Using Generalized Forces in Modal Finite Element Analysis to Represent Distributed Loads

by: Charles F. Emki
Lockheed Martin Corporation

Abstract:

Generalized modal forces applied to a finite element model can be a significantly more efficient way to generate a loading condition than forces applied to discrete degrees of freedom. The current version of MDI ADAMS requires all forces applied to a finite element model must be applied to discrete degrees of freedom. MDI gave the authors access to experimental capability that allows the application of generalized modal forces. This capability is under investigation for release in the ADAMS 10.0 solver.

Utilizing the new capability, a launch vehicle payload fairing jettison analysis was performed using a finite element representation of each of the payload fairing halves. For this simulation, a preload due to a thermal gradient was necessary in order to represent the correct initial conditions. The thermal gradient effectively loaded all the discrete degrees of freedom in the very large finite element models, making the problem size prohibitively large if the forces had to be represented discretely. Reducing each of the fairing half finite element models to their physical attachment points (and modal coordinates) and representing the thermal load as a generalized force allowed for an efficient solution of the problem. In addition, residual vectors were employed to improve accuracy while further reducing the problem size.

Problem description:

The problem of including distributed preloads on a structure (see figure 1) for a mechanical system can be daunting since the number of discrete forces can number well into the thousands. This can create a problem size and solution time that requires enormous computer resources to solve. If it is necessary to represent a distributed load discretely, an extremely large executable is required to accommodate the enormous number of modes calculated from including all the discrete degrees of freedom. Putting forces on the grid points without making the points external would significantly reduce the problem size, but not having the grid points external could give significant errors.

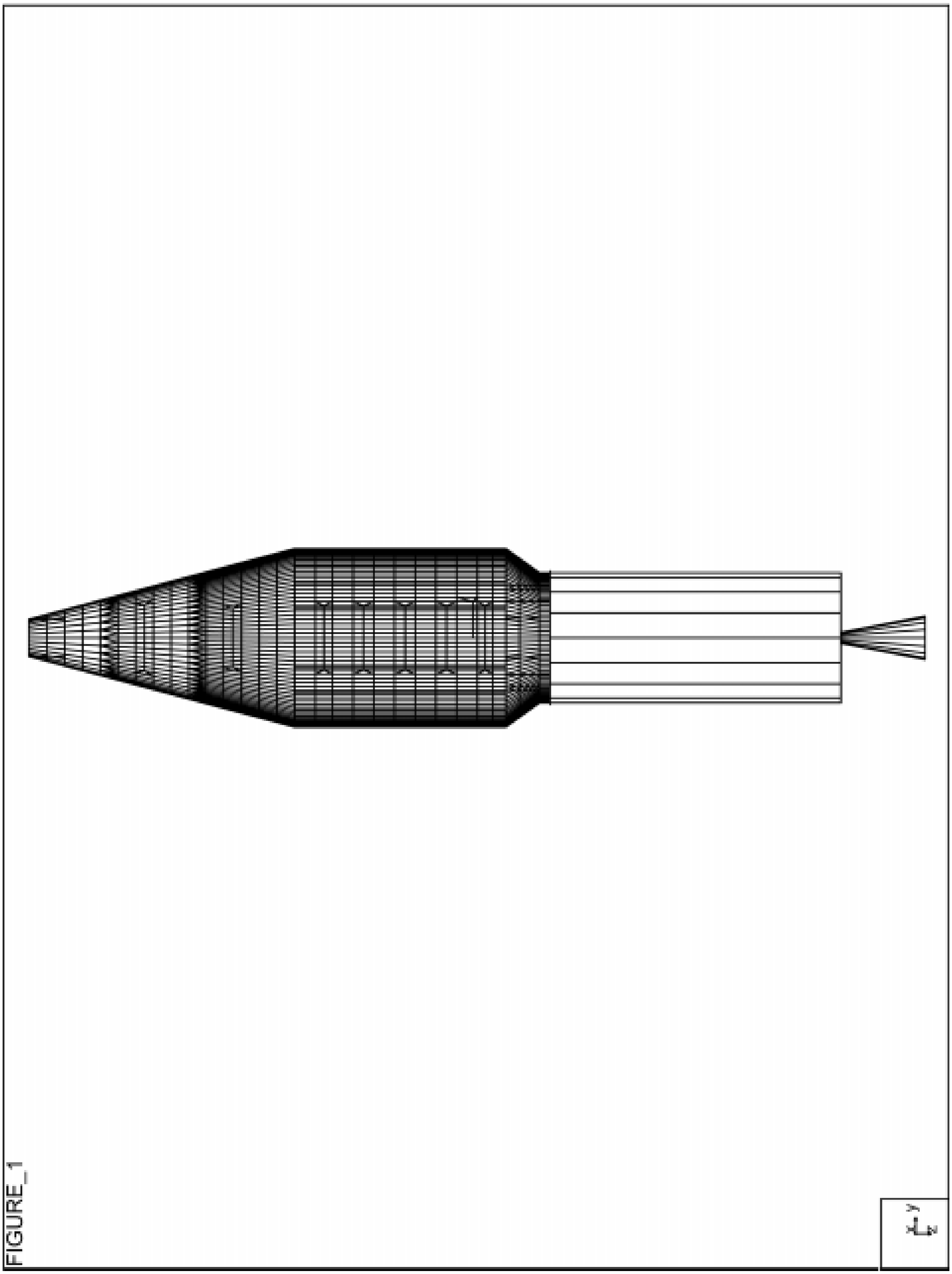
FIGURE_1

Problem Solution:

It is possible to accurately reduce the problem size by representing a distributed preload as a generalized force. MSC/NASTRAN and other finite element solvers have the capability to calculate the discrete forces due to a distributed preload (in our case a load due to a thermal gradient) and output the generalized forces consistent with a Craig-Bampton boundary model.

The boundary model has only the discrete degrees of freedom necessary for the ADAMS simulation, and the rest of the degrees of freedom are generalized.

By using the DMAP customization features of NASTRAN to output the generalized normal forces and modal information one can take this reduced set of information and use it as input to a Mechanical System Simulation program (ADAMS). The ADAMS/FLEX package allow the input of the FEA modal information. Also, MDI provided us with a hook to input the generalized modal forces. It also required us to generate some software to read and process the generalized modal forces and add them into the solution.

We tested the features out on several test problems (see figure 2) and ran dynamic simulations that could be duplicated in NASTRAN to compare results. This was critical in figuring out what exactly had to be output to get correct results. Also, we used the residual flexibility capability of NASTRAN to reduce problem size and improve results.

The residual flexibility did not change results dramatically since the model was truncated at a high enough frequency to be accurate without the addition of residual vectors. The test comparisons to NASTRAN showed that the boundary (external grid points of the superelement) was extremely good. The internal points had more error, but it was deemed acceptable.

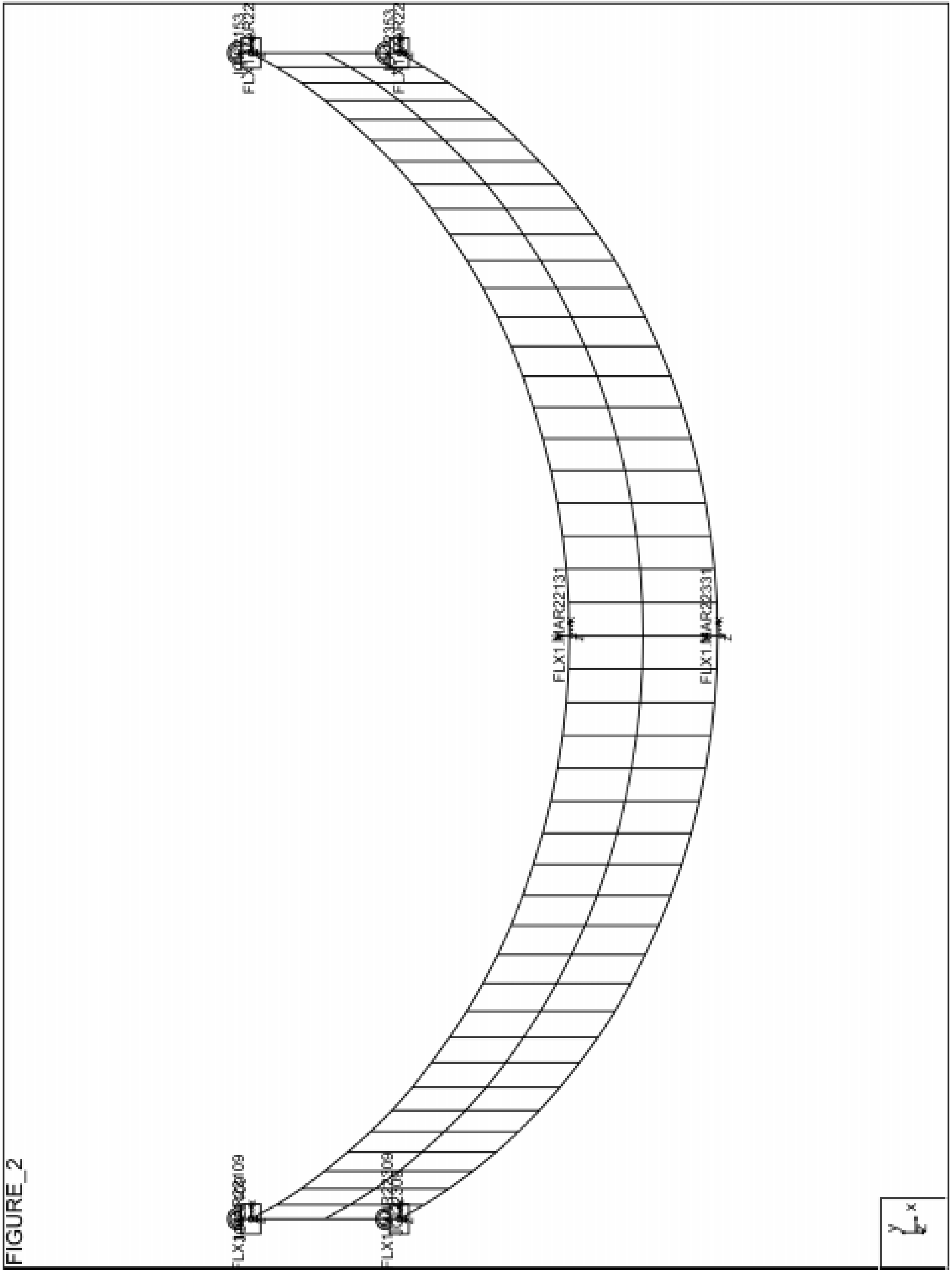
FIGURE_2
FLX1.MAR22131
FLX1.MAR22331

Problem Solution continued:

The choice was made in the beginning to set up ADAMS/VIEW command files (.cmd) to process the input and generate the models. This proved to be an important feature of ADAMS/VIEW that saved enormous amounts of time. It took many hours to set up and process a test problem by hand. But once one was done a command file was created using the ADAMS/VIEW log file as the template. Now it takes less than an hour to create a model that is ready to run. We did a lot of test cases to work out the details for generating the modal and generalized force information from NASTRAN for the ADAMS analyses. Many analyses were generated with only small changes to the ADAMS model or only changes to the NASTRAN modal information. The command files saved much time working out the details.

A rigid body simulation of the payload fairing deployment was developed in parallel to the flexible model. This allowed us to test out the simulation details with a model that ran in minutes rather than hours. An ADAMS/VIEW command file was also developed for this simulation.

Now that all the preliminary testing and analyses were finished, we needed to set up the payload fairing deployment model. Since we had the command files already developed and proven from the test cases, we used them to create the command files for generating the final flexible body payload fairing model. The advantage of this was that it took days to build the model by hand and just over an hour to do it with the command files. Since there was a lot of trial and error getting all the features in the model, the command files were invaluable. (see figure 3)

Another advantage of the AVIEW command files was that other payload fairings simulations could be set up quickly with only minor editing of the command files. This is because the payload fairing models are all derivatives of a basic payload fairing model. Also it allowed another person to quickly build and run simulations correctly. It eliminated manual errors and increased the reliability of the analyses.

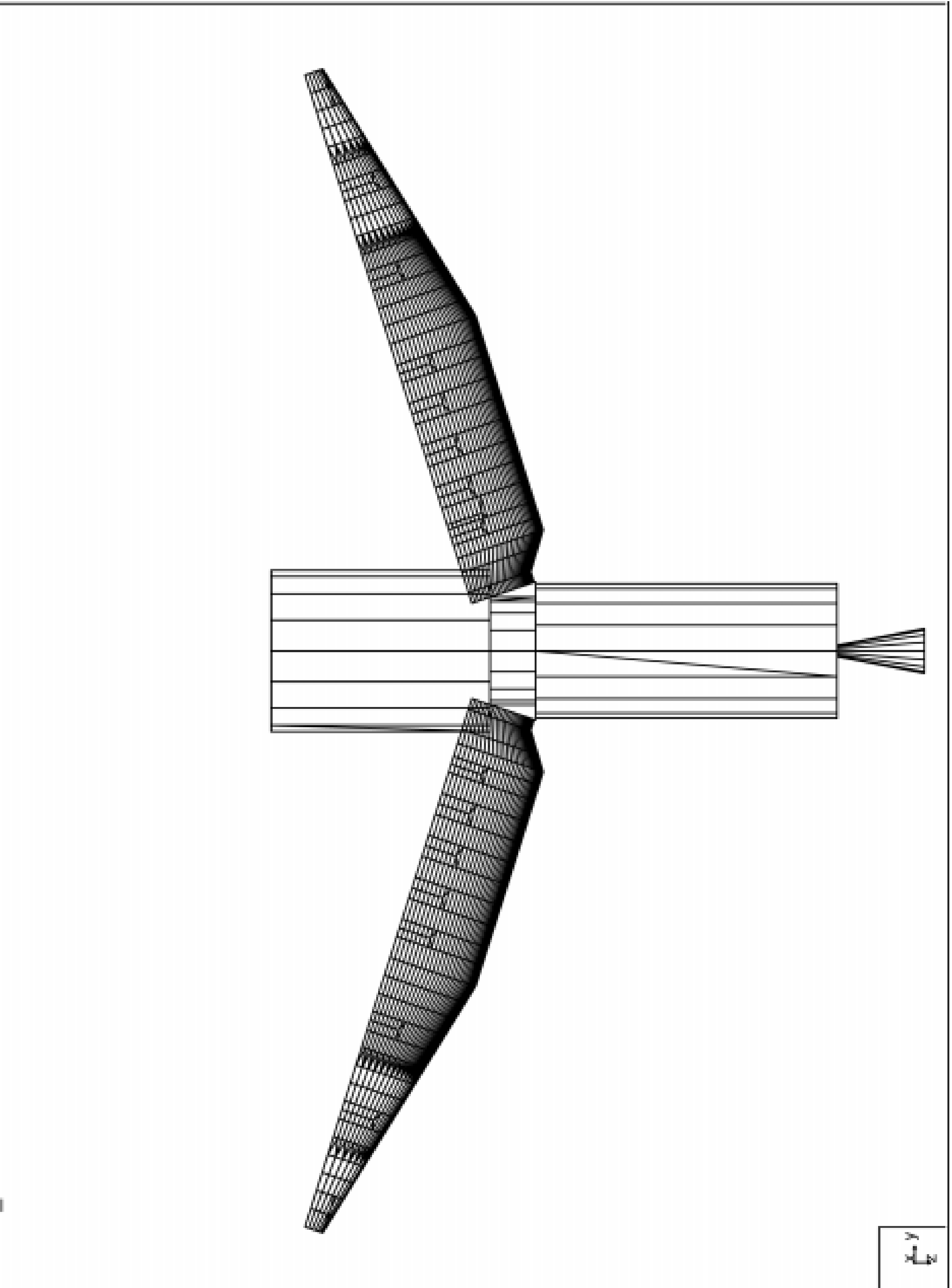

FIGURE_3

Conclusions:

The payload fairing deployment using generalized modal forces is a viable way to reduce problem size and get good results.

Adding residual flexibility from NASTRAN improves results while reducing problem size.

Setting up command files to generate the models saves much time and reduces errors.

Visual inspection of the graphical model in AVIEW is necessary to find and correct errors. Some errors would be extremely difficult to find otherwise.

Animating results is very important for checking results.

Command files for postprocessing results are invaluable for processing results quickly and accurately from a suite of runs.

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