Particle Damping in Vibrating Cantilever Beams

Test Equipment Data Package

Completed February 17, 2004

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Address: 2101 Burton Dr Apt 1055
Austin, TX 78741-4103-55
<table>
<thead>
<tr>
<th>Rev.</th>
<th>Date</th>
<th>Process Owner Alternates</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic</td>
<td>February 2004</td>
<td>William D. Tandy Timothy C. Allison Robert Ross John Hatlelid</td>
<td>Initial Release</td>
</tr>
</tbody>
</table>


KC-135 Quick Reference Data Sheet

Principal Investigator: William D. Tandy, Jr.

Contact Information: risus@wireweb.net, (512) 203-7930

Experiment Title: Particle Damping in Vibrating Cantilever Beams

Flight Date(s): April 1-10, 2004

Overall Assembly Weight (lbs.): 280

Assembly Dimensions (L x W x H): 4 X 2 X 4 ft

Equipment Orientation Requests: Cabinet against fuselage wall, facing inward

Proposed Floor Mounting Strategy (Bolts/Studs or Straps): Bolts/Studs

Gas Cylinder Requests (Type and Quantity): N/A

Overboard Vent Requests (Yes or No): No

Power Requirement (Voltage and Current Required): 110 VAC

Free Float Experiment (Yes or No): No

Flyer Names for Each Proposed Flight Day: April 7/9 - Tim Allison and Bill Tandy
April 8/10 - Rob Ross and John Hatlelid

Camera Pole and/or Video Support: 1 pole with universal camera mount.
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1. Flight Manifest

If possible, the team would prefer to fly on April 7-8. Table 1 describes the team members who will be flying:

Table 1: Flight manifest table.

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Preferred Flight Date</th>
<th>Flown on KC-135 Previously?</th>
</tr>
</thead>
<tbody>
<tr>
<td>William Tandy</td>
<td>Flight Crew</td>
<td>April 7/9</td>
<td>No</td>
</tr>
<tr>
<td>Robert Ross</td>
<td>Flight Crew</td>
<td>April 8/10</td>
<td>No</td>
</tr>
<tr>
<td>John Hatlelid</td>
<td>Flight Crew</td>
<td>April 8/10</td>
<td>No</td>
</tr>
<tr>
<td>Timothy Allison</td>
<td>Flight Crew</td>
<td>April 7/9</td>
<td>No</td>
</tr>
<tr>
<td>Christopher Gilmore</td>
<td>Alternate Flyer</td>
<td>As needed</td>
<td>No</td>
</tr>
</tbody>
</table>

2. Experiment Background

This experiment is being flown on the KC-135 to determine the effect of a microgravity environment on particle damping. Particle damping offers a possible solution to unwanted vibrations in aerospace structures, but the concept has never been implemented because it has not been tested in a microgravity environment. If the results of our experiment are promising, we anticipate that future experiments will also be conducted to determine the feasibility of particle damping in aerospace structures.

3. Experiment Description

The team will research the effects of particle damping in one g and zero g environments and compare the results. The transient and steady-state responses of 24 harmonically excited cantilever beam samples will be measured with the National Instruments’ LabView software package. The samples will be constructed from hollow aluminum rods and be filled to specific fill ratios with various particles. As each rod is excited with a vibrator, data from accelerometers placed on the sample and on a reference
point will be acquired with LabView for post-experimental analysis. Our goal is to isolate the effects of particle mass, diameter, fill ratio, and gravity on the vibrating system. We anticipate that the absence of a gravitational field will allow particles to collide for greater period of time, dissipating more energy and damping out the beam vibrations more quickly than in a one g environment.

4. Equipment Description

4.1 Equipment

Figures 1 through 3 show the experimental setup and the hardware components and parts are summarized in Table 2. The experiment will be attached to the aluminum floor spacers in the KC-135 test cabin; it will not free float. Table 3 is a list of components that are not pictured in Figures 1 through 3.

Table 2: Hardware components and parts

<table>
<thead>
<tr>
<th>Component Name</th>
<th>Size</th>
<th>Location</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Bolts</td>
<td>8-32X 1.25 in</td>
<td>5’ L-clamps to base</td>
<td>0.1 oz</td>
</tr>
<tr>
<td>2 Bolts</td>
<td>8-32 X 0.5 in</td>
<td>A-iron to A-iron</td>
<td>0.5 oz/10</td>
</tr>
<tr>
<td>3 Bolts</td>
<td>8-32 X 0.75 in</td>
<td>7-ply to A-iron</td>
<td>0.7 oz/10</td>
</tr>
<tr>
<td>4 Screw Nuts</td>
<td>Aug-32</td>
<td>To all 8-32 bolts</td>
<td>0.3 oz/10</td>
</tr>
<tr>
<td>5 Washers</td>
<td>#8</td>
<td>A-iron &amp; L-clamps</td>
<td>0.2 oz</td>
</tr>
<tr>
<td>6 Washers</td>
<td>1 in</td>
<td>Base</td>
<td>0.2 oz</td>
</tr>
<tr>
<td>7 L-Clamps</td>
<td>5 in</td>
<td>Frame to Base</td>
<td>6.3 oz</td>
</tr>
<tr>
<td>8 L-Clamps</td>
<td>2.5 in</td>
<td>Frame to Shelves</td>
<td>1.0 oz</td>
</tr>
<tr>
<td>9 T-hinge</td>
<td>4 in</td>
<td>Frame to Doors</td>
<td>1.8 oz</td>
</tr>
<tr>
<td>10 Safety Hasp (locks)</td>
<td>2.5 in</td>
<td>Doors</td>
<td>0.9 oz</td>
</tr>
<tr>
<td>11 Angle Iron</td>
<td>6 ft</td>
<td>Frame</td>
<td>0.875 lb/ft</td>
</tr>
<tr>
<td>12 Support Iron</td>
<td>6 ft</td>
<td>Frame</td>
<td>0.267 lb/ft</td>
</tr>
<tr>
<td>13 Caster Wheels</td>
<td>1.5 in</td>
<td>Bottom of base</td>
<td>1 lbs</td>
</tr>
<tr>
<td>14 7-ply</td>
<td>4 x 8 ft</td>
<td>Walls of base</td>
<td>1.1625 lb/ft^2</td>
</tr>
<tr>
<td>15 Plexiglass</td>
<td>4 x 4 ft</td>
<td>Lower Door</td>
<td>1.43 lb/ft^2</td>
</tr>
<tr>
<td>16 MDF</td>
<td>4 x 8 ft</td>
<td>Base of test bay</td>
<td>1.875 lb/ft^2</td>
</tr>
<tr>
<td>17 Primer</td>
<td>Gallon</td>
<td>Test bay</td>
<td>15 lbs</td>
</tr>
<tr>
<td>18 MA 35 Accelerometer</td>
<td>2” x .75”</td>
<td>Test Specimens</td>
<td>1.4 oz</td>
</tr>
<tr>
<td></td>
<td>Item</td>
<td>Location</td>
<td>Weight</td>
</tr>
<tr>
<td>---</td>
<td>------------------------------------------</td>
<td>----------------</td>
<td>---------</td>
</tr>
<tr>
<td>19</td>
<td>SCC Line Conditioner</td>
<td>In test bay</td>
<td>3 lbs</td>
</tr>
<tr>
<td>20</td>
<td>NI SCC-ACC01</td>
<td>In SCC conditioner</td>
<td>1 oz</td>
</tr>
<tr>
<td>21</td>
<td>Laptop</td>
<td>Top shelf</td>
<td>5 lbs</td>
</tr>
<tr>
<td>22</td>
<td>DAQ Card</td>
<td>In laptop</td>
<td>2 oz</td>
</tr>
<tr>
<td>23</td>
<td>Function generator</td>
<td>2\textsuperscript{nd} shelf</td>
<td>6 lbs</td>
</tr>
<tr>
<td>24</td>
<td>Shaker</td>
<td>Base level</td>
<td>8.25 lbs</td>
</tr>
<tr>
<td>25</td>
<td>Shaker Amplifier</td>
<td>2\textsuperscript{nd} shelf</td>
<td>15 lbs</td>
</tr>
<tr>
<td>26</td>
<td>Surge Protector</td>
<td>Top shelf</td>
<td>0.5 lbs</td>
</tr>
<tr>
<td>27</td>
<td>Digital Video Camera</td>
<td>Attached to universal camera mount</td>
<td>0.5 lbs</td>
</tr>
<tr>
<td>28</td>
<td>Cantilever Beams</td>
<td>2 ft</td>
<td>0.5 lbs</td>
</tr>
<tr>
<td>29</td>
<td>Fill Material</td>
<td>N/A</td>
<td>0.5 lbs</td>
</tr>
<tr>
<td><strong>28</strong></td>
<td><strong>Total Weight</strong></td>
<td></td>
<td><strong>280 lbs</strong></td>
</tr>
</tbody>
</table>

Figure 1: Frame base & walls attachment schematic.
Figure 2: Angle iron upper corner assembly for frame.

Figure 3: Test bay schematic
Table 3: Components not illustrated and their specific locations

<table>
<thead>
<tr>
<th>Component Name</th>
<th>Size</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Bolts 8-32 X 0.75 in</td>
<td>Used to attach the 7-ply to the frame</td>
</tr>
<tr>
<td>6</td>
<td>Washers 1 in</td>
<td>Used in the base for strength between the MDF and 5'' L-clamps</td>
</tr>
<tr>
<td>8</td>
<td>L-Clamps 2.5 in</td>
<td>Used to secure shelves to frame</td>
</tr>
<tr>
<td>13</td>
<td>Caster Wheels 1.5 in</td>
<td>Temporary wheels used to aid test bay movement</td>
</tr>
<tr>
<td>17</td>
<td>Primer</td>
<td>Gallon Used to seal the test bay base and walls</td>
</tr>
<tr>
<td>19</td>
<td>SCC Line Conditioner</td>
<td>Will be located on the 2nd shelf with components 23 &amp; 25</td>
</tr>
<tr>
<td>20</td>
<td>NI SCC-ACC01</td>
<td>Located in the SCC Line conditioner</td>
</tr>
<tr>
<td>26</td>
<td>Surge Protector</td>
<td>Will be located on the top shelf with component 21</td>
</tr>
<tr>
<td>29</td>
<td>Fill Material</td>
<td>N/A Located inside the cantilever beam</td>
</tr>
</tbody>
</table>

4.2 Proposed Layout

Figures 5 and 6 depict the test cabin layout. Experimenter restraints are required forward and aft of the assembly, as well as in front of the cabinet doors. Note that overall test bay placement in the aft or forward of the aircraft is lenient.

Figure 5: Experiment layout on KC-135, cross-section.
5. Structural Analysis

5.1 Test Assembly Loading

The structure was analyzed for failure points in the prescribed maximum gravity loading environment described by NASA. I-DEAS 10 was utilized for its finite element modeling and structural solver routines.

Figures 7 through 11 display the outcome of the analysis. The images were enhanced by displaying the maximum stress for each solution both to verify the accuracy of the solution and to show the areas that experience the highest loading. The highest loading on the structure occurred at 9 g’s, in the forward direction at 1,620 PSI. The highest allowable loading for the structure is 3,500 PSI. Table 4 lists the different gravity
vectors and their corresponding stress levels, as well as the calculated factor of safety. From the data collected it was thus determined that the structure would be well within the safety limits. The final structure will also include angle irons and braces so that the final factors of safety will increase beyond the current minimum case scenario.

Table 4: Summary of structural analysis

<table>
<thead>
<tr>
<th>Gravity Vector</th>
<th>Magnitude (g's)</th>
<th>Max Stress (PSI)</th>
<th>Factor of Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Down</td>
<td>6</td>
<td>300</td>
<td>11</td>
</tr>
<tr>
<td>Forward</td>
<td>9</td>
<td>1620</td>
<td>2</td>
</tr>
<tr>
<td>Aft</td>
<td>3</td>
<td>540</td>
<td>6</td>
</tr>
<tr>
<td>Lateral</td>
<td>2</td>
<td>360</td>
<td>9</td>
</tr>
<tr>
<td>Up</td>
<td>2</td>
<td>250</td>
<td>14</td>
</tr>
</tbody>
</table>

Figure 7: Gravitational loading in the ‘Up’ direction with a 2g magnitude
Figure 8: Gravitational loading in the ‘Aft’ direction with a 3g magnitude

Figure 9: Gravitational loading in the ‘Down’ direction with a 6g magnitude
Figure 10: Gravitational loading in the ‘Forward’ direction with a 9g magnitude

Figure 11: Gravitational loading in the ‘Lateral’ direction with a 2g magnitude
5.2 Floor Load Analysis

The allowable floor load of the KC-135 is 200 lbs per spacer used to anchor the test specimen. Our test specimen weighs 280 lbs and will use six spacers to anchor to the KC-135. Therefore our test specimen is over supported by 920 lbs. Our test specimen does not exceed the maximum floor load of the KC-135. The tensile and shear strength of the bolts used to attach the specimen to the floor is 5000 lbs. Figure 12 is a free body diagram of the maximum shear stress experience by the bolts. This is the case of a 9 g forward load. The load is 2520 lbs, which is below the shear strength of even one bolt. With six bolts, the factor of safety is 11. This shows that our test specimen will clearly remain attached to the KC-135 in this case.

Figure 12: Shear loading of the floor support
Figure 13 is a free body diagram of the maximum tensile load experience by the bolts. This is the case of a 9 g top load. The load is 2520 lbs, which is below the tensile strength of one bolt. Under this loading condition our test specimen will remain attached to the KC-135.

5.3 Component Attachments

Each component inside the assembly will be attached to the shelves a minimum of four steel bolts (and a metal bracket for the laptop). The heaviest component is the shaker amplifier, which will weigh 135 lbs under 9 g conditions. Over four bolts, this is
33.75 lbs/bolt. Each bolt has a cross-sectional area of 0.05 sq. inches, meaning that the shear stress on each bolt will be 688 psi. The shear strength of the bolt steel is 18 ksi, meaning that the factor of safety is 26. Because this is the heaviest component in the assembly, factors of safety for all other components will be even higher than 26.

6. Electrical Analysis

6.1 Schematic

Figure 14 shows a graphical schematic drawing showing the top-level electrical design of the experiment:

![Figure 14: Electrical Schematic](image.png)
6.2 Load Tables

Table 5 and 6 are the power source details and load analysis respectively. They describe the electrical power drawn from the external power supply:

Table 5: Power source details

<table>
<thead>
<tr>
<th>Name:</th>
<th>Power Cord 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage:</td>
<td>115 V, 60 HZ</td>
</tr>
<tr>
<td>Wire Gauge:</td>
<td>12</td>
</tr>
<tr>
<td>Max Outlet Current</td>
<td>20 amps</td>
</tr>
</tbody>
</table>

Table 6: Load Analysis

<table>
<thead>
<tr>
<th>Accelerometer Module 1:</th>
<th>4 mA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accelerometer Module 2:</td>
<td>4 mA</td>
</tr>
<tr>
<td>Laptop Power Supply:</td>
<td>1.5 A</td>
</tr>
<tr>
<td>Function Generator/Amplifier:</td>
<td>5 A</td>
</tr>
<tr>
<td>Shaker</td>
<td>Drawn from Function generator</td>
</tr>
<tr>
<td>Total Amps</td>
<td>6.508 A</td>
</tr>
</tbody>
</table>

6.3 Electrical Kill Switch

In the interest of simplicity, we have decided to utilize the cutoff switch provided on the surge protector as our main cutoff switch. Our test bay will be connected directly to the aircraft’s AC power source via a six-plug surge protector, and all components of the experiment will be connected to that surge protector. Killing the power to the experiment will merely consist of turning off the surge protector.

6.4 Loss of Electrical Power

In the event of a power loss, the experiment will simply stop working. The experiment is self contained in the cabinet and all motion depends on the experiment having electrical power. If electrical power is lost, the shaker will stop providing motion to the system and the experiment will come to rest. The laptop will continue operating...
because it automatically diverts to battery power when not connected AC power. There will be no potential hazards from the loss of electrical power.

7. Pressure/Vacuum System Documentation

This section is not applicable to our project; our experimental setup does not involve any pressure/vacuum system.

8. Laser Certification

This section is not applicable to our project; our experimental setup does not involve use of a laser.

9. Parabola Details and Crew Assistance

It will be necessary to fly at least forty 20-second parabolas over the two flight days in order to test every sample. Flying more than forty parabolas would be helpful in case errors occur in some testing runs. The typical sets of 8-10 parabolas with a 2-3 minute break between parabolas will be sufficient as long as there are enough sets to total forty parabolas.

Because the experiment is designed to be run in a zero g environment, crew notification of a steady zero g state is requested. No other crew assistance will be necessary.

10. Free-Float Requirements

This section is not applicable to our project; the experiment will not free float.
11. Institutional Review Board (IRB)

An IRB approval is not needed for this experiment.

12. Hazard Analysis

The following is a report on the hazard analysis of our materials used.

12.1 Hazard Sources

Table 7 is the Hazard source checklist.

<table>
<thead>
<tr>
<th></th>
<th>Hazard Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Flammable/combustible material, fluid (liquid, vapor, or gas)</td>
</tr>
<tr>
<td>NA</td>
<td>Toxic/noxious/corrosive/hot/cold material, fluid (liquid, vapor, gas)</td>
</tr>
<tr>
<td>NA</td>
<td>High pressure system (static or dynamic)</td>
</tr>
<tr>
<td>NA</td>
<td>Evacuated container (implosion)</td>
</tr>
<tr>
<td>NA</td>
<td>Frangible material</td>
</tr>
<tr>
<td>NA</td>
<td>Stress corrosion susceptible material</td>
</tr>
<tr>
<td>2</td>
<td>Inadequate structural design (i.e., low safety factor)</td>
</tr>
<tr>
<td>NA</td>
<td>High intensity light source (including laser)</td>
</tr>
<tr>
<td>NA</td>
<td>Ionizing/electromagnetic radiation</td>
</tr>
<tr>
<td>NA</td>
<td>Rotation device</td>
</tr>
<tr>
<td>3</td>
<td>Extendible/deployable/articulation experiment element (collision)</td>
</tr>
<tr>
<td>4</td>
<td>Stowage restraint failure</td>
</tr>
<tr>
<td>NA</td>
<td>Stored energy device (i.e., mechanical spring under compression)</td>
</tr>
<tr>
<td>NA</td>
<td>Vacuum vent failure (i.e., loss of pressure/atmosphere)</td>
</tr>
<tr>
<td>NA</td>
<td>Heat transfer (habitable area over-temperature)</td>
</tr>
<tr>
<td>5</td>
<td>Over-temperature explosive rupture (including electrical battery)</td>
</tr>
<tr>
<td>6</td>
<td>High/Low touch temperature</td>
</tr>
<tr>
<td>NA</td>
<td>Hardware cooling/heating loss (i.e., loss of thermal control)</td>
</tr>
<tr>
<td>NA</td>
<td>Pyrotechnic/explosive device</td>
</tr>
<tr>
<td>NA</td>
<td>Propulsion system (pressurized gas or liquid/solid propellant)</td>
</tr>
<tr>
<td>NA</td>
<td>High acoustic noise level</td>
</tr>
<tr>
<td>NA</td>
<td>Toxic off-gassing material</td>
</tr>
<tr>
<td>NA</td>
<td>Mercury/mercury compound</td>
</tr>
<tr>
<td>NA</td>
<td>Other JSC 11123, section 3.8 hazardous material</td>
</tr>
<tr>
<td>NA</td>
<td>Organic/microbiological (pathogenic) contamination source</td>
</tr>
<tr>
<td>7</td>
<td>Sharp corner/edge/protrusion/protuberance</td>
</tr>
<tr>
<td>8</td>
<td>Flammable/combustible material, fluid ignition source (i.e., short circuit; under-sized wiring/fuse/circuit/beaker)</td>
</tr>
<tr>
<td>9</td>
<td>High voltage (electrical shock)</td>
</tr>
<tr>
<td>NA</td>
<td>High static electrical discharge producer</td>
</tr>
<tr>
<td>10</td>
<td>Software error or compute fault</td>
</tr>
<tr>
<td>NA</td>
<td>Carcinogenic material</td>
</tr>
<tr>
<td>11</td>
<td>Other: Dust/debris</td>
</tr>
</tbody>
</table>
12.2 Detailed Hazard Description

1) Paint
   • Hazard Description
     Paint increases the combustibility of the test bay because paint is flammable.
   • Hazard Causes
     1) Electrical spark/surge ignites paint
     2) Outside source ignites paint
   • Hazard Controls
     Extra attention will be taken to ensure that significant fire possibilities are at a very minimum. (see section 6: Electrical Analysis)

2) Structural design
   • Hazard Description
     Structural failure or destruction of test bay under high loads
   • Hazard Causes
     1) High G-loads
     2) Violent detachment of experiment hardware
     3) Defective bolt attachment
   • Hazard Controls
     Structural analysis was performed and the test bay was not damaged by the loading conditions specified by JSC. Support steel adds stiffness to the test bay walls. This is to prevent hardware from fracturing the walls. Each piece of hardware will also be tethered to the test bay. Loctite will be used to ensure the tightness of the bolts and nuts.

3) Test bay doors
   • Hazard Description
     Test bay doors could open and collide with people onboard the aircraft.
• Hazard Causes
  1) Inadequate door restraint

• Hazard Controls
  The doors will be secured shut with a latching mechanism.

4) Hardware restraints
• Hazard Description
  The restraints holding the test equipment in place could fail.

• Hazard Causes
  1) Excessive loading of the hardware restraints

• Hazard Controls
  The test cabinet will contain any hardware that become detached from its original position. There will also be separation between the test area, specimen storage area, and computer / electrical area.

5) Computer battery
• Hazard Description
  The computer will be driven by AC power. However, there is a battery in the computer that could rupture.

• Hazard Causes
  1) Inappropriate voltages and currents running the computer could cause the battery to rupture.

• Hazard Controls
  The computer will be connected to AC power using the correct AC adapter provided by the manufacturer.

6) Hardware devices that produce heat
• Hazard Description
  Overheated computer (or other electrically driven devices) can cause burns if touched.

• Hazard Causes
1) Computer (or other hardware) begins operating improperly and overheating

- Hazard Controls
  The experiment will have to be shut down in such an event. Each electrically driven component will be plugged into a single surge protector. There will be an emergency shutoff -switch incorporated into this surge protector. The computer will have to be shut down manually.

7) Test bay edges

- Hazard Description
  The corners and edges of the test bay could cause bodily injury if collided with.

- Hazard Causes
  1) Inappropriate zero-g movements in the vicinity of the test bay.

- Hazard Controls
  Hose insulation foam will pad the corners and edges of the test bay.

8) Electrical circuits

- Hazard Description
  Fire can be caused by short circuit of the electrical system.

- Hazard Causes
  1) Exposed wires crossing
  2) Voltage surge for AC power supply
  3) Liquids (i.e., water, vomit)

- Hazard Controls
  All the wiring will be insulated and inspected for the integrity of its insulation. The surge protector will protect against any other malfunctions by automatically tripping its reset.

9) Electrical shock

- Hazard Description
  The voltages being used can cause injury to a person being shocked by them.
• Hazard Causes
  1) Exposed electrical wires
  2) Uncovered surge protector outlets

• Hazard Controls
  All the wiring will be insulated and inspected for the integrity of its insulation. Outlet covers will be used to shield unused outlets.

10) Software failure
• Hazard Description
  Function generator begins driving at a heightened improper frequency.
• Hazard Causes
  1) Improper software setup
  2) Software malfunction
• Hazard Controls
  In this situation the only option will be to hit the emergency kill switch.

11) Splinters and dust
• Hazard Description
  Splinter and dust could come free from the test bay and cause breathing problems to occupants and affect other experiments onboard.
• Hazard Causes
  1) Micro-particles
• Hazard Controls
  The test bay will be sanded and painted to minimize the presence of micro-particles. The bay will be vacuumed before flight.

12) Electromagnetic field
• Hazard Description
  While the experiment is being conducted the shaker will produce an electromagnetic field that could cause problems with the experiment’s equipment.
• Hazard Causes
1) The electromagnetic field is produced by the shaker

- Hazard Controls

The shaker will be positioned at the lowest point in the test bay. There will be a 2 ft. clearance between the first shelf and the base as well as a 3 ft. clearance between the 2nd shelf and the base. Therefore, all the equipment that could be sensitive to the electromagnetic field will be placed at least two and a half feet above the shaker. This will be sufficient clearance.

13. Tool Requirements

The only tools necessary are those used to attach the experimental setup to the aircraft’s floor spacers via bolts/studs (such as ratchets or a monkey wrench) and will be borrowed from the RGO if possible.

14. Photo Requirements

Neither a photographer nor a videographer is requested for in-flight documentation. The S-band downlink is not necessary, either. One digital camcorder will be used to document the experiment; only one universal camera pole will be necessary.

15. Aircraft Loading

A forklift and lifting pallet will be sufficient for loading the experimental setup into the airplane. The assembly weighs 280 lbs and will be mounted on 4 removable casters for movement on the ground and in the test cabin, placing 70 pounds on each wheel. After the equipment is moved into place, the casters will be removed and taken
out of the airplane. The total weight of 280 lbs will be distributed over a base area of 8 square feet, exerting 35 lbs/sq. ft. on the floor.

16. Ground Support Requirements

After loading the equipment onto the plane, the casters will be removed and left on the ground. Upon landing, the casters must be available for removal of the assembly. Ratchets or monkey wrenches required to bolt the assembly to the test cabin floor are requested.

17. Hazardous Material

Our experiment does not involve the use of any hazardous materials.

18. Material Safety Data Sheets (MSDS)

Our experiment does not involve the use of any chemicals or fluids; no MSDS are required.

19. Procedures

19.1 Equipment Shipment to Ellington Field

The team will be bringing the test assembly to Houston in a minivan on March 31, and to Ellington Field on April 1, 2004. The assembly should be stored in a weatherproof (indoor) facility and should not have heavy items placed on top of it. Because the assembly dimensions are 4 x 2 x 4 ft., a minimum 4 x 2 ft. floor storage space is required.
19.2 Ground Operations

To operate the experimental setup on the ground, a 120-V ac electrical outlet is required. After attaching a laptop to the bracket on top of the assembly, the team will attach a rod to the vibrator. An electrical signal will be sent to the vibrator by turning on the function generator, and accelerometer data will be acquired with LabView for approximately 20 seconds. This test will ensure that all components and electrical connections are working correctly. Prior to loading, there will be a general inspection of the test bay which will include vacuuming the cabinet.

19.3 Loading

The assembly will be loaded into the KC-135 test cabin with a forklift and lifting pallet. Four casters will be inserted into holes on the bottom of the assembly base, and the assembly will be wheeled into place along one wall of the test cabin. The casters will be removed and the assembly base will be bolted to the aluminum floor spacers on the KC-135. The team requests crew assistance to ensure that the assembly is securely bolted down in the test cabin.

19.4 Pre-Flight

Just prior to flight, we will conduct another general pre-flight inspection of the test bay’s security to the KC-135, and we will insure that all components are still in their correct operation modes. A 120-V ac outlet is required to power the experiment. While still on the ground, LabView will be configured so that only one button will need to be pushed during the tests in order to begin data acquisition.

19.5 Take-off/Landing

During take-off and landing, the crew will situate themselves in a safe place inside the test cabin. Because the computer will have already been prepared to begin
testing, we request that power be provided throughout take-off. There are no special equipment stowage requirements.

19.6 In-Flight
The flight team will alternate between running an experiment and then preparing for the next experiment on consecutive parabolas. Following are three checklists, two for the experimental procedures and one for emergency procedures:

**Checklist for Running Experiment**
- Prior to parabola, move into position in front of experimental assembly
- Upon notification of steady-state zero g status, depress “start” key on computer
- After 20 seconds, depress “finish” key on computer

**Checklist for Preparing for Next Experiment**
- Prior to parabola, move into position in front of experimental assembly
- Unlatch plexiglass door
- Remove safety pins from specimens
- Remove point mass from specimen
- Remove specimen from base mass
- Unlatch Upper Bay doors
- Select next specimen from storage bay
- Note new specimen selected
- Replace previous specimen in storage bay
- Close and latch upper bay doors
- Insert new specimen into base mass
- Attach point mass
- Insert safety pins
- Close and latch Plexiglas bay door
- Configure LabView for next parabola

**Checklist for Emergency Procedures**
- Hit the electrical kill switch
- Inform pilot of the nature of the emergency
- Attempt to safely resolve the situation (depends on what emergency occurs)
- Follow any emergency instructions provided by the RGO.
19.7 Post-Flight
Upon completing a flight, all experimental data will be backed up onto a second laptop computer. A post-flight inspection will be conducted to ensure that all rods are stored correctly for beginning the next day’s flight.

19.8 Off-loading
After the assembly has been unbolted from the test cabin floor, casters will be inserted into the base and the assembly will be wheeled onto a lifting pallet and off-loaded by a forklift. The team will remove the equipment from NASA property via minivan on their way home.

20. Bibliography
This section does not apply to this document; no external works were referred to.