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Update on the Production Redesign of the HAM Large Triple Suspension Structure

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1 Introduction

The purpose of this document is to record the status of the frequency analysis of the HAM Large Triple Suspension (HLTS) structure. Frequency analysis of the prototype version of the structure and comparison of the FEA model to experimental results was reported earlier in T080319; the first natural frequency of the HLTS prototype was found to be 149 Hz, as determined by FEA.

2 Design Requirements/Redesign Goals

As discussed previously in Section 3 of T080319, one design requirement for the HLTS structure (that has never been formally captured) is that the structure shall not have a resonant frequency below 150 Hz. This requirement is based on the need to have structural frequencies that do not compromise the unity gain frequency of the HAM-ISI controller, which is approximately 60 Hz. During the redesign of the HAM Small Triple Suspension (HSTS) structure detailed in T080318, it was found that the first natural frequency could not be increased to the goal of 150 Hz while maintaining the required footprint. Instead, effort was redirected to developing ways of damping the structural modes, including damping struts and tuned mass dampers. The current first natural frequency of the HSTS structure, as determined by FEA, is 121 Hz.

Another design requirement for the HLTS structure is that it must be able to be clamped securely to the HAM-ISI table, especially near the legs of the HLTS structure, after being placed in the chamber using the HAM Installation Arm (see T1000031). Since the position and angle of the HLTS structure on the table does not necessarily line up with the grid of tapped holes on the HAM-ISI table, the clamps must attach to the HLTS structure at various angles. The small "mouse-holes" included in the gussets of the prototype HLTS structure are not large enough to allow a clamp to pass through unless the clamp is aligned with the structure. Even if the "mouse-holes" are suitable for the initial position of the HLTS, it may be necessary to move the HLTS in position or orientation, and the clamping pattern must suit both the old and new positions.

A third requirement for the HLTS structure is for all interfaces between it and all other components external to the HLTS to be defined and agreed upon between the designers of the HLTS and the external components. These external components include installation and alignment tooling, electronics cables, spacers between the HLTS and the HAM-ISI table, vibration absorbers and damping struts.

Based on these requirements, the goals of the HLTS structure redesign include increasing the area available for the clamping the HLTS structure to the HAM-ISI table while keeping the first structural frequency as high as possible (with a minimum frequency of 121 Hz to stay at or above that of the HSTS structure). The interfaces between the HLTS structure and other external components must be defined.

3 Finite Element Analysis Modeling Results

The frequency response of the HLTS structure was analyzed using the ANSYS FEA software package with a solid model of the structure created using the SolidWorks CAD program. Eight separate configurations were analyzed: the prototype HLTS structure and seven separate modifications. All of the configurations were analyzed as machined (meaning that the large 1-inch diameter access holes and the flycutting on the top surface are included) and with lumped masses to simulate the effects of the non-suspended mass of the HLTS assembly (which includes blade guards, earthquake stops and brackets, etc.).

3.1 Prototype HLTS Structure

As described in T080319, the frequencies of the prototype HLTS structure as determined using FEA are – longitudinal: 149 Hz, lateral: 156 Hz, yaw: 221 Hz.

3.2 Case 1 – Additional Access Holes

The first configuration analyzed as part of the HLTS structure redesign is a slight modification of the prototype structure. Additional 1-inch diameter access holes were added to the crossbeams on the front of the structure to allow for easier access to the earthquake stop and OSEM brackets mounted on the inside rear of the structure (see Figure 1).

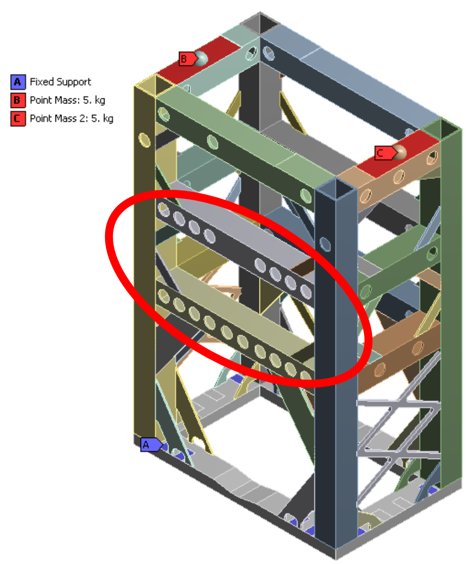

Figure 1: HLTS Structure Redesign (Case 1 - Additional Access Holes)

The frequencies of this version of the HLTS structure, as determined using FEA, are: longitudinal – 148 Hz, lateral – 152 Hz, yaw – 220 Hz.

3.3 Case 2 – Outer Lower Gussets Removed

The second configuration is based on the first. The difference is that the gussets around the outer perimeter of the structure connecting the legs to the base plate have been removed (see Figure 2).

This change allows clamps to be placed in any orientation without having to deal with small "mouse-holes".

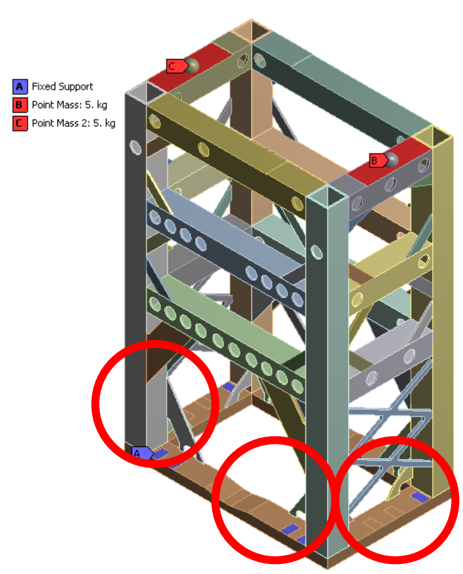

Figure 2: HLTS Structure Redesign (Case 2 – Outer Lower Gussets Removed)

The frequencies of this version of the HLTS structure, as determined using FEA, are: longitudinal – 139 Hz, lateral – 146 Hz, yaw – 207 Hz.

3.4 Case 3 – Modified Lower Gussets

The third configuration is also based on the first. The difference is that the lower gussets have been modified; specifically, the "mouse-holes" on the front and rear gussets have been combined and "mouse-holes" on the left and right gussets have been enlarged (see Figure 3). This change allows for clamps to be placed in a wider range of orientations.

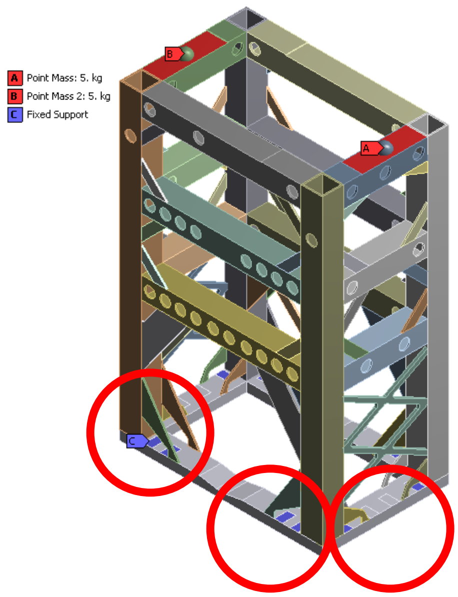

Figure 3: HLTS Structure Redesign (Case 3 – Modified Lower Gussets)

The frequencies of this version of the HLTS structure, as determined using FEA, are: longitudinal – 145 Hz, lateral – 150 Hz, yaw – 216 Hz.

3.5 Case 4 – Thick Modified Lower Gussets

The fourth configuration is based on Case 3. The difference is that each pair of inner and outer gussets (of the shapes of the modified lower gussets from Case 3) has been combined into one gusset with a thickness twice that of each individual gusset from Case 3 that is located halfway between the locations of the original gussets (see Figure 4). This change allows for clamps to be placed in an even wider range of orientations compared to Case 3.

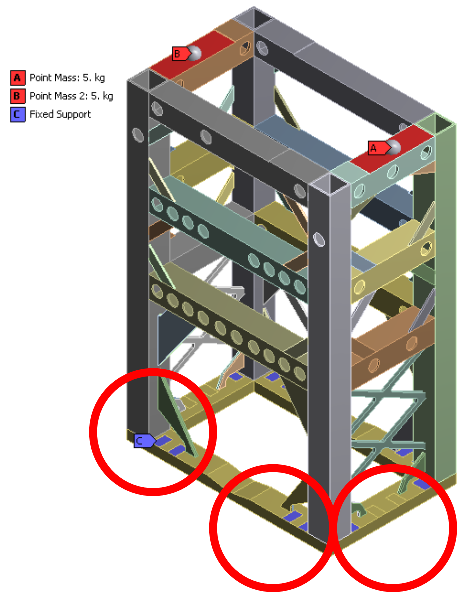

Figure 4: HLTS Structure Redesign (Case 4 – Thick Modified Lower Gussets)

The frequencies of this version of the HLTS structure, as determined using FEA, are: longitudinal – 138 Hz, lateral – 143 Hz, yaw – 205 Hz.

3.6 Case 5 – Repositioned Modified Lower Gussets

The fifth configuration is also based on Case 3. The difference is that the outer gussets (of the shapes of the modified lower gussets from Case 3) have been moved inward by 1/3 of original distance between the inner and outer gussets (see Figure 5). This change allows for clamps to be placed in a range of orientations between Case 3 and Case 4.

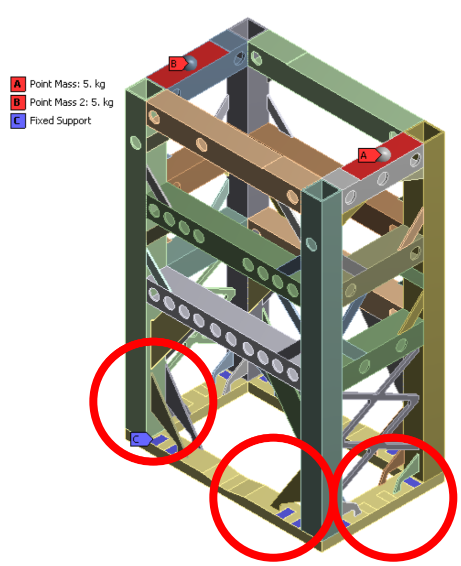

Figure 5: HLTS Structure Redesign (Case 5 – Repositioned Modified Lower Gussets)

The frequencies of this version of the HLTS structure, as determined using FEA, are: longitudinal – 144 Hz, lateral – 148 Hz, yaw – 209 Hz.

3.7 Case 6 – Outer Lower Gussets Removed, Front and Rear "Mouse-Holes" Removed

The sixth configuration is based on the Case 2. The gussets around the outer perimeter of the structure connecting the legs to the base plate have been removed, as in Case 2, but the "mouse-holes" in the front and rear lower gussets have been removed (see Figure 6). This change allows clamps to be placed in almost any orientation while allowing for stiffness with the solid front and rear lower gussets.

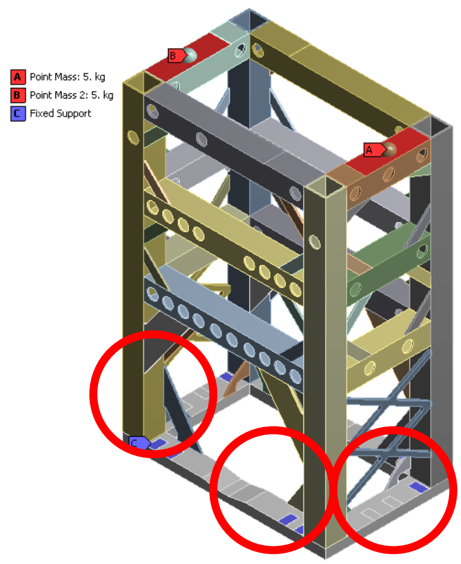

Figure 6: HLTS Structure Redesign (Case 6 - Outer lower gussets removed, front and rear "mouse-holes" removed)

The frequencies of this version of the HLTS structure, as determined using FEA, are: longitudinal – 139 Hz, lateral – 146 Hz, yaw – 206 Hz.

3.8 Case 7 - Outer Lower and Top Side Gussets Removed, Front and Rear "Mouse-Holes" Removed

The seventh configuration is based on Case 6. The difference is that the top side gussets have also been removed (see Figure 7). The advantages in this case is that there is more room to insert the Upper Mass/Coil Holder during assembly and that there is more space along the top piece of structural tubing to attach the vibration absorbers designed by the Systems group.

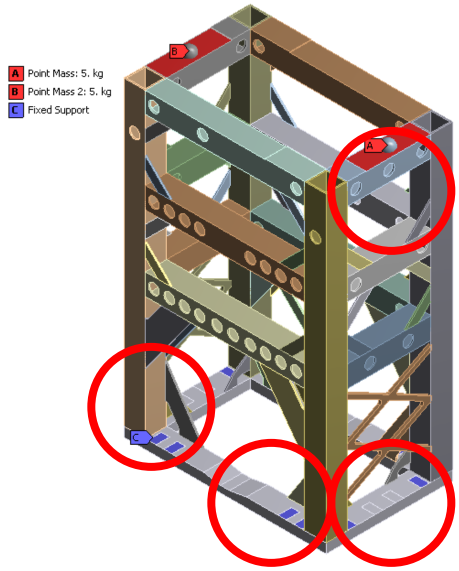

Figure 7: HLTS Structure Redesign (Case 7 – Outer Lower and Top Side Gussets Removed, Front and Rear "Mouse-Holes" Removed)

The frequencies of this version of the HLTS structure, as determined using FEA, are: longitudinal – 138 Hz, lateral – 146 Hz, yaw – 206 Hz.

3.9 FEA Summary

Table 1 below lists the structural frequencies for each of the configurations considered during the HLTS structure redesign effort.

Table 1: Frequencies of HLTS Structure Redesign Configurations

Configuration	Main Modifications	Longitudinal [Hz]	Lateral [Hz]	Yaw [Hz]
Prototype	N/A	149	156	221
Case 1	Additional access holes	148	152	220
Case 2	Outer lower gussets removed	139	146	207
Case 3	Modified lower gussets	145	150	216
Case 4	Thick modified lower gussets	138	143	205
Case 5	Repositioned modified lower gussets	144	148	209
Case 6	Outer lower gussets removed, front and rear “mouse-holes” removed	139	146	206
Case 7	Outer lower and top side gussets removed, front and rear “mouse-holes” removed	138	146	206

4 Interface Design

All interfaces between the HLTS structure and all other components external to the HLTS must be defined and agreed upon between the designers of the HLTS and the external components. The following is a list of external components and how their interfaces with the HLTS structure have been implemented:

- HAM Installation Arm – A series of ¼” clearance holes has been included along the top lateral crossbeams of the HLTS structure so that the HAM Installation Arm can support the weight of the fully assembled HLTS during installation. The hole pattern is a modified version of that shown in the redlined HLTS Structural Weldment drawing (D070442-v3) called out in the interface RODA (M1000047-v1).
- Damping Struts – A pattern of ¼” clearance holes has been placed on each of the top corners of the HLTS structure (6 holes per corner) so that damping struts can be attached. This pattern is also a modified version of that from D070442-v3.
- Vibration Absorbers – The current design of the vibration absorbers (also referred to as tuned mass dampers) attaches to the HLTS by being clamped around a portion of the 2” X

2” structural tubing. Case 7 of the structure redesign (see Section 3.8 above) eliminates some smaller gussets so that there is more space for clamping the vibration absorbers.

- Electronics Cabling – A pattern of ¼” clearance holes has been added along the legs of all four sides of the HLTS structure so that cable clamps can be attached to the structure.
- Corner Pads for Damping – A pattern of ¼” clearance holes has been added to the legs of the HLTS structure so that corner pads can be attached at the lower corners. This pattern is a modified version of that shown in D070442-v3.
- Dog Clamps – Much of the redesign work involved enlarging the area available for clamping the HLTS to the HAM-ISI table. See Section 3 above.
- Alignment Tooling – Tapped holes have been added to the base plate of the HLTS structure at the direction of Doug Cook for the IAS group in order to mount alignment fixtures.
- Spacers – A pattern of ¼-20 tapped holes has been added to the base plate of the HLTS structure so that a spacer can be mounted on the bottom of the HLTS. This pattern is a slightly modified version of that shown in D070442-v3.

5 Welding Processes of the HLTS Structure

A number of suggestions have arisen based on discussions with the welding shop that is fabricating the HSTS structures. One suggestion that applies to the HLTS structure is to include a boss on the four corners of the base plate where it attaches to the structural tubing for the legs. This would allow for a simpler weld between the base plate and the legs, since these bosses would be of the same cross-section as the legs.

6 Conclusions

The configuration chosen for the production version of the HLTS structure must have a first structural frequency equal to or greater than that of the HSTS structure (which is 121 Hz), while allowing for adequate clamping to the HAM-ISI table. Without sufficient clamping, the HLTS/HAM-ISI system will have a lower combined frequency; although the prototype and Case 1 have first frequencies of 148-149 Hz, this number is not realistic since the HLTS cannot be sufficiently clamped to the HAM-ISI table in these configurations.

From Table 1 above, all configurations that were considered have first structural frequencies greater than 121 Hz. Cases 2, 6 and 7 allow for the best arrangement of clamps, although they also have the lowest frequencies. Case 7 is the simplest of these three configurations, since the “mouse-holes” are removed from the front and rear gussets and the top side gussets are deleted altogether. This case also allows for a wider range to position vibration absorbers. None of the other interfaces between the HLTS and external components would be affected by these design changes. These simplifications should also result in reduced weight, reduced complexity, reduced fabrication costs, and easier assembly of the overall HLTS. For these reasons, the authors recommend the selection of the Case 7 configuration for the production version of the HLTS structure.