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A SIMPLIFIED MODAL PLOTTING TECHNIQUE FOR THE REPRESENTATION OF COMPLEX STRUCTURAL MODELS

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SUMMARY

A plotting method has been developed that has proven to be useful in rapidly defining the mode shapes of a complex spacecraft. The reduction of the complex model to a simple "stick" plot is accomplished by augmenting the existing NASTRAN plot package with constrained plot elements. Both the existing NASTRAN modal plot package and the "stick" plots of a representative mode are presented for comparison.

INTRODUCTION

The NASTRAN plot package provides the capability of generating modal deformations (mode shapes) resulting from real eigenvalue analysis. These modal deformations of the structural model may be displayed in the deformed shape either alone or superimposed on the undeformed shape. Another available method of displaying the modal deformations is by means of displacement vectors at the grid points.

NASTRAN MODEL OF THE SPACECRAFT

When a complex structural model, such as the Applications Technology Satellite (ATS), is being analysed, problems arise in rapidly identifying characteristic mode shapes with the existing plot package. Figure 1 shows the NASTRAN plot of the undeformed structure in the launch configuration. This model consists of 311 grid points, 519 beam elements, 137 plate elements with 1696 degrees of freedom. The model was reduced to 217 dynamic degrees of freedom by the ASET option for the eigenvalue analysis, rigid format no. 3.

Figure 2, showing the deformed shape of the ATS structure superimposed on the undeformed shape, illustrates the difficulty in interpreting the mode shape from this type of plot. Orthographic projections of the modal deformations such as the side view shown in Figure 3 and the top view shown in Figure 4 are helpful but these are confusing also because of all the lines crossing over each other. Plots of subassemblies or selected structural elements may also be generated but then all of the components must be put together to get the total composite mode shape.

This approach would require a considerable number of separate plots and views to obtain one mode shape. For the example of the ATS model, there are at least six (6) separate structural subassemblies that would have to be plotted and compared.

The use of displacement vector plots causes even more lines to be generated on the already crowded plot picture which only tends to confuse the modal representation of this complex structure.

SIMPLIFIED PLOTS

TRW Corporation of Redondo Beach, California has written a simplified modal plot routine for interpreting mode shapes. This routine is used to generate modal plots of structures undergoing modal vibration tests in their Computer Oriented Modal Control and Appraisal System (COMCAS). This routine consists of plotting the relative displacement of selected points on the structure being tested (in this case, the ATS spacecraft). These points are instrumented (directly or indirectly) on the structure for obtaining modal displacement response data. Orthographic "stick" type plots of these modal displacements in the three principle displacement axes versus the spacecraft longitudinal or vertical axis are generated. Figure 5 is typical of the TRW stick plots comparable to a NASTRAN projection of a mode shape shown in Figure 3.

CONVERSION OF NASTRAN MODAL PLOT TO STICK PLOTS

In order to compare the NASTRAN mode shapes with the TRW plotted mode shapes, the ATS structural model was "modified" to provide TRW type stick plots. The basic idea was that the TRW stick plot grid points are "tied" to the NASTRAN model by the use of SPC and MPC cards and the plotting program was instructed to plot only the stick points. A "Z"-axis for the structural model was generated with PLOTEL cards. This generated Z-axis was coincident with the Z-axis of the basic coordinate system. Spacecraft stations along this axis were indicated with appropriate numeric labels. Points representing structural components of the ATS were selected on this Z-axis to correspond with the TRW points. These points were then fully constrained to the original structural model by SPC and MPC cards to yield the desired displacements. For example, to obtain a plot of Y-axis modal displacement vs. Z-axis location, all degrees of freedom of the plot points except the Y-axis components are constrained. The purpose of this is to locate the position of the undeformed zero deflection upon the newly created Z-axis. (Incidentally this creates a raft of user warning messages about unconnected internal grid points). Then these points were appropriately connected by PLOTEL cards to give a continuous stick type plot of the spacecraft. The NASTRAN produced stick plot shown in Figure 6 is the equivalent of the TRW plot of Figure 5. By comparison of these two figures it is quite evident that the modal representations are the same. Obviously a separate set of MPC and SPC cards is required to

represent each displacement direction. Thus each plot point on the spacecraft will have to be designated by a new grid point identification for each specific modal displacement plot desired. The displacements may be enlarged by scaling factors to emphasize the modal deflections (or to get closer agreement in this case). An ordinate axis could be created for the NASTRAN generated stick plot by introducing more PLOTEL's and labeling them accordingly. This would have to be done in combination with a printout of the modal displacements from the NASTRAN solution. By selecting different plotting symbols it is possible to follow the modal displacement of the prime structural components of the spacecraft.

CONCLUDING REMARKS

A quick glance at the simplified plots of the three (3) principal displacement axes will make the identification of the mode shape much easier than with the standard plot package. Bending modes and torsional modes become quite obvious with these plots as seen in Figures 7 and 8. For the ATS spacecraft, six (6) plots were generated for each mode. In addition to the three (3) plots of the X, Y and Z displacements, three (3) separate plots of the solar array portion of the spacecraft were generated to provide complete modal data. This was necessary in order to give a better representation of the breathing modes of this very flexible portion of the spacecraft. The organization of the stick plot package should be carefully planned in advance to give the maximum amount of modal data with the minimum number of plots. It is felt that this type of simplified stick plot will be helpful for investigating the mode shapes of complex structural models.

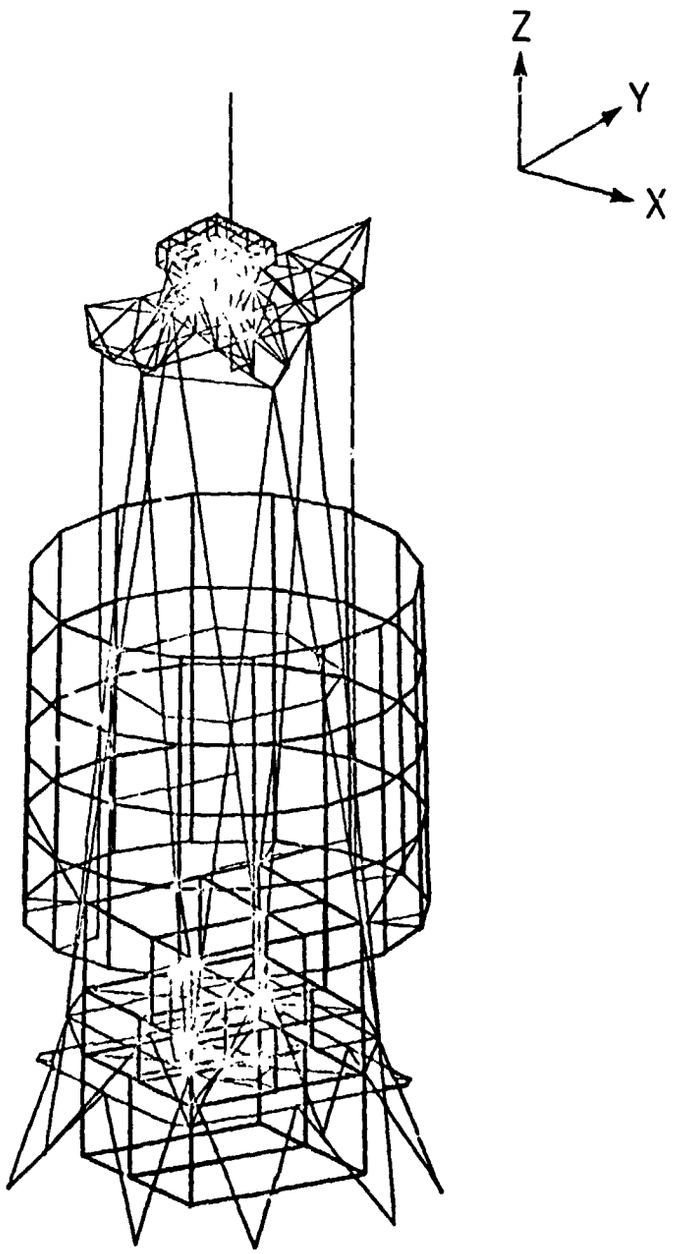

Figure 1.- NASTRAN Plot of the Undeformed Structural Model of the Applications Technology Satellite (ATS) in the Launch Configuration. (This figure is the best quality reproduction that could be made from the original computer-generated plot obtained by the author.)

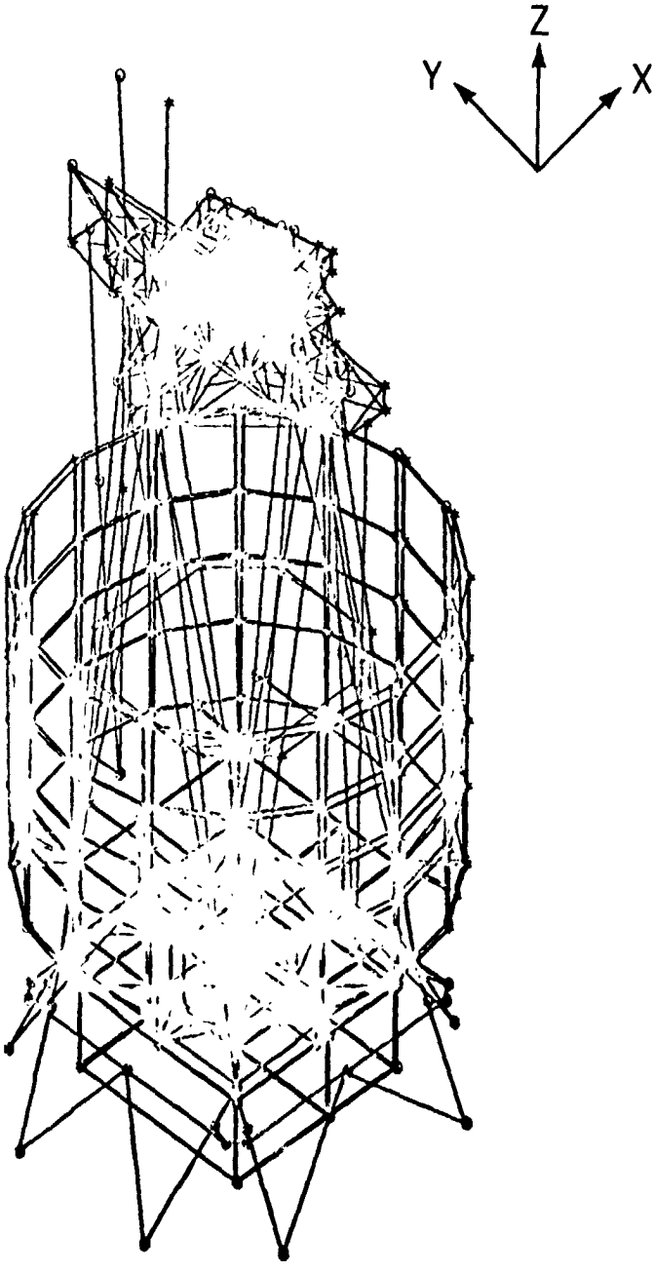

Figure 2.- NASTRAN Plot of Modal Deformation Superimposed on the Undeformed Shape (mode shape 1). (This figure is the best quality reproduction that could be made from the original computer-generated plot obtained by the author.)

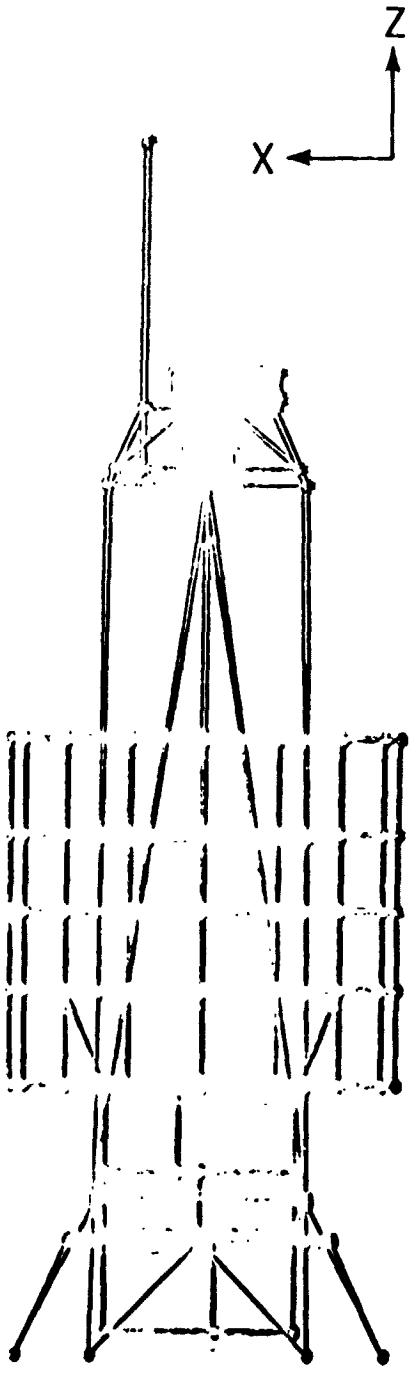

Figure 3.- NASTRAN Plot (Z-X plane, side view) of Modal Deformation Superimposed on Undeformed Shape (mode shape 1). (This figure is the best quality reproduction that could be made from the original computer-generated plot obtained by the author.)

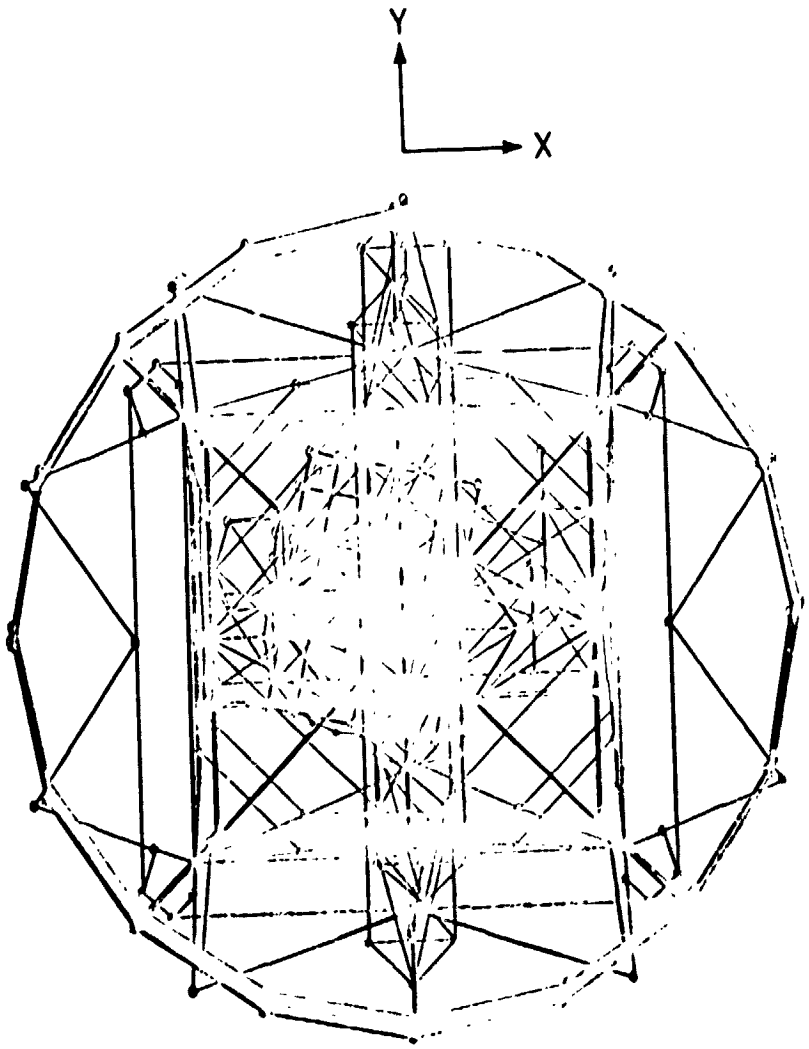

Figure 4.- NASTRAN Plot (X-Y plane, top view) of Modal Deformation Superimposed on the Undeformed Shape (mode 1). (This figure is the best quality reproduction that could be made from the original computer-generated plot obtained by the author.)

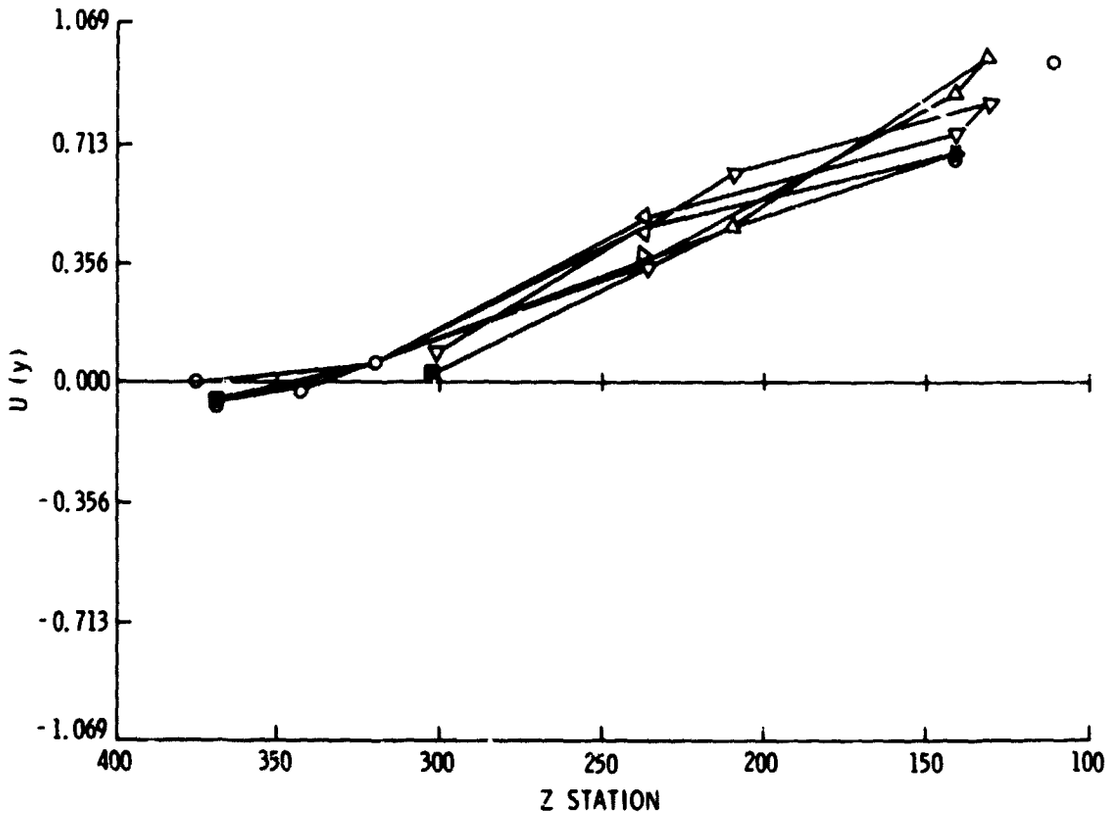

Figure 5.- TRW Stick Plot of Y-Displacement Along X-Axis from Vibration Test (experimentally determined plot).

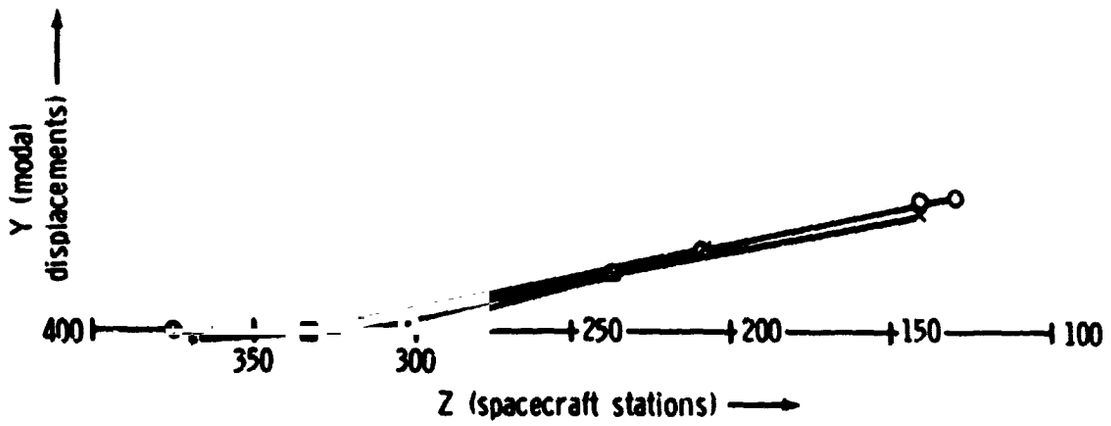

Figure 6.- NASTRAN Stick Plot of Y-Displacement Along the Z-Axis (analytically determined plot).

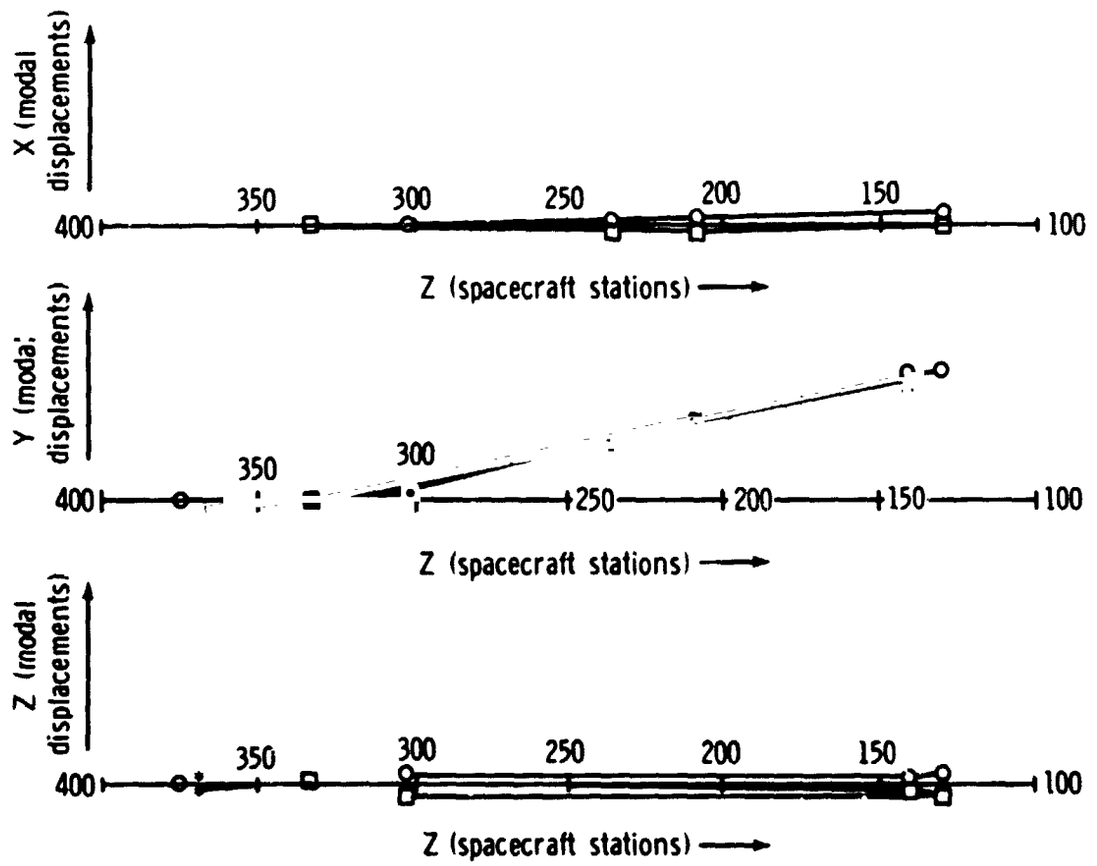

Figure 7.- NASTRAN Stick Plots of ATS Spacecraft Y-Axis Bending Mode.

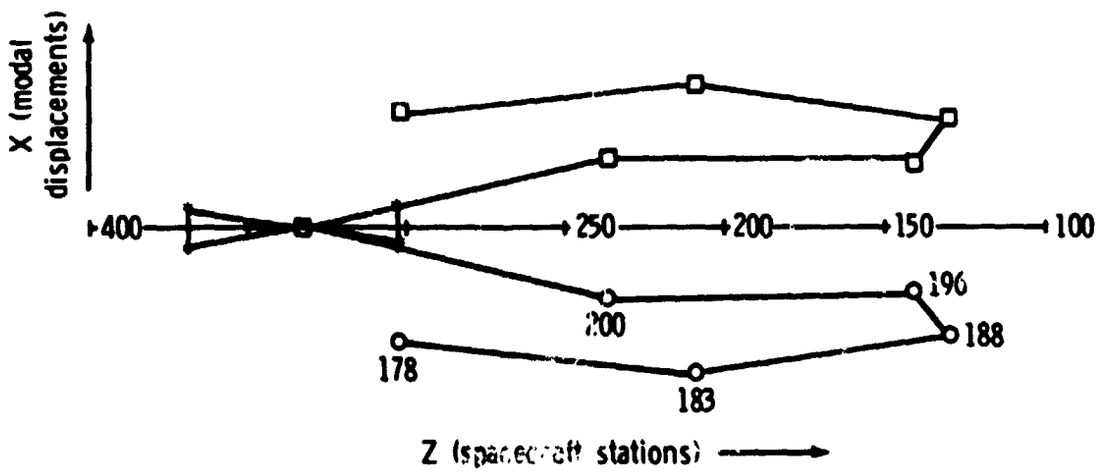

Figure 8.- ATS Spacecraft Torsional Mode Shape in Stick Plot Format.