APPENDIX C

GUIDELINES FOR THE PREPARATION AND DELIVERY OF FINITE ELEMENT MODELS (FEMs) TO SPACEHAB

CONTENTS

1. INTRODUCTION

According to NSTS 37329, SPACEHAB is required to provide a verified NASTRAN dynamic Finite Element Model (FEM) each mission to support the Verification Coupled Loads Analysis (VCLA) performed by the Space Shuttle Program (SSP). The SPACEHAB FEM must be representative of the mission configuration and contain all dynamic characteristics through 50 Hz. The SPACEHAB FEM is combined with the Orbiter and companion payloads and then the loads analyses are performed on the coupled system. Results from these analyses are in the form of accelerations, forces and displacements, and are used to verify the structural integrity of the hardware for the particular mission.

Experiment models that are necessary for SPACEHAB FEM integration must be provided prior to L-10 months. Experiment models are required for all rack payloads and for any experiment that exhibits significant modes of vibration below 50 Hz.

2. MODEL VERIFICATION

The forcing functions used in the loads analyses contain dynamic input through 35 Hz. According to NSTS 14046, any component that possesses significant modes of vibration below 50 Hz must be verified by a test. The SPACEHAB module FEM has been verified by a modal survey test through 50 Hz. In order that the integrated SPACEHAB FEM remains valid for the loads analyses, experiments that possess significant modes below 50 Hz must be verified by a test.

To determine the natural frequencies, the experiment structure must be constrained (i.e., displacement = 0) at the SPACEHAB interfaces. The significant modes of vibration are generally identified by modal participation. If it is determined that the experiment exhibits significant modes of vibration below 50 Hz, a test will be required. As a minimum, a sine sweep vibration test of the experiment can be used to determine the natural frequencies; however, a modal survey test may be required to determine both natural frequency and mode shape characteristics. Coordination with a Boeing-Huntsville/SPACEHAB analyst will ensure acceptable methodology has been used to determine the natural frequency and that a proper model verification approach is implemented.

3. MODEL PREPARATION

In order to promote a mutual understanding of the experiment model and hardware design, the model development should be discussed with the Boeing-Huntsville/SPACEHAB analysts. This is especially important if the design is complex or if it incorporates unique components, such as isolators.

The experiment model must be developed in MSC/NASTRAN format corresponding to version 70.5, or later, using the English system of units and employing only linear elastic techniques. The fidelity of the model is governed by the complexity of the structure. All of the major load paths should be adequately represented and the distribution of mass should be similar to the actual experiment hardware. Special attention should be given to the accuracy of the structural connections and the modeling of the interface with SPACEHAB hardware.

If test verification is necessary, then a description of the test, including a demonstration of successful data acquisition, test results and model correlation must be provided in a report. Model correlation is established by demonstrating the similarity between the measured natural frequencies and mode shapes and those predicted by the model. Mode shape correlation can be analytically confirmed using Modal Assurance Criteria (MAC) and cross-orthogonality. Correlation criteria are established in NSTS 14046.

The experiment model must not contain more than 1000 degrees-of-freedom (DOF). If a reduction technique is employed, then the reduced model must accurately describe all of the significant modes of the unreduced model. As a minimum, the model must contain all SPACEHAB interfaces and should contain the DOF that contain significant mass.

4. MODEL DELIVERY

Although there is considerable flexibility in the format and detail of the model and accompanying data, several conditions should be met when delivering the model to Boeing-Huntsville analysts. Following these guidelines will help ensure efficient and accurate model transfer and subsequent SPACEHAB FEM integration. The following items are provided as a model delivery guide:

- The model must be in the consistent English system of units, where: length is in inches (in), time is in seconds (sec), force is in pounds (lbf), and mass is in units of lbf-sec^2/in, where: g = 386.1 $^{in}/_{sec^2}$.
- The model must be compatible with MSC/NASTRAN and the delivered files should include the bulk data listing (i.e., file beginning with the "BEGIN BULK" card and ending with the "ENDDATA" card), as well as the case control and executive control decks necessary to perform the modal solution and matrix checks.
- Documentation should accompany the model, providing the following information:
  - Concise hardware and model description, including drawings or schematics, modeling assumptions, boundary conditions and interface descriptions.
  - Materials used and the property characteristics.
  - Model coordinate system definitions and identifications, with the Basic Coordinate System parallel to the Orbiter coordinate system and preferably originating from a SPACEHAB interface node.
  - Model mass and CG summary, including a NASTRAN grid point weight generator table and a comparison to the actual hardware.
  - Undeformed plots (orthographic and perspective views) of the model showing nodal topology with SPACEHAB interfaces and other significant nodes identified and labeled, including MSC/NASTRAN GRID identifications and coordinates
  - Eigenvalue output from constrained and unconstrained (i.e., "free-free") boundary conditions that must be reproducible given the delivered case control, executive control and bulk data listings. The unconstrained model solution must be performed

to validate the composition of the stiffness matrix and the six rigid body frequencies should not exceed 0.005 Hz.

- Mode shape descriptions with deformed plots, if necessary.
- Model reduction technique and reduction validation, if necessary.

- The model files, in ASCII format, can be delivered to Boeing-Huntsville using one of the following methods, the specific details of the transfer can be arranged at the time of delivery:
  - 3 ½"-diskette or CD-ROM in MS/DOS or Unix compatible format.
  - Electronic transfer using ftp or E-mail.

Data access information must be included to identify the file formats, filenames, dates, and description of file contents. This information can be included in a text file and delivered electronically.

5. SUMMARY

Experiment models necessary for the mission VCLA must be delivered by Launch-10 months. A model is required for all rack payloads and for any experiment that does not meet the intent of the minimum natural frequency requirement. The model can be transferred to Boeing-Huntsville/SPACEHAB electronically, or provided on disk storage media in MS/DOS or Unix compatible format. Included with the model delivery should be a concise model description. The model description should provide all of the necessary information for Boeing-Huntsville/ SPACEHAB to execute the MSC/NASTRAN files, verify that the model is complete and then integrate it with the SPACEHAB FEM. In addition, a test report documenting successful model correlation should be included if test verification is necessary.

THIS PAGE INTENTIONALLY LEFT BLANK