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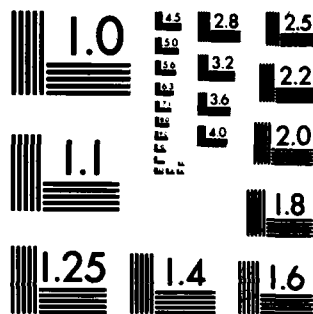
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**RADC-TR-83-56**  
**Final Technical Report**  
**March 1983**



# **MODIFICATIONS TO ACOSS MODEL #2 DESIGN**

**The Charles Stark Draper Laboratory, Inc.**

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**Defense Advanced Research Projects Agency (DOD)**  
**ARPA Order No. 3655**

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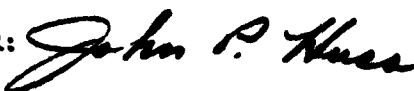
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# MODIFICATIONS TO ACROSS MODEL #2 DESIGN

Timothy Henderson

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| 20. ABSTRACT (Continue on reverse side if necessary and identify by block number)<br>An updated version of the Active Control of Space Structure (ACOSS) Evaluation Model, ACOSS Model #2, has been designed and analyzed. This updated model reflects the need for closer correlation between model performance and actual system performance at the cost of increased model complexity. Using this updated model, two additional models have been created to fulfill the needs of the VOCSS program. The first VOCSS model is a minimum mass, flexible design. A vibration control system including hardware |                                     |                                                                                      |

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specifications will be designed for this model. This design will be compared with that based on the second VCOSS model. This model is a maximum mass, stiffness controlled design. The purpose of this design is to reduce control system requirements by stiffening the structure in order to raise critical modal frequencies. The MSC/NASTRAM finite element models for all three designs are listed in the Appendices.

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## TABLE OF CONTENTS

| <u>Section</u>                             | <u>Page</u> |
|--------------------------------------------|-------------|
| 1 INTRODUCTION.....                        | 1           |
| 2 UPDATED STRUCTURAL DESIGN.....           | 4           |
| 2.1 Introduction.....                      | 4           |
| 2.2 Mirror Design Modifications.....       | 4           |
| 2.2.1 Primary Mirror.....                  | 8           |
| 2.2.2 Secondary Mirror.....                | 9           |
| 2.2.3 Tertiary Mirror.....                 | 9           |
| 2.2.4 Focal Plane.....                     | 9           |
| 2.3 Equipment Section Modifications.....   | 12          |
| 2.4 Line-of-Sight-Error Model Changes..... | 12          |
| 2.5 Analysis.....                          | 15          |
| 3 STRENGTH CONTROLLED DESIGN.....          | 17          |
| 3.1 Introduction.....                      | 17          |
| 3.2 Analysis.....                          | 18          |
| 4 STIFFNESS CONTROLLED DESIGN.....         | 21          |
| 4.1 Introduction.....                      | 21          |
| 4.2 Analysis.....                          | 23          |
| 5 SUMMARY.....                             | 26          |
| APPENDIX A.....                            | 27          |
| APPENDIX B.....                            | 35          |
| APPENDIX C.....                            | 48          |

## SECTION 1

### INTRODUCTION

In recent years the development of the technology for active control of structural vibrations of Large Space Structures (LSS) has been addressed in the Active Control of Space Structures (ACOSS) program. Early in the program a need for a common design model to allow evaluation and comparison of the various approaches was identified. The first design model, ACOSS Model 1, was developed in 1979. This structure, a simple ground attached tetrahedron, provided a means of evaluating control designs but lacked any real physical relationship with typical LSS. Because of the desire for an evaluation model which had dimensions, materials, optical system, and performance more closely related to actual structures, ACOSS Model #2 was developed in May 1980. In order to meet the design goal of a low-order structural model, many simplifying assumptions were made in the modelling of the optical system mirrors and the supporting structure. This was consistent with the desire to use the model to evaluate control design methods without concern for detailed mechanical design of the components. This model has provided a simple means of comparing and evaluating the control designs of the various ACOSS contractors. A complete description of the model along with a set of disturbances is contained in Reference 1.

The Vibration Control of Space Structures (VCOSS) program is intended to study the application of ACOSS technology to an actual spacecraft design. This includes specification of sensor and actuator hardware and assessment of the performance of the system including these components. The system model will be based on ACOSS Model #2, but with modifications to reduce the structural mass to the minimum required to maintain structural stability. This system will rely entirely upon the control system for vibration suppression to meet the performance requirements. This will be compared with another model which is also a modification of ACOSS Model #2. This second design will be a strengthened version of Model #2. The goal of this design is to meet the performance specifications by passive means: structural stiffening and passive damping. The structure will be stiffened by increasing the sizes of the existing members in Model #2 until the total system mass is equal to the maximum cargo capacity of the shuttle into polar orbit, 15000 kg. No additional structural members will be added so that the only difference between the two designs will be the size of the members.

The first step in modifying ACOSS Model #2 to generate the two models required for the VCOSS program was to reassess the basic assumptions which were used in the design. This is necessary because in order to establish the hardware requirements of a vibration control system the system model must accurately reflect the mechanical properties of an actual system. In this structure the important properties are the interaction of the rigid mirrors with the flexible support and the interface

between the equipment section and the optical support truss. In the original design of ACOSS Model #2, the goal of minimizing the total number of degrees-of-freedom in the system resulted in a simple method of including the mirror mass effects. This approach did not include details of the kinematic connection of the mirrors to the structure or of the motion of the mirror centroids. The modelling of the equipment section did not provide adequate space for the isolation system which will separate the two bodies.

Section 2 describes an updated version of ACOSS Model #2. This update reflects the need for a more detailed model which more closely reflects the behavior of an actual spacecraft and can be used as a basis for the hardware implementation studies required in the VCOSS program. In this updated design the original geometry and stiffness are retained as much as possible. Changes were made to the structural model to include the rigid body inertia properties of each mirror and a detailed kinematic mount connecting it to the support structure. In addition, the model of the equipment section was changed to include a more representative mass distribution and to provide clearance for the isolation system hardware.

Using this updated design as a baseline, the two VCOSS models were generated. Section 3 describes the minimum mass, strength-controlled design. In this model, the size of each structural member has been reduced to the minimum allowed by constraints on local buckling, member natural frequency and minimum wall thickness for the tube sections. The updated finite element model and natural frequency tables are listed.

The stiffness-controlled design is described in Section 4. Each structural member has been increased in order to uniformly increase the stiffness of the structure. A limit of 15000 kg has been placed on the total mass of the system to allow for placement into a polar orbit by the shuttle. The updated finite element model and natural frequency tables are given.

In order to avoid confusion between the original ACOSS Model #2 and the three new versions of it which are described in this report, a system of revision numbers has been established. This will provide a means of easily identifying the existing versions as well as all those which may be generated in the future.

Revision 0: The original ACOSS Model #2, first presented in May 1980.

Revision 1: Updated version of the original design which includes more detailed mirror and equipment section modes. This design is described in Section 2.

Revision 3: The strength controlled, minimum mass design based on Revision 1. This is the VCOSS actively controlled design. Details of the model are presented in Section 3.

Revision 4: The stiffness controlled maximum mass design based on Revision 1. This design is presented in Section 4.

Reference 1

RADC-TR-80-377, Interim Report, Jan 1981, "ACOSS Six (Active Control of Space Structures)

## SECTION 2

### UPDATED STRUCTURAL DESIGN

#### 2.1 Introduction

The baseline design for the two VCOSS models is the original ACOSS Model #2 shown in Figure 2.1. This model was generated in May 1980 to provide a simple, unclassified tool to evaluate the active control philosophies proposed by a variety of sources. As the needs of the users of the model have changed, the model has been changed to provide the required fidelity. An updated ACOSS Model #2 is presented in this section. Stiffness controlled and strength controlled versions of this updated model will be described in following chapters. The design changes which were incorporated into this update reflect the need to provide better correlation between this simplified model and typical large space structures.

The changes which were made to Model #2 are confined to two areas, the details of the mirror support structures and the equipment section. The metering truss, which separates the upper and lower mirrors, the solar panels, and the isolation springs are unchanged from the original design. The modifications to the structural design and the finite element model are described in the following sections. The NASTRAN input data for this model is listed in Appendix A. The finite element model for Revision 1 is shown in Figure 2.2.

In order to facilitate these modifications and the structural modifications in the VCOSS designs, the structural and non-structural mass have been uncoupled. In Revision 0, the structural mass was added to the non-structural mass and lumped at the mirror support points. In the new model, the non-structural mass is lumped at the mirror centroids and support points and the structural mass is lumped at all node points. The structural mass will be computed automatically by NASTRAN using the length and area of each member and the material density of  $1720 \text{ kg/m}^3$ . The structural and non-structural mass at each node point and the system mass properties for Revision 1 are listed in Table 2.1.

#### 2.2 Mirror Design Modifications

Modifications were made to the models of the mirrors in the system in order to reflect, in detail, the interaction between the rigid mirrors and the flexible optical support truss. In the original design, (Revision 0), in which the number of lumped masses was kept to a minimum, it was assumed that the masses of each mirror and its supporting structure were evenly distributed to its support points without regard to the detail of the connection.

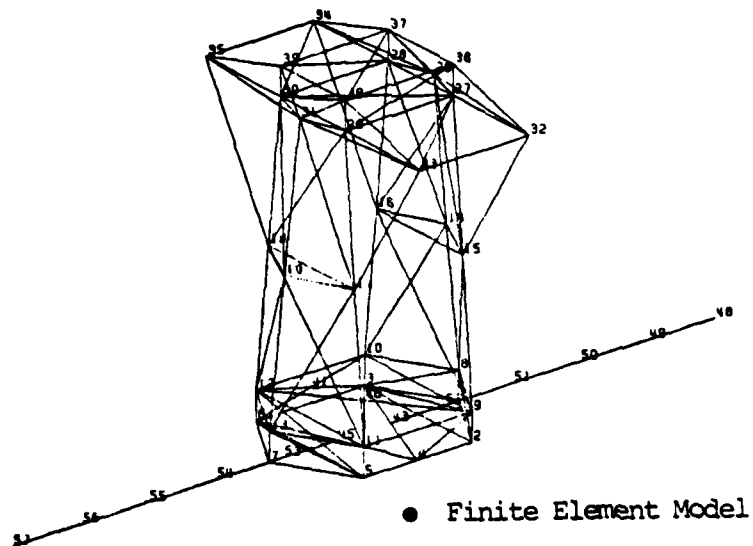
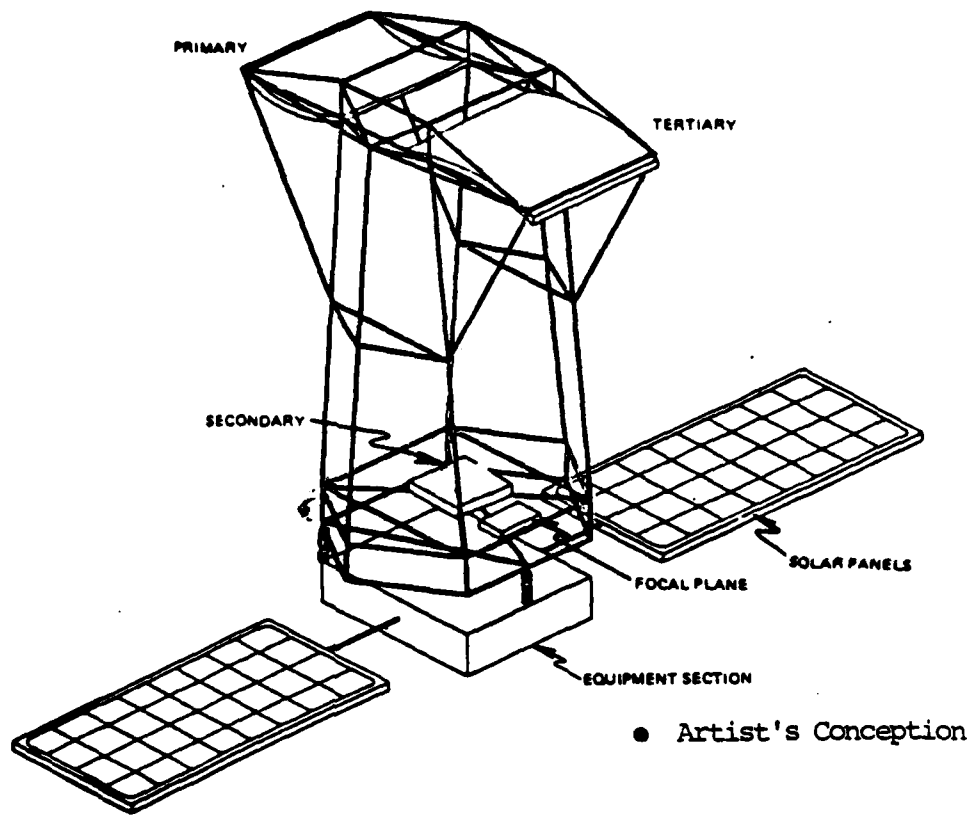


Figure 2.1. ACOSS Model #2 (Revision 0)

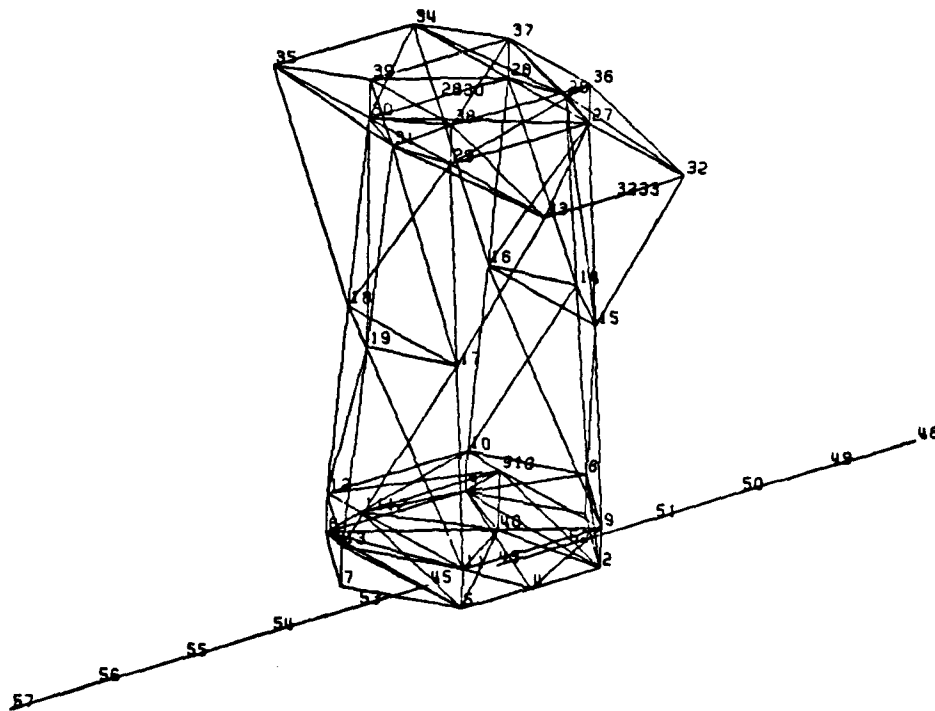


Figure 2.2: ACOSS Model #2 (Revision 1)

Table 2.1. Lumped mass distribution

| node   | structural | non-struct. | node | structural | non-struct. |
|--------|------------|-------------|------|------------|-------------|
|        | mass (kg)  | mass (kg)   |      | mass (kg)  | mass (kg)   |
| 1      | 7.34       |             | 36   | 9.99       |             |
| 2      | 21.97      |             | 37   | 12.17      |             |
| 3      | 34.03      |             | 38   | 12.17      |             |
| 4      | 20.86      |             | 39   | 9.99       |             |
| 5      | 21.97      |             | 40   | 26.85      |             |
| 6      | 33.83      |             | 42   | 0.0        |             |
| 7      | 7.34       |             | 43   | 3.24       |             |
| 8      | 21.13      |             | 44   | 0.0        | 3500.       |
| 9      | 25.40      | 67.4        | 45   | 3.24       |             |
| 10     | 21.50      | 67.4        | 46   | 0.0        |             |
| 11     | 25.40      | 67.4        | 47   | 0.0        |             |
| 12     | 21.57      | 67.4        | 48   | 4.05       | 81.91       |
| 13     | 21.13      |             | 49   | 8.09       |             |
| 14     | 16.59      |             | 50   | 8.09       | 163.82      |
| 15     | 21.48      |             | 51   | 8.09       |             |
| 16     | 22.71      |             | 52   | 7.28       | 73.82       |
| 17     | 21.48      |             | 53   | 7.28       | 73.82       |
| 18     | 22.71      |             | 54   | 8.09       |             |
| 19     | 16.59      |             | 55   | 8.09       | 163.82      |
| 26     | 17.53      |             | 56   | 8.09       |             |
| 27     | 23.00      | 69.50       | 57   | 4.05       | 81.91       |
| 28     | 45.94      | 6.74        | 910  | 23.51      |             |
| 29     | 17.25      | 69.50       | 1001 |            | 1000.0      |
| 30     | 51.70      | 6.74        | 1002 |            | 800.0       |
| 31     | 17.53      |             | 1003 |            | 1200.0      |
| 32     | 43.51      | 6.74        | 1004 |            | 600.0       |
| 33     | 47.09      | 6.74        | 1112 | 23.64      |             |
| 34     | 18.41      | 69.50       | 2330 | 62.76      |             |
| 35     | 14.83      | 69.50       | 3233 | 62.76      |             |
| Totals |            |             |      | 1023.34    | 9313.66     |

Total mass = 9337 kg

Center of Mass Location

x = 0.0 m

y = -0.237 m

z = 6.933 m

The new mirror models assume that each surface is a planar rigid body which is connected to the support structure by kinematic mounts. This type of mount can only transmit rigid body motion between the support structure and the mirror. Elastic motion of the support points relative to each other will not cause any deformation of the mirror surface. The finite element model has been changed so that the translational and rotational inertia properties of each mirror are lumped at a node point at its center of mass. This node is connected to the three support points of the surface by rigid elements which are attached at the six degrees of freedom required for the kinematic mount. The details of a kinematic mount are shown in Figure 2.3. In the drawing, point A is supported in the x, y, and z directions, point B is supported in the y and z directions, and point C is supported in the z direction.

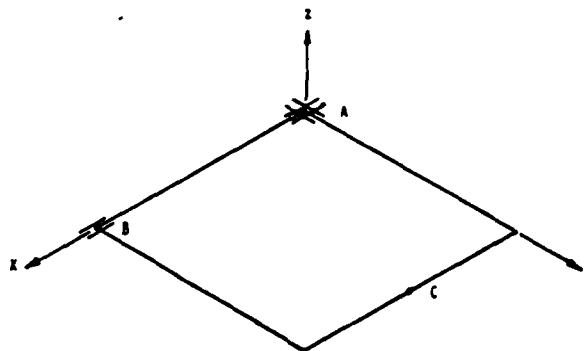


Figure 2.3: Typical kinematic mount

The new model of each mirror will be described in the following sections. A summary of these models is given in Table 2.2.

### 2.2.1 Primary Mirror

The primary mirror is one of the two large mirrors at the top level of the optical support truss. In the original design (Revision 0) masses were lumped at nodes 34, 35, 28, and 30 to represent the structural and non-structural mass associated with this surface. The motion of the mirror was defined by a kinematic mount with point A at 34, point B at node 35, and point C located midway between nodes 28 and 30. The displacement at point C was interpolated from the two nodal values. This kinematic mount was not included in the finite element model but was used only in the line-of-sight error model.

In the new design, two new node points are added to the finite element model. One, node 1001, is located at the center of mass. The second, node 2830, lies midway between nodes 28 and 30 to provide the third

support point for the kinematic mount. The beam element connecting nodes 28 and 30 and containing node 2830 has been strengthened to support the mass of the mirror. The stiffened beam is a tubular truss as shown in Figure 2.4. It is designed to prevent significant line-of-sight errors due to bending at frequencies below 40 Hz. The center of mass is connected to the support points by rigid elements which are constrained in the six degrees of freedom required for the kinematic mount. The new model of the primary mirror is shown in Figure 2.5.

#### 2.2.2 Secondary Mirror

The motion of the secondary mirror was defined in Revision 0 by the six degrees of freedom (three translations and three rotations) at node 40. The mass was lumped at the edge nodes of the lower support truss so that the motion of the mirror plane was equal to the motion of node 40. In the new model, the mass of the secondary will be lumped at its center of mass, node 1002, which will be attached to the supporting structure by a kinematic mount as shown in Figure 2.6. The structural design was altered to include the additional support points for the secondary. The finite element model was changed by adding the two support point nodes, node 910 and node 1112, moving node 40, and including the members required to brace the supports. Point A of the mount will be node 910, point B will be node 1112, and point C will be node 40. Rigid bars provide the connection between the mount degrees of freedom and the center of mass.

#### 2.2.3 Tertiary Mirror

The changes in the model of the tertiary mirror are similar to those made in the model of the primary. The center of mass is located at node 1003. It is kinematically mounted on the support truss by connections to node 27 (point A), node 29 (point B), and node 3233 (point C). Node 3233 is located midway between nodes 32 and 33 on the stiffened beam connecting them. The new configuration of the tertiary mirror model is shown in Figure 2.5.

#### 2.2.4 Focal Plane

The only change made to the model of the focal plane consists of the addition of the kinematic mount. The mass properties of the focal plane are lumped at its center of mass, node 1004. Rigid bars connect it to the three support points, node 11 (point A), node 9 (point B), and node 40 (point C). The new configuration is shown in Figure 2.6.

Table 2.2. Modified Mirror Models

Primary:

Mass = 1000 kg  
 $I_{xx} = 4083.33 \text{ kg-m}^2$   
 $I_{yy} = 5333.33 \text{ kg-m}^2$   
 $I_{zz} = 9416.67 \text{ kg-m}^2$

Center of Mass: node 1001

Support Points:

Node 34 dof 1,2,3

Node 35 dof 2,3

Node 2830 dof 3

Secondary:

Mass = 800 kg  
 $I_{xx} = 1666.67 \text{ kg-m}^2$   
 $I_{yy} = 4266.67 \text{ kg-m}^2$   
 $I_{zz} = 5933.33 \text{ kg-m}^2$

Center of Mass: node 1002

Support Points:

Node 910 dof 1,2,3

Node 1112 dof 2,3

Node 40 dof 3

Tertiary:

Mass = 1200 kg  
 $I_{xx} = 4900.00 \text{ kg-m}^2$   
 $I_{yy} = 6400.00 \text{ kg-m}^2$   
 $I_{zz} = 11300.0 \text{ kg-m}^2$

Center of Mass: node 1003

Support Points:

Node 27 dof 1,2,3

Node 29 dof 2,3

Node 3233 dof 3

Focal Plane:

Mass = 600 kg  
 $I_{xx} = 200.00 \text{ kg-m}^2$   
 $I_{yy} = 800.00 \text{ kg-m}^2$   
 $I_{zz} = 1000.00 \text{ kg-m}^2$

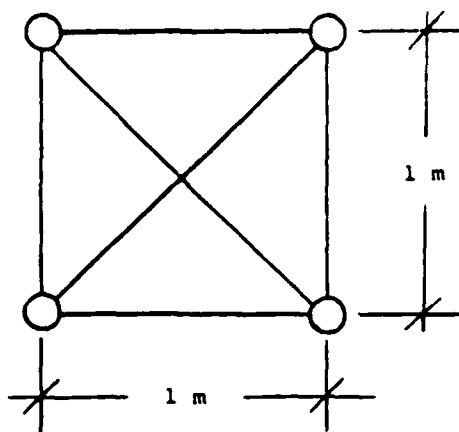
Center of Mass: node 1004

Support Points:

Node 11 dof 1,2,3

Node 9 dof 2,3

Node 40 dof 3



Tube Properties:

Radius = 0.11 m

t = 0.0022 m

Area = 0.00152 m<sup>2</sup>

Section Properties:

Area = 4 A<sub>tube</sub> = 0.00608 m<sup>2</sup>

I = 0.00152 m<sup>4</sup>

J = 0.00304 m<sup>4</sup>

Mass/L = 15.69 kg/m

Figure 2.4. Stiffened mirror support beam

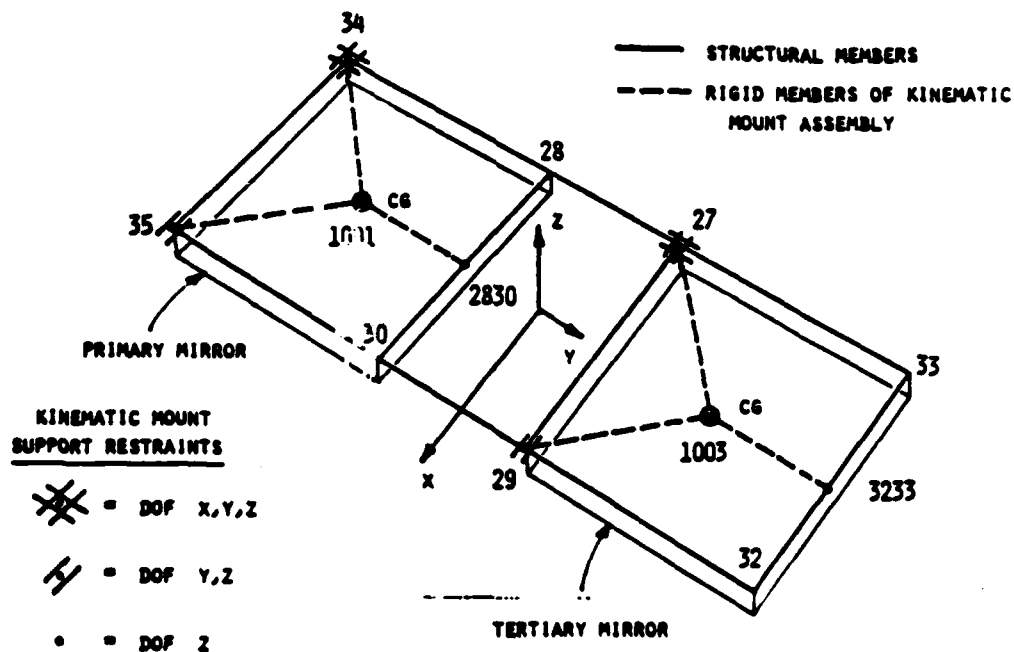


Figure 2.5. Modified primary and tertiary mirror models

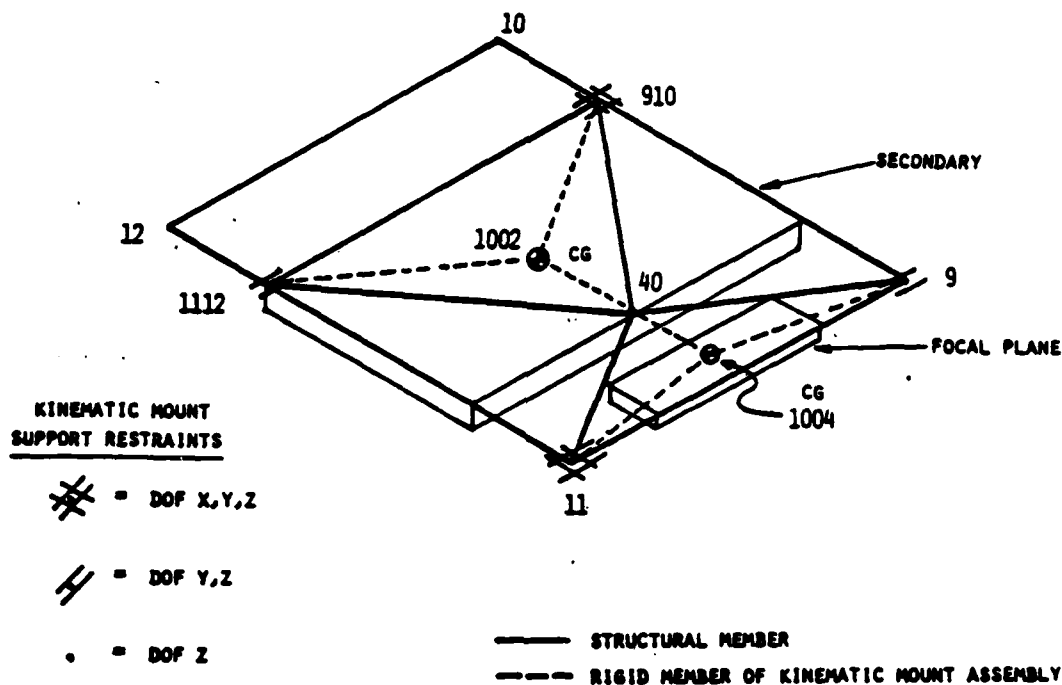


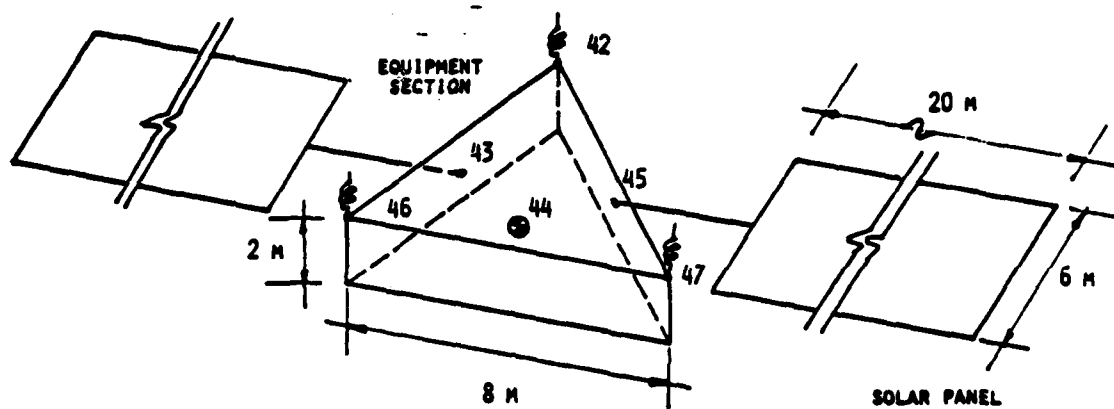
Figure 2.6. Modified secondary and focal plane mirror models

### 2.3 EQUIPMENT SECTION MODIFICATIONS

Changes were also made to the model of the equipment section. In the original design the equipment section was modelled as a rigid plate and located at the same point on the z-axis as the lower chord of the optical support truss. The two sections were connected by springs as part of the isolation system. While this configuration is mathematically correct, in an actual system the springs will have a finite length. The equipment section will now be modelled as a uniform rigid body, triangular in shape and two meters in depth. The equipment section and the optical support truss will be separated by thirty centimeters to allow room for the isolation system. The new mass properties and location of the equipment section are given in Figure 2.7.

### 2.4 LINE-OF-SIGHT-ERROR MODEL CHANGES

Due to changes in the models of the mirrors and their support points, a few minor changes are necessary in the implementation of the line-of-sight error model for Revision 1 and all later versions. This



- EQUIPMENT SECTION MODELLED AS RIGID BODY

Mass = 3500 kg

Center of Mass (node 44)

$I_{xx} = 20611.11 \text{ kg-m}^2$

$x = 0.0 \text{ m}$

$I_{yy} = 10500.00 \text{ kg-m}^2$

$y = -1.67 \text{ m}$

$I_{zz} = 28777.77 \text{ kg-m}^2$

$z = -1.30 \text{ m}$

Figure 2.7. Equipment section properties

error model relates the rotation about the x and y axes and the defocus of the line-of-sight to the displacements of the mirror support point nodes in the finite element model. Full details about the theory and implementation of the error model are given in CSDL Report C-5437. The changes in the updated version are due to the addition of the nodes 2830 and 3233 in the kinematic mount models for the primary and tertiary mirrors and the addition of the kinematic mount for the support of the secondary. The updated equations relating LOS errors to node point displacements are:

$$\begin{aligned} \text{LOSX} = & - (.0186)Y_{34} - (.1429)Z_{34} - (.0186)Y_{35} - (.1429)Z_{35} \\ & + (.2857)Z_{2830} + (.0807)Y_{27} - (.3549)Z_{27} + (.0807)Y_{29} \\ & - (.3549)Z_{29} + (.7098)Z_{3233} - (3.4842)\theta_{1002} - (.0621)Y_{11} \\ & - (.0621)Y_9 \end{aligned}$$

$$\begin{aligned} \text{LOSY} = & - (.0371)X_{34} - (.0464)Y_{34} - (.2500)Z_{34} + (.0464)Y_{34} \\ & + (.2500)Z_{35} + (.1613)X_{27} - (.0605)Y_{27} - (.6211)Z_{27} \\ & + (.0605)Y_{29} + (.6211)Z_{29} + (3.4842)\theta_{1002} - (.1242)X_{11} \\ & - (.0776)Y_{11} + (.0776)Y_9 \end{aligned}$$

$$\begin{aligned} \text{DEFOCUS} = & - (.0191)Z_{34} - (.0191)Z_{35} + (.1274)Z_{2830} \\ & + (.7780)Z_{27} + (.7780)Z_{29} - (.4668)Z_{3233} - (2.000)Z_{40} \\ & - (.1785)Z_{1002} + (.5000)Z_9 + (.5000)Z_{11} \end{aligned}$$

Since this model is a linear function of the nodal displacements it is included as a set of constraint equations in the NASTRAN finite element model. The three line-of-sight components are assigned to an added node which is not part of the structural model. In all revisions of ACOSS Model #2 the line-of-sight errors are included at node 100 so that:

node 100 dof 1 = losx  
node 100 dof 2 = losy  
node 100 dof 3 = defocus

## 2.5 ANALYSIS

A normal modes analysis of the finite element model containing all of the changes, Revision 1, was performed using the MSC/NASTRAN finite element program. The resulting frequencies are shown in Table 2.3. Also listed in the table are the components of the line-of-sight errors for each mode, node 100. These are based on modes which have been normalized to a unit generalized mass.

Table 2.3. ACOSS Model #2: Revision 1

| NODE | FREQ(HZ) | LOSX       | LOSZ       | DEFOCUS    | NODE | FREQ(HZ) | LOSX       | LOSZ       | DEFOCUS    |
|------|----------|------------|------------|------------|------|----------|------------|------------|------------|
| 1    | 0.0      | -.8878E-14 | -.1153E-09 | -.6815E-16 | 79   | 72.250   | -.7813E-02 | 0.2153E-04 | -.1135E-01 |
| 2    | 0.0      | -.1002E-08 | -.1652E-13 | -.1854E-15 | 80   | 73.513   | 0.5732E-13 | -.5121E-14 | -.6889E-13 |
| 3    | 0.0      | -.1595E-07 | -.9235E-08 | -.1712E-08 | 81   | 73.830   | 0.3987E-07 | 0.3572E-07 | 0.9469E-07 |
| 4    | 0.0      | 0.9144E-03 | -.7006E-08 | 0.1010E-08 | 82   | 74.293   | 0.4285E-03 | 0.8287E-03 | 0.5426E-02 |
| 5    | 0.0      | 0.1445E-06 | -.8877E-03 | 0.4225E-11 | 83   | 77.776   | 0.1032E-02 | 0.4277E-02 | -.5006E-02 |
| 6    | 0.0      | 0.1259E-07 | -.6244E-04 | 0.2997E-12 | 84   | 79.399   | -.2269E-02 | -.1715E-02 | -.8344E-02 |
| 7    | 0.148    | 0.2944E-07 | -.3898E-03 | 0.4941E-06 | 85   | 84.253   | 0.4545E-02 | 0.1570E-02 | 0.4250E-02 |
| 8    | 0.282    | 0.1019E-05 | 0.1405E-03 | 0.2903E-04 | 86   | 87.805   | -.6527E-03 | 0.1018E-02 | -.1919E-02 |
| 9    | 0.319    | -.2994E-04 | -.2654E-06 | 0.3597E-05 | 87   | 97.949   | 0.2215E-02 | -.1655E-02 | 0.7885E-02 |
| 10   | 0.335    | -.2318E-03 | 0.6659E-09 | -.1997E-05 | 88   | 99.172   | 0.3870E-02 | -.8096E-03 | 0.1305E-02 |
| 11   | 0.468    | -.3502E-05 | -.7817E-06 | 0.1190E-04 | 89   | 104.967  | -.7456E-02 | 0.2126E-02 | -.7777E-03 |
| 12   | 0.503    | 0.8321E-03 | 0.6739E-06 | 0.2198E-04 | 90   | 106.887  | 0.7992E-02 | 0.1626E-02 | 0.1391E-01 |
| 13   | 0.601    | 0.2635E-05 | -.7260E-03 | 0.4251E-05 | 91   | 107.630  | 0.1531E-02 | -.1353E-02 | -.1734E-02 |
| 14   | 0.673    | -.4559E-04 | 0.8519E-06 | -.9385E-05 | 92   | 112.129  | 0.9765E-03 | 0.3154E-03 | 0.8478E-02 |
| 15   | 0.960    | 0.3227E-05 | 0.1137E-03 | 0.1875E-05 | 93   | 114.245  | 0.8932E-03 | 0.2148E-02 | -.3439E-02 |
| 16   | 1.092    | -.6245E-06 | 0.2142E-03 | 0.7325E-06 | 94   | 114.871  | -.8217E-14 | 0.8866E-14 | 0.8866E-14 |
| 17   | 1.839    | -.1215E-04 | -.1146E-06 | -.2534E-05 | 95   | 115.621  | 0.1090E-02 | -.2416E-03 | -.1509E-02 |
| 18   | 1.844    | 0.1361E-05 | -.2285E-06 | 0.2419E-05 | 96   | 116.412  | 0.1080E-06 | -.4333E-07 | 0.6044E-07 |
| 19   | 1.889    | 0.1181E-13 | 0.5645E-15 | 0.3941E-17 | 97   | 119.079  | -.6016E-04 | 0.4370E-03 | 0.9195E-04 |
| 20   | 1.990    | -.1223E-04 | -.5338E-06 | 0.2071E-05 | 98   | 122.151  | 0.1554E-02 | 0.1645E-02 | 0.2502E-02 |
| 21   | 2.060    | 0.5702E-05 | 0.3210E-03 | 0.3580E-05 | 99   | 123.852  | 0.1775E-02 | -.8444E-03 | -.5039E-02 |
| 22   | 2.452    | -.3870E-04 | -.2272E-02 | -.2578E-04 | 100  | 127.143  | -.1758E-02 | 0.4654E-02 | -.4293E-02 |
| 23   | 2.472    | 0.3831E-04 | 0.3097E-02 | 0.3108E-04 | 101  | 129.399  | -.3709E-02 | 0.1164E-02 | -.7794E-02 |
| 24   | 3.242    | 0.3480E-05 | -.1982E-01 | -.1468E-03 | 102  | 136.398  | -.1356E-03 | 0.2072E-02 | 0.5545E-02 |
| 25   | 5.162    | -.1299E-13 | -.4795E-15 | -.5870E-16 | 103  | 136.446  | 0.2937E-02 | 0.1920E-02 | 0.2138E-03 |
| 26   | 5.170    | 0.2129E-05 | 0.2360E-07 | -.6659E-07 | 104  | 140.536  | -.1947E-02 | -.8602E-04 | 0.3327E-02 |
| 27   | 7.877    | -.5425E-13 | 0.3615E-15 | -.2031E-17 | 105  | 141.447  | -.3233E-03 | 0.2992E-02 | 0.7711E-04 |
| 28   | 7.918    | -.6440E-05 | -.4719E-07 | -.2121E-05 | 106  | 144.816  | 0.4310E-03 | -.1334E-02 | 0.5262E-02 |
| 29   | 8.772    | -.3142E-02 | -.8166E-05 | -.2629E-02 | 107  | 146.063  | -.7033E-03 | -.4956E-02 | -.3082E-02 |
| 30   | 8.776    | 0.2061E-01 | 0.5367E-04 | 0.1725E-01 | 108  | 147.833  | 0.3421E-03 | 0.1752E-02 | -.2428E-02 |
| 31   | 8.838    | -.1379E-03 | -.2637E-06 | -.1190E-03 | 109  | 154.900  | 0.1284E-02 | 0.4461E-03 | -.4775E-02 |
| 32   | 8.980    | -.1254E-05 | 0.4521E-05 | -.1074E-05 | 110  | 156.024  | -.2166E-03 | 0.1605E-02 | 0.1514E-02 |
| 33   | 9.620    | 0.1002E-06 | 0.3876E-04 | 0.7746E-06 | 111  | 158.434  | -.1109E-02 | -.1000E-02 | -.2531E-02 |
| 34   | 10.395   | 0.2826E-04 | -.6607E-02 | 0.7576E-03 | 112  | 159.792  | -.3527E-02 | 0.8519E-03 | -.8458E-02 |
| 35   | 11.673   | -.1582E-02 | 0.7234E-03 | 0.2424E-01 | 113  | 163.294  | -.9617E-03 | 0.1130E-03 | -.1783E-02 |
| 36   | 12.266   | -.1564E-03 | 0.6938E-03 | 0.1362E-02 | 114  | 163.678  | 0.1831E-03 | -.1196E-02 | 0.9422E-04 |
| 37   | 13.387   | -.1267E-01 | 0.2097E-02 | -.6898E-01 | 115  | 169.528  | -.5951E-03 | -.3781E-03 | 0.1387E-03 |
| 38   | 13.616   | 0.3277E-02 | 0.1034E-01 | 0.1220E-01 | 116  | 173.140  | -.5497E-03 | 0.1010E-02 | 0.1929E-02 |
| 39   | 14.771   | 0.2091E-01 | 0.1710E-03 | 0.1023E-01 | 117  | 177.783  | -.2961E-06 | -.3091E-03 | 0.1400E-02 |
| 40   | 16.432   | 0.1461E-02 | -.1737E-01 | -.5131E-03 | 118  | 178.984  | -.6788E-03 | 0.3023E-03 | 0.1443E-02 |
| 41   | 20.832   | 0.6767E-03 | 0.4490E-02 | -.2820E-02 | 119  | 183.455  | 0.8591E-03 | -.1740E-03 | 0.1299E-02 |
| 42   | 21.792   | -.2018E-01 | 0.2340E-02 | -.2074E-01 | 120  | 183.708  | -.8814E-04 | 0.2891E-03 | 0.1375E-02 |
| 43   | 21.845   | 0.1289E-05 | -.9632E-07 | 0.5591E-06 | 121  | 185.574  | 0.9748E-03 | -.9084E-03 | -.4031E-02 |
| 44   | 21.849   | 0.2475E-04 | -.2563E-05 | 0.3027E-04 | 122  | 187.134  | 0.2476E-02 | 0.3247E-03 | 0.1224E-01 |
| 45   | 21.849   | -.2202E-05 | -.1995E-05 | -.2268E-05 | 123  | 197.901  | -.8149E-03 | 0.6895E-03 | 0.2083E-02 |
| 46   | 21.880   | 0.2317E-05 | 0.4840E-05 | 0.2596E-05 | 124  | 205.905  | 0.1183E-02 | -.6374E-03 | 0.1176E-01 |
| 47   | 23.755   | -.1275E-02 | -.3947E-01 | -.1180E-01 | 125  | 207.733  | 0.2965E-03 | 0.1695E-02 | 0.3375E-02 |
| 48   | 24.472   | 0.3467E-02 | 0.4696E-02 | -.6944E-01 | 126  | 214.931  | 0.6214E-02 | -.6000E-02 | -.6966E-02 |
| 49   | 24.941   | -.1052E-01 | -.1291E-01 | 0.7234E-01 | 127  | 215.240  | 0.2675E-02 | 0.5615E-03 | 0.1469E-01 |
| 50   | 25.876   | 0.3684E-02 | -.4148E-01 | -.2241E-01 | 128  | 219.442  | -.7244E-03 | 0.5581E-03 | -.1840E-02 |
| 51   | 26.489   | 0.4406E-12 | 0.4621E-11 | 0.9903E-11 | 129  | 220.762  | -.2509E-02 | -.2675E-02 | -.1032E-02 |
| 52   | 27.978   | 0.8897E-02 | 0.4942E-02 | -.3277E-02 | 130  | 227.008  | 0.1002E-02 | 0.1359E-03 | 0.1647E-02 |
| 53   | 29.345   | 0.4164E-05 | -.1570E-04 | -.4634E-05 | 131  | 231.044  | 0.7337E-05 | -.2353E-03 | -.1771E-02 |
| 54   | 29.670   | 0.2779E-02 | -.8639E-02 | -.1765E-02 | 132  | 234.869  | 0.3940E-02 | 0.4031E-02 | -.8914E-02 |
| 55   | 31.959   | -.6839E-01 | -.2392E-02 | -.2078E-01 | 133  | 241.078  | 0.9821E-03 | 0.6534E-03 | 0.7271E-03 |
| 56   | 32.833   | 0.1412E-01 | -.1261E-01 | 0.3278E-01 | 134  | 244.629  | -.4445E-04 | -.2472E-02 | -.1596E-02 |
| 57   | 33.324   | -.7804E-06 | 0.5322E-06 | 0.7398E-06 | 135  | 249.454  | 0.7256E-04 | 0.2936E-03 | -.9663E-02 |
| 58   | 33.329   | -.4767E-05 | 0.1225E-05 | -.3518E-05 | 136  | 258.552  | -.4618E-02 | -.4399E-04 | -.7507E-02 |
| 59   | 33.331   | -.6191E-06 | 0.2991E-05 | 0.2355E-05 | 137  | 266.619  | -.4646E-04 | 0.2489E-02 | -.2899E-04 |
| 60   | 33.356   | 0.7496E-07 | -.2058E-05 | -.5950E-06 | 138  | 275.833  | 0.1692E-03 | 0.2223E-02 | -.4779E-03 |
| 61   | 33.755   | 0.5599E-02 | -.1923E-01 | -.2965E-01 | 139  | 278.953  | -.1535E-02 | -.1933E-03 | 0.4192E-02 |
| 62   | 34.601   | 0.1051E-01 | 0.6828E-02 | -.4371E-01 | 140  | 287.187  | 0.2177E-02 | 0.7193E-03 | -.1909E-02 |
| 63   | 38.746   | -.2363E-02 | -.6005E-02 | -.8444E-02 | 141  | 289.542  | -.1469E-03 | 0.1130E-02 | -.2800E-03 |
| 64   | 41.133   | 0.1950E-01 | -.4147E-02 | 0.5592E-02 | 142  | 292.944  | 0.8417E-05 | -.8588E-04 | 0.8193E-04 |
| 65   | 41.724   | -.7059E-02 | -.4430E-02 | -.4963E-02 | 143  | 298.738  | -.2699E-03 | 0.4304E-05 | 0.1281E-02 |
| 66   | 43.805   | 0.2279E-01 | 0.1176E-02 | 0.1960E-01 | 144  | 308.429  | -.4890E-03 | -.8453E-04 | 0.5642E-03 |
| 67   | 46.039   | -.6690E-03 | 0.1740E-02 | -.3381E-03 | 145  | 304.112  | -.7469E-04 | -.2095E-04 | 0.7899E-04 |
| 68   | 46.774   | 0.3618E-02 | 0.1139E-01 | 0.2937E-03 | 146  | 325.365  | 0.9380E-05 | 0.2396E-03 | 0.5419E-04 |
| 69   | 52.189   | -.2345E-02 | 0.2039E-02 | 0.2402E-01 | 147  | 307.073  | -.2356E-13 | 0.6394E-15 | 0.2271E-13 |
| 70   | 53.678   | -.4079E-02 | -.1187E-01 | -.3937E-02 | 148  | 387.074  | 0.4021E-12 | 0.7094E-11 | -.4009E-12 |
| 71   | 56.037   | -.2481E-02 | -.4465E-02 | 0.9039E-03 | 149  | 391.407  | -.1993E-13 | 0.5730E-15 | 0.1937E-13 |
| 72   | 57.443   | -.1831E-03 | -.2345E-02 | 0.1559E-03 | 150  | 391.408  | -.4475E-12 | -.7291E-11 | 0.4790E-12 |
| 73   | 60.417   | 0.5449E-02 | -.8419E-02 | 0.1368E-01 | 151  | 425.985  | 0.3974E-04 | 0.8044E-05 | 0.7220E-04 |
| 74   | 61.499   | 0.2343E-02 | 0.3762E-02 | 0.2755E-02 | 152  | 429.984  | -.1626E-04 | 0.1074E-04 | -.3127E-04 |
| 75   | 63.199   | 0.3177E-02 | -.4234E-02 | 0.1829E-02 | 153  | 449.529  | 0.1122E-04 | -.4983E-05 | 0.3975E-05 |
| 76   | 65.105   | -.1755E-03 | -.3168E-02 | 0.2474E-02 | 154  | 494.333  | -.1547E-05 | -.1797E-05 | -.5082E-05 |
| 77   | 70.714   | -.4470E-02 | 0.4027E-03 | -.4756E-02 | 155  | 731.187  | 0.1010E-01 | 0.3132E-04 | -.3754E-02 |
| 78   | 72.554   | -.8842E-03 | 0.2164E-02 | -.1374E-02 | 156  | 737.587  | 0.2200E-01 | -.2027E-04 | -.2313E-01 |

## SECTION 3

### STRENGTH CONTROLLED DESIGN

#### 3.1 Introduction

The strength controlled design (Revision 3) was created by resizing the structural members in the updated ACOSS Model #2 (Revision 1) to meet the minimum requirements for local stability and frequency. The non-structural mass due to the mirrors and solar panels, which represents 90% of the total system mass in revision 1, is unchanged in this design. Because of this, even though the structural mass was reduced by 50% the total mass was reduced by only 373 kg to 8963 kg. This results in a very flexible structure with very low natural frequencies.

The design constraints were established to prevent local failure of individual elements in the structure due to buckling or excessive dynamic interaction due to low member natural frequency. The local buckling load,  $P_{cr}$ , is directly related to the slenderness ( $l/r$ ) of each beam by the formula:

$$P_{cr} = \frac{\pi^2 EA}{(K \cdot \frac{l}{r})^2}$$

since the element forces are expected to be small, a slenderness limit of  $l/r = 400$  was used, and  $K$  equals .7 to account for end fixity. Using this equation, the minimum buckling load in the structure is 1060N. The natural frequency of each member was constrained to be greater than 10 Hz to prevent significant interaction between system vibrations and local vibrations. Finally, the wall thickness of the tubes was constrained to be a minimum of .03 cm. The NASTRAN input deck is listed in Appendix B. The tubular truss elements used to support the primary and tertiary mirrors were not changed. Reducing the size of these elements would have resulted in an unsound structure design due to the very low frequency local vibrations of these mirrors. These local effects would not be present in actual systems and would yield misleading results for this test model. The mass properties of this design are listed in Table 3.1.

### 3.2 Analysis

A normal modes analysis of the finite element model containing all of the changes, Revision 3, was performed using the MSC/NASTRAN finite element program. The resulting frequencies are shown in Table 3.2 along with the LOS errors for each mode. These LOS errors are based on a unit amplitude for each mode assuming they have been normalized to a unit generalized mass.

Table 3.1. Lumped mass distribution

| node   | structural<br>mass (kg) | non-struct.<br>mass (kg) | node | structural<br>mass (kg) | non-struct.<br>mass (kg) |
|--------|-------------------------|--------------------------|------|-------------------------|--------------------------|
| 1      | .80                     |                          | 36   | 2.68                    |                          |
| 2      | 5.37                    |                          | 37   | 4.41                    |                          |
| 3      | 10.72                   |                          | 38   | 4.41                    |                          |
| 4      | 7.35                    |                          | 39   | 2.68                    |                          |
| 5      | 5.37                    |                          | 40   | 9.48                    |                          |
| 6      | 10.67                   |                          | 42   | 0.0                     |                          |
| 7      | .80                     |                          | 43   | 2.10                    |                          |
| 8      | 7.59                    |                          | 44   | 0.0                     | 3500.                    |
| 9      | 14.12                   | 67.4                     | 45   | 2.10                    |                          |
| 10     | 8.70                    | 67.4                     | 46   | 0.0                     |                          |
| 11     | 14.12                   | 67.4                     | 47   | 0.0                     |                          |
| 12     | 8.72                    | 67.4                     | 48   | 2.62                    | 81.91                    |
| 13     | 7.59                    |                          | 49   | 5.25                    |                          |
| 14     | 12.12                   |                          | 50   | 5.25                    | 163.82                   |
| 15     | 17.25                   |                          | 51   | 5.25                    |                          |
| 16     | 25.78                   |                          | 52   | 4.73                    | 73.82                    |
| 17     | 17.25                   |                          | 53   | 4.73                    | 73.82                    |
| 18     | 25.78                   |                          | 54   | 5.25                    |                          |
| 19     | 12.12                   |                          | 55   | 5.25                    | 163.82                   |
| 26     | 10.78                   |                          | 56   | 5.25                    |                          |
| 27     | 15.50                   | 69.50                    | 57   | 2.62                    | 81.91                    |
| 28     | 38.49                   | 6.74                     | 910  | 3.57                    |                          |
| 29     | 10.80                   | 69.50                    | 1001 |                         | 1000.0                   |
| 30     | 43.19                   | 6.74                     | 1002 |                         | 800.0                    |
| 31     | 10.78                   |                          | 1003 |                         | 1200.0                   |
| 32     | 39.20                   | 6.74                     | 1004 |                         | 600.0                    |
| 33     | 42.17                   | 6.74                     | 1112 | 3.60                    |                          |
| 34     | 11.51                   | 69.50                    | 2830 | 62.76                   |                          |
| 35     | 8.54                    | 69.50                    | 3233 | 62.76                   |                          |
| Totals |                         |                          |      | 649.97                  | 8313.66                  |

Total mass = 8963 kg

Center of Mass Location

x = 0.0 m

y = -0.240 m

z = 6.991 m

Table 3.2. ACOSS Model #2: Revision 3

| NODE | FREQ(HZ) | LOSX        | LOSZ        | DEFOCUS     | NODE | FREQ(HZ) | LOSX        | LOSZ        | DEFOCUS     |
|------|----------|-------------|-------------|-------------|------|----------|-------------|-------------|-------------|
| 1    | 0.0      | 0.1637E-14  | -0.1177E-09 | -0.1029E-14 | 73   | 49.697   | -0.127E-02  | -0.155E-02  | -0.391E-02  |
| 2    | 0.0      | -0.1023E-08 | 0.2509E-14  | -0.7944E-15 | 80   | 50.871   | -0.631E-03  | 0.4497E-02  | -0.390E-02  |
| 3    | 0.0      | -0.2154E-13 | -0.2378E-14 | -0.1731E-08 | 81   | 54.458   | 0.1432E-02  | -0.1799E-02 | 0.7890E-02  |
| 4    | 0.0      | 0.9306E-03  | -0.7743E-14 | 0.1045E-08  | 82   | 55.556   | -0.1485E-03 | -0.4424E-02 | -0.3416E-02 |
| 5    | 0.0      | 0.1306E-06  | -0.9047E-03 | 0.1453E-12  | 83   | 59.887   | -0.1097E-16 | -0.6184E-17 | -0.2401E-17 |
| 6    | 0.0      | 0.1007E-07  | -0.6662E-04 | 0.1103E-13  | 84   | 60.129   | -0.6912E-07 | -0.5003E-07 | -0.1725E-06 |
| 7    | 0.114    | -0.1513E-06 | 0.2207E-03  | -0.3412E-05 | 85   | 61.339   | -0.1397E-02 | -0.2563E-02 | -0.2147E-04 |
| 8    | 0.147    | -0.4974E-05 | -0.2335E-06 | 0.3105E-05  | 86   | 63.528   | -0.1482E-02 | -0.9710E-03 | -0.1942E-01 |
| 9    | 0.150    | -0.1678E-03 | -0.9344E-09 | -0.8232E-06 | 87   | 64.270   | 0.2112E-04  | 0.6196E-03  | 0.3222E-02  |
| 10   | 0.175    | -0.1374E-05 | -0.1204E-03 | 0.1901E-05  | 88   | 67.163   | -0.5422E-02 | 0.6071E-03  | -0.1522E-01 |
| 11   | 0.455    | -0.1047E-04 | -0.6797E-05 | 0.8500E-04  | 89   | 69.498   | 0.2391E-03  | -0.7217E-03 | 0.8870E-03  |
| 12   | 0.557    | 0.2471E-05  | 0.7663E-03  | 0.1431E-04  | 90   | 70.874   | 0.5584E-02  | -0.3206E-03 | 0.1061E-02  |
| 13   | 0.596    | -0.8856E-03 | 0.9047E-08  | -0.8065E-04 | 91   | 72.243   | -0.2048E-02 | 0.9027E-03  | -0.4744E-02 |
| 14   | 0.615    | -0.6295E-05 | -0.5541E-03 | 0.3427E-05  | 92   | 74.935   | 0.8392E-03  | -0.2156E-02 | 0.1009E-02  |
| 15   | 0.636    | -0.2323E-03 | 0.2751E-05  | -0.6674E-04 | 93   | 76.704   | -0.1378E-01 | 0.4236E-05  | 0.2406E-02  |
| 16   | 0.642    | 0.8353E-05  | -0.7826E-04 | -0.1254E-04 | 94   | 79.755   | -0.2222E-03 | 0.2012E-03  | 0.3004E-03  |
| 17   | 0.815    | -0.3501E-04 | -0.1306E-05 | 0.7612E-05  | 95   | 86.536   | 0.8548E-02  | 0.6259E-04  | -0.1169E-01 |
| 18   | 0.816    | -0.1054E-03 | 0.6144E-06  | -0.2771E-04 | 96   | 94.263   | 0.2195E-17  | 0.1431E-17  | -0.1594E-17 |
| 19   | 0.823    | -0.2942E-13 | -0.9640E-16 | -0.1624E-15 | 97   | 95.376   | -0.4447E-02 | 0.2252E-02  | 0.5679E-02  |
| 20   | 0.916    | -0.3398E-04 | -0.3563E-05 | 0.3586E-04  | 98   | 95.495   | 0.5449E-05  | -0.1495E-05 | -0.9202E-05 |
| 21   | 0.972    | -0.1047E-04 | -0.4472E-03 | 0.1345E-04  | 99   | 96.093   | 0.3025E-02  | 0.4132E-02  | -0.3211E-02 |
| 22   | 1.159    | -0.2313E-06 | -0.2838E-02 | -0.4502E-04 | 100  | 99.325   | 0.6422E-02  | -0.3595E-03 | -0.5844E-02 |
| 23   | 1.551    | 0.2201E-04  | 0.2013E-01  | -0.2520E-03 | 101  | 102.489  | -0.3311E-03 | -0.2398E-02 | 0.1086E-02  |
| 24   | 1.773    | 0.4702E-04  | 0.8534E-03  | -0.1182E-03 | 102  | 102.705  | -0.1070E-02 | 0.1379E-02  | 0.2415E-02  |
| 25   | 2.250    | -0.1012E-12 | -0.3082E-15 | -0.3790E-16 | 103  | 108.868  | 0.9167E-05  | 0.2229E-02  | 0.1145E-03  |
| 26   | 2.254    | 0.3360E-05  | 0.6148E-07  | -0.3122E-05 | 104  | 109.695  | 0.4806E-02  | 0.2432E-04  | -0.1675E-02 |
| 27   | 3.434    | -0.4866E-12 | 0.3377E-14  | 0.2880E-17  | 105  | 111.198  | -0.1067E-04 | 0.3681E-03  | -0.2490E-02 |
| 28   | 3.452    | -0.5544E-05 | -0.2212E-06 | 0.5171E-05  | 106  | 112.074  | 0.2379E-03  | -0.1711E-02 | -0.8295E-03 |
| 29   | 3.957    | -0.7354E-05 | -0.1306E-06 | -0.1644E-04 | 107  | 116.974  | 0.4663E-03  | 0.1523E-03  | -0.1346E-03 |
| 30   | 3.967    | 0.2073E-05  | 0.4305E-06  | -0.2214E-04 | 108  | 117.639  | 0.4818E-03  | 0.1093E-02  | 0.3742E-03  |
| 31   | 4.052    | 0.8105E-06  | -0.3769E-04 | 0.2638E-06  | 109  | 118.199  | 0.1553E-03  | 0.4375E-03  | -0.2529E-02 |
| 32   | 4.339    | 0.1846E-06  | -0.1349E-03 | -0.2936E-06 | 110  | 119.915  | -0.2610E-02 | -0.3872E-03 | -0.5290E-02 |
| 33   | 6.563    | -0.2192E-01 | -0.5622E-04 | -0.6466E-01 | 111  | 120.398  | 0.5274E-02  | -0.8547E-03 | 0.2395E-02  |
| 34   | 8.065    | 0.1188E-02  | 0.1300E-01  | -0.6518E-02 | 112  | 131.127  | -0.1973E-02 | 0.1581E-03  | -0.3275E-02 |
| 35   | 8.453    | 0.1993E-02  | 0.1631E-02  | 0.5918E-01  | 113  | 132.091  | -0.7368E-04 | -0.1593E-02 | -0.2694E-03 |
| 36   | 8.854    | -0.2209E-03 | -0.9022E-03 | 0.1289E-01  | 114  | 135.631  | 0.2330E-02  | -0.3408E-03 | -0.5438E-03 |
| 37   | 9.010    | -0.1421E-01 | 0.2431E-02  | 0.2635E-01  | 115  | 139.911  | 0.1018E-02  | -0.3292E-02 | 0.1878E-03  |
| 38   | 10.340   | 0.1817E-02  | 0.1744E-01  | -0.5568E-02 | 116  | 140.146  | -0.2049E-02 | -0.2409E-02 | 0.1010E-02  |
| 39   | 10.523   | 0.1415E-02  | 0.8693E-02  | 0.2043E-03  | 117  | 140.954  | 0.6685E-03  | 0.4520E-03  | 0.1615E-01  |
| 40   | 11.550   | 0.1490E-01  | -0.4415E-01 | 0.1336E-01  | 118  | 142.352  | 0.4545E-03  | -0.1522E-02 | -0.5954E-02 |
| 41   | 11.651   | 0.9554E-06  | -0.4623E-05 | 0.2162E-04  | 119  | 143.436  | -0.3655E-04 | 0.1808E-02  | -0.2002E-02 |
| 42   | 11.652   | -0.6264E-05 | -0.4098E-05 | -0.5652E-05 | 120  | 144.897  | 0.1574E-02  | -0.9695E-03 | 0.7227E-02  |
| 43   | 11.652   | 0.2878E-04  | -0.3223E-04 | 0.2348E-04  | 121  | 154.044  | 0.2135E-03  | -0.5861E-03 | -0.2520E-02 |
| 44   | 11.641   | -0.3909E-04 | 0.5747E-04  | -0.3146E-04 | 122  | 157.527  | -0.5346E-03 | -0.8743E-03 | 0.7692E-03  |
| 45   | 11.841   | 0.2795E-01  | 0.3078E-01  | 0.2469E-01  | 123  | 160.629  | -0.2481E-03 | -0.8585E-03 | 0.1710E-02  |
| 46   | 13.497   | -0.2979E-01 | 0.7018E-02  | -0.1897E-01 | 124  | 164.853  | 0.2037E-02  | -0.2806E-02 | -0.2010E-02 |
| 47   | 14.104   | -0.3922E-01 | 0.1877E-02  | -0.5539E-01 | 125  | 165.339  | 0.1553E-02  | -0.2314E-02 | -0.5946E-02 |
| 48   | 15.030   | 0.6588E-02  | 0.2534E-01  | 0.6388E-02  | 126  | 169.179  | 0.1567E-02  | -0.1404E-02 | -0.1448E-02 |
| 49   | 16.741   | 0.2155E-02  | 0.8370E-03  | -0.5170E-01 | 127  | 169.816  | 0.1733E-02  | -0.1490E-02 | -0.2540E-02 |
| 50   | 17.322   | -0.1753E-02 | 0.9305E-02  | -0.2498E-02 | 128  | 173.988  | 0.3064E-03  | 0.5402E-03  | -0.1784E-02 |
| 51   | 17.613   | 0.1322E-01  | -0.1624E-03 | 0.9533E-02  | 129  | 183.641  | -0.5348E-03 | 0.4362E-03  | -0.1394E-03 |
| 52   | 17.767   | -0.2940E-06 | -0.3020E-06 | 0.1237E-05  | 130  | 183.923  | 0.6702E-03  | 0.1536E-02  | 0.3394E-03  |
| 53   | 17.768   | -0.6065E-06 | 0.4774E-05  | -0.8795E-07 | 131  | 188.640  | 0.2352E-03  | -0.4086E-04 | 0.3394E-03  |
| 54   | 17.749   | -0.1347E-05 | -0.4390E-06 | -0.4134E-05 | 132  | 193.180  | -0.1407E-02 | 0.2262E-03  | 0.1334E-02  |
| 55   | 17.777   | -0.5849E-06 | -0.4628E-05 | -0.2865E-06 | 133  | 197.432  | 0.7819E-03  | -0.6222E-03 | -0.2747E-02 |
| 56   | 21.317   | 0.4011E-01  | 0.3462E-03  | -0.3428E-01 | 134  | 200.285  | 0.1408E-02  | 0.7555E-03  | -0.3444E-02 |
| 57   | 21.681   | 0.2915E-15  | -0.8912E-15 | -0.3480E-15 | 135  | 206.248  | 0.1327E-02  | 0.1739E-02  | -0.2921E-02 |
| 58   | 22.165   | -0.7403E-04 | -0.2408E-01 | 0.4199E-02  | 136  | 210.842  | -0.2314E-03 | -0.7880E-03 | -0.1802E-03 |
| 59   | 23.891   | 0.1758E-01  | -0.3848E-02 | -0.6371E-01 | 137  | 211.115  | 0.7208E-04  | -0.6524E-03 | -0.1387E-03 |
| 60   | 23.944   | 0.7349E-04  | 0.1162E-04  | -0.2542E-03 | 138  | 215.294  | -0.0630E-03 | -0.2013E-03 | -0.1339E-02 |
| 61   | 24.559   | 0.3843E-03  | 0.4230E-02  | 0.2523E-02  | 139  | 232.302  | 0.1593E-02  | 0.1774E-02  | -0.2716E-02 |
| 62   | 24.660   | 0.1050E-01  | 0.8207E-04  | -0.2234E-01 | 140  | 236.788  | -0.7737E-03 | -0.8215E-03 | -0.1301E-02 |
| 63   | 25.673   | 0.6772E-02  | 0.1194E-01  | -0.7809E-03 | 141  | 237.321  | 0.1137E-03  | -0.4270E-04 | -0.1225E-02 |
| 64   | 26.110   | 0.1497E-01  | -0.6579E-03 | 0.5574E-02  | 142  | 244.598  | -0.6822E-03 | -0.2367E-03 | 0.1262E-02  |
| 65   | 26.799   | 0.2987E-01  | 0.5931E-02  | 0.2687E-01  | 143  | 261.883  | -0.1735E-02 | 0.2351E-04  | -0.3105E-02 |
| 66   | 28.411   | 0.2495E-01  | -0.1081E-01 | 0.3053E-01  | 144  | 272.780  | -0.8467E-05 | -0.3367E-04 | -0.1690E-04 |
| 67   | 29.016   | 0.1950E-02  | -0.4754E-02 | 0.1106E-03  | 145  | 273.877  | 0.5170E-03  | -0.4088E-05 | 0.8864E-03  |
| 68   | 32.375   | -0.2862E-02 | -0.1507E-01 | 0.4530E-02  | 146  | 291.365  | 0.8617E-05  | 0.2812E-03  | 0.5548E-05  |
| 69   | 33.112   | -0.8899E-02 | -0.2291E-02 | 0.2921E-02  | 147  | 318.313  | 0.6732E-05  | 0.6640E-05  | -0.1172E-05 |
| 70   | 33.542   | 0.6071E-03  | 0.7511E-02  | 0.2196E-01  | 148  | 319.434  | -0.1155E-04 | 0.2529E-04  | 0.1054E-05  |
| 71   | 35.370   | -0.1094E-02 | 0.7359E-02  | 0.3449E-02  | 149  | 385.374  | 0.3054E-17  | 0.1751E-16  | 0.3546E-17  |
| 72   | 36.590   | -0.0044E-02 | 0.6947E-03  | 0.9467E-02  | 150  | 385.396  | 0.2800E-12  | 0.1640E-11  | 0.2114E-12  |
| 73   | 39.439   | 0.5492E-02  | 0.3070E-02  | -0.1991E-01 | 151  | 387.946  | 0.3739E-05  | 0.4073E-05  | -0.2991E-04 |
| 74   | 40.170   | 0.6103E-03  | 0.1727E-02  | -0.1993E-02 | 152  | 387.946  | -0.2229E-05 | 0.6491E-05  | -0.1748E-04 |
| 75   | 40.433   | 0.4377E-03  | -0.3576E-02 | -0.5974E-02 | 153  | 388.299  | -0.1145E-17 | -0.5773E-18 | -0.2222E-18 |
| 76   | 42.804   | -0.3747E-03 | -0.2972E-02 | 0.1165E-02  | 154  | 389.299  | -0.2944E-12 | -0.1402E-11 | -0.2222E-12 |
| 77   | 44.116   | 0.7552E-12  | 0.1544E-02  | -0.1017E-01 | 155  | 503.267  | 0.1347E-05  | 0.1513E-05  | 0.1447E-07  |
| 78   | 45.241   | -0.4644E-02 | 0.2254E-02  | 0.1052E-01  | 156  | 503.459  | 0.1242E-05  | -0.6126E-05 | -0.1215E-07 |

## SECTION 4

### STIFFNESS CONTROLLED DESIGN

#### 4.1 Introduction

The stiffness controlled structural design (Revision 4) is one component of the passively controlled system. In theory, the penalty paid for the increased mass of the stiffened system will be offset by a lighter, less complex passive control system. This will be true if the effect of the disturbances is reduced significantly by local stiffening or increasing the natural frequencies of the system.

The design of a stiffened structure can be approached in a number of ways depending on the desired results. The simplest approach is to use a trial and error method based on engineering judgement to increase member sizes and natural frequencies. At the other end of the spectrum are optimization techniques in which a performance index, which is a function of structural parameters, is optimized subject to constraints on the variables. The computation requirements for this type of approach can be extensive. The approach which was used to generate this model falls between these two extremes.

The objective of the redesign of this system is to improve the performance by reducing the effects of the disturbances. This is complicated by the fact that most of the elastic modes, except for those of the solar panels, will be excited by the disturbances and cause large errors. Normal improvement approaches employing frequency separation between the disturbances and the structural modes will not be effective because of the high bandwidth of these forces. It will be impossible to add sufficient stiffness to raise the low frequency bending modes above 15 Hz. The maximum achievable frequency of these modes may be well below this point. Based on the considerations, the goal of this redesign will be to raise all frequencies of the optical support truss as much as possible and to raise the solar panel modes out of the bandwidth of the isolator modes.

Starting with the baseline design (Revision 1) a maximum mass model was generated by increasing the size of all members to the maximum permitted by the constraints.

Radius/thickness = 50

Length/radius = 40

Maximum thickness = 1.0 cm

The maximum allowable area based on these constraints is the minimum of:

$$AMAX1 = 2\pi \cdot L/40 \cdot L/40 \cdot 1/50 = 7.854 \times 10^{-5} L^2$$

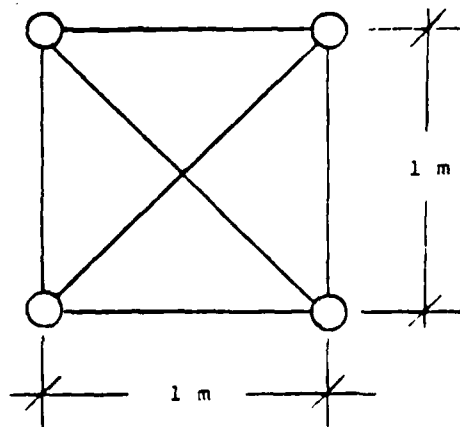
$$AMAX2 = 2\pi \cdot L/40 \cdot .01 = 1.5708 \times 10^{-3} L$$

AMAX1 controls for all members in this model since it has the minimum value for elements with length less than twenty meters. The structural mass required for the maximum mass design is

$$\text{Mass} = \sum A_i L_i \rho$$

This must be scaled to meet the structural mass constraint of 6686 kg and total constraint of 15000 kg. All areas will be scaled uniformly to meet these constraints. Since the member areas are proportional to  $L^2$ , the stiffness matrix in both the axial and bending directions is proportional to the length  $L$ . If there is a wide range of lengths in the model, the shorter elements may not have sufficient strength. An analysis of this design showed significant strain energy in the short elements of the lower optical support truss. This was corrected by modifying the mass scale factor to account for the inverse of the length. This will result in areas which are proportional to the length and axial stiffness which is independent of length and equal for all elements. Analysis results using these modified section properties showed a significant improvement in frequency and a better distribution of strain energy.

To raise the frequencies of the solar panels above 1 Hz, and avoid overly large sections, the solar panel support booms were redesigned as a truss. The design, shown in Figure 4.1, is modelled by an equivalent beam in the finite element model.



Tube Properties:

$$\text{Radius} = 0.05 \text{ m}$$

$$t = 0.001 \text{ m}$$

$$\text{Area} = 0.000314 \text{ m}^2$$

Section Properties:

$$\text{Area} = 4 A_{\text{tube}} = 0.001257 \text{ m}^2$$

$$I = 0.000314 \text{ m}^4$$

$$J = 0.000628 \text{ m}^4$$

$$\text{Mass/L} = 3.82 \text{ kg/m}$$

Figure 4.1. Solar panel support boom design

The section properties of the members in this design are listed in Appendix C. The structural and non-structural mass lumped at each node point are listed in Table 4.1.

#### 4.2 Analysis

A normal modes analysis of the finite element model of the stiffness controlled design, Revision 4, was performed using the MSC/NASTRAN finite element program. The resulting frequencies are shown in Table 4.2 along with the LOS error for each mode. These LOS errors are based on a unit amplitude for each mode assuming they have been normalized to a unit generalized mass.

Table 4.1. Lumped mass distribution - Revision 4

| node   | structural | non-struct. | node | structural | non-struct. |
|--------|------------|-------------|------|------------|-------------|
|        | mass (kg)  | mass (kg)   |      | mass (kg)  | mass (kg)   |
| 1      | 29.22      |             | 36   | 96.98      |             |
| 2      | 113.01     |             | 37   | 126.20     |             |
| 3      | 209.68     |             | 38   | 126.20     |             |
| 4      | 123.35     |             | 39   | 96.98      |             |
| 5      | 113.01     |             | 40   | 134.51     |             |
| 6      | 207.15     |             | 42   | 0.0        |             |
| 7      | 29.22      |             | 43   | 11.96      |             |
| 8      | 151.76     |             | 44   | 0.0        | 3500.       |
| 9      | 195.78     | 67.4        | 45   | 11.96      |             |
| 10     | 164.84     | 67.4        | 46   | 0.0        |             |
| 11     | 195.78     | 67.4        | 47   | 0.0        |             |
| 12     | 165.76     | 67.4        | 48   | 14.96      | 81.91       |
| 13     | 151.76     |             | 49   | 29.91      |             |
| 14     | 196.39     |             | 50   | 29.91      | 163.82      |
| 15     | 269.43     |             | 51   | 29.91      |             |
| 16     | 305.14     |             | 52   | 26.92      | 73.82       |
| 17     | 269.43     |             | 53   | 26.92      | 73.82       |
| 18     | 305.14     |             | 54   | 29.91      |             |
| 19     | 196.39     |             | 55   | 29.91      | 163.82      |
| 26     | 189.90     |             | 56   | 29.91      |             |
| 27     | 270.24     | 69.50       | 57   | 14.96      | 81.91       |
| 28     | 185.98     | 6.74        | 910  | 125.08     |             |
| 29     | 195.18     | 69.50       | 1001 |            | 1000.0      |
| 30     | 261.05     | 6.74        | 1002 |            | 800.0       |
| 31     | 189.90     |             | 1003 |            | 1200.0      |
| 32     | 168.94     | 6.74        | 1004 |            | 600.0       |
| 33     | 214.79     | 6.74        | 1112 | 126.70     |             |
| 34     | 209.38     | 69.50       | 2830 | 62.76      |             |
| 35     | 163.52     | 69.50       | 3233 | 62.76      |             |
| Totals |            |             |      | 6686.40    | 8313.66     |

Total mass = 15000 kg

Center of Mass Location

x = 0.0 m

y = -0.201 m

z = 3.833 m

Table 4.2. ACOSS Model #2: Revision 4

| MODE | FREQINZ1 | LOSX        | LOSZ        | DEFOCUS     | MODE | FREQINZ1 | LOSX        | LOSZ        | DEFOCUS     |
|------|----------|-------------|-------------|-------------|------|----------|-------------|-------------|-------------|
| 1    | 0.0      | 0.2423E-14  | - .9049E-10 | - .7644E-16 | 79   | 85.168   | 0.4452E-02  | - 8.705E-02 | 0.1465E-01  |
| 2    | 0.0      | - .7049E-09 | 0.1625E-13  | - .3702E-15 | 80   | 85.930   | - .4629E-03 | 0.1156E-01  | 0.4966E-02  |
| 3    | 0.0      | - .1042E-12 | 0.4109E-13  | - .1339E-08 | 81   | 90.312   | - .3990E-02 | - 2546E-02  | 0.5612E-02  |
| 4    | 0.0      | 0.7281E-03  | 0.3454E-14  | 0.0221E-09  | 82   | 91.779   | 0.1783E-02  | 0.4047E-03  | - .4701E-02 |
| 5    | 0.0      | 0.9702E-06  | - .7085E-03 | 0.1095E-11  | 83   | 92.489   | - .3618E-02 | - 2131E-02  | - .2366E-02 |
| 6    | 0.0      | 0.5776E-07  | - .3305E-04 | 0.6514E-13  | 84   | 92.773   | 0.1351E-02  | 0.1367E-02  | - .1924E-02 |
| 7    | 0.141    | - .3948E-04 | 0.3209E-03  | - .1604E-06 | 85   | 98.423   | 0.1061E-02  | - .1808E-02 | 0.2066E-02  |
| 8    | 0.278    | - .1494E-06 | - .8981E-06 | 0.2238E-06  | 86   | 99.689   | 0.3430E-02  | - .1761E-02 | 0.4597E-02  |
| 9    | 0.371    | - .3750E-04 | - .1020E-06 | 0.1760E-09  | 87   | 100.523  | 0.3029E-02  | - .6649E-03 | 0.4103E-02  |
| 10   | 0.449    | - .5288E-03 | - .4116E-05 | - .2273E-05 | 88   | 104.895  | - .9921E-03 | - .1860E-02 | - .6470E-02 |
| 11   | 0.467    | - .6040E-05 | 0.3642E-03  | 0.3415E-06  | 89   | 105.838  | 0.7171E-02  | - .7161E-03 | 0.4206E-02  |
| 12   | 0.647    | - .2497E-04 | 0.4488E-07  | 0.1892E-05  | 90   | 109.051  | - .5397E-02 | 0.7852E-03  | - .6037E-02 |
| 13   | 1.305    | - .1913E-06 | - .4498E-07 | - .6670E-04 | 91   | 116.634  | - .1272E-02 | - .1202E-03 | 0.2760E-02  |
| 14   | 1.346    | 0.3680E-06  | 0.7921E-07  | - .1315E-05 | 92   | 117.555  | - .1024E-17 | 0.2433E-10  | 0.4037E-17  |
| 15   | 3.145    | - .7695E-06 | - .9709E-05 | 0.6045E-06  | 93   | 119.409  | - .4461E-08 | - .4771E-07 | 0.1627E-07  |
| 16   | 3.893    | - .3949E-06 | 0.3818E-04  | 0.8697E-06  | 94   | 121.105  | 0.5590E-02  | 0.7792E-03  | - .1057E-01 |
| 17   | 5.004    | - .6909E-06 | - .2571E-02 | 0.4376E-04  | 95   | 122.452  | 0.3730E-02  | - .6320E-02 | - .7161E-02 |
| 18   | 5.616    | 0.4149E-06  | - .1092E-01 | - .1733E-03 | 96   | 123.287  | - .3919E-02 | 0.3734E-02  | 0.8671E-02  |
| 19   | 6.926    | - .7421E-06 | 0.5759E-07  | - .4070E-06 | 97   | 125.595  | - .7543E-03 | - .3407E-02 | - .3890E-02 |
| 20   | 6.940    | 0.1895E-06  | - .3528E-08 | - .5605E-06 | 98   | 126.122  | - .4326E-02 | - .3676E-02 | 0.5456E-02  |
| 21   | 7.735    | 0.5825E-13  | - .3582E-15 | - .3239E-16 | 99   | 127.297  | - .2991E-02 | - .2954E-02 | 0.7909E-04  |
| 22   | 7.835    | 0.1256E-06  | 0.7363E-06  | - .1210E-06 | 100  | 128.238  | 0.4313E-02  | - .1762E-02 | 0.6915E-02  |
| 23   | 8.884    | 0.9376E-06  | 0.5110E-07  | - .7905E-06 | 101  | 130.710  | 0.0257E-03  | 0.5910E-03  | 0.1333E-01  |
| 24   | 9.470    | 0.5591E-07  | 0.1732E-04  | 0.1245E-06  | 102  | 131.467  | - .4160E-02 | 0.2357E-02  | 0.5075E-02  |
| 25   | 11.858   | - .1910E-02 | - .0612E-04 | - .3953E-02 | 103  | 132.741  | - .1523E-02 | - .4136E-02 | 0.5242E-02  |
| 26   | 12.779   | 0.3564E-02  | 0.6784E-03  | 0.2391E-02  | 104  | 135.324  | 0.3082E-02  | - .5959E-02 | - .4469E-02 |
| 27   | 12.851   | 0.1047E-02  | - .2578E-02 | 0.1067E-02  | 105  | 136.166  | 0.2060E-03  | 0.5572E-02  | - .6325E-02 |
| 28   | 13.511   | - .1007E-04 | - .4695E-04 | - .2577E-03 | 106  | 138.043  | - .6088E-02 | - .1873E-02 | - .8415E-02 |
| 29   | 21.134   | - .2899E-12 | 0.4002E-15  | 0.1870E-15  | 107  | 138.485  | 0.4185E-02  | - .3137E-02 | - .7906E-02 |
| 30   | 21.169   | - .4501E-06 | - .7249E-08 | - .6343E-07 | 108  | 140.797  | 0.3352E-02  | - .5305E-02 | 0.3676E-02  |
| 31   | 23.710   | 0.2970E-01  | - .8217E-04 | 0.4395E-01  | 109  | 141.534  | 0.1603E-02  | 0.1297E-02  | 0.2720E-02  |
| 32   | 26.683   | - .4624E-03 | 0.2659E-04  | - .6580E-01 | 110  | 143.867  | - .6327E-02 | 0.3901E-02  | 0.1158E-02  |
| 33   | 27.589   | - .1050E-15 | - .9001E-16 | 0.3545E-15  | 111  | 147.051  | - .2116E-02 | - .5916E-02 | - .1205E-01 |
| 34   | 28.691   | 0.1392E-05  | - .2749E-07 | - .1839E-05 | 112  | 147.716  | 0.5188E-02  | - .4728E-02 | 0.2883E-02  |
| 35   | 28.894   | 0.3787E-06  | - .1819E-06 | - .2311E-05 | 113  | 150.219  | 0.2172E-02  | 0.7479E-03  | - .4769E-02 |
| 36   | 29.026   | 0.3205E-06  | 0.1808E-05  | 0.1234E-09  | 114  | 151.104  | - .4497E-03 | 0.3934E-02  | - .7146E-02 |
| 37   | 29.686   | 0.3491E-03  | 0.7331E-02  | 0.1788E-02  | 115  | 152.872  | - .5366E-02 | 0.3724E-03  | 0.5543E-02  |
| 38   | 31.656   | 0.8707E-07  | - .2205E-05 | - .4101E-06 | 116  | 155.135  | 0.1204E-02  | - .5634E-02 | - .5167E-02 |
| 39   | 31.794   | - .3003E-07 | 0.1193E-05  | 0.6559E-06  | 117  | 159.920  | 0.1109E-02  | 0.4252E-02  | 0.3077E-02  |
| 40   | 32.242   | - .5443E-03 | - .3043E-02 | 0.2067E-02  | 118  | 160.687  | 0.5266E-03  | 0.2629E-02  | - .2679E-02 |
| 41   | 32.252   | 0.5368E-12  | 0.1495E-12  | - .1027E-12 | 119  | 161.480  | - .1358E-02 | - .1133E-02 | - .1475E-02 |
| 42   | 32.439   | 0.5194E-07  | 0.1567E-06  | - .3176E-05 | 120  | 163.747  | - .1536E-02 | - .3194E-02 | 0.3964E-02  |
| 43   | 34.827   | - .2731E-02 | - .4974E-03 | 0.3939E-01  | 121  | 163.942  | - .1780E-02 | - .1159E-02 | 0.7290E-02  |
| 44   | 38.004   | - .1167E-01 | 0.3064E-02  | 0.3694E-01  | 122  | 165.756  | - .3109E-02 | - .1220E-02 | 0.9248E-02  |
| 45   | 37.833   | - .1304E-02 | - .3794E-01 | 0.2637E-02  | 123  | 168.052  | 0.2908E-02  | 0.2633E-02  | - .9578E-02 |
| 46   | 42.727   | 0.1229E-01  | - .8419E-02 | 0.2425E-02  | 124  | 169.261  | - .6341E-02 | 0.3303E-02  | 0.1517E-01  |
| 47   | 44.248   | 0.4201E-01  | 0.4041E-02  | 0.4691E-02  | 125  | 171.174  | 0.2024E-03  | - .4217E-02 | - .3915E-02 |
| 48   | 44.789   | - .9995E-02 | 0.4549E-02  | 0.4175E-02  | 126  | 173.651  | 0.2829E-02  | - .4446E-03 | - .3986E-02 |
| 49   | 48.943   | - .1002E-01 | - .3926E-02 | 0.4874E-03  | 127  | 175.770  | - .2054E-02 | - .3430E-02 | 0.1233E-01  |
| 50   | 48.790   | - .6378E-02 | 0.5272E-02  | - .1212E-03 | 128  | 177.875  | - .1135E-03 | - .4050E-02 | - .2093E-02 |
| 51   | 51.205   | 0.1822E-06  | 0.2387E-07  | 0.3613E-06  | 129  | 185.072  | 0.2532E-02  | - .1834E-02 | - .7819E-02 |
| 52   | 51.242   | 0.3140E-05  | - .1512E-05 | 0.2117E-05  | 130  | 188.516  | 0.3110E-03  | - .2027E-03 | - .2473E-02 |
| 53   | 51.330   | - .5598E-06 | 0.1694E-05  | - .6728E-06 | 131  | 189.341  | - .4936E-03 | 0.6462E-04  | 0.1973E-02  |
| 54   | 51.521   | - .2145E-02 | 0.9055E-02  | - .2782E-02 | 132  | 196.230  | 0.1201E-02  | - .1717E-02 | - .2782E-02 |
| 55   | 51.614   | - .1290E-05 | 0.2766E-05  | - .1448E-05 | 133  | 196.618  | - .1128E-02 | 0.5189E-03  | 0.4644E-02  |
| 56   | 51.921   | 0.9333E-02  | 0.1739E-03  | 0.5020E-02  | 134  | 197.302  | - .9306E-03 | 0.1222E-02  | 0.1431E-02  |
| 57   | 54.076   | 0.2256E-01  | - .2141E-02 | 0.2170E-01  | 135  | 199.020  | - .1698E-02 | - .1709E-02 | 0.2856E-02  |
| 58   | 56.157   | - .5394E-03 | 0.2702E-02  | 0.1401E-02  | 136  | 205.877  | - .8170E-04 | 0.9111E-03  | - .1151E-02 |
| 59   | 59.940   | - .9582E-03 | 0.1236E-01  | 0.3056E-02  | 137  | 212.588  | - .1249E-03 | 0.6570E-04  | - .6920E-04 |
| 60   | 61.139   | - .1243E-01 | - .2123E-02 | - .2845E-01 | 138  | 214.778  | 0.6951E-03  | - .4754E-03 | - .1266E-02 |
| 61   | 63.515   | 0.1845E-01  | 0.3543E-02  | 0.5829E-02  | 139  | 224.868  | - .2130E-03 | 0.4484E-03  | 0.1314E-04  |
| 62   | 65.297   | - .2571E-02 | 0.2091E-02  | - .1219E-02 | 140  | 227.004  | - .3680E-03 | - .2489E-03 | - .3675E-03 |
| 63   | 68.555   | 0.6943E-03  | - .1602E-01 | 0.7723E-02  | 141  | 228.722  | - .7933E-03 | 0.1758E-03  | - .1403E-03 |
| 64   | 68.310   | 0.2381E-04  | 0.7090E-02  | 0.1244E-01  | 142  | 239.862  | - .3578E-17 | - .2523E-17 | 0.1122E-16  |
| 65   | 69.685   | 0.1300E-02  | 0.1641E-02  | - .2777E-01 | 143  | 239.875  | - .1931E-09 | 0.5013E-08  | - .4623E-09 |
| 66   | 72.661   | 0.6038E-02  | - .8827E-02 | - .8691E-02 | 144  | 241.435  | - .9549E-04 | 0.1205E-02  | - .1771E-04 |
| 67   | 75.644   | - .1040E-01 | 0.4276E-02  | - .3361E-03 | 145  | 242.196  | - .1338E-03 | - .6014E-03 | 0.4594E-03  |
| 68   | 77.174   | 0.7128E-02  | 0.1119E-01  | - .4450E-02 | 146  | 246.060  | 0.1596E-02  | 0.5379E-04  | - .5851E-03 |
| 69   | 77.739   | - .7716E-07 | - .1095E-06 | - .3310E-06 | 147  | 247.842  | 0.1622E-17  | - .3501E-19 | - .4991E-17 |
| 70   | 77.793   | 0.4675E-06  | 0.6764E-06  | - .5233E-06 | 148  | 247.555  | - .2380E-09 | 0.2373E-08  | 0.6849E-10  |
| 71   | 77.798   | - .5534E-07 | 0.1499E-06  | 0.4784E-06  | 149  | 252.731  | - .2289E-04 | 0.1700E-32  | 0.1477E-03  |
| 72   | 78.186   | 0.1223E-05  | 0.1671E-05  | 0.5208E-06  | 150  | 253.078  | 0.6561E-03  | - .3362E-04 | - .1510E-02 |
| 73   | 78.441   | - .1614E-02 | - .7357E-02 | - .1367E-01 | 151  | 258.111  | - .2654E-03 | - .5886E-04 | - .8555E-03 |
| 74   | 78.449   | 0.2723E-14  | 0.1254E-13  | 0.2360E-13  | 152  | 258.441  | 0.4061E-04  | - .6467E-03 | 0.2069E-04  |
| 75   | 78.945   | 0.6122E-02  | - .5134E-02 | - .2016E-01 | 153  | 300.990  | - .1413E-03 | - .9952E-05 | - .2431E-03 |
| 76   | 78.999   | - .3999E-07 | 0.6057E-06  | 0.1458E-05  | 154  | 301.544  | 0.4708E-06  | - .2066E-03 | 0.2062E-04  |
| 77   | 81.274   | - .1454E-03 | - .4763E-02 | 0.1924E-02  | 155  | 417.994  | 0.5745E-05  | - .2339E-04 | - .9536E-07 |
| 78   | 83.055   | - .8864E-02 | - .2513E-02 | 0.2366E-01  | 156  | 428.562  | - .6392E-05 | - .7395E-05 | - .0011E-06 |

## SECTION 5

### SUMMARY

In order to meet the needs of the VCOSS program for two models which represent the extremes of structural stiffness and were detailed enough to allow specification of control system hardware, modifications were made to the design of ACOSS Model #2. Three new revisions of this model were created and are described in this report. The MSC/NASTRAN input for each revision is included in an Appendix.

The first model, Revision 1, is an updated version of the original design, Revision 0. The design has been changed to add more detail to the models of the mirrors, mirror support structure and equipment section. The basic geometry and the stiffness of the structural members were not changed from the original ACOSS Model #2. The dynamic characteristics of this model are close to those exhibited by Revision 0.

Using this updated model as a baseline, two new revised models were created. These two new revised models, a lightweight, flexible design (Revision 3) and a heavy, stiff design (Revision 4) can be used to study the trade-offs between structural mass and control system complexity.

APPENDIX A

```

ID DRAPER,MODEL2
SOL 3
CHKPNT YES
TIME 10
CEND
TITLE = ***** ACROSS MODEL #2 *****
SUBTITLE = UPDATED ORIGINAL MODEL - REV 1
MPC = 100
METHOD = 600
DISP = ALL
#ESE =ALL
BEGIN BULK
PARAM,USETPRT,1
PARAM GRDPNT 0
EIGR 600 GIV
+10 MASS
$
$ KINEMATIC MOUNT: TERTIARY MIRROR
$
RBE1,1003,27,123,29,23,3233,3,,+RB31
+RB31,UM,1003,123456
$
$ KINEMATIC MOUNT: PRIMARY MIRROR
$
RBE1,1001,34,123,35,23,2830,3,,+RB11
+RB11,UM,1001,123456
$
$ KINEMATIC MOUNT: FOCAL PLANE
$
RBE1,1004,11,123,9,23,40,3,,+RB41
+RB41,UM,1004,123456
$
$ KINEMATIC MOUNT: SECONDARY MIRROR
$
RBE1,1002,910,123,1112,23,40,3,,+RB21
+RB21,UM,1002,123456
$
$ RIGID EQUIPMENT SECTION
$
RBE2 141 44 123456 42 43 45 46 47
$
$ NODE POINT LOCATIONS
$
$ NODE # X(M) Y(M) Z(M)
$
GRID 1 -7.0 0.0 0.0
GRID 2 -4.0 5.0 0.0
GRID 3 -4.0 -5.0 0.0
GRID 4 0.0 5.0 0.0
GRID 5 4.0 5.0 0.0
GRID 6 4.0 -5.0 0.0
GRID 7 7.0 0.0 0.0
GRID 8 -7.0 0.0 2.0
GRID 9 -4.0 5.0 2.0
GRID 1004 0.0 4.0 2.0
GRID 10 -4.0 -5.0 2.0
GRID 910 -4.0 -2.5 2.0
GRID 1112 4.0 -2.5 2.0

```

|      |      |        |        |      |
|------|------|--------|--------|------|
| GRID | 11   | 4.0    | 5.0    | 2.0  |
| GRID | 12   | 4.0    | -5.0   | 2.0  |
| GRID | 13   | 7.0    | 0.0    | 2.0  |
| GRID | 14   | -6.0   | 0.0    | 12.  |
| GRID | 15   | -4.0   | 4.0    | 12.  |
| GRID | 16   | -4.0   | -4.0   | 12.  |
| GRID | 17   | 4.0    | 4.0    | 12.  |
| GRID | 18   | 4.0    | -4.0   | 12.  |
| GRID | 19   | 6.0    | 0.0    | 12.0 |
| GRID | 26   | -5.0   | 0.0    | 22.0 |
| GRID | 27   | -4.0   | 3.0    | 22.0 |
| GRID | 28   | -4.0   | -3.0   | 22.0 |
| GRID | 2830 | 0.0    | -3.0   | 22.0 |
| GRID | 1001 | 0.0    | -6.5   | 22.0 |
| GRID | 29   | 4.0    | 3.0    | 22.0 |
| GRID | 30   | 4.0    | -3.0   | 22.0 |
| GRID | 31   | 5.0    | 0.0    | 22.0 |
| GRID | 32   | -4.0   | 10.0   | 22.0 |
| GRID | 3233 | 0.0    | 10.0   | 22.0 |
| GRID | 1003 | 0.0    | 6.5    | 22.0 |
| GRID | 33   | 4.0    | 10.0   | 22.0 |
| GRID | 34   | -4.0   | -10.0  | 22.0 |
| GRID | 35   | 4.0    | -10.0  | 22.0 |
| GRID | 36   | -4.0   | 3.0    | 24.0 |
| GRID | 37   | -4.0   | -3.0   | 24.0 |
| GRID | 38   | 4.0    | 3.0    | 24.0 |
| GRID | 39   | 4.0    | -3.0   | 24.0 |
| GRID | 40   | 0.0    | 2.5    | 2.0  |
| GRID | 1002 | 0.0    | 0.0    | 2.0  |
| GRID | 42   | 0.0    | 5.0    | -0.3 |
| GRID | 43   | -2.0   | 0.0    | -1.3 |
| GRID | 44   | 0.0    | -1.667 | -1.3 |
| GRID | 45   | 2.0    | 0.0    | -1.3 |
| GRID | 46   | -4.0   | -5.0   | -0.3 |
| GRID | 47   | 4.0    | -5.0   | -0.3 |
| GRID | 48   | -26.0  | 0.0    | -1.3 |
| GRID | 49   | -21.00 | 0.0    | -1.3 |
| GRID | 50   | -16.0  | 0.0    | -1.3 |
| GRID | 51   | -11.0  | 0.0    | -1.3 |
| GRID | 52   | -6.0   | 0.0    | -1.3 |
| GRID | 53   | 6.0    | 0.0    | -1.3 |
| GRID | 54   | 11.0   | 0.0    | -1.3 |
| GRID | 55   | 16.0   | 0.0    | -1.3 |
| GRID | 56   | 21.00  | 0.0    | -1.3 |
| GRID | 57   | 26.0   | 0.0    | -1.3 |
| GRID | 100  | 0.0    | 0.0    | 0.0  |

456

\$ ELEMENT CONNECTION DATA

| \$    | ELEM# | PROP# | NODE | NODE | LOCAL AXIS ORIENTATION VECTOR |     |     |   |
|-------|-------|-------|------|------|-------------------------------|-----|-----|---|
| \$    |       |       |      |      | 1.0                           | 0.0 | 0.0 | 1 |
| BAROR |       |       |      |      |                               |     |     |   |
| CBAR  | 1     | 200   | 1    | 2    |                               |     |     |   |
| CBAR  | 2     | 200   | 1    | 3    |                               |     |     |   |
| CBAR  | 3     | 200   | 2    | 3    |                               |     |     |   |
| CBAR  | 4     | 200   | 2    | 4    | 0.0                           | 1.0 | 0.0 | 1 |
| CBAR  | 5     | 200   | 3    | 4    |                               |     |     |   |

|      |     |     |      |      |     |     |     |   |
|------|-----|-----|------|------|-----|-----|-----|---|
| CBAR | 6   | 200 | 4    | 5    | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 7   | 200 | 4    | 6    |     |     |     |   |
| CBAR | 8   | 200 | 3    | 6    | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 9   | 200 | 5    | 6    |     |     |     |   |
| CBAR | 10  | 200 | 5    | 7    |     |     |     |   |
| CBAR | 11  | 200 | 6    | 7    |     |     |     |   |
| CBAR | 12  | 200 | 1    | 8    |     |     |     |   |
| CBAR | 13  | 200 | 2    | 9    |     |     |     |   |
| CBAR | 14  | 200 | 3    | 10   |     |     |     |   |
| CBAR | 15  | 200 | 5    | 11   |     |     |     |   |
| CBAR | 16  | 200 | 6    | 12   |     |     |     |   |
| CBAR | 17  | 200 | 7    | 13   |     |     |     |   |
| CBAR | 18  | 200 | 3    | 8    |     |     |     |   |
| CBAR | 19  | 200 | 2    | 8    |     |     |     |   |
| CBAR | 21  | 200 | 4    | 9    |     |     |     |   |
| CBAR | 22  | 200 | 4    | 11   |     |     |     |   |
| CBAR | 24  | 200 | 5    | 13   |     |     |     |   |
| CBAR | 25  | 200 | 6    | 13   |     |     |     |   |
| CBAR | 30  | 200 | 8    | 9    |     |     |     |   |
| CBAR | 31  | 200 | 8    | 10   |     |     |     |   |
| CBAR | 32  | 200 | 9    | 910  |     |     |     |   |
| CBAR | 232 | 200 | 910  | 10   |     |     |     |   |
| CBAR | 33  | 200 | 9    | 40   |     |     |     |   |
| CBAR | 34  | 200 | 910  | 40   |     |     |     |   |
| CBAR | 35  | 200 | 11   | 40   |     |     |     |   |
| CBAR | 36  | 200 | 1112 | 40   |     |     |     |   |
| CBAR | 201 | 200 | 910  | 1112 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 202 | 200 | 2    | 910  |     |     |     |   |
| CBAR | 203 | 200 | 3    | 910  |     |     |     |   |
| CBAR | 204 | 200 | 5    | 1112 |     |     |     |   |
| CBAR | 205 | 200 | 6    | 1112 |     |     |     |   |
| CBAR | 207 | 200 | 12   | 910  |     |     |     |   |
| CBAR | 26  | 200 | 1112 | 3    |     |     |     |   |
| CBAR | 27  | 200 | 6    | 10   |     |     |     |   |
| CBAR | 37  | 200 | 9    | 11   | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 38  | 200 | 10   | 12   | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 39  | 200 | 11   | 1112 |     |     |     |   |
| CBAR | 239 | 200 | 1112 | 12   |     |     |     |   |
| CBAR | 40  | 200 | 11   | 13   |     |     |     |   |
| CBAR | 41  | 200 | 12   | 13   |     |     |     |   |
| CBAR | 42  | 300 | 14   | 15   |     |     |     |   |
| CBAR | 43  | 300 | 14   | 16   |     |     |     |   |
| CBAR | 44  | 300 | 16   | 15   |     |     |     |   |
| CBAR | 45  | 300 | 17   | 18   |     |     |     |   |
| CBAR | 46  | 300 | 17   | 19   |     |     |     |   |
| CBAR | 47  | 300 | 18   | 19   |     |     |     |   |
| CBAR | 54  | 300 | 25   | 27   |     |     |     |   |
| CBAR | 55  | 300 | 26   | 28   |     |     |     |   |
| CBAR | 56  | 300 | 27   | 28   |     |     |     |   |
| CBAR | 57  | 300 | 29   | 30   |     |     |     |   |
| CBAR | 58  | 300 | 29   | 31   |     |     |     |   |
| CBAR | 59  | 300 | 30   | 31   |     |     |     |   |
| CBAR | 60  | 300 | 27   | 29   | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 61  | 300 | 27   | 30   |     |     |     |   |
| CBAR | 62  | 62  | 28   | 2830 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 184 | 62  | 2830 | 30   | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 63  | 300 | 27   | 36   |     |     |     |   |

|      |     |     |      |      |     |     |     |   |
|------|-----|-----|------|------|-----|-----|-----|---|
| CBAR | 64  | 300 | 28   | 37   |     |     |     |   |
| CBAR | 65  | 300 | 30   | 39   |     |     |     |   |
| CBAR | 66  | 300 | 29   | 38   |     |     |     |   |
| CBAR | 67  | 300 | 29   | 36   |     |     |     |   |
| CBAR | 68  | 300 | 27   | 37   |     |     |     |   |
| CBAR | 69  | 300 | 28   | 39   |     |     |     |   |
| CBAR | 70  | 300 | 30   | 38   |     |     |     |   |
| CBAR | 71  | 300 | 36   | 37   |     |     |     |   |
| CBAR | 72  | 300 | 37   | 39   | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 73  | 300 | 39   | 38   |     |     |     |   |
| CBAR | 74  | 300 | 36   | 38   | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 75  | 300 | 37   | 38   |     |     |     |   |
| CBAR | 127 | 300 | 26   | 37   |     |     |     |   |
| CBAR | 128 | 300 | 26   | 36   |     |     |     |   |
| CBAR | 129 | 300 | 31   | 39   |     |     |     |   |
| CBAR | 130 | 300 | 31   | 38   |     |     |     |   |
| CBAR | 76  | 400 | 8    | 14   |     |     |     |   |
| CBAR | 77  | 400 | 10   | 14   |     |     |     |   |
| CBAR | 78  | 400 | 10   | 16   |     |     |     |   |
| CBAR | 79  | 400 | 16   | 9    |     |     |     |   |
| CBAR | 80  | 400 | 9    | 15   |     |     |     |   |
| CBAR | 181 | 400 | 8    | 15   |     |     |     |   |
| CBAR | 182 | 200 | 6    | 40   |     |     |     |   |
| CBAR | 183 | 200 | 2    | 40   |     |     |     |   |
| CBAR | 186 | 200 | 3    | 40   |     |     |     |   |
| CBAR | 187 | 200 | 5    | 40   |     |     |     |   |
| CBAR | 81  | 400 | 11   | 17   |     |     |     |   |
| CBAR | 82  | 400 | 11   | 18   |     |     |     |   |
| CBAR | 83  | 400 | 12   | 18   |     |     |     |   |
| CBAR | 84  | 400 | 12   | 19   |     |     |     |   |
| CBAR | 85  | 400 | 13   | 19   |     |     |     |   |
| CBAR | 86  | 400 | 13   | 17   |     |     |     |   |
| CBAR | 87  | 400 | 14   | 26   |     |     |     |   |
| CBAR | 88  | 400 | 14   | 28   |     |     |     |   |
| CBAR | 89  | 400 | 16   | 28   |     |     |     |   |
| CBAR | 90  | 400 | 16   | 27   |     |     |     |   |
| CBAR | 91  | 400 | 15   | 27   |     |     |     |   |
| CBAR | 92  | 400 | 15   | 26   |     |     |     |   |
| CBAR | 93  | 400 | 17   | 29   |     |     |     |   |
| CBAR | 94  | 400 | 18   | 29   |     |     |     |   |
| CBAR | 95  | 400 | 18   | 30   |     |     |     |   |
| CBAR | 96  | 400 | 19   | 30   |     |     |     |   |
| CBAR | 97  | 400 | 19   | 31   |     |     |     |   |
| CBAR | 98  | 400 | 17   | 31   |     |     |     |   |
| CBAR | 99  | 400 | 15   | 32   |     |     |     |   |
| CBAR | 100 | 400 | 16   | 34   |     |     |     |   |
| CBAR | 101 | 400 | 17   | 33   |     |     |     |   |
| CBAR | 102 | 400 | 18   | 35   |     |     |     |   |
| CBAR | 111 | 400 | 26   | 32   |     |     |     |   |
| CBAR | 112 | 400 | 27   | 32   |     |     |     |   |
| CBAR | 113 | 400 | 27   | 33   |     |     |     |   |
| CBAR | 114 | 400 | 29   | 33   |     |     |     |   |
| CBAR | 115 | 400 | 31   | 33   |     |     |     |   |
| CBAR | 116 | 62  | 32   | 3233 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 185 | 62  | 3233 | 33   | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 117 | 400 | 26   | 34   |     |     |     |   |
| CBAR | 118 | 400 | 28   | 34   |     |     |     |   |

|      |     |     |    |    |     |     |     |   |
|------|-----|-----|----|----|-----|-----|-----|---|
| CBAR | 119 | 400 | 30 | 34 |     |     |     |   |
| CBAR | 120 | 400 | 30 | 35 |     |     |     |   |
| CBAR | 121 | 400 | 31 | 35 |     |     |     |   |
| CBAR | 122 | 400 | 34 | 35 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 123 | 400 | 32 | 36 |     |     |     |   |
| CBAR | 124 | 400 | 33 | 38 |     |     |     |   |
| CBAR | 125 | 400 | 34 | 37 |     |     |     |   |
| CBAR | 126 | 400 | 35 | 39 |     |     |     |   |
| CBAR | 131 | 500 | 48 | 49 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 132 | 500 | 49 | 50 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 133 | 500 | 50 | 51 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 134 | 500 | 51 | 52 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 135 | 500 | 52 | 43 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 136 | 500 | 45 | 53 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 137 | 500 | 53 | 54 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 138 | 500 | 54 | 55 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 139 | 500 | 55 | 56 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 140 | 500 | 56 | 57 | 0.0 | 1.0 | 0.0 | 1 |

\$  
\$ ISOLATOR SPRINGS

|        | ELEM# | K<br>(N/M) | NODE<br>A | DOF<br>A | NODE<br>B | DOF<br>B |
|--------|-------|------------|-----------|----------|-----------|----------|
| CELAS2 | 142   | 5.79E3     | 4         | 1        | 42        | 1        |
| CELAS2 | 143   | 5.79E3     | 4         | 2        | 42        | 2        |
| CELAS2 | 144   | 5.79E3     | 4         | 3        | 42        | 3        |
| CELAS2 | 145   | 5.79E3     | 3         | 1        | 46        | 1        |
| CELAS2 | 146   | 5.79E3     | 3         | 2        | 46        | 2        |
| CELAS2 | 147   | 5.79E3     | 3         | 3        | 46        | 3        |
| CELAS2 | 148   | 5.79E3     | 6         | 1        | 47        | 1        |
| CELAS2 | 149   | 5.79E3     | 6         | 2        | 47        | 2        |
| CELAS2 | 150   | 5.79E3     | 6         | 3        | 47        | 3        |

\$  
\$ MATERIAL PROPERTY DATA

|      | MAT # | E        | NU  | RHO   |
|------|-------|----------|-----|-------|
| MAT1 | 100   | 1.24E+11 | 0.3 | 1720. |
| MAT1 | 200   | 1.24E+11 | 0.3 | 1720. |
| MAT1 | 300   | 1.24E+11 | 0.3 |       |

\$  
\$ LUMPED MASS DATA

| \$CONM2 | ELEM# | NODE# | MASS |     | +XXXX |
|---------|-------|-------|------|-----|-------|
| \$+XXXX | IXX   |       | IYY  | IZZ |       |

\$  
\$ MIRRORS

|       |         |      |         |         |       |
|-------|---------|------|---------|---------|-------|
| CONM2 | 1001    | 1001 | 1000.   |         | +1001 |
| +1001 | 4083.33 |      | 5333.33 | 9416.67 |       |
| CONM2 | 1002    | 1002 | 800.    |         | +4040 |
| +4040 | 1666.67 |      | 4266.67 | 5933.33 |       |
| CONM2 | 1003    | 1003 | 1200.   |         | +1003 |
| +1003 | 4900.   |      | 6400.   | 11300.  |       |
| CONM2 | 1004    | 1004 | 600.    |         | +1004 |

```

+1004    200.          800.          1000.
$
$      EQUIPMENT SECTION
$
CONM2    544    44          3500.          +544
+544    20611.          10500.          28777.
$
$      SOLAR PANELS
$
CONM2    548    48          81.91          +548
+548    270.0
CONM2    550    50          163.82          +550
+550    540.0
CONM2    552    52          73.82          +552
+552    270.0
CONM2    553    53          73.82          +553
+553    270.0
CONM2    557    57          81.91          +557
+555    540.0
CONM2    555    55          163.82          +555
+557    270.0
$
$      ADDITIONAL NON-STRUCTURAL MASS AT MIRROR SUPPORTS
$
CONM2    501    27          69.5
CONM2    502    28          6.74
CONM2    503    29          69.5
CONM2    504    30          6.74
CONM2    505    32          6.74
CONM2    506    33          6.74
CONM2    507    34          69.5
CONM2    508    35          69.5
CONM2    509    9          67.4
CONM2    510    10         67.4
CONM2    511    11         67.4
CONM2    512    12         67.4
$
$      BEAM SECTION PROPERTIES
$
$      PROP#    MAT#    AREA    IYY    IZZ    J    NSM
$
PBAR    200    100    6.250E-43.095E-63.095E-66.189E-6
PBAR    300    100    3.133E-41.509E-61.509E-63.118E-6
PBAR    400    100    3.919E-43.049E-63.049E-66.099E-6
PBAR    500    100    9.407E-41.874E-51.874E-53.749E-5
PBAR    62     300    6.082E-31.521E-31.521E033.041E-3 15.69
$
$
$      MULTI-POINT CONSTRAINT FOR X-AXIS LOS ERROR (NCDE 100 DOF 1)
$
MPC#    100          100          1          -1.0*1000000
*1000000          34          2    -0.01855287570    *1000001
*1000001          35          3    -0.14285714286*1000002
*1000002          35          2    -0.0185528757    *1000003
*1000003          35          3    -0.14285714286*1000004
*1000004          2830        3    0.28571428572    *1000005

```

|          |      |    |                |                |          |
|----------|------|----|----------------|----------------|----------|
| *1000005 |      | 30 | 3              | 0.0            | *1000006 |
| *1000006 | 27   | 2  | 0.08065681999  |                | *1000007 |
| *1000007 |      | 27 | 3              | -0.35489000795 | *1000008 |
| *1000008 | 29   | 2  | 0.08065681999  |                | *1000009 |
| *1000009 |      | 29 | 3              | -0.35489000795 | *1000010 |
| *1000010 | 3233 | 3  | 0.70978001590  |                | *1000011 |
| *1000011 |      | 33 | 3              | 0.0            | *1000012 |
| *1000012 | 1002 | 4  | -3.48423005566 |                | *1000013 |
| *1000013 |      | 11 | 2              | -0.06210394429 | *1000014 |
| *1000014 | 9    | 2  | -0.06210394429 |                |          |

\$  
\$ MULTI-POINT CONSTRAINT FOR Y-AXIS LOS ERROR (NODE 100 DOF 2)  
\$

|          |      |     |                |                |          |
|----------|------|-----|----------------|----------------|----------|
| MPC*     | 100  | 100 | 2              | -1.0           | *2000000 |
| *2000000 | 34   | 1   | -0.03710575139 |                | *2000001 |
| *2000001 |      | 34  | 2              | -0.04638218924 | *2000002 |
| *2000002 | 34   | 3   | -0.25000000000 |                | *2000003 |
| *2000003 |      | 35  | 2              | 0.04638218924  | *2000004 |
| *2000004 | 35   | 3   | 0.25000000000  |                | *2000005 |
| *2000005 |      | 27  | 1              | 0.16131363998  | *2000006 |
| *2000006 | 27   | 2   | -0.06049261499 |                | *2000007 |
| *2000007 |      | 27  | 3              | -0.62105751391 | *2000008 |
| *2000008 | 29   | 2   | 0.06049261499  |                | *2000009 |
| *2000009 |      | 29  | 3              | 0.62105751391  | *2000010 |
| *2000010 | 1002 | 5   | 3.48423005566  |                | *2000011 |
| *2000011 |      | 11  | 1              | -0.12420788859 | *2000012 |
| *2000012 | 11   | 2   | -0.07762993037 |                | *2000013 |
| *2000013 |      | 9   | 2              | 0.07762993037  | *2000014 |
| *2000014 |      |     |                |                |          |

\$  
\$ MULTI-POINT CONSTRAINT EQUATION FOR DEFOCUS (NODE 100 DOF 3)  
\$

|          |      |      |                |                |          |
|----------|------|------|----------------|----------------|----------|
| MPC*     | 100  | 100  | 3              | -1.0           | *3000000 |
| *3000000 | 34   | 3    | -0.01912393776 |                | *3000001 |
| *3000001 |      | 35   | 3              | -0.01912393776 | *3000002 |
| *3000002 | 2830 | 3    | 0.12749291836  |                | *3000003 |
| *3000003 |      | 30   | 3              | 0.0            | *3000004 |
| *3000004 | 27   | 3    | 0.77803217347  |                | *3000005 |
| *3000005 |      | 29   | 3              | 0.77803217347  | *3000006 |
| *3000006 | 3233 | 3    | -0.46681930408 |                | *3000007 |
| *3000007 |      | 1002 | 3              | -0.17849008571 | *3000008 |
| *3000008 | 9    | 3    | 0.50000000000  |                | *3000009 |
| *3000009 |      | 11   | 3              | 0.50000000000  | *3000010 |
| *3000010 | 40   | 3    | -2.00000000000 |                |          |

\$  
\$ RIGID BODY SUPPORT  
\$

SUPORT,44,123456  
ENDDATA

\*\*\*\*\* END OF MEMBER REV01 391 RECORDS \*\*\*\*\*

APPENDIX B

```

ID DRAPER,MODEL2
SOL 3
CHKPNT YES
CEND
TITLE = ACOSS MODEL #2 - REVISION 3
SUBTITLE = VCOSS DESIGN MODEL
LABEL = 156 MODES AND FREQUENCIES
MPC = 100
METHOD = 600
DISP = ALL
$ESE = ALL
BEGIN BULK
PARAM,USETPRT,1
PARAM GRDPNT 0
EIGR 600 GIV 200 +10
+10 MASS
$
$ KINEMATIC MOUNT: TERTIARY MIRROR
$
RBE1,1003,27,123,29,23,3233,3,,+RB31
+RB31,UM,1003,123456
$
$ KINEMATIC MOUNT: PRIMARY MIRROR
$
RBE1,1001,34,123,35,23,2830,3,,+RB11
+RB11,UM,1001,123456
$
$ KINEMATIC MOUNT: FOCAL PLANE
$
RBE1,1004,11,123,9,23,40,3,,+RB41
+RB41,UM,1004,123456
$
$ KINEMATIC MOUNT: SECONDARY MIRROR
$
RBE1,1002,910,123,1112,23,40,3,,+RB21
+RB21,UM,1002,123456
$
$ RIGID EQUIPMENT SECTION
$
RBE2 141 44 123456 42 43 45 46 47
$
$ NODE POINT LOCATIONS
$
$ NODE# X (M) Y (M) Z (M)
$
GRID 1 -7.0 0.0 0.0
GRID 2 -4.0 5.0 0.0
GRID 3 -4.0 -5.0 0.0
GRID 4 0.0 5.0 0.0
GRID 5 4.0 5.0 0.0
GRID 6 4.0 -5.0 0.0
GRID 7 7.0 0.0 0.0
GRID 8 -7.0 0.0 2.0
GRID 9 -4.0 5.0 2.0
GRID 1004 0.0 4.0 2.0
GRID 10 -4.0 -5.0 2.0
GRID 11 4.0 5.0 2.0
GRID 12 4.0 -5.0 2.0

```

|      |      |        |        |      |
|------|------|--------|--------|------|
| GRID | 910  | -4.0   | -2.5   | 2.0  |
| GRID | 1112 | 4.0    | -2.5   | 2.0  |
| GRID | 13   | 7.0    | 0.0    | 2.0  |
| GRID | 14   | -6.0   | 0.0    | 12.  |
| GRID | 15   | -4.0   | 4.0    | 12.  |
| GRID | 16   | -4.0   | -4.0   | 12.  |
| GRID | 17   | 4.0    | 4.0    | 12.  |
| GRID | 18   | 4.0    | -4.0   | 12.  |
| GRID | 19   | 6.0    | 0.0    | 12.0 |
| GRID | 26   | -5.0   | 0.0    | 22.0 |
| GRID | 27   | -4.0   | 3.0    | 22.0 |
| GRID | 28   | -4.0   | -3.0   | 22.0 |
| GRID | 2830 | 0.0    | -3.0   | 22.0 |
| GRID | 1001 | 0.0    | -6.5   | 22.0 |
| GRID | 29   | 4.0    | 3.0    | 22.0 |
| GRID | 30   | 4.0    | -3.0   | 22.0 |
| GRID | 31   | 5.0    | 0.0    | 22.0 |
| GRID | 32   | -4.0   | 10.0   | 22.0 |
| GRID | 3233 | 0.0    | 10.0   | 22.0 |
| GRID | 1003 | 0.0    | 6.5    | 22.0 |
| GRID | 33   | 4.0    | 10.0   | 22.0 |
| GRID | 34   | -4.0   | -10.0  | 22.0 |
| GRID | 35   | 4.0    | -10.0  | 22.0 |
| GRID | 36   | -4.0   | 3.0    | 24.0 |
| GRID | 37   | -4.0   | -3.0   | 24.0 |
| GRID | 38   | 4.0    | 3.0    | 24.0 |
| GRID | 39   | 4.0    | -3.0   | 24.0 |
| GRID | 40   | 0.0    | 2.5    | 2.0  |
| GRID | 1002 | 0.0    | 0.0    | 2.0  |
| GRID | 42   | 0.0    | 5.0    | -0.3 |
| GRID | 43   | -2.0   | 0.0    | -1.3 |
| GRID | 44   | 0.0    | -1.667 | -1.3 |
| GRID | 45   | 2.0    | 0.0    | -1.3 |
| GRID | 46   | -4.0   | -5.0   | -0.3 |
| GRID | 47   | 4.0    | -5.0   | -0.3 |
| GRID | 48   | -26.0  | 0.0    | -1.3 |
| GRID | 49   | -21.00 | 0.0    | -1.3 |
| GRID | 50   | -16.0  | 0.0    | -1.3 |
| GRID | 51   | -11.0  | 0.0    | -1.3 |
| GRID | 52   | -6.0   | 0.0    | -1.3 |
| GRID | 53   | 6.0    | 0.0    | -1.3 |
| GRID | 54   | 11.0   | 0.0    | -1.3 |
| GRID | 55   | 16.0   | 0.0    | -1.3 |
| GRID | 56   | 21.00  | 0.0    | -1.3 |
| GRID | 57   | 26.0   | 0.0    | -1.3 |
| GRID | 100  | 0.0    | 0.0    | 0.0  |

456

\$

\$ ELEMENT CONNECTION DATA

\$

| \$ | ELEM# | PROP# | NODE<br>A | NODE<br>B | LOCAL AXIS ORIENTATION VECTOR |     |     |   |
|----|-------|-------|-----------|-----------|-------------------------------|-----|-----|---|
| \$ |       |       |           |           |                               |     |     |   |
| \$ | BAROR |       |           |           | 1.0                           | 0.0 | 0.0 | 1 |
|    | CBAR  | 1     | 1         | 2         |                               |     |     |   |
|    | CBAR  | 2     | 1         | 3         |                               |     |     |   |
|    | CBAR  | 3     | 2         | 3         |                               |     |     |   |
|    | CBAR  | 4     | 2         | 4         | 0.0                           | 1.0 | 0.0 | 1 |

|      |     |     |      |      |     |     |     |   |
|------|-----|-----|------|------|-----|-----|-----|---|
| CBAR | 5   | 5   | 3    | 4    |     |     |     |   |
| CBAR | 6   | 6   | 4    | 5    | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 7   | 7   | 4    | 6    |     |     |     |   |
| CBAR | 8   | 8   | 3    | 6    | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 9   | 9   | 5    | 6    |     |     |     |   |
| CBAR | 10  | 10  | 5    | 7    |     |     |     |   |
| CBAR | 11  | 11  | 6    | 7    |     |     |     |   |
| CBAR | 12  | 12  | 1    | 8    |     |     |     |   |
| CBAR | 13  | 13  | 2    | 9    |     |     |     |   |
| CBAR | 14  | 14  | 3    | 10   |     |     |     |   |
| CBAR | 15  | 15  | 5    | 11   |     |     |     |   |
| CBAR | 16  | 16  | 6    | 12   |     |     |     |   |
| CBAR | 17  | 17  | 7    | 13   |     |     |     |   |
| CBAR | 18  | 18  | 3    | 8    |     |     |     |   |
| CBAR | 19  | 19  | 2    | 8    |     |     |     |   |
| CBAR | 21  | 21  | 4    | 9    |     |     |     |   |
| CBAR | 22  | 22  | 4    | 11   |     |     |     |   |
| CBAR | 24  | 24  | 5    | 13   |     |     |     |   |
| CBAR | 25  | 25  | 6    | 13   |     |     |     |   |
| CBAR | 26  | 26  | 1112 | 3    |     |     |     |   |
| CBAR | 27  | 27  | 6    | 10   |     |     |     |   |
| CBAR | 30  | 30  | 8    | 9    |     |     |     |   |
| CBAR | 31  | 31  | 8    | 10   |     |     |     |   |
| CBAR | 32  | 32  | 9    | 910  |     |     |     |   |
| CBAR | 232 | 232 | 910  | 10   |     |     |     |   |
| CBAR | 33  | 33  | 9    | 40   |     |     |     |   |
| CBAR | 34  | 34  | 910  | 40   |     |     |     |   |
| CBAR | 35  | 35  | 11   | 40   |     |     |     |   |
| CBAR | 36  | 36  | 1112 | 40   |     |     |     |   |
| CBAR | 37  | 37  | 9    | 11   | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 38  | 38  | 10   | 12   | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 39  | 39  | 11   | 1112 |     |     |     |   |
| CBAR | 239 | 239 | 1112 | 12   |     |     |     |   |
| CBAR | 201 | 201 | 910  | 1112 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 202 | 202 | 2    | 910  |     |     |     |   |
| CBAR | 203 | 203 | 3    | 910  |     |     |     |   |
| CBAR | 204 | 204 | 5    | 1112 |     |     |     |   |
| CBAR | 205 | 205 | 6    | 1112 |     |     |     |   |
| CBAR | 207 | 207 | 12   | 910  |     |     |     |   |
| CBAR | 40  | 40  | 11   | 13   |     |     |     |   |
| CBAR | 41  | 41  | 12   | 13   |     |     |     |   |
| CBAR | 42  | 42  | 14   | 15   |     |     |     |   |
| CBAR | 43  | 43  | 14   | 16   |     |     |     |   |
| CBAR | 44  | 44  | 16   | 15   |     |     |     |   |
| CBAR | 45  | 45  | 17   | 18   |     |     |     |   |
| CBAR | 46  | 46  | 17   | 19   |     |     |     |   |
| CBAR | 47  | 47  | 18   | 19   |     |     |     |   |
| CBAR | 54  | 54  | 26   | 27   |     |     |     |   |
| CBAR | 55  | 55  | 26   | 28   |     |     |     |   |
| CBAR | 56  | 56  | 27   | 28   |     |     |     |   |
| CBAR | 57  | 57  | 29   | 30   |     |     |     |   |
| CBAR | 58  | 58  | 29   | 31   |     |     |     |   |
| CBAR | 59  | 59  | 30   | 31   |     |     |     |   |
| CBAR | 60  | 60  | 27   | 29   | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 61  | 61  | 27   | 30   |     |     |     |   |
| CBAR | 62  | 62  | 28   | 2830 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 184 | 184 | 2830 | 30   | 0.0 | 1.0 | 0.0 | 1 |

|      |     |     |      |      |     |     |     |   |
|------|-----|-----|------|------|-----|-----|-----|---|
| CBAR | 63  | 63  | 27   | 36   |     |     |     |   |
| CBAR | 64  | 64  | 28   | 37   |     |     |     |   |
| CBAR | 65  | 65  | 30   | 39   |     |     |     |   |
| CBAR | 66  | 66  | 29   | 38   |     |     |     |   |
| CBAR | 67  | 67  | 29   | 36   |     |     |     |   |
| CBAR | 68  | 68  | 27   | 37   |     |     |     |   |
| CBAR | 69  | 69  | 28   | 39   |     |     |     |   |
| CBAR | 70  | 70  | 30   | 38   |     |     |     |   |
| CBAR | 71  | 71  | 36   | 37   |     |     |     |   |
| CBAR | 72  | 72  | 37   | 39   | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 73  | 73  | 39   | 38   |     |     |     |   |
| CBAR | 74  | 74  | 36   | 38   | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 75  | 75  | 37   | 38   |     |     |     |   |
| CBAR | 127 | 127 | 26   | 37   |     |     |     |   |
| CBAR | 128 | 128 | 26   | 36   |     |     |     |   |
| CBAR | 129 | 129 | 31   | 39   |     |     |     |   |
| CBAR | 130 | 130 | 31   | 38   |     |     |     |   |
| CBAR | 76  | 76  | 8    | 14   |     |     |     |   |
| CBAR | 77  | 77  | 10   | 14   |     |     |     |   |
| CBAR | 78  | 78  | 10   | 16   |     |     |     |   |
| CBAR | 79  | 79  | 16   | 9    |     |     |     |   |
| CBAR | 80  | 80  | 9    | 15   |     |     |     |   |
| CBAR | 181 | 181 | 8    | 15   |     |     |     |   |
| CBAR | 182 | 182 | 6    | 40   |     |     |     |   |
| CBAR | 183 | 183 | 2    | 40   |     |     |     |   |
| CBAR | 186 | 186 | 3    | 40   |     |     |     |   |
| CBAR | 187 | 187 | 5    | 40   |     |     |     |   |
| CBAR | 81  | 81  | 11   | 17   |     |     |     |   |
| CBAR | 82  | 82  | 11   | 18   |     |     |     |   |
| CBAR | 83  | 83  | 12   | 18   |     |     |     |   |
| CBAR | 84  | 84  | 12   | 19   |     |     |     |   |
| CBAR | 85  | 85  | 13   | 19   |     |     |     |   |
| CBAR | 86  | 86  | 13   | 17   |     |     |     |   |
| CBAR | 87  | 87  | 14   | 26   |     |     |     |   |
| CBAR | 88  | 88  | 14   | 28   |     |     |     |   |
| CBAR | 89  | 89  | 16   | 28   |     |     |     |   |
| CBAR | 90  | 90  | 16   | 27   |     |     |     |   |
| CBAR | 91  | 91  | 15   | 27   |     |     |     |   |
| CBAR | 92  | 92  | 15   | 26   |     |     |     |   |
| CBAR | 93  | 93  | 17   | 29   |     |     |     |   |
| CBAR | 94  | 94  | 18   | 29   |     |     |     |   |
| CBAR | 95  | 95  | 18   | 30   |     |     |     |   |
| CBAR | 96  | 96  | 19   | 30   |     |     |     |   |
| CBAR | 97  | 97  | 19   | 31   |     |     |     |   |
| CBAR | 98  | 98  | 17   | 31   |     |     |     |   |
| CBAR | 99  | 99  | 15   | 32   |     |     |     |   |
| CBAR | 100 | 100 | 16   | 34   |     |     |     |   |
| CBAR | 101 | 101 | 17   | 33   |     |     |     |   |
| CBAR | 102 | 102 | 18   | 35   |     |     |     |   |
| CBAR | 111 | 111 | 26   | 32   |     |     |     |   |
| CBAR | 112 | 112 | 27   | 32   |     |     |     |   |
| CBAR | 113 | 113 | 27   | 33   |     |     |     |   |
| CBAR | 114 | 114 | 29   | 33   |     |     |     |   |
| CBAR | 115 | 115 | 31   | 33   |     |     |     |   |
| CBAR | 116 | 116 | 32   | 3233 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 185 | 185 | 3233 | 33   | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 117 | 117 | 26   | 34   |     |     |     |   |

|      |     |     |    |    |     |     |     |   |
|------|-----|-----|----|----|-----|-----|-----|---|
| CBAR | 118 | 118 | 28 | 34 |     |     |     |   |
| CBAR | 119 | 119 | 30 | 34 |     |     |     |   |
| CBAR | 120 | 120 | 30 | 35 |     |     |     |   |
| CBAR | 121 | 121 | 31 | 35 |     |     |     |   |
| CBAR | 122 | 122 | 34 | 35 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 123 | 123 | 32 | 36 |     |     |     |   |
| CBAR | 124 | 124 | 33 | 38 |     |     |     |   |
| CBAR | 125 | 125 | 34 | 37 |     |     |     |   |
| CBAR | 126 | 126 | 35 | 39 |     |     |     |   |
| CBAR | 131 | 131 | 48 | 49 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 132 | 132 | 49 | 50 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 133 | 133 | 50 | 51 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 134 | 134 | 51 | 52 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 135 | 135 | 52 | 43 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 136 | 136 | 45 | 53 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 137 | 137 | 53 | 54 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 138 | 138 | 54 | 55 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 139 | 139 | 55 | 56 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 140 | 140 | 56 | 57 | 0.0 | 1.0 | 0.0 | 1 |

ISOLATOR SPRINGS

| ELEM#  | K<br>(N/M) | NODE<br>A | DOF<br>A | NODE<br>B | DOF<br>B |   |
|--------|------------|-----------|----------|-----------|----------|---|
| CELAS2 | 142        | 5.79E3    | 4        | 1         | 42       | 1 |
| CELAS2 | 143        | 5.79E3    | 4        | 2         | 42       | 2 |
| CELAS2 | 144        | 5.79E3    | 4        | 3         | 42       | 3 |
| CELAS2 | 145        | 5.79E3    | 3        | 1         | 46       | 1 |
| CELAS2 | 146        | 5.79E3    | 3        | 2         | 46       | 2 |
| CELAS2 | 147        | 5.79E3    | 3        | 3         | 46       | 3 |
| CELAS2 | 148        | 5.79E3    | 6        | 1         | 47       | 1 |
| CELAS2 | 149        | 5.79E3    | 6        | 2         | 47       | 2 |
| CELAS2 | 150        | 5.79E3    | 6        | 3         | 47       | 3 |

MATERIAL PROPERTY DATA

| MAT# | E   | NU       | RHO |         |
|------|-----|----------|-----|---------|
| MAT1 | 100 | 1.24E+11 | 0.3 | 1720.   |
| MAT1 | 200 | 1.24E+11 | 0.3 | 1720.   |
| MAT1 | 300 | 1.24E+11 | 0.3 | 2579.70 |

LUMPED MASS DATA

| CONM2 | ELEM# | NODE# | MASS | IZZ | +XXXX |
|-------|-------|-------|------|-----|-------|
| +XXXX | IXX   | IYY   |      |     |       |

MIRRORS

|       |         |         |       |         |       |
|-------|---------|---------|-------|---------|-------|
| CONM2 | 1001    | 1001    | 1000. |         | +1001 |
| +1001 | 4083.33 | 5333.33 |       | 9416.67 |       |
| CONM2 | 1002    | 1002    | 800.  |         | +4040 |
| +4040 | 1666.67 | 4266.67 |       | 5933.33 |       |
| CONM2 | 1003    | 1003    | 1200. |         | +1003 |
| +1003 | 4900.   | 6400.   |       | 11300.  |       |
| CONM2 | 1004    | 1004    | 600.  |         | +1004 |

|         |                                                   |              |              |               |       |
|---------|---------------------------------------------------|--------------|--------------|---------------|-------|
| +1004   | 200.                                              | 800.         | 1000.        |               |       |
| \$      |                                                   |              |              |               |       |
| \$      | EQUIPMENT SECTION                                 |              |              |               |       |
| \$      |                                                   |              |              |               |       |
| CONM2   | 544                                               | 44           | 3500.        | +544          |       |
| +544    | 20611.                                            | 10500.       | 28777.       |               |       |
| \$      |                                                   |              |              |               |       |
| \$      | SOLAR PANELS                                      |              |              |               |       |
| \$      |                                                   |              |              |               |       |
| CONM2   | 548                                               | 48           | 81.91        | +548          |       |
| +548    | 270.0                                             |              |              |               |       |
| CONM2   | 550                                               | 50           | 163.82       | +550          |       |
| +550    | 540.0                                             |              |              |               |       |
| CONM2   | 552                                               | 52           | 73.82        | +552          |       |
| +552    | 270.0                                             |              |              |               |       |
| CONM2   | 553                                               | 53           | 73.82        | +553          |       |
| +553    | 270.0                                             |              |              |               |       |
| CONM2   | 557                                               | 57           | 81.91        | +557          |       |
| +555    | 540.0                                             |              |              |               |       |
| CONM2   | 555                                               | 55           | 163.82       | +555          |       |
| +557    | 270.0                                             |              |              |               |       |
| \$      |                                                   |              |              |               |       |
| \$      | ADDITIONAL NON-STRUCTURAL MASS AT MIRROR SUPPORTS |              |              |               |       |
| \$      |                                                   |              |              |               |       |
| CONM2   | 501                                               | 27           | 69.5         |               |       |
| CONM2   | 502                                               | 28           | 6.74         |               |       |
| CONM2   | 503                                               | 29           | 69.5         |               |       |
| CONM2   | 504                                               | 30           | 6.74         |               |       |
| CONM2   | 505                                               | 32           | 6.74         |               |       |
| CONM2   | 506                                               | 33           | 6.74         |               |       |
| CONM2   | 507                                               | 34           | 69.5         |               |       |
| CONM2   | 508                                               | 35           | 69.5         |               |       |
| CONM2   | 509                                               | 9            | 67.4         |               |       |
| CONM2   | 510                                               | 10           | 67.4         |               |       |
| CONM2   | 511                                               | 11           | 67.4         |               |       |
| CONM2   | 512                                               | 12           | 67.4         |               |       |
| \$      |                                                   |              |              |               |       |
| \$      | BEAM SECTION PROPERTIES                           |              |              |               |       |
| \$      |                                                   |              |              |               |       |
| \$PBAR  | PROP#                                             | MAT#         | AREA         | I11           | ***** |
| \$***** | I22                                               | J            |              |               |       |
| \$      |                                                   |              |              |               |       |
| PBAR*   | 1                                                 | 100          | 0.678583E-04 | 0.439721E-07* | 1     |
| *       | 0.439721E-07                                      | 0.879442E-07 |              |               |       |
| PBAR*   | 2                                                 | 100          | 0.678583E-04 | 0.439721E-07* | 2     |
| *       | 0.439721E-07                                      | 0.879442E-07 |              |               |       |
| PBAR*   | 3                                                 | 100          | 0.255098E-03 | 0.621422E-06* | 3     |
| *       | 0.621422E-06                                      | 0.124284E-05 |              |               |       |
| PBAR*   | 4                                                 | 100          | 0.678583E-04 | 0.439721E-07* | 4     |
| *       | 0.439721E-07                                      | 0.879443E-07 |              |               |       |
| PBAR*   | 5                                                 | 100          | 0.343532E-03 | 0.112695E-05* | 5     |
| *       | 0.112695E-05                                      | 0.225391E-05 |              |               |       |
| PBAR*   | 6                                                 | 100          | 0.678583E-04 | 0.439721E-07* | 6     |
| *       | 0.439721E-07                                      | 0.879443E-07 |              |               |       |
| PBAR*   | 7                                                 | 100          | 0.343532E-03 | 0.112695E-05* | 7     |
| *       | 0.112695E-05                                      | 0.225391E-05 |              |               |       |
| PBAR*   | 8                                                 | 100          | 0.104152E-03 | 0.103587E-06* | 8     |

|       |              |              |              |               |    |  |
|-------|--------------|--------------|--------------|---------------|----|--|
| * 8   | 0.103587E-06 | 0.207174E-06 |              |               |    |  |
| PBAR* | 9            | 100          | 0.255098E-03 | 0.621422E-06* | 9  |  |
| * 9   | 0.621422E-06 | 0.124284E-05 |              |               |    |  |
| PBAR* | 10           | 100          | 0.678583E-04 | 0.439721E-07* | 10 |  |
| * 10  | 0.439721E-07 | 0.879442E-07 |              |               |    |  |
| PBAR* | 11           | 100          | 0.678583E-04 | 0.439721E-07* | 11 |  |
| * 11  | 0.439721E-07 | 0.879442E-07 |              |               |    |  |
| PBAR* | 12           | 100          | 0.678583E-04 | 0.439721E-07* | 12 |  |
| * 12  | 0.439721E-07 | 0.879443E-07 |              |               |    |  |
| PBAR* | 13           | 100          | 0.678583E-04 | 0.439721E-07* | 13 |  |
| * 13  | 0.439721E-07 | 0.879443E-07 |              |               |    |  |
| PBAR* | 14           | 100          | 0.678583E-04 | 0.439721E-07* | 14 |  |
| * 14  | 0.439721E-07 | 0.879443E-07 |              |               |    |  |
| PBAR* | 15           | 100          | 0.678583E-04 | 0.439721E-07* | 15 |  |
| * 15  | 0.439721E-07 | 0.879443E-07 |              |               |    |  |
| PBAR* | 16           | 100          | 0.678583E-04 | 0.439721E-07* | 16 |  |
| * 16  | 0.439721E-07 | 0.879443E-07 |              |               |    |  |
| PBAR* | 17           | 100          | 0.678583E-04 | 0.439721E-07* | 17 |  |
| * 17  | 0.439721E-07 | 0.879442E-07 |              |               |    |  |
| PBAR* | 18           | 100          | 0.678583E-04 | 0.439721E-07* | 18 |  |
| * 18  | 0.439721E-07 | 0.879442E-07 |              |               |    |  |
| PBAR* | 19           | 100          | 0.678583E-04 | 0.439721E-07* | 19 |  |
| * 19  | 0.439721E-07 | 0.879442E-07 |              |               |    |  |
| PBAR* | 21           | 100          | 0.678583E-04 | 0.439721E-07* | 21 |  |
| * 21  | 0.439721E-07 | 0.879443E-07 |              |               |    |  |
| PBAR* | 22           | 100          | 0.678583E-04 | 0.439721E-07* | 22 |  |
| * 22  | 0.439721E-07 | 0.879443E-07 |              |               |    |  |
| PBAR* | 24           | 100          | 0.678583E-04 | 0.439721E-07* | 24 |  |
| * 24  | 0.439721E-07 | 0.879442E-07 |              |               |    |  |
| PBAR* | 25           | 100          | 0.678583E-04 | 0.439721E-07* | 25 |  |
| * 25  | 0.439721E-07 | 0.879442E-07 |              |               |    |  |
| PBAR* | 26           | 100          | 0.140494E-03 | 0.188490E-06* | 26 |  |
| * 26  | 0.188490E-06 | 0.376979E-06 |              |               |    |  |
| PBAR* | 27           | 100          | 0.140494E-03 | 0.188490E-06* | 27 |  |
| * 27  | 0.188490E-06 | 0.376979E-06 |              |               |    |  |
| PBAR* | 30           | 100          | 0.678583E-04 | 0.439721E-07* | 30 |  |
| * 30  | 0.439721E-07 | 0.879442E-07 |              |               |    |  |
| PBAR* | 31           | 100          | 0.678583E-04 | 0.439721E-07* | 31 |  |
| * 31  | 0.439721E-07 | 0.879442E-07 |              |               |    |  |
| PBAR* | 32           | 100          | 0.804583E-04 | 0.618177E-07* | 32 |  |
| * 32  | 0.618177E-07 | 0.123635E-06 |              |               |    |  |
| PBAR* | 33           | 100          | 0.678583E-04 | 0.439721E-07* | 33 |  |
| * 33  | 0.439721E-07 | 0.879443E-07 |              |               |    |  |
| PBAR* | 34           | 100          | 0.678583E-04 | 0.439721E-07* | 34 |  |
| * 34  | 0.439721E-07 | 0.879443E-07 |              |               |    |  |
| PBAR* | 35           | 100          | 0.678583E-04 | 0.439721E-07* | 35 |  |
| * 35  | 0.439721E-07 | 0.879443E-07 |              |               |    |  |
| PBAR* | 36           | 100          | 0.678583E-04 | 0.439721E-07* | 36 |  |
| * 36  | 0.439721E-07 | 0.879443E-07 |              |               |    |  |
| PBAR* | 37           | 100          | 0.104152E-03 | 0.103587E-06* | 37 |  |
| * 37  | 0.103587E-06 | 0.207174E-06 |              |               |    |  |
| PBAR* | 38           | 100          | 0.104152E-03 | 0.103587E-06* | 38 |  |
| * 38  | 0.103587E-06 | 0.207174E-06 |              |               |    |  |
| PBAR* | 39           | 100          | 0.804583E-04 | 0.618177E-07* | 39 |  |
| * 39  | 0.618177E-07 | 0.123635E-06 |              |               |    |  |
| PBAR* | 40           | 100          | 0.678583E-04 | 0.439721E-07* | 40 |  |
| * 40  | 0.439721E-07 | 0.879442E-07 |              |               |    |  |

|       |              |              |     |              |               |    |
|-------|--------------|--------------|-----|--------------|---------------|----|
| PBAR* |              | 41           | 100 | 0.678583E-04 | 0.439721E-07* | 41 |
| * 41  | 0.439721E-07 | 0.879442E-07 |     |              |               |    |
| PBAR* |              | 42           | 100 | 0.678583E-04 | 0.439721E-07* | 42 |
| * 42  | 0.439721E-07 | 0.879443E-07 |     |              |               |    |
| PBAR* |              | 43           | 100 | 0.678583E-04 | 0.439721E-07* | 43 |
| * 43  | 0.439721E-07 | 0.879443E-07 |     |              |               |    |
| PBAR* |              | 44           | 100 | 0.104152E-03 | 0.103587E-06* | 44 |
| * 44  | 0.103587E-06 | 0.207174E-06 |     |              |               |    |
| PBAR* |              | 45           | 100 | 0.104152E-03 | 0.103587E-06* | 45 |
| * 45  | 0.103587E-06 | 0.207174E-06 |     |              |               |    |
| PBAR* |              | 46           | 100 | 0.678583E-04 | 0.439721E-07* | 46 |
| * 46  | 0.439721E-07 | 0.879443E-07 |     |              |               |    |
| PBAR* |              | 47           | 100 | 0.678583E-04 | 0.439721E-07* | 47 |
| * 47  | 0.439721E-07 | 0.879443E-07 |     |              |               |    |
| PBAR* |              | 54           | 100 | 0.678583E-04 | 0.439721E-07* | 54 |
| * 54  | 0.439721E-07 | 0.879442E-07 |     |              |               |    |
| PBAR* |              | 55           | 100 | 0.678583E-04 | 0.439721E-07* | 55 |
| * 55  | 0.439721E-07 | 0.879442E-07 |     |              |               |    |
| PBAR* |              | 56           | 100 | 0.678583E-04 | 0.439721E-07* | 56 |
| * 56  | 0.439721E-07 | 0.879442E-07 |     |              |               |    |
| PBAR* |              | 57           | 100 | 0.678583E-04 | 0.439721E-07* | 57 |
| * 57  | 0.439721E-07 | 0.879442E-07 |     |              |               |    |
| PBAR* |              | 58           | 100 | 0.678583E-04 | 0.439721E-07* | 58 |
| * 58  | 0.439721E-07 | 0.879442E-07 |     |              |               |    |
| PBAR* |              | 59           | 100 | 0.678583E-04 | 0.439721E-07* | 59 |
| * 59  | 0.439721E-07 | 0.879442E-07 |     |              |               |    |
| PBAR* |              | 60           | 100 | 0.104152E-03 | 0.103587E-06* | 60 |
| * 60  | 0.103587E-06 | 0.207174E-06 |     |              |               |    |
| PBAR* |              | 61           | 100 | 0.255098E-03 | 0.621422E-06* | 61 |
| * 61  | 0.621422E-06 | 0.124284E-05 |     |              |               |    |
| PBAR* |              | 62           | 300 | 0.0060821    | 0.0015205 *   | 62 |
| * 62  | 0.0015205    | 0.0030410    |     |              |               |    |
| PBAR* |              | 63           | 100 | 0.678583E-04 | 0.439721E-07* | 63 |
| * 63  | 0.439721E-07 | 0.879443E-07 |     |              |               |    |
| PBAR* |              | 64           | 100 | 0.678583E-04 | 0.439721E-07* | 64 |
| * 64  | 0.439721E-07 | 0.879443E-07 |     |              |               |    |
| PBAR* |              | 65           | 100 | 0.678583E-04 | 0.439721E-07* | 65 |
| * 65  | 0.439721E-07 | 0.879443E-07 |     |              |               |    |
| PBAR* |              | 66           | 100 | 0.678583E-04 | 0.439721E-07* | 66 |
| * 66  | 0.439721E-07 | 0.879443E-07 |     |              |               |    |
| PBAR* |              | 67           | 100 | 0.117640E-03 | 0.132154E-06* | 67 |
| * 67  | 0.132154E-06 | 0.264308E-06 |     |              |               |    |
| PBAR* |              | 68           | 100 | 0.678583E-04 | 0.439721E-07* | 68 |
| * 68  | 0.439721E-07 | 0.879442E-07 |     |              |               |    |
| PBAR* |              | 69           | 100 | 0.117640E-03 | 0.132154E-06* | 69 |
| * 69  | 0.132154E-06 | 0.264308E-06 |     |              |               |    |
| PBAR* |              | 70           | 100 | 0.678583E-04 | 0.439721E-07* | 70 |
| * 70  | 0.439721E-07 | 0.879442E-07 |     |              |               |    |
| PBAR* |              | 71           | 100 | 0.678583E-04 | 0.439721E-07* | 71 |
| * 71  | 0.439721E-07 | 0.879442E-07 |     |              |               |    |
| PBAR* |              | 72           | 100 | 0.104152E-03 | 0.103587E-06* | 72 |
| * 72  | 0.103587E-06 | 0.207174E-06 |     |              |               |    |
| PBAR* |              | 73           | 100 | 0.678583E-04 | 0.439721E-07* | 73 |
| * 73  | 0.439721E-07 | 0.879442E-07 |     |              |               |    |
| PBAR* |              | 74           | 100 | 0.104152E-03 | 0.103587E-06* | 74 |
| * 74  | 0.103587E-06 | 0.207174E-06 |     |              |               |    |
| PBAR* |              | 75           | 100 | 0.255098E-03 | 0.621422E-06* | 75 |

|       |              |              |              |               |     |  |
|-------|--------------|--------------|--------------|---------------|-----|--|
| * 75  | 0.621422E-06 | 0.124284E-05 |              |               |     |  |
| PBAR* | 76           | 100          | 0.259503E-03 | 0.643065E-06* | 76  |  |
| * 76  | 0.643065E-06 | 0.128613E-05 |              |               |     |  |
| PBAR* | 77           | 100          | 0.424114E-03 | 0.171765E-05* | 77  |  |
| * 77  | 0.171765E-05 | 0.343531E-05 |              |               |     |  |
| PBAR* | 78           | 100          | 0.259503E-03 | 0.643065E-06* | 78  |  |
| * 78  | 0.643065E-06 | 0.128613E-05 |              |               |     |  |
| PBAR* | 79           | 100          | 0.833904E-03 | 0.664055E-05* | 79  |  |
| * 79  | 0.664055E-05 | 0.132811E-04 |              |               |     |  |
| PBAR* | 80           | 100          | 0.259503E-03 | 0.643065E-06* | 80  |  |
| * 80  | 0.643065E-06 | 0.128613E-05 |              |               |     |  |
| PBAR* | 81           | 100          | 0.259503E-03 | 0.643065E-06* | 81  |  |
| * 81  | 0.643065E-06 | 0.128613E-05 |              |               |     |  |
| PBAR* | 82           | 100          | 0.833904E-03 | 0.664055E-05* | 82  |  |
| * 82  | 0.664055E-05 | 0.132811E-04 |              |               |     |  |
| PBAR* | 83           | 100          | 0.259503E-03 | 0.643065E-06* | 83  |  |
| * 83  | 0.643065E-06 | 0.128613E-05 |              |               |     |  |
| PBAR* | 84           | 100          | 0.424114E-03 | 0.171765E-05* | 84  |  |
| * 84  | 0.171765E-05 | 0.343531E-05 |              |               |     |  |
| PBAR* | 85           | 100          | 0.259503E-03 | 0.643065E-06* | 85  |  |
| * 85  | 0.643065E-06 | 0.128613E-05 |              |               |     |  |
| PBAR* | 86           | 100          | 0.398135E-03 | 0.151367E-05* | 86  |  |
| * 86  | 0.151367E-05 | 0.302735E-05 |              |               |     |  |
| PBAR* | 87           | 100          | 0.259503E-03 | 0.643065E-06* | 87  |  |
| * 87  | 0.643065E-06 | 0.128613E-05 |              |               |     |  |
| PBAR* | 88           | 100          | 0.325124E-03 | 0.100942E-05* | 88  |  |
| * 88  | 0.100942E-05 | 0.201883E-05 |              |               |     |  |
| PBAR* | 89           | 100          | 0.259503E-03 | 0.643065E-06* | 89  |  |
| * 89  | 0.643065E-06 | 0.128613E-05 |              |               |     |  |
| PBAR* | 90           | 100          | 0.566323E-03 | 0.306267E-05* | 90  |  |
| * 90  | 0.306267E-05 | 0.612533E-05 |              |               |     |  |
| PBAR* | 91           | 100          | 0.259503E-03 | 0.643065E-06* | 91  |  |
| * 91  | 0.643065E-06 | 0.128613E-05 |              |               |     |  |
| PBAR* | 92           | 100          | 0.348640E-03 | 0.116072E-05* | 92  |  |
| * 92  | 0.116072E-05 | 0.232143E-05 |              |               |     |  |
| PBAR* | 93           | 100          | 0.259503E-03 | 0.643065E-06* | 93  |  |
| * 93  | 0.643065E-06 | 0.128613E-05 |              |               |     |  |
| PBAR* | 94           | 100          | 0.566323E-03 | 0.306267E-05* | 94  |  |
| * 94  | 0.306267E-05 | 0.612533E-05 |              |               |     |  |
| PBAR* | 95           | 100          | 0.259503E-03 | 0.643065E-06* | 95  |  |
| * 95  | 0.643065E-06 | 0.128613E-05 |              |               |     |  |
| PBAR* | 96           | 100          | 0.325124E-03 | 0.100942E-05* | 96  |  |
| * 96  | 0.100942E-05 | 0.201883E-05 |              |               |     |  |
| PBAR* | 97           | 100          | 0.259503E-03 | 0.643065E-06* | 97  |  |
| * 97  | 0.643065E-06 | 0.128613E-05 |              |               |     |  |
| PBAR* | 98           | 100          | 0.348640E-03 | 0.116072E-05* | 98  |  |
| * 98  | 0.116072E-05 | 0.232143E-05 |              |               |     |  |
| PBAR* | 99           | 100          | 0.470559E-03 | 0.211446E-05* | 99  |  |
| * 99  | 0.211446E-05 | 0.422892E-05 |              |               |     |  |
| PBAR* | 100          | 100          | 0.470559E-03 | 0.211446E-05* | 100 |  |
| * 100 | 0.211446E-05 | 0.422892E-05 |              |               |     |  |
| PBAR* | 101          | 100          | 0.470559E-03 | 0.211446E-05* | 101 |  |
| * 101 | 0.211446E-05 | 0.422892E-05 |              |               |     |  |
| PBAR* | 102          | 100          | 0.470559E-03 | 0.211446E-05* | 102 |  |
| * 102 | 0.211446E-05 | 0.422892E-05 |              |               |     |  |
| PBAR* | 111          | 100          | 0.259503E-03 | 0.643065E-06* | 111 |  |
| * 111 | 0.643065E-06 | 0.128613E-05 |              |               |     |  |

|       |              |              |              |               |     |
|-------|--------------|--------------|--------------|---------------|-----|
| PBAR* | 112          | 100          | 0.678583E-04 | 0.439721E-07* | 112 |
| * 112 | 0.439721E-07 | 0.879443E-07 |              |               |     |
| PBAR* | 113          | 100          | 0.325124E-03 | 0.100942E-05* | 113 |
| * 113 | 0.100942E-05 | 0.201883E-05 |              |               |     |
| PBAR* | 114          | 100          | 0.678583E-04 | 0.439721E-07* | 114 |
| * 114 | 0.439721E-07 | 0.879443E-07 |              |               |     |
| PBAR* | 115          | 100          | 0.259503E-03 | 0.643065E-06* | 115 |
| * 115 | 0.643065E-06 | 0.128613E-05 |              |               |     |
| PBAR* | 116          | 300          | 0.0060821    | 0.0015205 *   | 116 |
| * 116 | 0.0015205    | 0.0030410    |              |               |     |
| PBAR* | 117          | 100          | 0.259503E-03 | 0.643065E-06* | 117 |
| * 117 | 0.643065E-06 | 0.128613E-05 |              |               |     |
| PBAR* | 118          | 100          | 0.678583E-04 | 0.439721E-07* | 118 |
| * 118 | 0.439721E-07 | 0.879443E-07 |              |               |     |
| PBAR* | 119          | 100          | 0.325124E-03 | 0.100942E-05* | 119 |
| * 119 | 0.100942E-05 | 0.201883E-05 |              |               |     |
| PBAR* | 120          | 100          | 0.678583E-04 | 0.439721E-07* | 120 |
| * 120 | 0.439721E-07 | 0.879443E-07 |              |               |     |
| PBAR* | 121          | 100          | 0.259503E-03 | 0.643065E-06* | 121 |
| * 121 | 0.643065E-06 | 0.128613E-05 |              |               |     |
| PBAR* | 122          | 100          | 0.104152E-03 | 0.103587E-06* | 122 |
| * 122 | 0.103587E-06 | 0.207174E-06 |              |               |     |
| PBAR* | 123          | 100          | 0.716806E-04 | 0.490653E-07* | 123 |
| * 123 | 0.490653E-07 | 0.981305E-07 |              |               |     |
| PBAR* | 124          | 100          | 0.716806E-04 | 0.490653E-07* | 124 |
| * 124 | 0.490653E-07 | 0.981305E-07 |              |               |     |
| PBAR* | 125          | 100          | 0.716806E-04 | 0.490653E-07* | 125 |
| * 125 | 0.490653E-07 | 0.981305E-07 |              |               |     |
| PBAR* | 126          | 100          | 0.716806E-04 | 0.490653E-07* | 126 |
| * 126 | 0.490653E-07 | 0.981305E-07 |              |               |     |
| PBAR* | 127          | 100          | 0.678583E-04 | 0.439721E-07* | 127 |
| * 127 | 0.439721E-07 | 0.879443E-07 |              |               |     |
| PBAR* | 128          | 100          | 0.678583E-04 | 0.439721E-07* | 128 |
| * 128 | 0.439721E-07 | 0.879443E-07 |              |               |     |
| PBAR* | 129          | 100          | 0.678583E-04 | 0.439721E-07* | 129 |
| * 129 | 0.439721E-07 | 0.879443E-07 |              |               |     |
| PBAR* | 130          | 100          | 0.678583E-04 | 0.439721E-07* | 130 |
| * 130 | 0.439721E-07 | 0.879443E-07 |              |               |     |
| PBAR* | 131          | 100          | 6.107256E-04 | 3.561752E-06* | 131 |
| * 131 | 3.561752E-06 | 7.123504E-06 |              |               |     |
| PBAR* | 132          | 100          | 6.107256E-04 | 3.561752E-06* | 132 |
| * 132 | 3.561752E-06 | 7.123504E-06 |              |               |     |
| PBAR* | 133          | 100          | 6.107256E-04 | 3.561752E-06* | 133 |
| * 133 | 3.561752E-06 | 7.123504E-06 |              |               |     |
| PBAR* | 134          | 100          | 6.107256E-04 | 3.561752E-06* | 134 |
| * 134 | 3.561752E-06 | 7.123504E-06 |              |               |     |
| PBAR* | 135          | 100          | 6.107256E-04 | 3.561752E-06* | 135 |
| * 135 | 3.561752E-06 | 7.123504E-06 |              |               |     |
| PBAR* | 136          | 100          | 6.107256E-04 | 3.561752E-06* | 136 |
| * 136 | 3.561752E-06 | 7.123504E-06 |              |               |     |
| PBAR* | 137          | 100          | 6.107256E-04 | 3.561752E-06* | 137 |
| * 137 | 3.561752E-06 | 7.123504E-06 |              |               |     |
| PBAR* | 138          | 100          | 6.107256E-04 | 3.561752E-06* | 138 |
| * 138 | 3.561752E-06 | 7.123504E-06 |              |               |     |
| PBAR* | 139          | 100          | 6.107256E-04 | 3.561752E-06* | 139 |
| * 139 | 3.561752E-06 | 7.123504E-06 |              |               |     |
| PBAR* | 140          | 100          | 6.107256E-04 | 3.561752E-06* | 140 |

|       |              |              |              |               |     |
|-------|--------------|--------------|--------------|---------------|-----|
| * 140 | 3.561752E-06 | 7.123504E-06 |              |               |     |
| PBAR* | 181          | 100          | 0.398135E-03 | 0.151367E-05* | 181 |
| * 181 | 0.151367E-05 | 0.302735E-05 |              |               |     |
| PBAR* | 182          | 100          | 0.343532E-03 | 0.112695E-05* | 182 |
| * 182 | 0.112695E-05 | 0.225391E-05 |              |               |     |
| PBAR* | 183          | 100          | 0.343532E-03 | 0.112695E-05* | 183 |
| * 183 | 0.112695E-05 | 0.225391E-05 |              |               |     |
| PBAR* | 184          | 300          | 0.0060821    | 0.0015205 *   | 184 |
| * 184 | 0.0015205    | 0.0030410    |              |               |     |
| PBAR* | 185          | 300          | 0.0060821    | 0.0015205 *   | 185 |
| * 185 | 0.0015205    | 0.0030410    |              |               |     |
| PBAR* | 186          | 100          | 0.343532E-03 | 0.112695E-05* | 186 |
| * 186 | 0.112695E-05 | 0.225391E-05 |              |               |     |
| PBAR* | 187          | 100          | 0.343532E-03 | 0.112695E-05* | 187 |
| * 187 | 0.112695E-05 | 0.225391E-05 |              |               |     |
| PBAR* | 201          | 100          | 0.104620E-03 | 0.104520E-06* | 201 |
| * 201 | 0.104520E-06 | 0.209040E-06 |              |               |     |
| PBAR* | 202          | 100          | 0.923628E-04 | 0.814640E-07* | 202 |
| * 202 | 0.814640E-07 | 0.162928E-06 |              |               |     |
| PBAR* | 203          | 100          | 0.678583E-04 | 0.439721E-07* | 203 |
| * 203 | 0.439721E-07 | 0.879442E-07 |              |               |     |
| PBAR* | 204          | 100          | 0.923628E-04 | 0.814640E-07* | 204 |
| * 204 | 0.814640E-07 | 0.162928E-06 |              |               |     |
| PBAR* | 205          | 100          | 0.678583E-04 | 0.439721E-07* | 205 |
| * 205 | 0.439721E-07 | 0.879442E-07 |              |               |     |
| PBAR* | 207          | 100          | 0.140494E-03 | 0.188490E-06* | 207 |
| * 207 | 0.188490E-06 | 0.376979E-06 |              |               |     |
| PBAR* | 232          | 100          | 0.678583E-04 | 0.439721E-07* | 232 |
| * 232 | 0.439721E-07 | 0.879442E-07 |              |               |     |
| PBAR* | 239100       |              | 0.678583E-04 | 0.439721E-07* | 239 |
| * 239 | 0.439721E-07 | 0.879442E-07 |              |               |     |

\$  
\$ MULTI-POINT CONSTRAINT EQUATION FOR X-AXIS LOS ERROR (NODE 100 DOF 1)  
\$

|          |      |     |                |                        |
|----------|------|-----|----------------|------------------------|
| MPC*     | 100  | 100 | 1              | -1.0*1000000           |
| *1000000 | 34   | 2   | -0.01855287570 | *1000001               |
| *1000001 |      | 34  | 3              | -0.14285714286*1000002 |
| *1000002 | 35   | 2   | -0.0185528757  | *1000003               |
| *1000003 |      | 35  | 3              | -0.14285714286*1000004 |
| *1000004 | 2830 | 3   | 0.28571428572  | *1000005               |
| *1000005 |      | 30  | 3              | 0.0                    |
| *1000006 | 27   | 2   | 0.08065681999  | *1000007               |
| *1000007 |      | 27  | 3              | -0.35489000795*1000008 |
| *1000008 | 29   | 2   | 0.08065681999  | *1000009               |
| *1000009 |      | 29  | 3              | -0.35489000795*1000010 |
| *1000010 | 3233 | 3   | 0.70978001590  | *1000011               |
| *1000011 |      | 33  | 3              | 0.0                    |
| *1000012 | 1002 | 4   | -3.48423005566 | *1000013               |
| *1000013 |      | 11  | 2              | -0.06210394429*1000014 |
| *1000014 | 9    | 2   | -0.06210394429 |                        |

\$  
\$ MULTI-POINT CONSTRAINT EQUATION FOR Y-AXIS LOS ERROR (NODE 100 DOF 2)  
\$

|          |     |     |                |                        |
|----------|-----|-----|----------------|------------------------|
| MPC*     | 100 | 100 | 2              | -1.0*2000000           |
| *2000000 | 34  | 1   | -0.03710575139 | *2000001               |
| *2000001 |     | 34  | 2              | -0.04638218924*2000002 |
| *2000002 | 34  | 3   | -0.25000000000 | *2000003               |

|          |      |    |                |                 |          |
|----------|------|----|----------------|-----------------|----------|
| *2000003 |      | 35 | 2              | 0.04638218924*  | 2000004  |
| *2000004 | 35   | 3  | 0.2500000000   |                 | *2000005 |
| *2000005 |      | 27 | 1              | 0.16131363998*  | 2000006  |
| *2000006 | 27   | 2  | -0.06049261499 |                 | *2000007 |
| *2000007 |      | 27 | 3              | -0.62105751391* | 2000008  |
| *2000008 | 29   | 2  | 0.06049261499  |                 | *2000009 |
| *2000009 |      | 29 | 3              | 0.62105751391*  | 2000010  |
| *2000010 | 1002 | 5  | 3.48423005566  |                 | *2000011 |
| *2000011 |      | 11 | 1              | -0.12420788859* | 2000012  |
| *2000012 | 11   | 2  | -0.07762993037 |                 | *2000013 |
| *2000013 |      | 9  | 2              | 0.07762993037*  | 2000014  |
| *2000014 |      |    |                |                 |          |

\$

\$ MULTI-POINT CONSTRAINT EQUATION FOR DEFOCUS (NODE 100 DOF 3)

\$

|          |      |      |                |                 |          |
|----------|------|------|----------------|-----------------|----------|
| MPC*     | 100  | 100  | 3              | -1.0*           | 3000000  |
| *3000000 | 34   | 3    | -0.01912393776 |                 | *3000001 |
| *3000001 |      | 35   | 3              | -0.01912393776* | 3000002  |
| *3000002 | 2830 | 3    | 0.12749291836  |                 | *3000003 |
| *3000003 |      | 30   | 3              | 0.0             | *3000004 |
| *3000004 | 27   | 3    | 0.77803217347  |                 | *3000005 |
| *3000005 |      | 29   | 3              | 0.77803217347*  | 3000006  |
| *3000006 | 3233 | 3    | -0.46681930408 |                 | *3000007 |
| *3000007 |      | 1002 | 3              | -0.17849008571* | 3000008  |
| *3000008 | 9    | 3    | 0.50000000000  |                 | *3000009 |
| *3000009 |      | 11   | 3              | 0.50000000000*  | 3000010  |
| *3000010 | 40   | 3    | -2.00000000000 |                 |          |

\$

\$ RIGID BODY SUPPORT

\$

SUPORT,44,123456

ENDDATA

\*\*\*\*\* END OF MEMBER REV03

659 RECORDS \*\*\*\*\*

APPENDIX C

```

ID DRAPER,MODEL2
SOL 3
CHKPNT YES
TIME 10
CEND
TITLE =      ACROSS MODEL #2
SUBTITLE = MODIFIED MODEL - REVISION 4
LABEL = VCOSS STIFFNESS MODEL
MPC = 100
METHOD = 600
DISP = ALL
ESE =ALL
BEGIN BULK
PARAM,USETPRT,1
PARAM  GRDPNT  0
EIGR   600     GIV
+10     MASS
200
+10
$
$   KINEMATIC MOUNT:  TERTIARY MIRROR
$
RBE1,1003,27,123,29,23,3233,3,,+RB31
+RB31,UM,1003,123456
$
$   KINEMATIC MOUNT:  PRIMARY MIRROR
$
RBE1,1001,34,123,35,23,2830,3,,+RB11
+RB11,UM,1001,123456
$
$   KINEMATIC MOUNT:  FOCAL PLANE
$
RBE1,1004,11,123,9,23,40,3,,+RB41
+RB41,UM,1004,123456
$
$   KINEMATIC MOUNT:  SECONDARY MIRROR
$
RBE1,1002,910,123,1112,23,40,3,,+RB21
+RB21,UM,1002,123456
$
$   RIGID EQUIPMENT SECTION
$
RBE2   141      44      123456  42      43      45      46      47
$
$   NODE POINT LOCATIONS
$   NODE#      X (M)  Y (M)  Z (M)
$
GRID    1      -7.0   0.0   0.0
GRID    2      -4.0   5.0   0.0
GRID    3      -4.0  -5.0   0.0
GRID    4       0.0   5.0   0.0
GRID    5       4.0   5.0   0.0
GRID    6       4.0  -5.0   0.0
GRID    7       7.0   0.0   0.0
GRID    8      -7.0   0.0   2.0
GRID    9      -4.0   5.0   2.0
GRID   1004     0.0   4.0   2.0
GRID    10     -4.0  -5.0   2.0
GRID    910     -4.0  -2.5   2.0

```

|      |      |        |        |      |
|------|------|--------|--------|------|
| GRID | 1112 | 4.0    | -2.5   | 2.0  |
| GRID | 11   | 4.0    | 5.0    | 2.0  |
| GRID | 12   | 4.0    | -5.0   | 2.0  |
| GRID | 13   | 7.0    | 0.0    | 2.0  |
| GRID | 14   | -6.0   | 0.0    | 12.  |
| GRID | 15   | -4.0   | 4.0    | 12.  |
| GRID | 16   | -4.0   | -4.0   | 12.  |
| GRID | 17   | 4.0    | 4.0    | 12.  |
| GRID | 18   | 4.0    | -4.0   | 12.  |
| GRID | 19   | 6.0    | 0.0    | 12.0 |
| GRID | 26   | -5.0   | 0.0    | 22.0 |
| GRID | 27   | -4.0   | 3.0    | 22.0 |
| GRID | 28   | -4.0   | -3.0   | 22.0 |
| GRID | 2830 | 0.0    | -3.0   | 22.0 |
| GRID | 1001 | 0.0    | -6.5   | 22.0 |
| GRID | 29   | 4.0    | 3.0    | 22.0 |
| GRID | 30   | 4.0    | -3.0   | 22.0 |
| GRID | 31   | 5.0    | 0.0    | 22.0 |
| GRID | 32   | -4.0   | 10.0   | 22.0 |
| GRID | 3233 | 0.0    | 10.0   | 22.0 |
| GRID | 1003 | 0.0    | 6.5    | 22.0 |
| GRID | 33   | 4.0    | 10.0   | 22.0 |
| GRID | 34   | -4.0   | -10.0  | 22.0 |
| GRID | 35   | 4.0    | -10.0  | 22.0 |
| GRID | 36   | -4.0   | 3.0    | 24.0 |
| GRID | 37   | -4.0   | -3.0   | 24.0 |
| GRID | 38   | 4.0    | 3.0    | 24.0 |
| GRID | 39   | 4.0    | -3.0   | 24.0 |
| GRID | 40   | 0.0    | 2.5    | 2.0  |
| GRID | 1002 | 0.0    | 0.0    | 2.0  |
| GRID | 42   | 0.0    | 5.0    | -0.3 |
| GRID | 43   | -2.0   | 0.0    | -1.3 |
| GRID | 44   | 0.0    | -1.667 | -1.3 |
| GRID | 45   | 2.0    | 0.0    | -1.3 |
| GRID | 46   | -4.0   | -5.0   | -0.3 |
| GRID | 47   | 4.0    | -5.0   | -0.3 |
| GRID | 48   | -26.0  | 0.0    | -1.3 |
| GRID | 49   | -21.00 | 0.0    | -1.3 |
| GRID | 50   | -16.0  | 0.0    | -1.3 |
| GRID | 51   | -11.0  | 0.0    | -1.3 |
| GRID | 52   | -6.0   | 0.0    | -1.3 |
| GRID | 53   | 6.0    | 0.0    | -1.3 |
| GRID | 54   | 11.0   | 0.0    | -1.3 |
| GRID | 55   | 16.0   | 0.0    | -1.3 |
| GRID | 56   | 21.00  | 0.0    | -1.3 |
| GRID | 57   | 26.0   | 0.0    | -1.3 |
| GRID | 100  | 0.0    | 0.0    | 0.0  |

456

```

$
$ ELEMENT CONNECTION DATA
$
$      ELEM#   PROP#   NODE   NODE   LOCAL AXIS ORIENTATION VECTOR
$              A      B
$
BAROR
CBAR      1      1      1      2      1.0      0.0      0.0      1
CBAR      2      2      1      3
CBAR      3      3      2      3

```

|      |     |     |      |      |     |     |     |   |
|------|-----|-----|------|------|-----|-----|-----|---|
| CSAR | 4   | 4   | 2    | 4    | 0.0 | 1.0 | 0.0 | 1 |
| CSAR | 5   | 5   | 3    | 4    |     |     |     |   |
| CSAR | 6   | 6   | 4    | 5    | 0.0 | 1.0 | 0.0 | 1 |
| CSAR | 7   | 7   | 4    | 6    |     |     |     |   |
| CSAR | 8   | 8   | 3    | 6    | 0.0 | 1.0 | 0.0 | 1 |
| CSAR | 9   | 9   | 5    | 6    |     |     |     |   |
| CSAR | 10  | 10  | 5    | 7    |     |     |     |   |
| CSAR | 11  | 11  | 6    | 7    |     |     |     |   |
| CSAR | 12  | 12  | 1    | 8    |     |     |     |   |
| CSAR | 13  | 13  | 2    | 9    |     |     |     |   |
| CSAR | 14  | 14  | 3    | 10   |     |     |     |   |
| CSAR | 15  | 15  | 5    | 11   |     |     |     |   |
| CSAR | 16  | 16  | 6    | 12   |     |     |     |   |
| CSAR | 17  | 17  | 7    | 13   |     |     |     |   |
| CSAR | 18  | 18  | 3    | 8    |     |     |     |   |
| CSAR | 19  | 19  | 2    | 8    |     |     |     |   |
| CSAR | 21  | 21  | 4    | 9    |     |     |     |   |
| CSAR | 22  | 22  | 4    | 11   |     |     |     |   |
| CSAR | 24  | 24  | 5    | 13   |     |     |     |   |
| CSAR | 25  | 25  | 6    | 13   |     |     |     |   |
| CSAR | 26  | 26  | 1112 | 3    |     |     |     |   |
| CSAR | 27  | 27  | 6    | 10   |     |     |     |   |
| CSAR | 30  | 30  | 8    | 9    |     |     |     |   |
| CSAR | 31  | 31  | 8    | 10   |     |     |     |   |
| CSAR | 32  | 32  | 9    | 910  |     |     |     |   |
| CSAR | 232 | 232 | 910  | 10   |     |     |     |   |
| CSAR | 33  | 33  | 9    | 40   |     |     |     |   |
| CSAR | 34  | 34  | 910  | 40   |     |     |     |   |
| CSAR | 35  | 35  | 11   | 40   |     |     |     |   |
| CSAR | 36  | 36  | 1112 | 40   |     |     |     |   |
| CSAR | 37  | 37  | 9    | 11   | 0.0 | 1.0 | 0.0 | 1 |
| CSAR | 38  | 38  | 10   | 12   | 0.0 | 1.0 | 0.0 | 1 |
| CSAR | 39  | 39  | 11   | 1112 |     |     |     |   |
| CSAR | 239 | 239 | 1112 | 12   |     |     |     |   |
| CSAR | 201 | 201 | 910  | 1112 | 0.0 | 1.0 | 0.0 | 1 |
| CSAR | 202 | 202 | 2    | 910  |     |     |     |   |
| CSAR | 203 | 203 | 3    | 910  |     |     |     |   |
| CSAR | 204 | 204 | 5    | 1112 |     |     |     |   |
| CSAR | 205 | 205 | 6    | 1112 |     |     |     |   |
| CSAR | 207 | 207 | 12   | 910  |     |     |     |   |
| CSAR | 40  | 40  | 11   | 13   |     |     |     |   |
| CSAR | 41  | 41  | 12   | 13   |     |     |     |   |
| CSAR | 42  | 42  | 14   | 15   |     |     |     |   |
| CSAR | 43  | 43  | 14   | 16   |     |     |     |   |
| CSAR | 44  | 44  | 16   | 15   |     |     |     |   |
| CSAR | 45  | 45  | 17   | 18   |     |     |     |   |
| CSAR | 46  | 46  | 17   | 19   |     |     |     |   |
| CSAR | 47  | 47  | 18   | 19   |     |     |     |   |
| CSAR | 54  | 54  | 26   | 27   |     |     |     |   |
| CSAR | 55  | 55  | 26   | 28   |     |     |     |   |
| CSAR | 56  | 56  | 27   | 28   |     |     |     |   |
| CSAR | 57  | 57  | 29   | 30   |     |     |     |   |
| CSAR | 58  | 58  | 29   | 31   |     |     |     |   |
| CSAR | 59  | 59  | 30   | 31   |     |     |     |   |
| CSAR | 60  | 60  | 27   | 29   | 0.0 | 1.0 | 0.0 | 1 |
| CSAR | 61  | 61  | 27   | 30   |     |     |     |   |
| CSAR | 62  | 62  | 28   | 2830 | 0.0 | 1.0 | 0.0 | 1 |

|      |     |     |      |      |     |     |     |   |
|------|-----|-----|------|------|-----|-----|-----|---|
| CBAR | 184 | 184 | 2830 | 30   | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 63  | 63  | 27   | 36   |     |     |     |   |
| CBAR | 64  | 64  | 28   | 37   |     |     |     |   |
| CBAR | 65  | 65  | 30   | 39   |     |     |     |   |
| CBAR | 66  | 66  | 29   | 38   |     |     |     |   |
| CBAR | 67  | 67  | 29   | 36   |     |     |     |   |
| CBAR | 68  | 68  | 27   | 37   |     |     |     |   |
| CBAR | 69  | 69  | 28   | 39   |     |     |     |   |
| CBAR | 70  | 70  | 30   | 38   |     |     |     |   |
| CBAR | 71  | 71  | 36   | 37   |     |     |     |   |
| CBAR | 72  | 72  | 37   | 39   | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 73  | 73  | 39   | 38   |     |     |     |   |
| CBAR | 74  | 74  | 36   | 38   | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 75  | 75  | 37   | 38   |     |     |     |   |
| CBAR | 127 | 127 | 26   | 37   |     |     |     |   |
| CBAR | 128 | 128 | 26   | 36   |     |     |     |   |
| CBAR | 129 | 129 | 31   | 39   |     |     |     |   |
| CBAR | 130 | 130 | 31   | 38   |     |     |     |   |
| CBAR | 76  | 76  | 8    | 14   |     |     |     |   |
| CBAR | 77  | 77  | 10   | 14   |     |     |     |   |
| CBAR | 78  | 78  | 10   | 16   |     |     |     |   |
| CBAR | 79  | 79  | 16   | 9    |     |     |     |   |
| CBAR | 80  | 80  | 9    | 15   |     |     |     |   |
| CBAR | 181 | 181 | 8    | 15   |     |     |     |   |
| CBAR | 182 | 182 | 6    | 40   |     |     |     |   |
| CBAR | 183 | 183 | 2    | 40   |     |     |     |   |
| CBAR | 186 | 186 | 3    | 40   |     |     |     |   |
| CBAR | 187 | 187 | 5    | 40   |     |     |     |   |
| CBAR | 81  | 81  | 11   | 17   |     |     |     |   |
| CBAR | 82  | 82  | 11   | 18   |     |     |     |   |
| CBAR | 83  | 83  | 12   | 18   |     |     |     |   |
| CBAR | 84  | 84  | 12   | 19   |     |     |     |   |
| CBAR | 85  | 85  | 13   | 19   |     |     |     |   |
| CBAR | 86  | 86  | 13   | 17   |     |     |     |   |
| CBAR | 87  | 87  | 14   | 26   |     |     |     |   |
| CBAR | 88  | 88  | 14   | 28   |     |     |     |   |
| CBAR | 89  | 89  | 16   | 28   |     |     |     |   |
| CBAR | 90  | 90  | 16   | 27   |     |     |     |   |
| CBAR | 91  | 91  | 15   | 27   |     |     |     |   |
| CBAR | 92  | 92  | 15   | 26   |     |     |     |   |
| CBAR | 93  | 93  | 17   | 29   |     |     |     |   |
| CBAR | 94  | 94  | 18   | 29   |     |     |     |   |
| CBAR | 95  | 95  | 18   | 30   |     |     |     |   |
| CBAR | 96  | 96  | 19   | 30   |     |     |     |   |
| CBAR | 97  | 97  | 19   | 31   |     |     |     |   |
| CBAR | 98  | 98  | 17   | 31   |     |     |     |   |
| CBAR | 99  | 99  | 15   | 32   |     |     |     |   |
| CBAR | 100 | 100 | 16   | 34   |     |     |     |   |
| CBAR | 101 | 101 | 17   | 33   |     |     |     |   |
| CBAR | 102 | 102 | 18   | 35   |     |     |     |   |
| CBAR | 111 | 111 | 26   | 32   |     |     |     |   |
| CBAR | 112 | 112 | 27   | 32   |     |     |     |   |
| CBAR | 113 | 113 | 27   | 33   |     |     |     |   |
| CBAR | 114 | 114 | 29   | 33   |     |     |     |   |
| CBAR | 115 | 115 | 31   | 33   |     |     |     |   |
| CBAR | 116 | 116 | 32   | 3233 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 185 | 185 | 3233 | 33   | 0.0 | 1.0 | 0.0 | 1 |

|      |     |     |    |    |     |     |     |   |
|------|-----|-----|----|----|-----|-----|-----|---|
| CBAR | 117 | 117 | 26 | 34 |     |     |     |   |
| CBAR | 118 | 118 | 28 | 34 |     |     |     |   |
| CBAR | 119 | 119 | 30 | 34 |     |     |     |   |
| CBAR | 120 | 120 | 30 | 35 |     |     |     |   |
| CBAR | 121 | 121 | 31 | 35 |     |     |     |   |
| CBAR | 122 | 122 | 34 | 35 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 123 | 123 | 32 | 36 |     |     |     |   |
| CBAR | 124 | 124 | 33 | 38 |     |     |     |   |
| CBAR | 125 | 125 | 34 | 37 |     |     |     |   |
| CBAR | 126 | 126 | 35 | 39 |     |     |     |   |
| CBAR | 131 | 131 | 48 | 49 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 132 | 132 | 49 | 50 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 133 | 133 | 50 | 51 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 134 | 134 | 51 | 52 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 135 | 135 | 52 | 43 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 136 | 136 | 45 | 53 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 137 | 137 | 53 | 54 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 138 | 138 | 54 | 55 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 139 | 139 | 55 | 56 | 0.0 | 1.0 | 0.0 | 1 |
| CBAR | 140 | 140 | 56 | 57 | 0.0 | 1.0 | 0.0 | 1 |

\$  
\$ ISOLATOR SPRINGS

| \$ | ELEM#  | K<br>(N/M) | NODE<br>A | DOF<br>A | NODE<br>B | DOF<br>B |   |
|----|--------|------------|-----------|----------|-----------|----------|---|
| \$ | CELAS2 | 142        | 5.79E3    | 4        | 1         | 42       | 1 |
| \$ | CELAS2 | 143        | 5.79E3    | 4        | 2         | 42       | 2 |
| \$ | CELAS2 | 144        | 5.79E3    | 4        | 3         | 42       | 3 |
| \$ | CELAS2 | 145        | 5.79E3    | 3        | 1         | 46       | 1 |
| \$ | CELAS2 | 146        | 5.79E3    | 3        | 2         | 46       | 2 |
| \$ | CELAS2 | 147        | 5.79E3    | 3        | 3         | 46       | 3 |
| \$ | CELAS2 | 148        | 5.79E3    | 6        | 1         | 47       | 1 |
| \$ | CELAS2 | 149        | 5.79E3    | 6        | 2         | 47       | 2 |
| \$ | CELAS2 | 150        | 5.79E3    | 6        | 3         | 47       | 3 |

\$  
\$ MATERIAL PROPERTY DATA

| \$ | MAT# | E   | NU       | RHO |       |
|----|------|-----|----------|-----|-------|
| \$ | MAT1 | 100 | 1.24E+11 | 0.3 | 1720. |
| \$ | MAT1 | 200 | 1.24E+11 | 0.3 | 1720. |
| \$ | MAT1 | 300 | 1.24E+11 | 0.3 |       |

\$  
\$ LUMPED MASS DATA

| \$ | CONM2   | ELEM#   | NODE#   | MASS  | IZZ     |       |
|----|---------|---------|---------|-------|---------|-------|
| \$ | +XXXX   | IXX     | IYY     |       |         | +XXXX |
| \$ | MIRRORS |         |         |       |         |       |
| \$ | CONM2   | 1001    | 1001    | 1000. |         | +1001 |
| \$ | +1001   | 4083.33 | 5333.33 |       | 9416.67 |       |
| \$ | CONM2   | 1002    | 1002    | 800.  |         | +4040 |
| \$ | +4040   | 1666.67 | 4266.67 |       | 5933.33 |       |

|            |                                                   |              |              |               |          |
|------------|---------------------------------------------------|--------------|--------------|---------------|----------|
| CONM2      | 1003                                              | 1003         | 1200.        |               | +1003    |
| +1003      | 4900.                                             |              | 6400.        | 11300.        |          |
| \$         |                                                   |              |              |               |          |
| CONM2      | 1004                                              | 1004         | 600.         |               | +1004    |
| +1004      | 200.                                              |              | 800.         | 1000.         |          |
| \$         |                                                   |              |              |               |          |
| \$         | EQUIPMENT SECTION                                 |              |              |               |          |
| \$         |                                                   |              |              |               |          |
| CONM2      | 544                                               | 44           | 3500.        |               | +544     |
| +544       | 20611.                                            |              | 10500.       | 28777.        |          |
| \$         |                                                   |              |              |               |          |
| \$         | SOLAR PANELS                                      |              |              |               |          |
| \$         |                                                   |              |              |               |          |
| CONM2      | 548                                               | 48           | 81.91        |               | +548     |
| +548       | 270.0                                             |              |              |               |          |
| CONM2      | 550                                               | 50           | 163.82       |               | +550     |
| +550       | 540.0                                             |              |              |               |          |
| CONM2      | 552                                               | 52           | 73.82        |               | +552     |
| +552       | 270.0                                             |              |              |               |          |
| CONM2      | 553                                               | 53           | 73.82        |               | +553     |
| +553       | 270.0                                             |              |              |               |          |
| CONM2      | 557                                               | 57           | 81.91        |               | +557     |
| +555       | 540.0                                             |              |              |               |          |
| CONM2      | 555                                               | 55           | 163.82       |               | +555     |
| +557       | 270.0                                             |              |              |               |          |
| \$         |                                                   |              |              |               |          |
| \$         | ADDITIONAL NON-STRUCTURAL MASS AT MIRROR SUPPORTS |              |              |               |          |
| \$         |                                                   |              |              |               |          |
| CONM2      | 501                                               | 27           | 69.5         |               |          |
| CONM2      | 502                                               | 28           | 6.74         |               |          |
| CONM2      | 503                                               | 29           | 69.5         |               |          |
| CONM2      | 504                                               | 30           | 6.74         |               |          |
| CONM2      | 505                                               | 32           | 6.74         |               |          |
| CONM2      | 506                                               | 33           | 6.74         |               |          |
| CONM2      | 507                                               | 34           | 69.5         |               |          |
| CONM2      | 508                                               | 35           | 69.5         |               |          |
| CONM2      | 509                                               | 9            | 67.4         |               |          |
| CONM2      | 510                                               | 10           | 67.4         |               |          |
| CONM2      | 511                                               | 11           | 67.4         |               |          |
| CONM2      | 512                                               | 12           | 67.4         |               |          |
| \$         |                                                   |              |              |               |          |
| \$         | BEAM SECTION PROPERTIES                           |              |              |               |          |
| \$         |                                                   |              |              |               |          |
| \$FBAR     | PROP#                                             | MAT#         | AREA         | I11           | *XXXXXXX |
| \$*XXXXXXX | I22                                               | J            |              |               |          |
| \$         |                                                   |              |              |               |          |
| PBAR*      |                                                   | 1100         | 0.275119E-02 | 0.301163E-04* | 1        |
| *          | 1                                                 | 0.301163E-04 | 0.602325E-04 |               |          |
| PBAR*      |                                                   | 2100         | 0.275119E-02 | 0.301163E-04* | 2        |
| *          | 2                                                 | 0.301163E-04 | 0.602325E-04 |               |          |
| PBAR*      |                                                   | 3100         | 0.471826E-02 | 0.885774E-04* | 3        |
| *          | 3                                                 | 0.885774E-04 | 0.177155E-03 |               |          |
| PBAR*      |                                                   | 4100         | 0.188730E-02 | 0.141724E-04* | 4        |
| *          | 4                                                 | 0.141724E-04 | 0.283447E-04 |               |          |
| PBAR*      |                                                   | 5100         | 0.503172E-02 | 0.102750E-03* | 5        |
| *          | 5                                                 | 0.102750E-03 | 0.205499E-03 |               |          |
| PBAR*      |                                                   | 6100         | 0.188730E-02 | 0.141724E-04* | 6        |

|       |    |              |              |              |               |    |
|-------|----|--------------|--------------|--------------|---------------|----|
| *     | 6  | 0.141724E-04 | 0.283447E-04 | 0.508172E-02 | 0.102750E-03* | 7  |
| PBAR* |    | 7100         |              |              |               |    |
| *     | 7  | 0.102750E-03 | 0.205499E-03 | 0.377461E-02 | 0.566895E-04* | 8  |
| PBAR* |    | 8100         |              |              |               |    |
| *     | 8  | 0.566895E-04 | 0.113379E-03 | 0.471826E-02 | 0.885774E-04* | 9  |
| PBAR* |    | 9100         |              |              |               |    |
| *     | 9  | 0.885774E-04 | 0.177155E-03 | 0.275119E-02 | 0.301163E-04* | 10 |
| PBAR* |    | 10100        |              |              |               |    |
| *     | 10 | 0.301163E-04 | 0.602325E-04 | 0.275119E-02 | 0.301163E-04* | 11 |
| PBAR* |    | 11100        |              |              |               |    |
| *     | 11 | 0.301163E-04 | 0.602325E-04 | 0.943651E-03 | 0.354309E-05* | 12 |
| PBAR* |    | 12100        |              |              |               |    |
| *     | 12 | 0.354309E-05 | 0.708619E-05 | 0.943651E-03 | 0.354309E-05* | 13 |
| PBAR* |    | 13100        |              |              |               |    |
| *     | 13 | 0.354309E-05 | 0.708619E-05 | 0.943651E-03 | 0.354309E-05* | 14 |
| PBAR* |    | 14100        |              |              |               |    |
| *     | 14 | 0.354309E-05 | 0.708619E-05 | 0.943651E-03 | 0.354309E-05* | 15 |
| PBAR* |    | 15100        |              |              |               |    |
| *     | 15 | 0.354309E-05 | 0.708619E-05 | 0.943651E-03 | 0.354309E-05* | 16 |
| PBAR* |    | 16100        |              |              |               |    |
| *     | 16 | 0.354309E-05 | 0.708619E-05 | 0.943651E-03 | 0.354309E-05* | 17 |
| PBAR* |    | 17100        |              |              |               |    |
| *     | 17 | 0.354309E-05 | 0.708619E-05 | 0.290853E-02 | 0.336594E-04* | 18 |
| PBAR* |    | 18100        |              |              |               |    |
| *     | 18 | 0.336594E-04 | 0.673188E-04 | 0.290853E-02 | 0.336594E-04* | 19 |
| PBAR* |    | 19100        |              |              |               |    |
| *     | 19 | 0.336594E-04 | 0.673188E-04 | 0.211007E-02 | 0.177155E-04* | 21 |
| PBAR* |    | 21100        |              |              |               |    |
| *     | 21 | 0.177155E-04 | 0.354309E-04 | 0.211007E-02 | 0.177155E-04* | 22 |
| PBAR* |    | 22100        |              |              |               |    |
| *     | 22 | 0.177155E-04 | 0.354309E-04 | 0.290853E-02 | 0.336594E-04* | 24 |
| PBAR* |    | 24100        |              |              |               |    |
| *     | 24 | 0.336594E-04 | 0.673188E-04 | 0.290853E-02 | 0.336594E-04* | 25 |
| PBAR* |    | 25100        |              |              |               |    |
| *     | 25 | 0.336594E-04 | 0.673188E-04 | 0.406565E-02 | 0.657686E-04* | 26 |
| PBAR* |    | 26100        |              |              |               |    |
| *     | 26 | 0.657686E-04 | 0.131537E-03 | 0.389078E-02 | 0.602326E-04* | 27 |
| PBAR* |    | 27100        |              |              |               |    |
| *     | 27 | 0.602326E-04 | 0.120465E-03 | 0.275119E-02 | 0.301163E-04* | 30 |
| PBAR* |    | 30100        |              |              |               |    |
| *     | 30 | 0.301163E-04 | 0.602325E-04 | 0.275119E-02 | 0.301163E-04* | 31 |
| PBAR* |    | 31100        |              |              |               |    |
| *     | 31 | 0.301163E-04 | 0.602325E-04 | 0.353869E-02 | 0.498248E-04* | 32 |
| PBAR* |    | 32100        |              |              |               |    |
| *     | 32 | 0.498248E-04 | 0.996495E-04 | 0.222560E-02 | 0.197085E-04* | 33 |
| PBAR* |    | 33100        |              |              |               |    |
| *     | 33 | 0.197085E-04 | 0.394169E-04 | 0.302116E-02 | 0.363167E-04* | 34 |
| PBAR* |    | 34100        |              |              |               |    |
| *     | 34 | 0.363167E-04 | 0.726334E-04 | 0.222560E-02 | 0.197085E-04* | 35 |
| PBAR* |    | 35100        |              |              |               |    |
| *     | 35 | 0.197085E-04 | 0.394169E-04 | 0.302116E-02 | 0.363167E-04* | 36 |
| PBAR* |    | 36100        |              |              |               |    |
| *     | 36 | 0.363167E-04 | 0.726334E-04 | 0.377461E-02 | 0.566895E-04* | 37 |
| PBAR* |    | 37100        |              |              |               |    |
| *     | 37 | 0.566895E-04 | 0.113379E-03 | 0.377461E-02 | 0.566895E-04* | 38 |
| PBAR* |    | 38100        |              |              |               |    |
| *     | 38 | 0.566895E-04 | 0.113379E-03 |              |               |    |

|       |              |       |              |              |               |    |
|-------|--------------|-------|--------------|--------------|---------------|----|
| PBAR* |              | 39100 |              | 0.353869E-02 | 0.498248E-04* | 39 |
| * 39  | 0.498248E-04 | 40100 | 0.996495E-04 |              |               |    |
| PBAR* |              | 40100 |              | 0.275119E-02 | 0.301163E-04* | 40 |
| * 40  | 0.301163E-04 | 41100 | 0.602325E-04 |              |               |    |
| PBAR* |              | 41100 |              | 0.275119E-02 | 0.301163E-04* | 41 |
| * 41  | 0.301163E-04 | 42100 | 0.602325E-04 |              |               |    |
| PBAR* |              | 42100 |              | 0.211007E-02 | 0.177155E-04* | 42 |
| * 42  | 0.177155E-04 | 43100 | 0.354309E-04 |              |               |    |
| PBAR* |              | 43100 |              | 0.211007E-02 | 0.177155E-04* | 43 |
| * 43  | 0.177155E-04 | 44100 | 0.354309E-04 |              |               |    |
| PBAR* |              | 44100 |              | 0.377461E-02 | 0.566895E-04* | 44 |
| * 44  | 0.566895E-04 | 45100 | 0.113379E-03 |              |               |    |
| PBAR* |              | 45100 |              | 0.377461E-02 | 0.566895E-04* | 45 |
| * 45  | 0.566895E-04 | 46100 | 0.113379E-03 |              |               |    |
| PBAR* |              | 46100 |              | 0.211007E-02 | 0.177155E-04* | 46 |
| * 46  | 0.177155E-04 | 47100 | 0.354309E-04 |              |               |    |
| PBAR* |              | 47100 |              | 0.211007E-02 | 0.177155E-04* | 47 |
| * 47  | 0.177155E-04 | 54100 | 0.354309E-04 |              |               |    |
| PBAR* |              | 54100 |              | 0.149204E-02 | 0.885772E-05* | 54 |
| * 54  | 0.885772E-05 | 55100 | 0.177154E-04 |              |               |    |
| PBAR* |              | 55100 |              | 0.149204E-02 | 0.885772E-05* | 55 |
| * 55  | 0.885772E-05 | 56100 | 0.177154E-04 |              |               |    |
| PBAR* |              | 56100 |              | 0.283095E-02 | 0.318878E-04* | 56 |
| * 56  | 0.318878E-04 | 57100 | 0.637757E-04 |              |               |    |
| PBAR* |              | 57100 |              | 0.283095E-02 | 0.318878E-04* | 57 |
| * 57  | 0.318878E-04 | 58100 | 0.637757E-04 |              |               |    |
| PBAR* |              | 58100 |              | 0.149204E-02 | 0.835772E-05* | 58 |
| * 58  | 0.885772E-05 | 59100 | 0.177154E-04 |              |               |    |
| PBAR* |              | 59100 |              | 0.149204E-02 | 0.885772E-05* | 59 |
| * 59  | 0.885772E-05 | 60100 | 0.177154E-04 |              |               |    |
| PBAR* |              | 60100 |              | 0.377461E-02 | 0.566895E-04* | 60 |
| * 60  | 0.566895E-04 | 61100 | 0.113379E-03 |              |               |    |
| PBAR* |              | 61100 |              | 0.471826E-02 | 0.885774E-04* | 61 |
| * 61  | 0.885774E-04 | 63100 | 0.177155E-03 |              |               |    |
| PBAR* |              | 63100 |              | 0.943651E-03 | 0.354309E-05* | 63 |
| * 63  | 0.354309E-05 | 64100 | 0.708619E-05 |              |               |    |
| PBAR* |              | 64100 |              | 0.943651E-03 | 0.354309E-05* | 64 |
| * 64  | 0.354309E-05 | 65100 | 0.708619E-05 |              |               |    |
| PBAR* |              | 65100 |              | 0.943651E-03 | 0.354309E-05* | 65 |
| * 65  | 0.354309E-05 | 66100 | 0.708619E-05 |              |               |    |
| PBAR* |              | 66100 |              | 0.943651E-03 | 0.354309E-05* | 66 |
| * 66  | 0.354309E-05 | 67100 | 0.708619E-05 |              |               |    |
| PBAR* |              | 67100 |              | 0.389078E-02 | 0.602326E-04* | 67 |
| * 67  | 0.602326E-04 | 68100 | 0.120465E-03 |              |               |    |
| PBAR* |              | 68100 |              | 0.298409E-02 | 0.354310E-04* | 68 |
| * 68  | 0.354310E-04 | 69100 | 0.708619E-04 |              |               |    |
| PBAR* |              | 69100 |              | 0.389078E-02 | 0.602326E-04* | 69 |
| * 69  | 0.602326E-04 | 70100 | 0.120465E-03 |              |               |    |
| PBAR* |              | 70100 |              | 0.298409E-02 | 0.354310E-04* | 70 |
| * 70  | 0.354310E-04 | 71100 | 0.708619E-04 |              |               |    |
| PBAR* |              | 71100 |              | 0.283095E-02 | 0.318878E-04* | 71 |
| * 71  | 0.318878E-04 | 72100 | 0.637757E-04 |              |               |    |
| PBAR* |              | 72100 |              | 0.377461E-02 | 0.566895E-04* | 72 |
| * 72  | 0.566895E-04 | 73100 | 0.113379E-03 |              |               |    |
| PBAR* |              | 73100 |              | 0.283095E-02 | 0.318878E-04* | 73 |
| * 73  | 0.318878E-04 | 74100 | 0.637757E-04 |              |               |    |
| PBAR* |              | 74100 |              | 0.377461E-02 | 0.566895E-04* | 74 |

|       |              |              |              |               |     |
|-------|--------------|--------------|--------------|---------------|-----|
| * 74  | 0.566895E-04 | 0.113379E-03 | 0.471826E-02 | 0.885774E-04* | 75  |
| PBAR* | 75100        |              |              |               |     |
| * 75  | 0.885774E-04 | 0.177155E-03 | 0.474179E-02 | 0.894631E-04* | 76  |
| PBAR* | 76100        |              |              |               |     |
| * 76  | 0.894631E-04 | 0.178926E-03 | 0.535890E-02 | 0.114265E-03* | 77  |
| PBAR* | 77100        |              |              |               |     |
| * 77  | 0.114265E-03 | 0.228529E-03 | 0.474179E-02 | 0.894631E-04* | 78  |
| PBAR* | 78100        |              |              |               |     |
| * 78  | 0.894631E-04 | 0.178926E-03 | 0.634776E-02 | 0.160325E-03* | 79  |
| PBAR* | 79100        |              |              |               |     |
| * 79  | 0.160325E-03 | 0.320650E-03 | 0.474179E-02 | 0.894631E-04* | 80  |
| PBAR* | 80100        |              |              |               |     |
| * 80  | 0.894631E-04 | 0.178926E-03 | 0.474179E-02 | 0.894631E-04* | 81  |
| PBAR* | 81100        |              |              |               |     |
| * 81  | 0.894631E-04 | 0.178926E-03 | 0.634776E-02 | 0.160325E-03* | 82  |
| PBAR* | 82100        |              |              |               |     |
| * 82  | 0.160325E-03 | 0.320650E-03 | 0.474179E-02 | 0.894631E-04* | 83  |
| PBAR* | 83100        |              |              |               |     |
| * 83  | 0.894631E-04 | 0.178926E-03 | 0.535890E-02 | 0.114265E-03* | 84  |
| PBAR* | 84100        |              |              |               |     |
| * 84  | 0.114265E-03 | 0.228529E-03 | 0.474179E-02 | 0.894631E-04* | 85  |
| PBAR* | 85100        |              |              |               |     |
| * 85  | 0.894631E-04 | 0.178926E-03 | 0.527517E-02 | 0.110722E-03* | 86  |
| PBAR* | 86100        |              |              |               |     |
| * 86  | 0.110722E-03 | 0.221444E-03 | 0.474179E-02 | 0.894631E-04* | 87  |
| PBAR* | 87100        |              |              |               |     |
| * 87  | 0.894631E-04 | 0.178926E-03 | 0.501557E-02 | 0.100092E-03* | 88  |
| PBAR* | 88100        |              |              |               |     |
| * 88  | 0.100092E-03 | 0.200185E-03 | 0.474179E-02 | 0.894631E-04* | 89  |
| PBAR* | 89100        |              |              |               |     |
| * 89  | 0.894631E-04 | 0.178926E-03 | 0.575936E-02 | 0.131980E-03* | 90  |
| PBAR* | 90100        |              |              |               |     |
| * 90  | 0.131980E-03 | 0.263960E-03 | 0.474179E-02 | 0.894631E-04* | 91  |
| PBAR* | 91100        |              |              |               |     |
| * 91  | 0.894631E-04 | 0.178926E-03 | 0.510358E-02 | 0.103636E-03* | 92  |
| PBAR* | 92100        |              |              |               |     |
| * 92  | 0.103636E-03 | 0.207271E-03 | 0.474179E-02 | 0.894631E-04* | 93  |
| PBAR* | 93100        |              |              |               |     |
| * 93  | 0.894631E-04 | 0.178926E-03 | 0.575936E-02 | 0.131980E-03* | 94  |
| PBAR* | 94100        |              |              |               |     |
| * 94  | 0.131980E-03 | 0.263960E-03 | 0.474179E-02 | 0.894631E-04* | 95  |
| PBAR* | 95100        |              |              |               |     |
| * 95  | 0.894631E-04 | 0.178926E-03 | 0.501557E-02 | 0.100092E-03* | 96  |
| PBAR* | 96100        |              |              |               |     |
| * 96  | 0.100092E-03 | 0.200185E-03 | 0.474179E-02 | 0.894631E-04* | 97  |
| PBAR* | 97100        |              |              |               |     |
| * 97  | 0.894631E-04 | 0.178926E-03 | 0.510358E-02 | 0.103636E-03* | 98  |
| PBAR* | 98100        |              |              |               |     |
| * 98  | 0.103636E-03 | 0.207271E-03 | 0.550238E-02 | 0.120465E-03* | 99  |
| PBAR* | 99100        |              |              |               |     |
| * 99  | 0.120465E-03 | 0.240930E-03 | 0.550238E-02 | 0.120465E-03* | 100 |
| PBAR* | 100100       |              |              |               |     |
| * 100 | 0.120465E-03 | 0.240930E-03 | 0.550238E-02 | 0.120465E-03* | 101 |
| PBAR* | 101100       |              |              |               |     |
| * 101 | 0.120465E-03 | 0.240930E-03 | 0.550238E-02 | 0.120465E-03* | 102 |
| PBAR* | 102100       |              |              |               |     |
| * 102 | 0.120465E-03 | 0.240930E-03 |              |               |     |

|       |              |              |              |               |     |
|-------|--------------|--------------|--------------|---------------|-----|
| PBAR* | 111100       |              | 0.474179E-02 | 0.894631E-04* | 111 |
| * 111 | 0.894631E-04 | 0.178926E-03 |              |               |     |
| PBAR* | 112100       |              | 0.330278E-02 | 0.434029E-04* | 112 |
| * 112 | 0.434029E-04 | 0.868059E-04 |              |               |     |
| PBAR* | 113100       |              | 0.501557E-02 | 0.100092E-03* | 113 |
| * 113 | 0.100092E-03 | 0.200185E-03 |              |               |     |
| PBAR* | 114100       |              | 0.330278E-02 | 0.434029E-04* | 114 |
| * 114 | 0.434029E-04 | 0.868059E-04 |              |               |     |
| PBAR* | 115100       |              | 0.474179E-02 | 0.894631E-04* | 115 |
| * 115 | 0.894631E-04 | 0.178926E-03 |              |               |     |
| PBAR* | 117100       |              | 0.474179E-02 | 0.894631E-04* | 117 |
| * 117 | 0.894631E-04 | 0.178926E-03 |              |               |     |
| PBAR* | 118100       |              | 0.330278E-02 | 0.434029E-04* | 118 |
| * 118 | 0.434029E-04 | 0.868059E-04 |              |               |     |
| PBAR* | 119100       |              | 0.501557E-02 | 0.100092E-03* | 119 |
| * 119 | 0.100092E-03 | 0.200185E-03 |              |               |     |
| PBAR* | 120100       |              | 0.330278E-02 | 0.434029E-04* | 120 |
| * 120 | 0.434029E-04 | 0.868059E-04 |              |               |     |
| PBAR* | 121100       |              | 0.474179E-02 | 0.894631E-04* | 121 |
| * 121 | 0.894631E-04 | 0.178926E-03 |              |               |     |
| PBAR* | 122100       |              | 0.377461E-02 | 0.566895E-04* | 122 |
| * 122 | 0.566895E-04 | 0.113379E-03 |              |               |     |
| PBAR* | 123100       |              | 0.343494E-02 | 0.469460E-04* | 123 |
| * 123 | 0.469460E-04 | 0.938920E-04 |              |               |     |
| PBAR* | 124100       |              | 0.343494E-02 | 0.469460E-04* | 124 |
| * 124 | 0.469460E-04 | 0.938920E-04 |              |               |     |
| PBAR* | 125100       |              | 0.343494E-02 | 0.469460E-04* | 125 |
| * 125 | 0.469460E-04 | 0.938920E-04 |              |               |     |
| PBAR* | 126100       |              | 0.343494E-02 | 0.469460E-04* | 126 |
| * 126 | 0.469460E-04 | 0.938920E-04 |              |               |     |
| PBAR* | 127100       |              | 0.176541E-02 | 0.124008E-04* | 127 |
| * 127 | 0.124008E-04 | 0.248016E-04 |              |               |     |
| PBAR* | 128100       |              | 0.176541E-02 | 0.124008E-04* | 128 |
| * 128 | 0.124008E-04 | 0.248016E-04 |              |               |     |
| PBAR* | 129100       |              | 0.176541E-02 | 0.124008E-04* | 129 |
| * 129 | 0.124008E-04 | 0.248016E-04 |              |               |     |
| PBAR* | 130100       |              | 0.176541E-02 | 0.124008E-04* | 130 |
| * 130 | 0.124008E-04 | 0.248016E-04 |              |               |     |
| PBAR* | 181100       |              | 0.527517E-02 | 0.110722E-03* | 181 |
| * 181 | 0.110722E-03 | 0.221444E-03 |              |               |     |
| PBAR* | 182100       |              | 0.412004E-02 | 0.675402E-04* | 182 |
| * 182 | 0.675402E-04 | 0.135080E-03 |              |               |     |
| PBAR* | 183100       |              | 0.241739E-02 | 0.232515E-04* | 183 |
| * 183 | 0.232515E-04 | 0.465031E-04 |              |               |     |
| PBAR* | 186100       |              | 0.412004E-02 | 0.675402E-04* | 186 |
| * 186 | 0.675402E-04 | 0.135080E-03 |              |               |     |
| PBAR* | 187100       |              | 0.241739E-02 | 0.232515E-04* | 187 |
| * 187 | 0.232515E-04 | 0.465031E-04 |              |               |     |
| PBAR* | 201100       |              | 0.377461E-02 | 0.566895E-04* | 201 |
| * 201 | 0.566895E-04 | 0.113379E-03 |              |               |     |
| PBAR* | 202100       |              | 0.366236E-02 | 0.533679E-04* | 202 |
| * 202 | 0.533679E-04 | 0.106736E-03 |              |               |     |
| PBAR* | 203100       |              | 0.151058E-02 | 0.907917E-05* | 203 |
| * 203 | 0.907917E-05 | 0.181583E-04 |              |               |     |
| PBAR* | 204100       |              | 0.366236E-02 | 0.533679E-04* | 204 |
| * 204 | 0.533679E-04 | 0.106736E-03 |              |               |     |
| PBAR* | 205100       |              | 0.151058E-02 | 0.907917E-05* | 205 |

|       |              |              |              |               |     |
|-------|--------------|--------------|--------------|---------------|-----|
| * 205 | 0.907917E-05 | 0.181583E-04 | 0.395462E-02 | 0.622256E-04* | 207 |
| PBAR* | 207100       |              |              |               |     |
| * 207 | 0.622256E-04 | 0.124451E-03 | 0.117957E-02 | 0.553610E-05* | 232 |
| PBAR* | 232100       |              |              |               |     |
| * 232 | 0.553610E-05 | 0.110722E-04 | 0.117957E-02 | 0.553610E-05* | 239 |
| PBAR* | 239100       |              |              |               |     |
| * 239 | 0.553610E-05 | 0.110722E-04 | 0.0060821    | 0.0015205 *   | 62  |
| PBAR* | 62300        |              | 15.69        |               |     |
| * 62  | 0.0015205    | 0.0030410    | 0.0060821    | 0.0015205 *   | 116 |
| PBAR* | 116300       |              | 15.69        |               |     |
| * 116 | 0.0015205    | 0.0030410    | 0.0060821    | 0.0015205 *   | 184 |
| PBAR* | 184300       |              | 15.69        |               |     |
| * 184 | 0.0015205    | 0.0030410    | 0.0060821    | 0.0015205 *   | 185 |
| PBAR* | 185300       |              | 15.69        |               |     |
| * 185 | 0.0015205    | 0.0030410    | 1.257E-3     | 3.142E-4      | 131 |
| PBAR* | 131200       |              | 3.82         |               |     |
| * 131 | 3.142E-4     | 6.285E-4     | 1.257E-3     | 3.142E-4*     | 132 |
| PBAR* | 132200       |              | 3.82         |               |     |
| * 132 | 3.142E-4     | 6.285E-4     | 1.257E-3     | 3.142E-4*     | 133 |
| PBAR* | 133200       |              | 3.82         |               |     |
| * 133 | 3.142E-4     | 6.285E-4     | 1.257E-3     | 3.142E-4*     | 134 |
| PBAR* | 134200       |              | 3.82         |               |     |
| * 134 | 3.142E-4     | 6.285E-4     | 1.257E-3     | 3.142E-4*     | 135 |
| PBAR* | 135200       |              | 3.82         |               |     |
| * 135 | 3.142E-4     | 6.285E-4     | 1.257E-3     | 3.142E-4*     | 136 |
| PBAR* | 136200       |              | 3.82         |               |     |
| * 136 | 3.142E-4     | 6.285E-4     | 1.257E-3     | 3.142E-4*     | 137 |
| PBAR* | 137200       |              | 3.82         |               |     |
| * 137 | 3.142E-4     | 6.285E-4     | 1.257E-3     | 3.142E-4*     | 138 |
| PBAR* | 138200       |              | 3.82         |               |     |
| * 138 | 3.142E-4     | 6.285E-4     | 1.257E-3     | 3.142E-4*     | 139 |
| PBAR* | 139200       |              | 3.82         |               |     |
| * 139 | 3.142E-4     | 6.285E-4     | 1.257E-3     | 3.142E-4*     | 140 |
| PBAR* | 140200       |              | 3.82         |               |     |
| * 140 | 3.142E-4     | 6.285E-4     |              |               |     |

MULTI-POINT CONSTRAINT FOR X-AXIS LOS ERROR (NODE 100 DOF 1)

|          |      |     |                |                        |
|----------|------|-----|----------------|------------------------|
| MPC*     | 100  | 100 | 1              | -1.0*1000000           |
| *1000000 | 34   | 2   | -0.01855287570 | *1000001               |
| *1000001 |      | 34  | 3              | -0.14285714286*1000002 |
| *1000002 | 35   | 2   | -0.0185528757  | *1000003               |
| *1000003 |      | 35  | 3              | -0.14285714286*1000004 |
| *1000004 | 2830 | 3   | 0.28571428572  | *1000005               |
| *1000005 |      | 30  | 3              | 0.0                    |
| *1000006 | 27   | 2   | 0.08065681999  | *1000007               |
| *1000007 |      | 27  | 3              | -0.35489000795*1000008 |
| *1000008 | 29   | 2   | 0.08065681999  | *1000009               |
| *1000009 |      | 29  | 3              | -0.35489000795*1000010 |
| *1000010 | 3233 | 3   | 0.70978001590  | *1000011               |
| *1000011 |      | 33  | 3              | 0.0                    |
| *1000012 | 1002 | 4   | -3.48423005566 | *1000013               |
| *1000013 |      | 11  | 2              | -0.06210394429*1000014 |
| *1000014 | 9    | 2   | -0.06210394429 |                        |

\$ MULTI-POINT CONSTRAINT FOR Y-AXIS LOS ERROR (NODE 100 DOF 2)

\$

| MPC*     | 100  |    | 100            | 2                      | -1.0*2000000 |
|----------|------|----|----------------|------------------------|--------------|
| *2000000 | 34   | 1  | -0.03710575139 | *2000001               |              |
| *2000001 |      | 34 | 2              | -0.04638218924*2000002 |              |
| *2000002 | 34   | 3  | -0.25000000000 | *2000003               |              |
| *2000003 |      | 35 | 2              | 0.04638218924*2000004  |              |
| *2000004 | 35   | 3  | 0.25000000000  | *2000005               |              |
| *2000005 |      | 27 | 1              | 0.16131363998*2000006  |              |
| *2000006 | 27   | 2  | -0.06049261499 | *2000007               |              |
| *2000007 |      | 27 | 3              | -0.62105751391*2000008 |              |
| *2000008 | 29   | 2  | 0.06049261499  | *2000009               |              |
| *2000009 |      | 29 | 3              | 0.62105751391*2000010  |              |
| *2000010 | 1002 | 5  | 3.48423005566  | *2000011               |              |
| *2000011 |      | 11 | 1              | -0.12420788859*2000012 |              |
| *2000012 | 11   | 2  | -0.07762993037 | *2000013               |              |
| *2000013 |      | 9  | 2              | 0.07762993037*2000014  |              |
| *2000014 |      |    |                |                        |              |

\$ MULTI-POINT CONSTRAINT EQUATION FOR DEFOCUS (NODE 100 DOF 3)

\$

| MPC*     | 100  |      | 100            | 3                      | -1.0*3000000 |
|----------|------|------|----------------|------------------------|--------------|
| *3000000 | 34   | 3    | -0.01912393776 | *3000001               |              |
| *3000001 |      | 35   | 3              | -0.01912393776*3000002 |              |
| *3000002 | 2830 | 3    | 0.12749291836  | *3000003               |              |
| *3000003 |      | 30   | 3              | 0.0                    |              |
| *3000004 | 27   | 3    | 0.77803217347  | *3000005               |              |
| *3000005 |      | 29   | 3              | 0.77803217347*3000006  |              |
| *3000006 | 3233 | 3    | -0.46681930408 | *3000007               |              |
| *3000007 |      | 1002 | 3              | -0.17849008371*3000008 |              |
| *3000008 | 9    | 3    | 0.50000000000  | *3000009               |              |
| *3000009 |      | 11   | 3              | 0.50000000000*3000010  |              |
| *3000010 | 40   | 3    | -2.00000000000 |                        |              |

\$ RIGID BODY SUPPORT

\$

SUPPORT,44,123456

ENDDATA

\*\*\*\*\* END OF MEMBER REV07

665 RECORDS \*\*\*\*\*

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| <p>Mr. Carman<br/>RADC/OCSE</p>                                                                                          | 5                   |
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