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Overview

- Vibration testing of SUMI was performed at both the experiment and payload levels. No accelerometers were installed inside the experiment during testing, but it is certain that component responses were very high. The environments experienced by optical and electronic components in these tests is an area of ongoing concern.

- The analysis supporting this presentation included a detailed finite element model of the SUMI experiment section, the dynamic response of which, correlated well with accelerometer measurements from the testing of the experimental section at Marshall Space Flight Center. The relatively short timeframe available to complete the task and the limited design information available was a limitation on the level of detail possible for the non-experiment portion of the model. However, since the locations of interest are buried in the experimental section of the model, the calculated responses should be enlightening both for the development of test criteria and for guidance in design.
### Sounding Rocket Vibration Test Criteria

#### (NSROC ENVIRONMENTAL TESTING POLICY MANUAL)

<table>
<thead>
<tr>
<th>Payload Test Criteria</th>
<th>Component Qualification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SIN</strong></td>
<td><strong>RAND</strong></td>
</tr>
<tr>
<td>Sweep Rate: 4 oct./min.</td>
<td>Sweep Rate: 4 oct./min.</td>
</tr>
<tr>
<td>Test Profile:</td>
<td>Test Profile:</td>
</tr>
<tr>
<td>3.84 in./s 5-24 Hz</td>
<td>5.90 in./s 5-24 Hz</td>
</tr>
<tr>
<td>1.53 g 24-110 Hz</td>
<td>2.30 g 24-110 Hz</td>
</tr>
<tr>
<td>3.50 g 110-800 Hz</td>
<td>5.25 g 110-800 Hz</td>
</tr>
<tr>
<td>10.0 g 800-2000 Hz</td>
<td>15.0 g 800-2000 Hz</td>
</tr>
<tr>
<td><strong>SAME IN ALL AXES</strong></td>
<td><strong>SAME IN ALL AXES</strong></td>
</tr>
</tbody>
</table>

- PI’s of new payloads commonly request that sine vibration only be performed on in the thrust axis.
- Component Qualification levels are used for new Black Brant avionics and do not necessarily envelope environments seen by components in the experiment section during payload testing, however these environments are often successfully used by experimenters.

**Configuration for Payload vibe**

![Configuration for Payload vibe](image)
Finite Element Modeling

- Finite Element Model (200,000 degrees of freedom)
- More detail in the modeling of the experiment than the rest of the payload.
- Eigenvector solutions in Nastran
- Dynamic response to base shake inputs calculated using Matlab based on NASTRAN Modal solution and the following assumed damping spectrum. The delta frequency employed to calculate the response was 1 Hz.
MSFC Testing

• Sine and Random Vibration testing of SUMI at MSFC consisted of the experiment section only.
  • 3-Axis Random
  • Z-axis Sine

• Finite Element Model responses compare well with accelerometer measurements.
FEA Response Comparison to Experiment Vibration Test
## Finite Element Response Locations

<table>
<thead>
<tr>
<th>Description</th>
<th>Node</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>101</td>
</tr>
<tr>
<td>Telescope Spider Structure Center of Telescope</td>
<td>2427</td>
</tr>
<tr>
<td>Primary Mirror</td>
<td>25865</td>
</tr>
<tr>
<td>Telescope Primary Mirror Mount Ring</td>
<td>25168</td>
</tr>
<tr>
<td>Optical Bench Surface Near Waveplate Electronics Cold Plate</td>
<td>110119</td>
</tr>
<tr>
<td>Middle of the Optical bench Surface Near CIV Fold Mirror</td>
<td>114164</td>
</tr>
<tr>
<td>Mg-II Camera Mount</td>
<td>18919</td>
</tr>
<tr>
<td>CIV Camera</td>
<td>403</td>
</tr>
<tr>
<td>H Grating</td>
<td>25866</td>
</tr>
<tr>
<td>V Grating</td>
<td>25867</td>
</tr>
<tr>
<td>Spectrograph Structure at Grating End</td>
<td>23146</td>
</tr>
</tbody>
</table>
Response Plot Key

Vibration type is indicated by row

Response direction is indicated by column

<table>
<thead>
<tr>
<th>Line Color</th>
<th>Line Represents:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Response resulting from Thrust Input Excitation</td>
</tr>
<tr>
<td></td>
<td>Response resulting from 0-180 Input Excitation</td>
</tr>
<tr>
<td></td>
<td>Response resulting from 90-270 Input Excitation</td>
</tr>
<tr>
<td></td>
<td>Input Excitation at the Base of the Payload</td>
</tr>
<tr>
<td></td>
<td>Typical Component Acceptance Level</td>
</tr>
<tr>
<td></td>
<td>Typical Component Qualification Level</td>
</tr>
</tbody>
</table>

*0-180 and 90-270 are orthogonal base shake or response directions in the two lateral axes
Telescope Spider Structure Center of Telescope
Primary Mirror
Telescope Primary Mount Ring

Random Resp. in 0-180 Dir.

Random Resp. in 90-270 Dir.

Random Resp. in Thrust Dir.

Sine Resp. in 0-180 Dir.

Sine Resp. in 90-270 Dir.

Sine Resp. in Thrust Dir.
Optical Bench Surface Near Waveplate Electronics Cold Plate

Random Resp. in 0-180 Dir.

Random Resp. in 90-270 Dir.

Random Resp. in Thrust Dir.

Sine Resp. in 0-180 Dir.

Sine Resp. in 90-270 Dir.

Sine Resp. in Thrust Dir.
Middle of the Optical Bench Near CIV Fold Mirror
Mg-II Camera Mount

**Random Response Plots:**
- Random Resp. in 0-180 Dir.
- Random Resp. in 90-270 Dir.
- Random Resp. in Thrust Dir.

**Sine Response Plots:**
- Sine Resp. in 0-180 Dir.
- Sine Resp. in 90-270 Dir.
- Sine Resp. in Thrust Dir.
CIV Camera

Graphs showing random response in various directions and frequency ranges.
H Grating

Random Resp. in 0-180 Dir.

Random Resp. in 90-270 Dir.

Random Resp. in Thrust Dir.

Sine Resp. in 0-180 Dir.

Sine Resp. in 90-270 Dir.

Sine Resp. in Thrust Dir.
V Grating
Spectrograph Structure at Grating End
Findings/Conclusions

– The first lateral bending modes of the rocket amplify the low frequency responses of components near the top of the experiment. The result is that these same components are significantly isolated from high frequency vibrations in the 0-180 and 90-270 directions.

– Small, high natural frequency avionics are less likely to be damaged by the amplified low frequency vibration and if oriented properly, can be spared the more damaging high frequency environments.

– If possible, avoid aligning the most sensitive axis of a component with the thrust axis. i.e. The most sensitive axis for a circuit card is the surface normal.
Findings/Conclusions

- Finite element results at high frequency can be unreliable. For that matter, even high frequency test data can be very inconsistent. The “same” test and what was purportedly the “same” response location on sounding rocket payload test showed dramatically different high frequency responses. Low anticipated levels at high frequency should not necessarily be used to justify low component test criteria.
Findings/Conclusions

- The response data presented may be of value for estimating design environments for other similar payloads or experiments. The users are encouraged to recognize that the new design will produce somewhat different response. Therefore, using these results to construct smoothed envelope vibration environment criteria may be appropriate. These vibration design envelope criteria should make use of uncertainty where the component response frequencies are concerned. Magnitude uncertainty would also be appropriate in the early stages of design.