Velocity, $\hat{r}$
TEMP, T	Static Temperature, T_∞ - °K or °R

SLENDER BODY ANALYSIS

BC	Boundary Condition

BC	SOLUTION
1	$\alpha = 0$
2	$\alpha = 1$ deg.
3	$\hat{q} = 1$
4	$\beta = 1$ deg.
5	$\hat{p} = 1$
6	$\hat{r} = 1$

CBAR	Input Reference Chord, C_{REF}
CL	Lift Coefficient, F_Z/qS_{REF}
CLL	Rolling Moment Coefficient, $M_X/q\ b_{REF}S_{REF}$

*Aerodynamic symbols conform to PART I definitions

CM	Pitching Moment Coefficient, $M_Y/q C_{REF} S_{REF}$
CN	Yawing Moment Coefficient, $M_Z/q b_{REF} S_{REF}$
CNB1	Sectional Normal Force Coefficient, n/qL at $\alpha = 0$
CNB2	Sectional Normal Force Slope, $\dfrac{d}{d\alpha} n/qL$
CY	Side Force Coefficient, $F_Y/q S_{REF}$
L	Body Length
S	Normalized Body Cross-sectional Area, S/L^2
SPAN	Input Reference Span, b_{REF}
SPX	Normalized Body Cross-sectional, Area First Derivative $\dfrac{dS/L^2}{dx/L}$
SPPX	Smoothed Normalized Body Cross-sectional, Area Second Derivative $\dfrac{d^2 S/L^2}{d\ x^2/L^2}$
SPPXR	Normalized Body Cross-sectional, Area Second Derivative $\dfrac{d^2 S/L^2}{dx^2/L^2}$
SREF	Input Reference Area, S_{REF}
WXL	Normalized Body Width, W/L
X	Axial Distance from Body Nose, X
X-CG	Axial Reference Point, X_{CG}
Y-CG	Lateral Reference Point, Y_{CG}
Z-CG	Vertical Reference Point, Z_{CG}

UNIFIED DISTRIBUTED PANEL ANALYSIS

ACTIVE	Indicator to denote which components are active. (e.g. "Active" Missile in presence of "Inactive" Carrier Aircraft)
	0 Inactive (Not Operational)
	1 Active
ALPHA	Angle of Attack, $\alpha°$

AREA	Normal Surface Area of Quadrilateral Panel
BETA	Angle of Sideslip, $\beta°$
CAVG	Average Chord, $S_{REF}/$(Component True Span)
CBAR	Input Reference Chord
CDL	Drag due to Lift, C_{D_L}
CDTHK	Total Nearfield Thickness Drag
CDTHK (BODY)	Body Nearfield Thickness Drag
CDVTX	Farfield Vortex Drag
CDO	Nearfield Drag Due to Lift, C_{D_O}
CD100	Farfield Drag Due to Lift, $C_{D_{100}}$
CHORD	Local Component Chord, C
CL	Lift Coefficient, C_L
CL*C/CAVG	Weighted Section Lift, $C_{\ell}C/C_{AVG}$
CN	Section Normal (to Surface)Force Coefficient , C_n
CN*C/CAVG	Surface Weighted Section Normal Force Coefficient, C_nC/C_{AVG}
CN*W/L	Body Weighted Section Normal Force Coefficient, C_n W/L
COS(THETA)	Cosine of Quadrilateral Panel Dihedral Angle
CP-NET	Net Pressure Across Quadrilateral Panel, $C_{P_{NET}}$
DELTA	Flap Deflection , $\delta°$
D1,D2...	Flap Deflection $\delta_1°$, δ_2...
ETA	Nondimensional Span Station, η = s/(Component True Span)
IMAGE	Quadrilateral Panel Image Indicator
INCIDENCE	Initial Component Incidence in Degrees (Same as constant Twist along Span)
LIFT	Lift Coefficient, C_L

NORMAL/SIDE	Total Force Coefficient Normal to Local Surface for Half of Component (Not Meaningful for Non-Planar Components)
P	Nondimensional Rolling Velocity, $\hat{p}$
PITCH	Pitching Moment Coefficient, C_m
Q	Nondimensional Pitching Velocity, $\hat{q}$
R	Nondimensional Yawing Velocity, $\hat{r}$
ROLL	Rolling Moment Coefficient, C_ℓ
SEMI-SPAN	Component Semi-Span Measured Along Surface (Total Span for Asymmetric Components)
SIDE	Side Force Coefficient, C_Y
SIN(THETA)	Sine of Quadrilateral Panel Dihedral Angle
SPANWISE PANELS	Number of Spanwise Quadrilateral Vortex/Source Panels
SUCTION	Average Level of Leading Edge Suction $(\widetilde{C_{D_L}} - C_{DL})/(\widetilde{C_{D_L}} - C_{D100})$ where $\widetilde{C_{D_L}} = C_{DL}$ for $K_S = 0$
SYMMETRY	Component Symmetry Indicator: 0 Asymmetric 1 Symmetric
TWIST (DEG)	Local Component Twist Angle, $\varepsilon°$
TYPE	Component Type: 3 Vertical Surface 4 Symmetrical Surface 5 Interference Shell
W/L	Ratio of Local Body Width to Body length, W/L
X	X Coordinates for Body Stations
XBAR	X Coordinate of Quadrilateral Panel Centroid
XC	X Coordinate of Quadrilateral Panel Control point

X1	X Coordinate of Quadrilateral Panel Inboard Leading Edge
X2	X Coordinate of Quadrilateral Panel Outboard Leading Edge
X3	X Coordinate of Quadrilateral Panel Inboard Trailing Edge
X4	X Coordinate of Quadrilateral Panel Outboard Trailing Edge
X/C C.P.	Nondimensional Chord Location of Section Center of Pressure
X/L	Nondimensional Coordinates for Body Stations
YAW	Yawing Moment Coefficient, C_n
YBAR	Y Coordinate of Quadrilateral Panel Centroid
Y1	Y Coordinate of Quadrilateral Panel Inboard Edge
Y2	Y Coordinate of Quadrilateral Panel Outboard Edge
ZBAR	Z Coordinate of Quadrilateral Panel Centroid
Z1	Z Coordinate of Quadrilateral Panel Inboard Edge
Z2	Z Coordinate of Quadrilateral Panel Outboard Edge

WAVE DRAG ANALYSIS

ALPHA	Angle of Attack, $\alpha°$
D/Q	Sectional Wave Drag, $d\,\dfrac{Dw/q}{d\theta}$
MACH	Mach Number, M
THETA	Cylindrical Angle, $\theta°$

SKIN FRICTION ANALYSIS

CDF SMOOTH	Hydraulically Smooth Skin Friction Drag Coefficient, C_{DF}
CDF ROUGH	Distributed Rough Skin Friction Drag Coefficient, C_{DF}
CDF USED	Maximum of CDF Smooth and CDF Rough
KS	Sand Grain Height, K_S - m or ft
PRESS	Static Pressure, P_∞ - Nt/m^2 or lb/ft^2

REYNOLDS   Length Reynolds Number $U_\infty C/U_\infty$ or $U_\infty L/U_\infty$

TEMP   Static Temperature, T_∞ - °K or °R

X/L TRANS   Component Normalized Transition Point, $X_{transition}/L$

APPENDIX D

DESCRIPTION OF SYSTEM SUBROUTINES

AAMAIN - APAS II main program.

AERO - Controls FORCE calculations.

ANGLE(X1,Y1,X2,Y2,S) - Evaluates angles for vector defined by (X1,Y1) and (X2,Y2) and returns the magnitude S.

ARDC62(ALT,PRESS,TEMP,C) - 1962 U.S. Standard Atmosphere. Input altitude (ALT) returns static pressure (PRESS- lbs/ft^2), temperature (TEMP-R) and the speed of sound (C-ft/sec).

AREAS - Makes cuts through a geometric component and tallys perimeter and cross-section area.

AREAW - Makes oblique cuts through geometric components and accumulates the projected cross-section areas.

ATMOS - Solves for the atmospheric properties using the 1962 U. S. Atmosphere.

BDYLD - Calculates longitudinal loading on the body components.

BLOCK - Initializes data arrays required in calculating equilibrium real gas properties of air.

BLOCK DATA - Used to initialize the page heading array.

BLUNT - Calculates the viscous forces on a blunt body including low density effects.

BMTX - Calculates $\sqrt{T^2 + \beta^2}$ for each of the quadrilateral panels, where T is the tangent of the leading edge sweep angle and $\beta^2 = 1 - M^2$.

BORDER(TITLE) - Places a border around a Tektronix screen and on the underlined title (TITLE) at the top of the page.

BOUND - Calculates the symmetric and antisymmetric boundary conditions for use with the aerodynamic influence matrices.

CLC(N,BUF1,I1,IBUF2,I2) - Compare N characters of BUF1 starting at character I1 against N characters in IBUF2 starting at I2.

CODIM(XI,YI,NI,T,ANS,NA) - Curve fit routine based on a second-order weighted average technique. NI input points (XI, YI arrays) are used to fill NA points in the ANS array using the values in array T.

COMEXT - Calculates component extents for scaling and display. Parameters used are from common/GEOM/.

COMPON - Component management routine. APAS commands processed (ATTACH, COPY, ETC) are clearly marked. Major parameters used are from commons /COMPO/, /INDEX/, and the first 7 words of /GEOM/.

COMPR - Calculates the local flow properties using oblique - shock relationships of NACA TR 1135.

CONCAT(A1,A2) - Concatenates two words into one left adjusted word. A double precision function on the PRIME computer.

CONE - Solves for the local properties about a cone in supersonic flow using empirically derived equations.

CONTROL - Changes the geometry data for control surfaces to the proper deflected position.

CONV(I1ST,BUF,ILAST) - Converts 1 Byte characters in BUF array to a real value starting at location I1ST through ILAST or until a delimiter (comma, space, 1, (,),) is encountered. Returns end point location in I1ST.

CPLOT(X,Y,NP,IND,ISKIP) - Simple display for wave drag area cuts. Plots Y versus X for NP points. IND = 1 to scale, 0 to use old scale, ISKIP = 0 solid line,>0 dashed line.

CRVFT - Calculates a least-square error curve fit for the set of points X_i, F_i, i = 1, n.

CUT(JCUT,XMP,ROT,YERO,ZERO,IDASH,LEFT) - Makes cuts through component indicated at the rotation indicated by ROT array and/or aircraft rotation system.

JCUT	- 1	:	component already in position retrieve data
	2	:	position component relative to ROT angles only
	3	:	position component relative to ROT and A/C location data
XMP	- Location of plane to be cut		
ROT	- Spacial position of plane		
YERO ZERO	- Origin of section in picture		
IDASH	- Dashed line indicator		
LEFT	- 1	:	Draw section to right of marker
	2	:	Draw section to left of marker

CUTSEC - Display cross-section cuts on a three-view for the component currently in common /GEOM/.

DIGIT - Digitize geometry components using the Tektronix tablet. Important
    variables are in commons /GEOM/, /DIGIT/, and /AXIS/. Variable IAXIS in
    /COMPO/ controls the drawing axis on the tablet.

DISP- Controls the type of display to be used (three-view or orthographic).

DQWS(IM,NM) - WAVE drag routine. Calculates total vehicle drag from S array in
    /COPT/. IM is current Mach number, NM is number of Mach numbers in
    calculation.

DRAG - Calculates untrimmed values of drag-due-to-lift
    for three angles of attack. These values are used to determine the coefficients
    in a parabolic drag polar equation.

EDIT - Executive routine for edit function. Controls calls to subroutines in the
    edit family and adjustments to parametric component data. Major variables are
    found in /GEOM/, /PANL/, /COMP/, /ED/, /EDD/.

EDITN - Screen edit routine uses a pictoral of a component and the cross hairs
    to make changes to the component's geometry. Major parameters are from
    /GEOM/, /COMPO/, /INDEX/, /ED/, and /EDD/.

EDPUT - Edit command interpretor. Converts alphanumeric terminal input into
    numerics in common/EDD/.

ELPI - Approximates the values of elliptic integrals of the first and second
    kind.

EMLORD(IT,DA) - Cross-section interpolation routine to enhance data supplied in
    the TERMINAL function. Uses an EMINTION LORD curve fit method. Variable
    IT is the type of body component, DA is the array to put the output data in.

EQUA - Calculates the parabolic drag due to lift equations from three data
    points.

EXPAND - Calculates local flow conditions using Prandtl-Meyer relationships
    of NACA TR 1135.

FILL - Fills intermediate locations in an array using cosine axial spacing.

FINDW(ICOL,ILAST,CCOL,VALUE,IFLG) - Searches a single character buffer, "COOL" and
    returns the first word encountered as a packed word "FINDW" double precision
    function on 32 bit machines.

    "ICOL" is the first position within CCOL to be searched, or return, ICOL =
    the position of the delimeter encountered immediately after the returned word.

    "ILAST" is the last position within CCOL to be searched, returned unaltered.

    "VALUE" is returned as the value of a number which follows the returned word
    immediately or one delimeter past.

If the word begins with a "C" it is assumed to be a data coefficient, such as "CL". If the coefficient is "CL", "CM", "CY", "CN", or "CR" any additional characters following are assumed to be a slope subscript. In the case of "CLA" the first part "CL" would be returned in "FINDW" and the variable name "A" would be returned in "VALUE".

ON RETURN IFLG=0   If a word is encountered and is followed by another.
           IFLG=99   If a double blank follows the returned word
           IFLG=100 If no word is encountered within the field
           IFLG=99   If a number returned in "VALUE" was preceded by a "("

FIT(N X,Y,NN,XX,YY,IOR,R,ITY) - interpolates broken line using spline fit or least squares smoothing up to tenth order._____

N: No. of input points, N>3
X,Y: Input point arrays
NN: No. output points
XX, YY: Output point arrays, XX must be specified.
IOR: Maximum desired least squares order
R: Initial radius of curvature of curve.
        -R, radius is calculated, least squares only.
ITY: 1- Least Squares; 2-CODIM fit; 3- Linear fit

FITWT(MUM,XX,XX,MM,XP,YP,R,N)

This subroutine fits a curve
$Y = SQRT(2.*R*X) + A(L)*X + A(2)*X**2 + ... +A(N)*X**N$
through the points X(I)) such that
1. The curve goes through (o,o) and (X(M), Y(M))
2. The initial radius of curvature is equal to R
3. The error (Y-Y(I)) is a minimum in the least square sense
4. If (ABS(Y(2)-Y(1)).LT.R) point is eliminated

    MUM is the number of points (X(I),Y(I)
    MM is the number of output points
    N is the order of the polynomial
    M must be greater than or equal to N
    All X(I) must be greater than 0.
    YY, A1, A2, A3, are scratch arrays of dimension M
    The solution is A(I) = A(I,1) I=1,...,N

FIT3(NN,X,Y,Z,NC,NS,XP,YP,ZP): Three dimensional linear curve fit. Input arrays XP and ZP are 2 dimensional.NC X NS, YP is dimensioned NA with one value of YP for each NC values of XP and ZP. The value of Z is interpolated for each value of X and Y for NN output points.

FLOSEP - Determines the effect of flow separation caused by the deflection of a control surface at hypersonic speeds.

FORCE - Determines the pressure coefficients on each quadrilateral element, resolves the force in the required body axis system, and sums the contributions of each element to give hypersonic six component characteristics.

FORCE - Controls the integration of the symmetric and antisymmetric net pressures in subsonic-supersonic analysis.

CENTB - Hypersonic paneling routine for body components. Tolerance (TOL = 1.500 degrees) determines panel spacing. Unwetted areas on bodies are bypassed. /GEOM/ and /GENT/ common blocks are used.

GENTS - Hypersonic paneling routine for surfaces. Uses /GEOM/ and /PANL/ to break out leading edge, flaps, and surfaces. Also uses common /GENT/.

GEOEX - Main executive command interpertor. Inputs an alphanumeric string from the terminal and converts it to numeric code variables in common /COMPO/.

GETRUN(JCONF) - Interrogates work (local) file and determines if a new or old configuration is stored. Inputs configuration parameters, SREF, CBAR, SPAN, XCG, YCG, ZCG for a new configuration. Uses common /OINDEX/ and /INDEX/.

GREEK(I) - Draws Greek symbols λ, Λ, and γ at current Tektronix screen location for I = 1,2, or 3, respectively.

GRID - Subroutine to produce a grid in subroutine PLOTIT. Inputs select scaling factors, grid type, axis orientation and zero point location.

HEADER - Provides a title at the top of each page of the output and advances the page counter.

HSHLDR - Function to solve systems of simultaneous equations using the Householder method. Non-square solution sets are solved least square.

IDATA - Inputs viscous drag calculation conditions. Commons /GEOM/, /COPTV/, /PLOTV/, and /CDAT/ are used.

INFO - Inputs and interprets basic surface definition parameters, SW, AR, λ, Γ. Will also draw a box in the upper right-hand corner of the screen if requested.

INTE - Subroutine for constructing interference shells. Uses a three-view and the graphics cursor to define the surface. Uses commons /GEOM/, /PANL/, and /INDEX/.

INTEG - Integrates net pressures to establish section and total loads for each component.

INTSCT - Calculates the intersection (X,Y) of two lines determined by connecting (X1,Y1), (X2,Y2) and (X3,Y3), (X4,Y4).

      INTSCT=0   Solution for (X, Y) completed
      INTSCT=1   Parallel lines, no solution
      INTSCT=1   The lines coincide

INVEST (NC,FILE,NCR,ITYPE) - Investigates ICOM array against the index array for requested files and returns the record number for each local component.

NC	- number of components on input list
FILE	- unit number to be investigated
NCR	- number of components being returned
ITYPE	-1 : normal find
	2 : find all components - and +
	3 : search for - components and place record number in ICOM array

ISIMEQ - Solves a system of linear equations by Gaussian elimination.

ISTRING(I1ST,ILAST,BUF,NTOT,VALUE) - Routine to convert a string of numbers, separated by commas or blanks, within buffer "BUF", beginning at character "I1ST" and ending when any delimiter or a double blank is encountered.

"ILAST" is the last character within BUF to be searched.

The array of integer converted values is returned within "VALUE".

"I1ST" is returned as the position of the next delimeter following the converted string or as the position immediately following a ")" at the end of the numeric string.

LIMIT(IC) - Calculates component (IC) limits for viscous drag section cuts. Input data from /GEOM/. Output stored in /CLIM/.

LIMITW - Computes component limits for wave drag oblique cuts. Input data from /GEOM/ and /CF1XW/. Output data stored in /CLIMW/ and /CFLOW/.

LINEAR(X1,Y1,N1,XO,YO,NO) - Linear curve fitting routine. Input array X1, Y1 of size N1 are used to interpolate NO values of YO at points in XO.

LIST - Terminal input edit function. Keyboard command interpreted by EDPUT are carried out in LIST. Section inserting, deleting, duplicating, point translation with graphics cursor, and listing cross-section displays. Section translation, scaling, and component scaling are also performed in LIST. Commons /GEOM/, /EDD, /ED/ contain most of the important variables.

LSEE - Interprets surface geometry in /GEOM/ for subsonic-supersonic paneling. Resulting data is displayed for model verification.

MAIN - Hypersonic analysis control program.

MAIN - Controls subsonic/supersonic calculations

MATMUL(M,NX,N,A,B,C,ITRANS) - Performs matrix multiplication A(M,NX) * B(NX,N) = C(M,N). A, B, C size is given in the dimension statement.

MATR(F,ANG) - Fills in 4 x 4 rotation matrix F based on yaw, pitch, and roll angles stored in ANG.

MATRIX - Compute coefficients for slender body wave drag equation in subroutine EMLORD.

MATRIX - Subrountine MATRIX calculates the aerodynamic influence matrices for both source (thickness) and vortex (lift) panels.

MAXIT(B,Y,NYS,YMIN,YMAX,YMID,DIV) = Given NYS values of X, MAXIT calculates the extents (YMIN, YMAX), the midpoint (YMID) and plot spacing B based on DIV grid spaces.

MENU - Menu of key functions in VIEW subcommand in EDIT. Displayed on screen.

MENUI - Menu of key steps in the INTERFERENCE command. Displayed on screen.

MENUP - Menu of key functions in the PANEL subcommand in EDIT. Displayed on screen.

MSOL - Subroutine MSOL uses the method of Householder to solve the linear set of aerodynamic influence equations.

MULTIB - Rings Tektronix bell for indicating errors in users input.

MULVEC(X1,Y1,Z1,H1,F,X,Y,Z,H) - Subroutine MULVEC multiplies the vector (X, Y, Z, H) by transformation matrix F with resulting vector of (X1, Y1, Z1, H1)

NEWTPM - Newtonian + Prandtl-Meyer blunt-body method.

NORMAL - Calculates normal wash in the Trefftz plane at each span station for farfield vortex drag.

ORIG(NP,IX,IY) - Displays NP rectangles on the screen at points defined by IX and IY arrays.

ORTH - Provides displays of components in rotations of yaw, pitch, and roll. Also allows windowing and perspective viewing.

PAGE - Writes the heading and page number at the top of each page.

PANEL - Subsonic-supersonic surface component paneling. Span-lines input with the graphics cursor break surfaces into regions which are paneled using numeric inputs through the keyboard.

PANSUB - Presents data in common /PANL/ based on surface geometry in /GEOM/.

PCURSR(ICHAR,IO) - Keyboard input routine using the graphics cursor. IO is subtracted from the ASC11 character value to get ICHAR.

PLOTIT(KIN,X,Y,NPC,NPL,NSM,NC,NCA,NCO,SA,SO,XS,YS,TITLE) - PLOTIT is a graphic display routine designed for plotting analytical and experimental data used in aerodynamic analysis and design. This version has 3 grid sizes and five display locations as shown below. The routine will plot with or without symbols and with any one of 5 hardware dashed lines supported by Tektronix enhanced graphics equipment.

KIN	- ABS = Grid Number	(-1) continue
		(+1) end plot display title
X	- Coordinate of abscissa input points	
Y	- Coordinate of ordinate input points	
NPC(I)	- Number of points in curve(I)	
NPL(I)	- Dash control for curve(I)	
	0 solid line	
	1 - 5 Tektronix hardware dash lines	
	> 5 Tektronix software dashed lines	
NSM(I)	- Symbol control for curve(I)	
	0 no symbol in curve	
	1 - 8 use symbol NSM(I) on curve input points	
NC	- Number of input curves	
NCA	- Array for horizontal label NCA(KIN) for grid KIN	
NCO	- Array for vertical label NCO(KIN) for grid KIN	
SA	- Grid increment for horizontal axis	
	0.0 arbitrary scaling	
SO	- Grid increment for vertical axis	
	0.0 arbitrary scaling	
XS	- (+1.0) standard plot horizontal	
	(-1.0) reverse grid	
YS	- (+1.0) standard plot vertical	
	(-1.0) reverse grid	
TITLE	- 80 character title for plot	

PLOTO - Displays analysis data which is stored in the output file. Alphanumeric
    input from the keyboard is interpreted and displays of the data requested
    are drawn on the screen. Uses commons /OINDEX/, and /CHAR/.

PLOTOT - Displays an outline of a surface component with or without sections.
    TYPE 4 surfaces are drawn in the X-Y plane, TYPE 3 in three
    view and TYPE 5 components are unwrapped. Commons /GEROM/, /ED/, and /EDD/
    are used.

PLTLNE(NPTS,X,Y,TOL,IDASH) - Display a line X-Y (of NPTS points) using only
    points required to meet tolerance (TOL(degrees)). IDASH=0=SOLID, IDASH >0 =
    dashed line.

PLTONE - Displays component in /GEOM/ in stick-figure form with
    orientation matrix AMAT.

POLY - Generates an N-th order polynomial.

PRESS - Calculates and stores the axial perturbation velocities and net pressures for
    each of the unit solutions on the plot output file. PRESS also calculates the
    perturbation velocities at field points.

PRINT - Used to print the source and vortex aerodynamic
    influence matrices. PRINT is called from the MAIN program and is normally
    a comment statement. If a print of the aero matrices is required for a
    specific case, the c must be removed from column 1 of the call statement,
    the MAIN program must be recompiled and the UDP program relinked.

PUNCH - Writes element data card images on tape 8.

QC - Determines the aerodynamic heating at the given wall temperature.

QINT - Calculates a quadratic interpolation with given values.

RADIUS - Calculate leading-edge radius using a polynomial fit.

READN(KEY,IIN,IOUT,VALUE) - Reads in numbers in free-format from KEY and loads them
    into VALUE array. IIN is the number of values to read in. IIN=0 for variable number,
    IOUT is the number of values actually returned. Alphanumeric inputs are
    interpreted as zero's.

REALOT(ABC) - Displays number ABC using Tektronix routine AOUTST and a F12.3
    format.

REANUM(N,NMAX,INP,ILIM) - Interprets a numerical value in alphanumeric array INP
    starting at location N and proceeding to NMAX or the first delimiter. The
    type of delimiter encountered is returned in ILIM.

REVERS - Reverses the storage order of the symmetric and
    antisymmetric boundary conditions and solutions.

ROMU - Calculates various equilibrium real gas properties for air.

RUNOUT - Calculates the linearized forces and moments, including wave drag and skin
    friction drag, for each of the wind tunnel run conditions. Where applicable,
    nonlinear force and moment increments due to leading-edge and side-edge vortex
    formation are included.

SAVEB - Digitizer curve-fit routine. Organizes data accumulated from DIGIT on
    scratch file. Determines number of points per segment and cross-sections.
    Curve fits and/or smooths digitized data for each cross-section. Some
    keyboard input required for max point determination and smoothing algorithms.

SCALE(ISCALE,AMAT,FILL,XM,XL,XR,YB,YT) - Scales a component(s) into a
    screen space for the orientation given by AMAT.

    ISCALE -
        1   SCALE bounds of initial component
        2   SCALE bounds of additional component
        3   SCALE present bounds into viewing space
        4   Finish initial SCALE and bound into viewing space
        5   Finish add SCALE and bound into viewing space

    AMAT   - Matrix of viewing space for ISCALE = 2

    FILL   - Percentage of screen to fill with image

    XM   - Array of computed boundaries

    XL   - Left boundary

    XR   - Right boundary

    YB   - Bottom boundary

    YT   - Top boundary

SCALIT(YMAX,SCALE,IS,YMID,IC,IXID) - Sets grid scaling factor (SCALE) based on
    approximate spacing (YMAX), selects format statement to be used to display
    the grid (IS), and determine parameters for locating the center grid line
    (IC, IXID) using the midpoint (YMID).

SDATA - Prepares geometry data for use by the rest of the program.

SDQ(DQWT,DQWN) - Calculates the area under curve (DQWT) then divides it by the length
    to get roll angle wave drag (DQWN). Commons /CFIXW/ and /CTHE/ provide integer
    and length values.

SECT(IND,VAL,ND,X,Y,Z,NPH,NH,ITYPE) - Section insert/delete.

        IND = 1 : CODIM interpolation
        IND = 2 : LINEAR interpolation
        IND = 3 : Delete section ND

        VAL = interpolation point

        X, Y, Z = geometry point arrays

        NPH = number of points/cross-section

        NH = number of cross-sections

        ITYPE = Type of component

SEEGEN(NCOMP,XM) - Hypersonic geometry display using limit parameters from GENTS
and GENTB (XM array). NCOMP components are read off
a scratch file and displayed on screen at angles of yaw, pitch, and roll.
Similar to ORTH.

SENDC(IR,IT) - Transmits geometry in file record IR and the panel geometry if a surface
component in record IT in card image form. Data is placed on the file designed
to transfer data in a distributed net work.

SENDR(IUNIT,N,ARRAY) - Writes N values of array ARRAY onto unit IUNIT using
a 6E12.5 format.

SET - Analysis set-up routine. Alphanumeric input from the keyboard is interpreted
by SET and placed in specific data locations on the analysis output (PLOT)
file. Missing data is requested by the routine. The last section of SET
sorts out required analysis runs and geometry and places them into the card
image data transmission file. Commons /OINDEX/ and /CONDTN/ contain the
primary variables used here.

SETGEM - Reviews the run index in the PLOT file prepared in SET and selects
configuration and analysis models required for review prior to sending the
data for analysis. Commons used are /GEOM/, /PANL/, /OINDEX/, and /CONDTN/.
Initial conditions of /GENT/ are filled in here.

SETHYP - Interrogative routine used to fill in hypersonic analysis methods.
Default methods and values are built into the routine. Fills
in DEFINE array in /GEOM/.

SHIFT(KC,ITYPE,SY,SZ) - Re-arranges KC points in SY, SZ arrays based on point
type (ITYPE array). Scheme is for AREAS and AREAW routines to assure
points from section cuts are integrated in the proper order.

SHKEXP - Performs a streamwise shock expansion analysis.

SKINF - Skin friction calculation. Uses general geometric quantities stores
in common /CDAT/ to calculate viscous drag at various input atmospheric or
wind-tunnel conditions.

SLEN - Slender body generation. Combines from one to six body sub-
     components into a single slender body with allowance for over-
     lapping. Common /GEOM/ contains all the input and output data.

SMOTHL(NN,X,DYDX,BC,IORDER) - A piecewise least squares smoothing routine
     which takes input points (X, BC), and smooths BC and determines the first
     derivative at each point in X. The resultant values are output in arrays Y
     and DYDX respectively.

SOLVE - Controls the solution of the symmetric and antisymmetric
     aerodynamic influence equations.

SORTER(N,X,Y) - Sorts N values of X and Y into ascending order based on X.

SOURCE - Calculates the influence of a constant or linearly varying
     source panel on a control point.

SPCTOL(TOL,WF,N,Y,Z,S,NPS,SS,XIN,XEND,DR,XN,SP) - Spaces points along the independent
     axis of a three-dimensional curve based on the relative angular change.

TOL	- Spacing increment (in degrees) degrees)
WF	- Weighting factor for spacing (0.0 - 1.0)
N	- Number of points input
NPS	- Number of points output

> < 0 - Calculate NPS only
> = 0 - Calculate NPS and SS array
> > 0 - Use old NPS and calculate SS array

Y	- First coordinate array
Z	- Second coordinate array
S	- S(I) = X(I)
	S(I) = SUM(I=1,N) SQRT((Y(I)-YO)**2+(Z(I)-Z0)**2)
SS	- Spaced values of S, SS(1)=0.0, SS(NPS)=1.0
DR, XN,SP	- Scratch arrays same size as SS array

STRING(I1ST,ILAST,BUF,NTOT,VALUE) - Routine to convert a string of numbers, separated
     by commas or blanks, within buffer "BUF", beginning at character "I1ST" and
     ending when any delimeter or a double blank is encountered.

"ILAST" is the last character within BUF to be searched.

The array of real converted values is returned within "VALUE".

238

"I1ST" is returned as the position of the next delimeter following the converted string or as the position immediately following a ")" at the end of the numeric string.

SYMLEG(MLEFT,MTOP,NCURV,RUNS,LABLE,VALUES,ORDFIX,NPD,ETAV) - Routine to draw a symbol legend of the form:

<div align="right">(MTOP)</div>

SYMBOL	RUN	"LABEL"	ETA
	"RUNS(1)"	"VALUES(1)"	"ETAV(1)"
	"RUNS(2)"	"VALUES(2)"	(CPPLOTS ONLY"
	. .	. .	
	. .	. .	
	"RUNS(INCURV)"	"VALUES(INCURV)"	

(MLEFT)   "MTOP" and "MLEFT" are Tektronix absolute coordinates

"SYMBOL" column is left off if "NCURV" is negative

ORDFIX is the ordinate plot parameter type for CP plots. ORDFIX=23 when both upper and lower surface pressures are plotted. In this case, upper is plotted with solid lines and lower is plotted with dashed lines and the same symbols. A line legend is plotted in this routine.

NPD is an array of symbols used for each lable type.

SYMM(I,M,N,K) - Symbol plotting routine. Plots symbol (I) of size (K) at screen location (M,N).

SYM(IX,IY) - Plots a triangle at screen location (IX,IY).

SYMV(X,Y) - Plots a triangle at virtual screen location (X,Y).

TEMP - Iterative procedure to calculate the surface equilibrium temperature for either an ideal or a real gas.

TERMIN - Simple keyboard inputs to create surface and body components. Common /GEOM/ and array DA are used.

THINER(IP,XG,YG,ZG,IT,TOL,SS,ST,XP,YP,ZP,SP,ISCR) - Reduces arrays XG, YG, ZG using YG and ZG as reference arrays. The value of TOL determines the tolerance of the spacing. IP is the number of points (in and out), IT is the number of points per section, ISCR is SCRATCH file unit number. All other arrays are SCRATCH arrays.

TLU(XI,YI,ZI,NI,XO,YO,ZO,NO) - Linear interpolation of YI and ZI based on XO. NI input points from arrays XI, YI, ZI are used to evaluate NO output points in XO, YO, ZO arrays.

TRAP - Keyboard definition of a simple trapezoidal surface. Inputs
of SW, AR, λ, Γ, t/c's and wing section type are used.

TRIM - Subroutine TRIM calculates control surface deflections and total lift for
trimmed flight at three angles of attack. Not operational.

TTABLE - Performs the interpolation to find the thickness correction factors.

UTILIT - Keyboard input routine for changing system file management, title and units
default parameters.

VALUE - Subroutine VALUE calculates the value of the integral $\int_0^\lambda f(X)\,dX$ where
$f(X) = a_1 X(1-X) + a_2 X^2(1-X)$.

VECTOR - Converts input thrust vector data to coefficients and adds the results to
the vehicle aerodynamic coefficients.

VIEWER(ISENSE,PX,PY,PZ,NPT,IDASH) - Checks a panel defined by PX, PY, and PZ
arrays to see if the normal vector is facing away or towards the screen.
ISENSE indicates if the panel is a clockwise or counterclockwise formation.
NPT is the number of points to display. IDASH = 0 solid, IDASH >0 dashed display.

VIEW3 - Three-view display. Geometry components listed in /COMPO/ are
input into /GEOM/ and displayed on the screen.

VISC - Viscous drag calculation control. Checks work file for a
configuration then controls input and calculations.

VORTEX - Calculates the influence of a constant pressure panel
on a control point.

VTX - Calculates farfield vortex drag for three angles of attack.

WAVE - Wave drag calculation control. Checks work file for a configuration,
then controls input and calculations.

WAVE - Stores geometry and pressure data for use in the wave drag
calculation.

WET(IX,XSURF) - Updates perimeter and area arrays in /CXXXV/ to reflect new section
cuts.

WSVP - Calculates and displays total surface area and volume.

XACALW - Global scaling for wave drag. Uses component parameters in /GEOM/
to fill in arrays in /CLIMW/.

XYZ(DA,L) - Card image data stored in DA is converted into surface and body
components and stored in /GEOM/.

XYZR - Geometry preparation for wave drag. Takes input geometry in /GEOM/,
adapts it for wave drag and stores its output in /CXXXW/.

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Part II Final Report

16. Abstract

An aerodynamic analysis system based on potential theory at subsonic/ supersonic speeds and impact type finite element solutions at hypersonic conditions is described. Three dimensional configurations having multiple non-planar surfaces of arbitrary planform and bodies of non-circular contour may be analyzed. Static, rotary, and control longitudinal and lateral-directional characteristics may be generated.

The analysis has been implemented on a time sharing system in conjunction with an input tablet digitizer and an interactive graphics input/output display and editing terminal to maximize its responsiveness to the preliminary analysis problem. CDC 175 computation time of 45 CPU seconds/Mach number at subsonic-supersonic speeds and 1 CPU second/Mach number/attitude at hypersonic conditions for a typical simulation indicates that program provides an efficient analysis for systematically performing various aerodynamic configuration tradeoff and evaluation studies.

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