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NASTRAN DATA GENERATION OF HELICOPTER FUSELAGES USING INTERACTIVE GRAPHICS

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SUMMARY

The development and implementation of a preprocessor system for the finite element analysis of helicopter fuselages is described. The system utilizes interactive graphics for the generation, display, and editing of NASTRAN data for fuselage models. It is operated from an IBM 2250 cathode ray tube (CRT) console driven by an IBM 370/145 computer. Real time interaction plus automatic data generation reduces the nominal 6 to 10 week time for manual generation and checking of data to a few days.

The interactive graphics system consists of a series of satellite programs operated from a central NASTRAN Systems Monitor. Fuselage structural models including the outer shell and internal structure may be rapidly generated. All numbering systems are automatically assigned. Hard copy plots of the model labeled with GRID or elements ID's are also available. General purpose programs for displaying and editing NASTRAN data are included in the system.

Utilization of the NASTRAN interactive graphics system has made possible the multiple finite element analysis of complex helicopter fuselage structures within design schedules.

INTRODUCTION

The problem of manual data generation for large finite element idealizations is well known. Helicopter fuselage models for static stress analysis with NASTRAN contain typically 2,000 to 10,000 input data cards. Manual generation and checking of data decks for these problems requires 6 to 10 weeks of tedious coding and corrections. With such large turnaround times, it is usually not possible to perform analysis of redesigned configurations within allotted design schedules.

The use of interactive graphics to display and check large structural models has been demonstrated (Reference 1). The automatic generation of data describing fuselage structures has been accomplished via batch type computer programs (References 2 and 3). This paper describes a system of programs for the automatic data generation, editing, and display of fuselage models which is fully interactive. Additional flexibility is acquired by including automatic data generation features in an interactive mode. This permits the rapid development

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of large data decks for complex structures which do not lend themselves totally to simple mesh generation techniques.

INTERACTIVE GRAPHICS MONITORING SYSTEM FOR NASTRAN

The preprocessors used for helicopter fuselage data generation are part of a system of interactive graphics programs shown in Figure 1. The system is activated and controlled from the IBM 2250 CRT console. Each module is accessed from the central System Monitor program by selecting the program name from a main menu. The modular construction of the system provides flexible usage. Some of the modules are more general purpose in nature (i.e., the Geometry, Display, and Edit programs) and thus may be used in a variety of NASTRAN problems. At any time during operation of the system, control may be transferred to any module via the System Monitor.

The graphics system creates card input for NASTRAN which is independently executed in a batch mode. Hard copy plotting of CRT input displays and NASTRAN output for fuselage models is currently under development.

FUSELAGE INPUT DATA GENERATION

A large percentage of the required NASTRAN input for the stress analysis of a helicopter fuselage may be created in an interactive mode using the Fuselage Data Generator module. This program interacts with other Geometry and Files modules via the NASTRAN System Monitor, creating card images for the following types of Bulk Data:

Element connectivity

Grid point coordinates

Element geometric properties

Multipoint constraints

The design philosophy for this preprocessor placed considerable emphasis on user convenience and operational speed. Wherever possible, default options are built into the program to ensure rapid data generation with the minimum of commands. Within this philosophy, all GRID and element ID's are internally defined by the program.

The data generation is separated into two phases. The first phase comprises the generation of the fuselage outer shell consisting of frames, stringers, and shear panels. The second phase involves the generation of all the internal details such as bulkheads, floors, longitudinal walls, etc. This distinction between phases is made for the following reasons:

1.) The outer shell, in addition to exhibiting a larger amount of topological repeatability, is necessary to define the boundaries of the internal structure.

2.) The internal details are generally more variable in geometry and connectivity than the outside shell, as illustrated in Figure 2, and thus different algorithms are required for efficient data generation.

The order in which subprograms are used in the generation of fuselage data is arbitrary. The user selects the next module to be called via light pen from a CRT display. This arrangement provides flexibility of operation not available in a batch data generation mode. The user may generate, display, and store data at any stage in the model development, reentering previously executed modules for corrections whenever necessary.

In the normal sequence of phase 1 operation, the user first defines all unique frame contours using the two-dimensional Geometry module. This subprogram provides a wide variety of options for construction of general two-dimensional contours. The frame contour is developed by interpolating between input points with straight lines, conic sections, or cubic splines. Intermediate points are located by intersecting the contour with lines, and/or by specifying equal arc increments between previously defined points. To reduce the amount of input required from the user, symmetric repetitions of geometry are obtained by the reflection of the previously defined contour about an axis of symmetry.

When all points on the desired frame contours have been defined, the coordinate information is stored in the 2-D Files module for future reference. The points describing two or more frames are then transferred to the 3-D Geometry module (FMILL) where they are used as bounding contours to develop a shell surface. If only two frames are transferred, as shown in Figure 3a, straight line interpolation between corresponding points is used to define the shell. If more than two frames are transferred, a piecewise cubic surface is constructed between them.

All additional frame contours and their corresponding points are automatically generated in the 3-D Geometry module by intersecting the 3-D surfaces with planes as illustrated in Figure 3b.

The output of the 3-D Geometry module is the positions and ordering of a set of points describing a "regularized" fuselage shell (Figure 3b). A permanent file within the module may be used to store this information for future reference.

The shell established in the 3-D Geometry module is transferred to the Fuselage Data Generator via the NASTRAN System Monitor where perturbations on the regularized topology are performed to produce the actual fuselage geometry and connectivity. To increase clarity of display, a limited portion of the shell may be transferred at any one time to the Fuselage Data Generator. A perspective view of the fuselage shell looking down the longitudinal axis of the aircraft (spider diagram) is used in this module as illustrated in Figure 4a. The spider diagram allows the maximum amount of display without the confusion of overlayed lines. Cutouts (e.g.,doors, windows, landing ramps, etc.) or partial frames are introduced by deleting lines via the light pen (Figure 4b). Points may be added by keying in coordinates from the console and connectivity modified by adding lines between points detected by the light pen. Such modification enables the line connectivity to depart from the initial regularized topology, permitting duplication of any required structural model.

When the geometry and line connectivity of the shell has been established, element types are defined individually by light penning associated points or, in zones, by light penning points at zonal extremities. A default option defines frames as BAR elements, stringers as RODS, and quadrilateral panels by SHEAR elements. A modified connectivity display illustrated in Figure 4c indicates the position and type of the elements defining the skin. When the element definition is completed, section properties may be keyed in from the console and assigned to individual elements or zones.

Following completion of the fuselage shell mesh definition, the user may transfer the information associated with the spider diagram(s) to a permanent NASTRAN File. At this time, the previously defined geometry, connectivity, and property information is converted into NASTRAN Bulk Data, and all elements are compiled into a SET for future display or hard copy plot generation. These plots may be labeled with GRID ID's or element ID's.

The user may define internal details to be added to the model by returning to the Geometry modules. By intersecting the 3-D shell surface with the plane of a detail (e.g., bulkhead), boundary points of this structural unit are defined, compatible with the previously generated fuselage shell. These points are transferred to the 2-D Geometry module where point and line algorithms are used to construct a connectivity breakup. This information is then transferred to the Data Generator module where the elements are defined, section properties assigned, and the resulting Bulk Data merged with the file for the previously generated fuselage shell.

The Fuselage Data Generator module may also be used to create multipoint constraint data for NASTRAN. Large sets of MPC data are required to enforce rigid body assumptions on some internal details of the fuselage. This feature eliminates the need for modeling stiff structural units such as full bulkheads. MPC's are also used to distribute concentrated applied loads to individual grid points around the fuselage shell.

DISPLAY AND EDIT PROGRAMS

Transfer of control to the Display and Edit preprocessors may be accomplished via the NASTRAN System Monitor at any time. These general purpose programs permit a much greater flexibility for displaying and editing NASTRAN input data than the Fuselage Data Generator.

The Display program enables arbitrary selections of data to be shown on the CRT screen with greater user convenience and speed. The user may display structural segments previously defined in the Fuselage Data Generator as SETS.

This significantly reduces the time necessary to define elements for display. To add flexibility to the system, however, new groups of elements comprising structural segments not specified by the SET option may be generated by selecting the required element types and element identification numbers. Table 1 lists geometry types and their corresponding element types recognized by the display program.

Following satisfactory element selection, a display of the structural model appears with a menu of options. Two of these options enable rotation of the display about three orthogonal axes, scaling and selective zooming to be implemented, thus permitting the user to obtain an optimum orientation for visual inspection. The axis system for structural rotations is fixed relative to the screen and is always displayed, enabling the user to remain oriented regarding rotational commands. To increase the number of elements that can be displayed and simultaneously reduce image flicker, the geometry is internally scanned for multiply defined lines and the redundant lines are eliminated.

At any time during execution of the Display program, two additional features open to the user are "selective data retrieval and editing" and "free boundary analysis". The first feature permits extraction and identification of any element or grid point. By light penning a displayed line image, all associated element ID's are displayed. By light penning any two intersecting line images, the associated GRID ID is displayed. The corresponding Bulk Data card images of the extracted element or grid point are simultaneously shown below the structural display, permitting temporary editing and automatic incorporation of the change into the structural display.

The free boundary analysis produces a display of singly defined lines in the structural model, permitting the location of missing elements. If a single quadrilateral element had been inadvertently omitted from manual input of a shell structure, for example, only that quadrilateral would be displayed in addition to any natural structural free boundaries. All other element line images would be absent because of their multiple line definitions.

Much greater flexibility for data editing may be obtained by transfer of control to the Edit program via the NASTRAN System Monitor. The Edit permits modification or deletion of current data and the insertion of new data in the Executive Control, Case Control, or Bulk Data decks. Since the IBM 2250 CRT is capable of displaying only 72 characters across the screen as compared to 80 columns in the NASTRAN data card format, each card is broken into two lines. A menu comprising nine options accompanies the Edit program. Included within these options is the ability to page forward or backward through the data or to locate any card type and ID. Editing of any data may be accomplished by keying in new values from the console.

Concluding the Display and Edit phase, the permanent storage files may be updated with corrected data by transfer of control to the FILES program via the NASTRAN System Monitor.

ILLUSTRATIVE EXAMPLE

The complete structural model used during the analysis and design of the UTTAS helicopter fuselage is shown in Figure 2 . To illustrate the versatility of the described interactive graphics preprocessors, the input data are generated and checked for the circled substructure known as the transition region.

The transition region was chosen for this example due to its variety of characteristics pertinent to most fuselage structures. It contains nine frames, three cutouts, two bulkheads, a floor, and a vertical shear web. Of the nine frames, four are independent in shape. The other five frames are generated by linear interpolation. Five of the nine frames are partial (i.e., they do not span the entire circumference of the fuselage).

The outside shell and the floor are used to illustrate operation of the Fuselage Data Generator. One of the bulkheads is manually generated and used to demonstrate features of the Display and Edit programs.

Figure 5a shows the CRT display listing the various subprograms available within the NASTRAN interactive graphics system. Light penning "2D GEOM" enables the shapes of the four independent frames to be generated (Figure 5b). Due to the generality of frame shapes, each grid point is introduced by keying in the appropriate coordinates in the YZ plane. Dummy points are introduced, at three of the four frames, to maintain an equal number of points (46) at all frames. Partial frames are also temporarily generated as full frames. The four frames are stored in the 2D FILES subprogram, and transferred to FMILL, the 3-D Geometry module, where the node points are connected by lines (Figure 5c). The frames are not closed due to the limitation of the FMILL subprogram which generates only open surfaces. The remaining five frames are generated by intersecting the surface with planes at the appropriate frame station coordinates (Figure 5d).

The final details of the fuselage generation concentrate on the forward seven frames between Stations 398 and 443 as shown in Figure 5d . Transfer of these frames to the "GENERATE" module yields a connectivity display shown in Figure 6a . Partial frames and cutouts are created at this stage by deleting unwanted lines, Figure 6b . Dummy points are also removed and the line element connectivity completed, Figure 6c .

The introduction of new lines and definition of panel element is now performed, resulting in the display shown in Figure 6d , quadrilaterals being indicated by the symbol X, and triangles by the symbol Y, etc.

A series of hard copy plots of this SET of structural elements may be generated, denoting the element and node point ID's for future reference. Figure 6e shows such a plot for the shear panels corresponding to Figure 6d . The same elements are also assigned a SET number, aiding in their recall for further modification in the Display and Edit programs. Figure 6f is the true view of the structure corresponding to that displayed in Figures 6a to 6e .

At this time, properties are defined and associated with appropriate elements by either the light penning of individual elements or the definition of property zones.

A structural SET is generated in a similar manner for the aft two bays between frame stations 443 to 485. For illustrative purposes, these two SETS have been called up together by the Display program. In other structures, however, it may be expedient to use the Display and Edit programs to perform final adjustments in the structural configuration rather than develop the exact structure in the Fuselage Generator program.

Figures 7a and 7b represent two views of the SHEAR and TRMEM element connectivity of the generated outside shell described above. Figure 7c illustrates the stringers or ROD element connectivity and Figure 7d the frames.

Display of a manually generated ulkhead for frame station 443, Figure 8a, clearly indicates an error. Light penning the upper two erroneous lines reveals the associated element numbers to be 2986 and 2985 and the corresponding erroneous node point to be 1893. The data card image for this GRID point is shown below the display. Editing this card image enables immediate regeneration of the correlated display, Figure 8b. The associated data card image in permanent storage (GRID 1893) is shown in Figure 8c by transfer to the Edit subprogram. Visually the display in Figure 8b appears to be correct. Initiating the free boundary analysis feature, however, reveals a missing SHEAR element, Figure 8d. This element can be introduced in the Edit subprogram by keying in the missing Bulk Data card.

The generation of internal structure, such as a floor, requires returning to the spider diagram (Figure 6d) of the Fuselage Generator program. Light penning the grid points common to the floor, the outside shell, and any other previously defined internal structure, generates a 2-D display of the boundary of the required floor, Figure 9a.

Generation of the interna 'ement connectivity is rapidly performed as shown in Figure 9b. Figure shows the floor and vertical web viewed from the Display program.

Structural data generation by the interactive graphics system is managed by manipulating the many features built into the programs. The order in which the subprograms are used is completely general and problem dependent. Optimum utilization of the system is only achieved with practice.

CONCLUDING REMARKS

Dramatic time reductions (by an order of magnitude) for the generation of NASTRAN input data for fuselage structures has been achieved by the development and utilization of the subject interactive graphics preprocessor.

The modular design of the NASTRAN interactive graphics system permits subprograms to be called in an arbitrary order, allowing rapid data generation for complex fuselage models. The generality of the geometry definition, display, editing, and storage features also provides versatility needed for generation of models for many other structures.

ACKNOWLEDGEMENTS

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1.) Cronk, Michael: An Interactive Computer Graphics Program for NASTRAN. NASTRAN: Users' Experiences, NASA TM X-2378, 1971, pp. 659-667.

2.) Galligan, D. A., and Wilson, H. E.: The Integration of NASTRAN into Helicopter Airframe Design/Analysis, presented at American Helicopter Society, May 1973.

3.) Giles, Gary L., and Blackburn, Charles L.: Procedure for Efficiently Generating, Checking, and Displaying NASTRAN Input and Output Data for Analysis of Aerospace Vehicle Structures. NASTRAN: Users' Experiences, NASA TM X-2378, 1971, pp. 679-696.

GEOMETRY TYPE	ELEMENT TYPE	MAX NUMBER
LINE	CROD, CBAR, CONROD, CTUBE, CVISC	1000
TRIANGLE	CTRMEM, CTRIA1, CTRIA2, CTRMPLT, CTRBSC	1000
QUADRILATERAL	CQDMEM, CSHEAR, CQUAD1, CQUAD2	1000
TRIANGULAR RING	CTRIARG	500
QUADRILATERAL RING	CTRAPRG	500
CONCENTRATED MASS POINTS	CONM1, CONM2	500

Table 1. Element Menu for Display and Edit Preprocessors

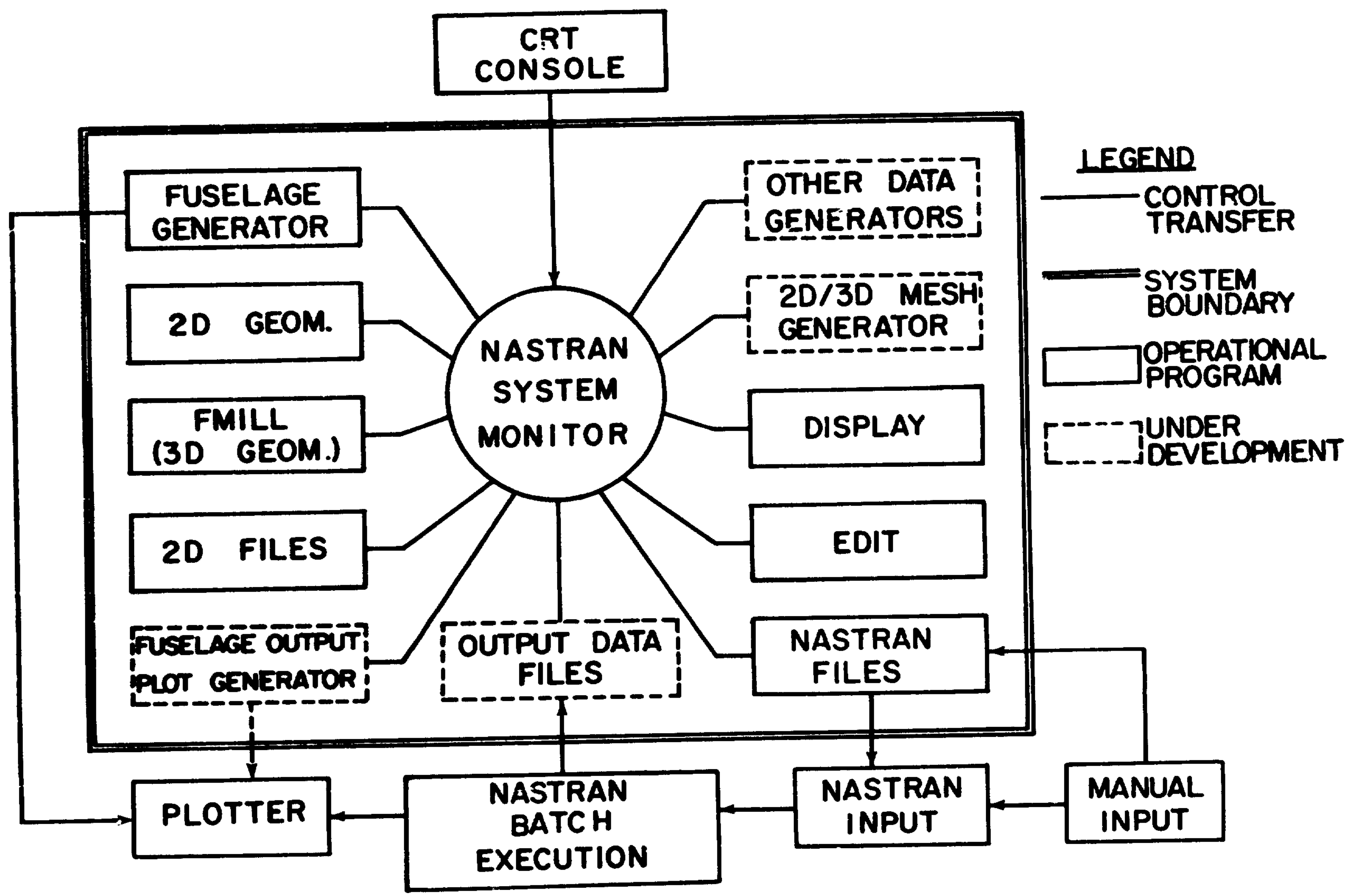


Figure 1. NASTRAN Interactive Graphics System

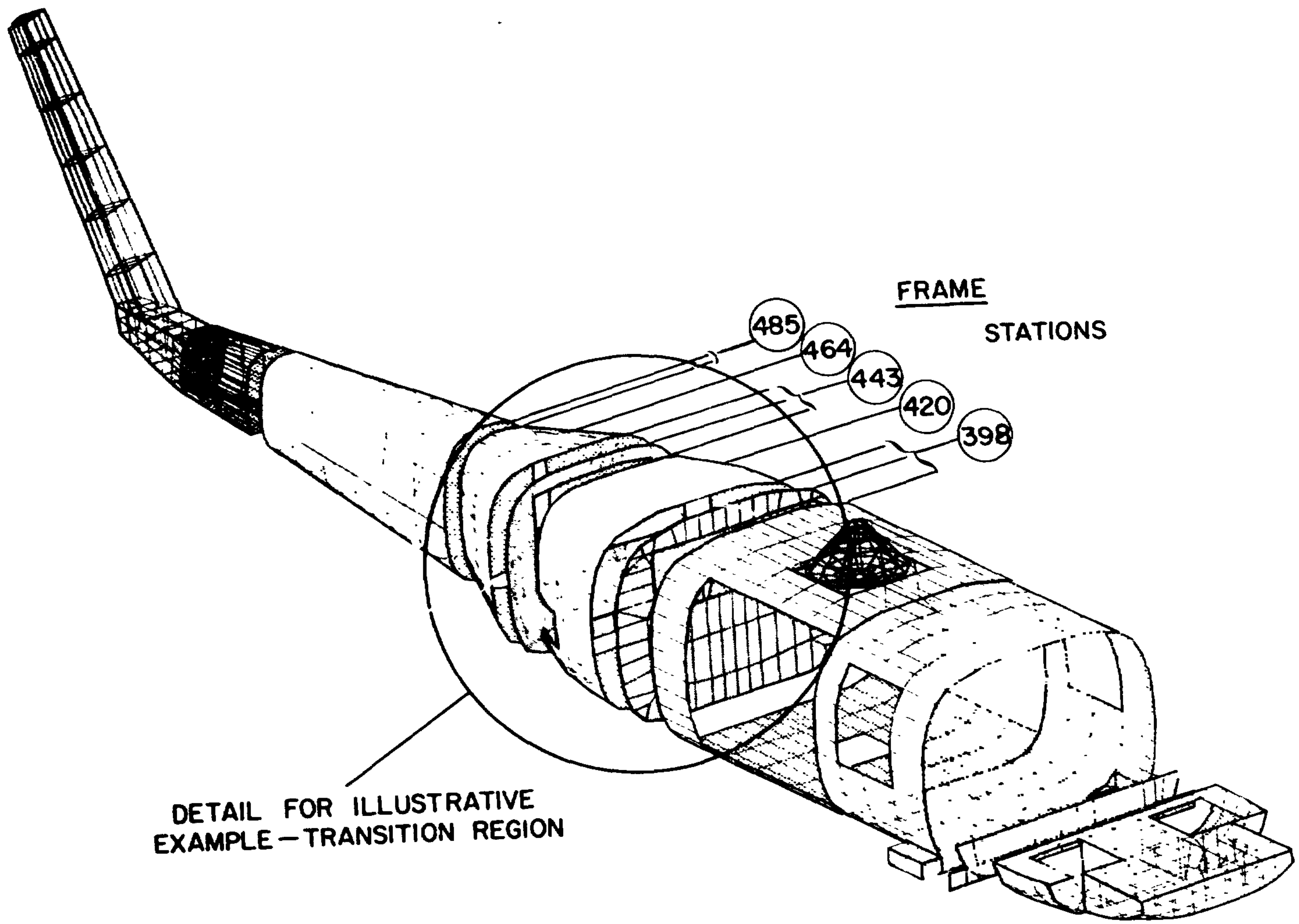
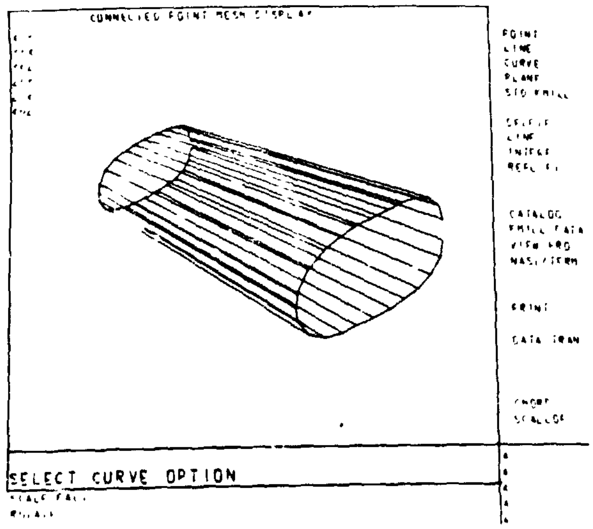
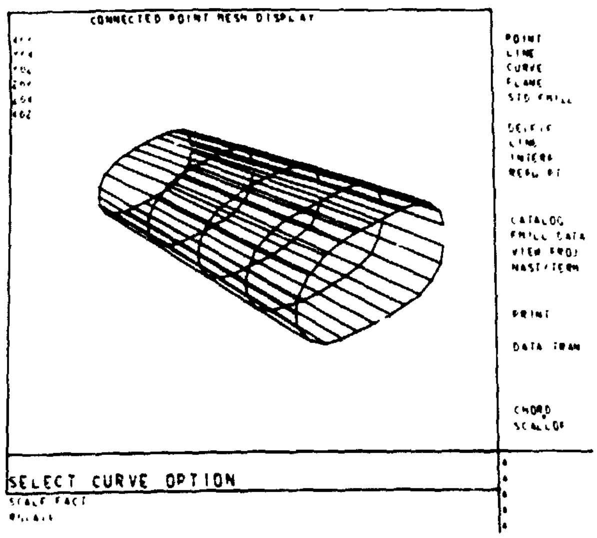


Figure 2. NASTRAN Structural Model for UTTAS Helicopter

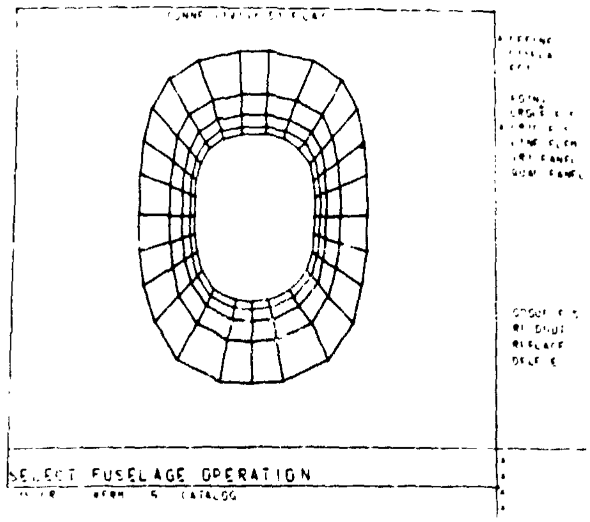


(a) Surface Definition

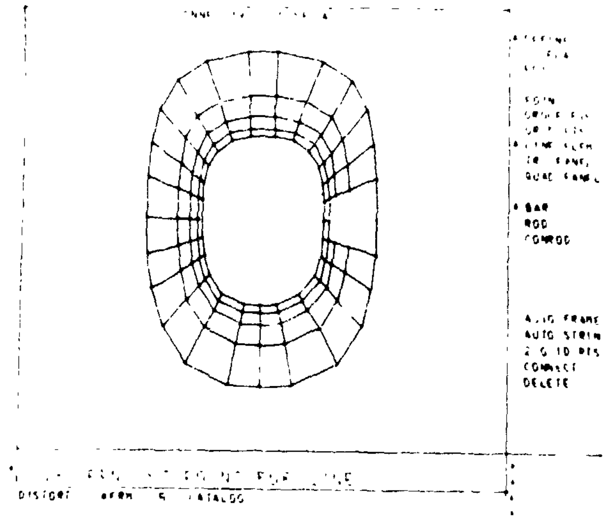


(b) Definition of Intermediate Frame Contours

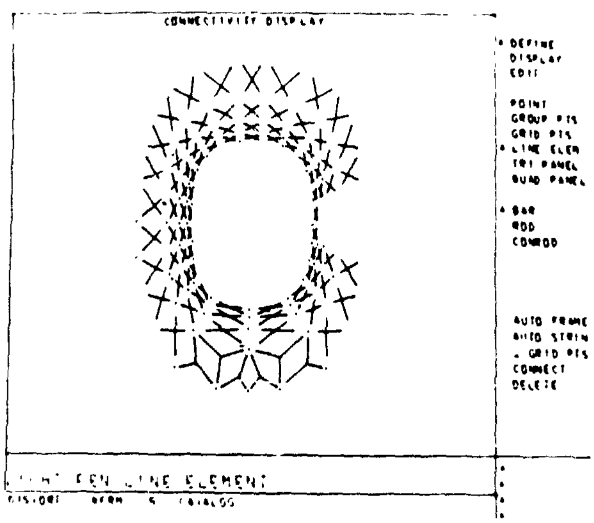
Figure 3. 3-D Geometry Definition



(a) Spider Diagram

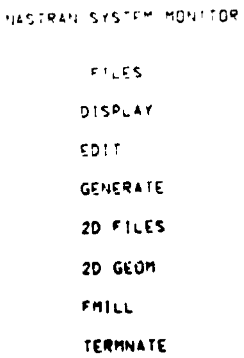


(b) Cutout Definition

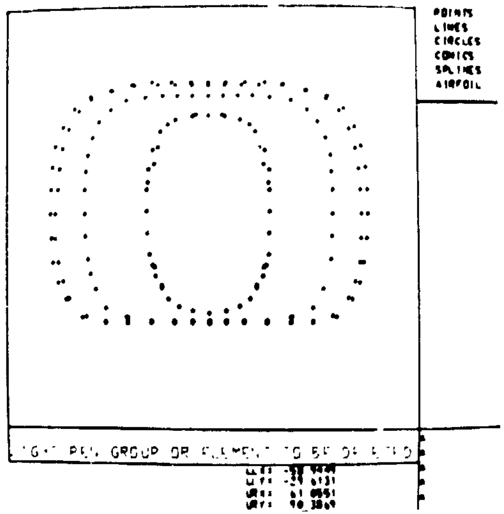


(c) Element Connectivity

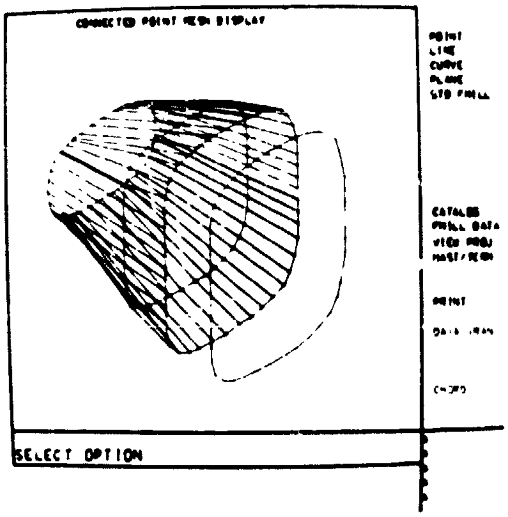
Figure 4. Fuselage Generator Display



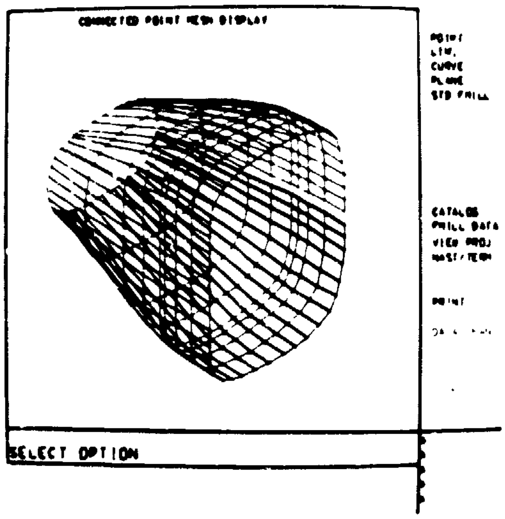
(a) NASTRAN System Monitor Program Selection Menu



(b) 2-D Frame Contours



(c) 3-D Line Connectivity



(d) Intermediate Frame Definition

Figure 5. UTTAS Transition Region - Geometry Definition

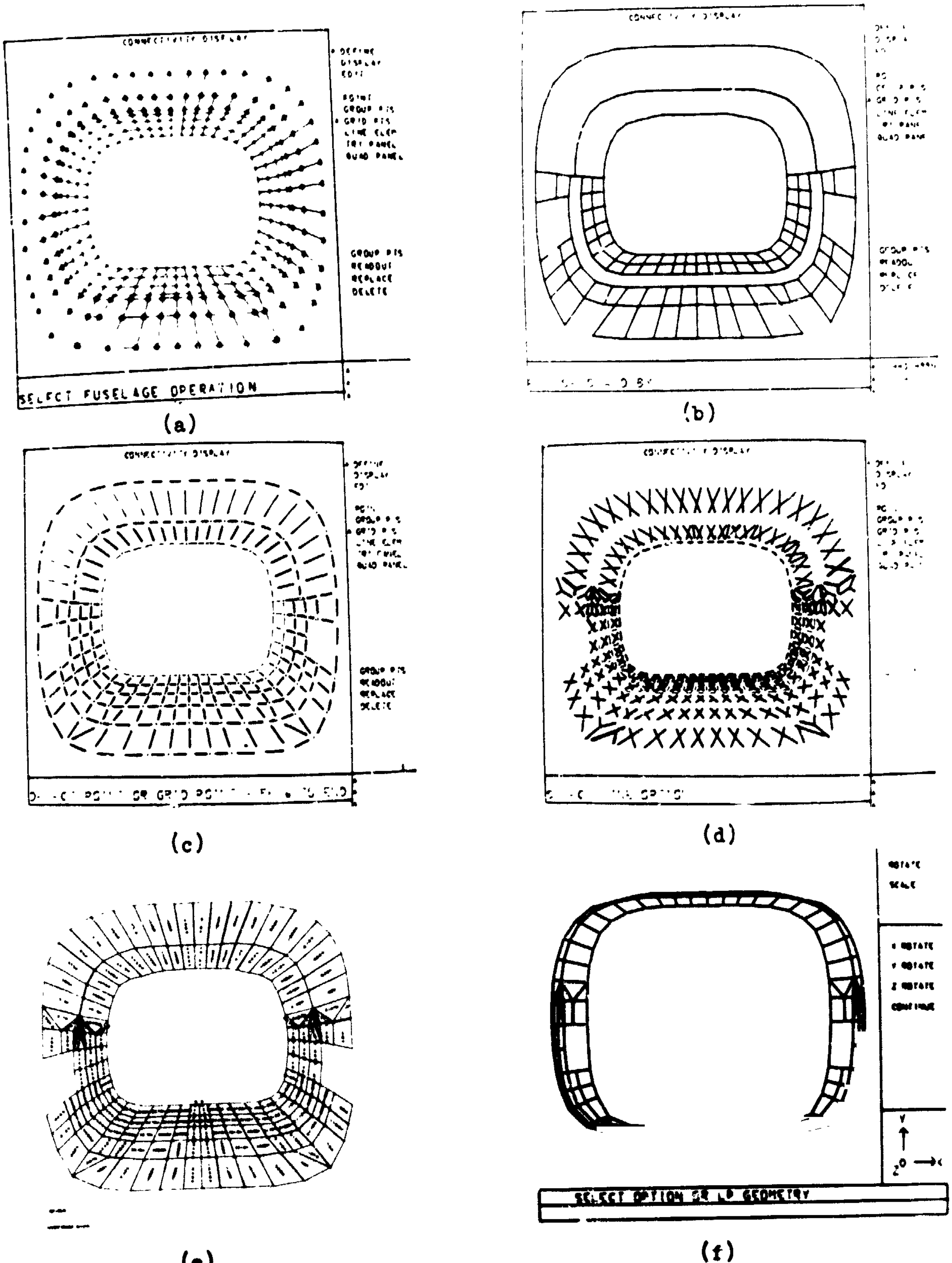
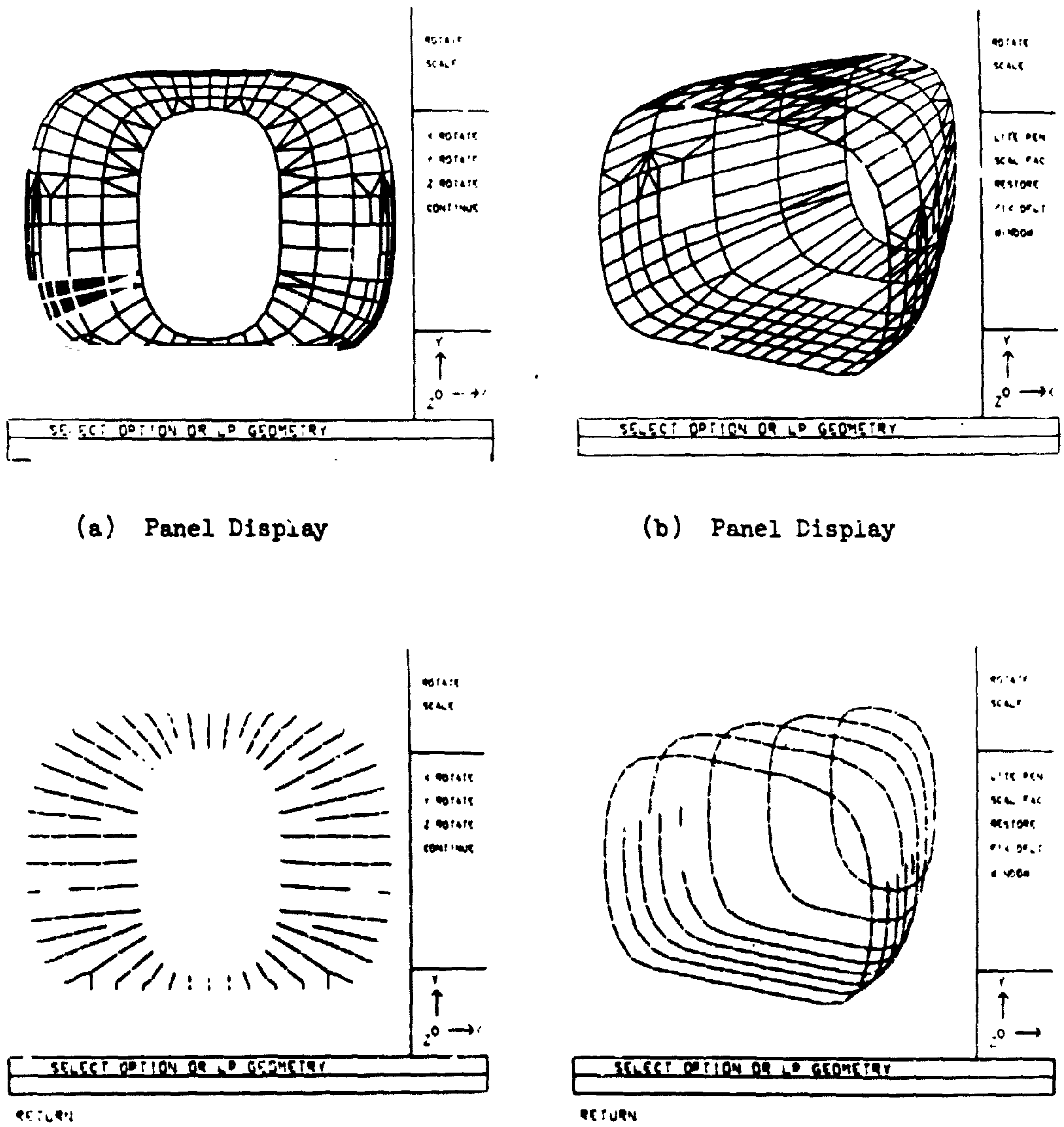


Figure 6. UTTAS Transition Region - Connectivity and Element Definition



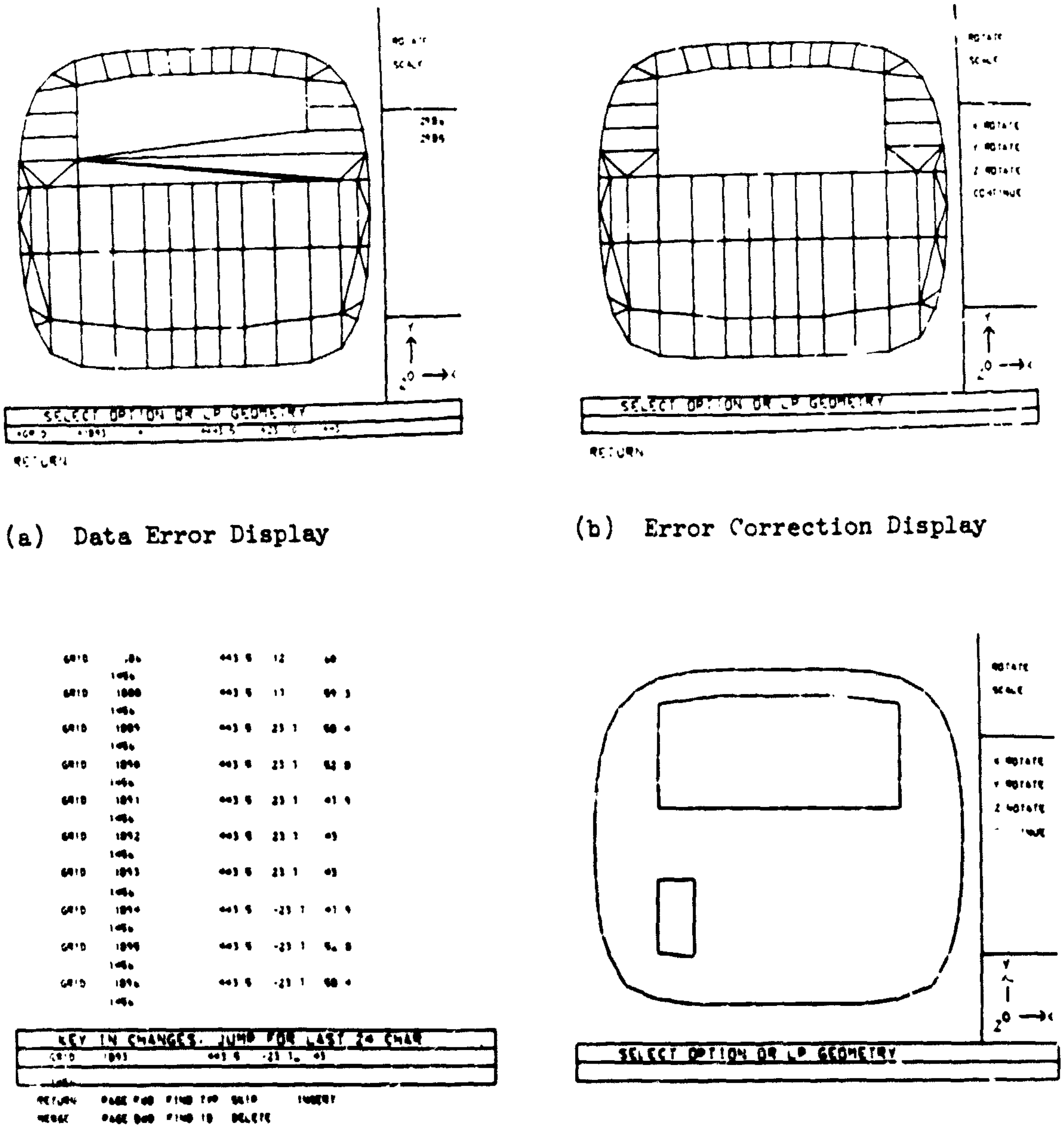
(a) Panel Display

(b) Panel Display

(c) Stringer Display

(d) Frame Display

Figure 7. UTTAS Transition Region - Display and Edit



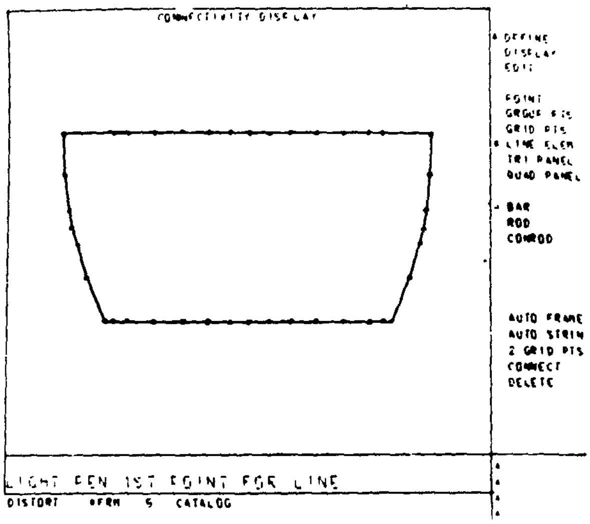
(a) Data Error Display

(b) Error Correction Display

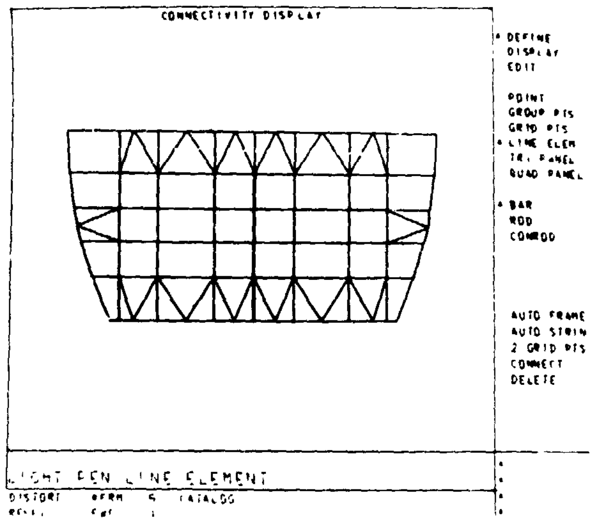
(c) Data Editing

(d) Free Boundary Analysis

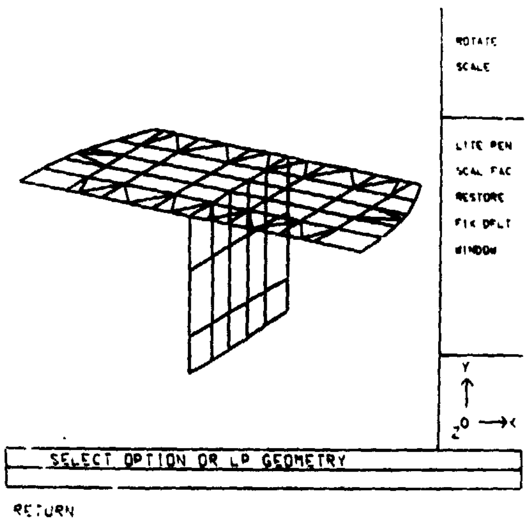
Figure 8. UTTAS Transition Region - Display and Editing of Manually Generated Bulkhead



(a) Floor Boundary



(b) Floor Connectivity



(c) Floor and Shear Web Display

Figure 9. UTTAS Transition Region - Generation of Floor and Shear Web