LIGO-T970237-00-D
HYTEC-TN-LIGO-12
01/15/97

HAM Support Assembly Analytical Design

Bernie Weinstein

January 15, 1997

Abstract

This note summarizes the analysis of a preliminary design for the HAM support structure. Results are presented for natural frequencies, effect of gravitational loading, and a pseudo earthquake condition. Buckling of the support structure under the load of the stack was also considered.

HYTEC Inc.
110 Eastgate Dr., Ste. 100
Los Alamos, NM 87544
(505) 662-0080 / Fax (505) 662-5179

LIGO PROJECT

TABLE OF CONTENTS

1. Introduction

The HAM support assembly, shown in Figure 1, consists of a support platform, 2 support beams, and 2 cross beams. The HAM seismic isolation stack rests on the support platform. The support beams penetrate the HAM chamber and are sealed by 4 welded diaphragm bellows. They align and hold the support platform. Cross beams on the outside of the chamber connect the ends of the support beams and interface with the coarse actuators.

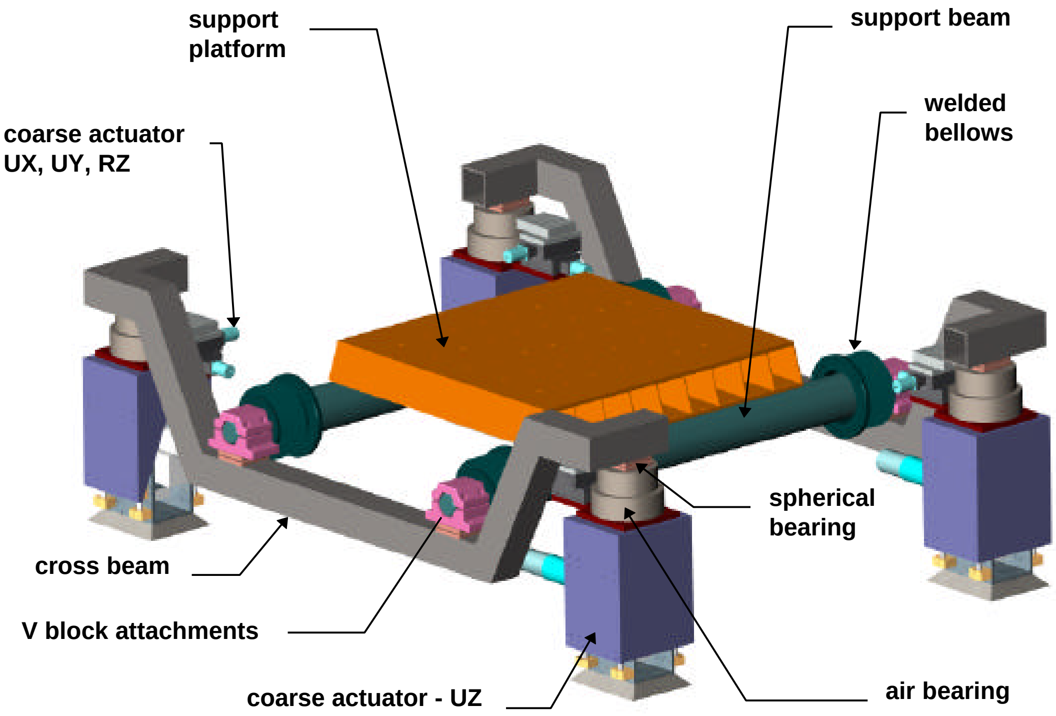


Figure 1. Ham Support Assembly

2. Description

Overall dimensions of the HAM support structure are shown in Fig. 2. The support platform is a welded aluminum structure with a 19.1 mm (.75”) thick upper face, a 12.7 mm (.5”) thick lower face, and 9 parallel stiffeners 6.4 mm (.25”) thick. Aluminum is used to minimize weight at the center of the support beam span. (The weight of the support platform is a major factor in determining the lowest resonant frequency).

The support beams are made of stainless steel tubing 191 mm (7.5”) in diameter with a wall thickness of 6.4 mm (.25”). Solid stainless steel plugs with a diameter of 114 mm (4.5”), are welded to the tube at each end. The plugs incorporate a knife edge and tapped holes to seal and mount the custom flange that is welded to one end of the bellows. The support beams are anchored to the cross beams by heavy V-block attachments. In the FEM model, these blocks are represented as solid steel connections from the support beam plugs to the upper walls of the cross beams (Fig. 2). Low carbon steel square tubing 152 x 152 x 9.5 mm (6 x 6 x .375”) form the crossbeams that carry the load to the actuators.

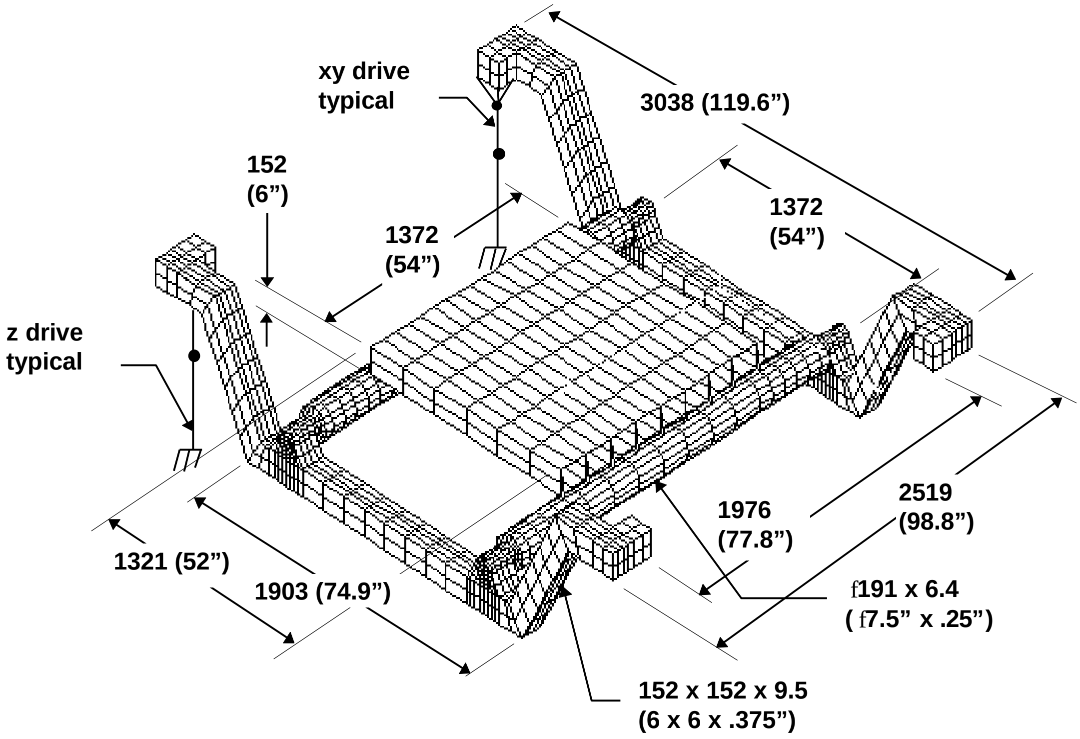


Figure 2. HAM Support Assembly

3. Performance

3.1 Resonant frequencies

Figure 3 shows the first 6 resonances of the support assembly. The assembly rests on 4 rigid beams that connect to another rigid beam representing the coarse x/y actuator. The function of the 4 beams is to spread the load more realistically. This rests on a simulated beam whose properties were adjusted to represent the compliance of the Z actuator within 3% of the 3 directional spring constants and the angular compliance about the 2 horizontal axes.

Initial modeling of the support system was done prior to providing room for the actuators. The cross beam in this analysis was straight. The mode at the lowest frequency was 26 Hz. Once the overall layout was completed, the crossbeam design had to take on a gull wing shape to provide clearance for the actuator column. For this configuration the first mode dropped to 18 Hz. Introducing the flexibility of the Z drive further lowered that frequency to 17 Hz as shown in Figure 3.

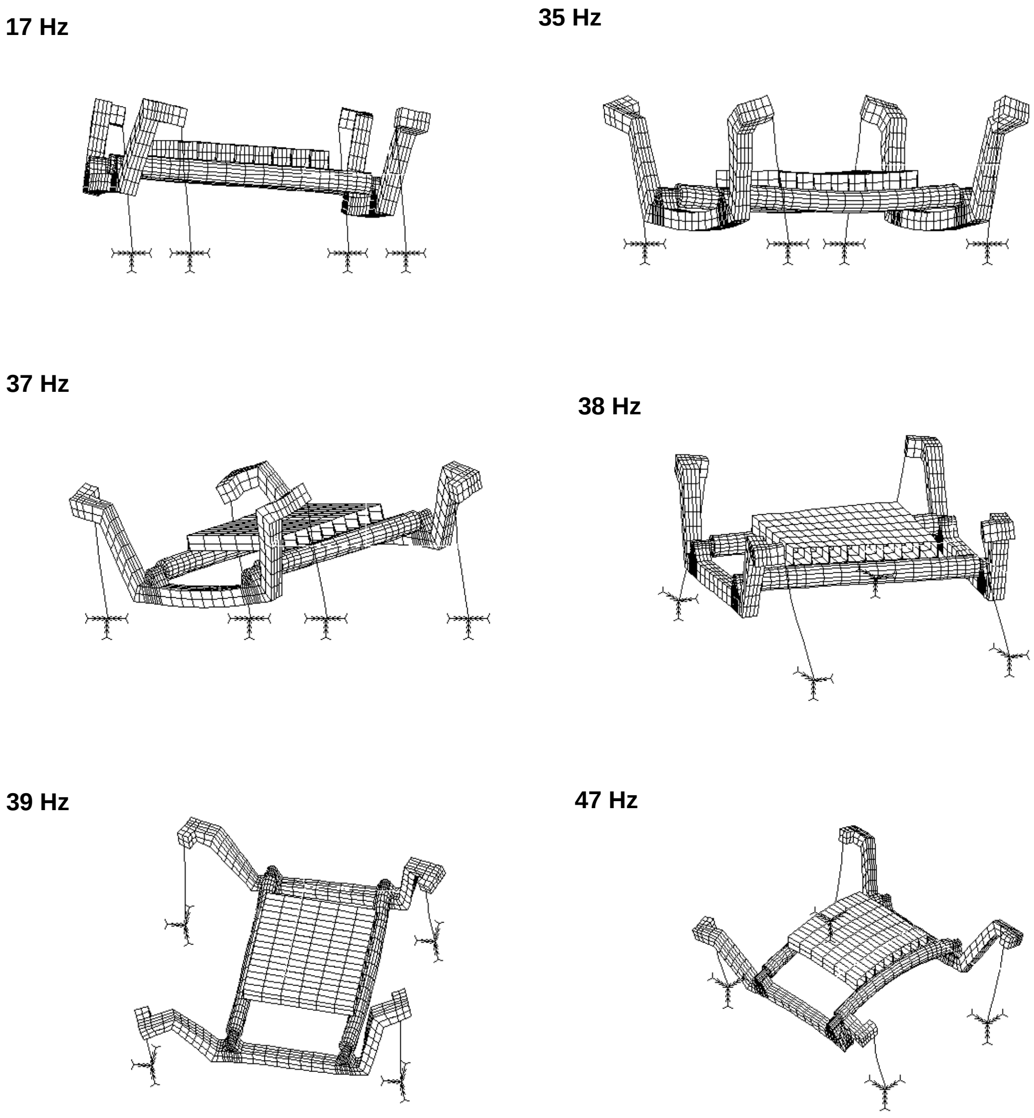


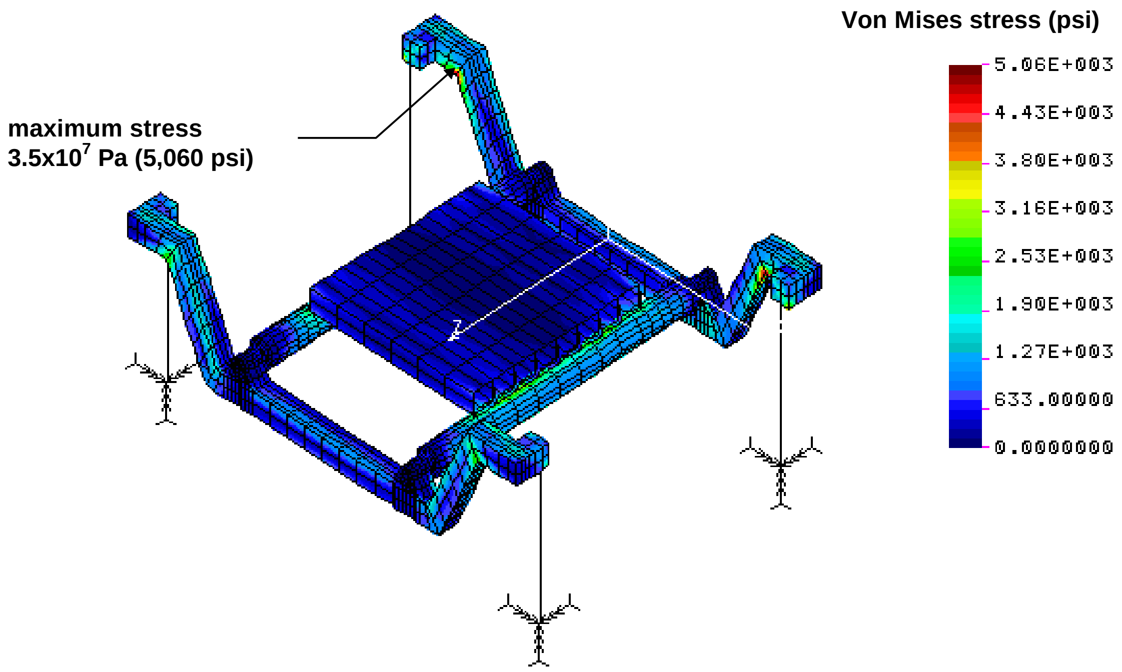
Figure 3. Mode shapes and natural frequencies of the HAM support system

3.2 Stresses and Deflections

3.2.1 Gravitational Loading

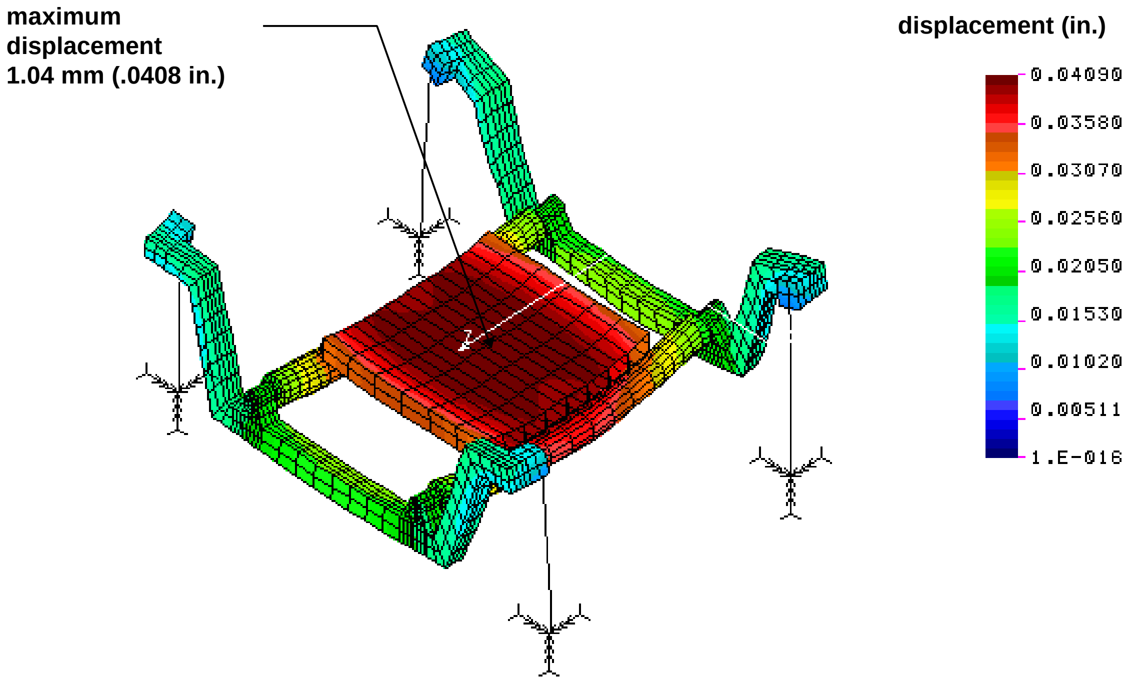
Gravitational loads are imposed on the support assembly in the form of forces located at the nodes within the footprints of the leg elements. The sum of these forces equals 7,851 N (3,891 lbs.) in the vertical direction. The 7,851 N (3,891 lbs.) is equivalent to the sum of the weights of the leg elements, optic table, and payload. The stresses and deflections are illustrated in Figs. 4 and 5.

The majority of the deflections are due to the bending of the structure, not compression of the actuators.



maximum stress
3.5x10^7 Pa (5,060 psi)

Figure 4. Stresses under gravitational loading



maximum
displacement
1.04 mm (.0408 in.)

Figure 5. Deflections under gravitational loading

3.2.2 Pseudo Earthquake Loading

Static loads are imposed on the support assembly to roughly simulate the effect of earthquakes. Forces are applied on the nodes within the footprints of the leg elements. These forces are equivalent to 17,300N (3,890 lbs.) in the vertical direction and 8,650N (1,945 lbs.) in the transverse directions. The 17,300N (3,890 lbs.) is the sum of the weights of the leg elements, optic table, and payload. The 8,650N (1,945 lbs.) represents the .5 g's of acceleration, more than equivalent to an earthquake load.* Figures 6 through 9 show the maximum stresses and deflections for the two load cases. Gravity is also considered in both load cases. Load case 1 has the transverse forces perpendicular to the beamline. In load case 2, they are parallel to the beamline.

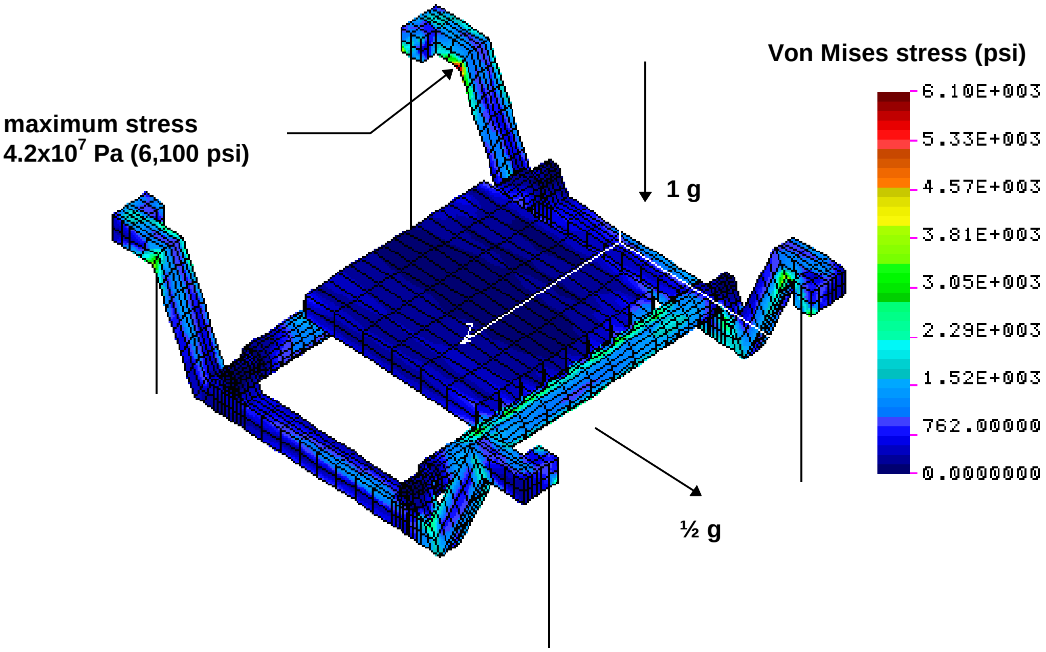


Figure 6. Stresses under pseudo earthquake loading - Case 1[*]

---

[*] pessimistic evaluation of equivalent horizontal static loads at the Hanford site (zone 2B) lead to 0.1g to 0.4g (per calculation procedures defined in the Uniform Building Code)

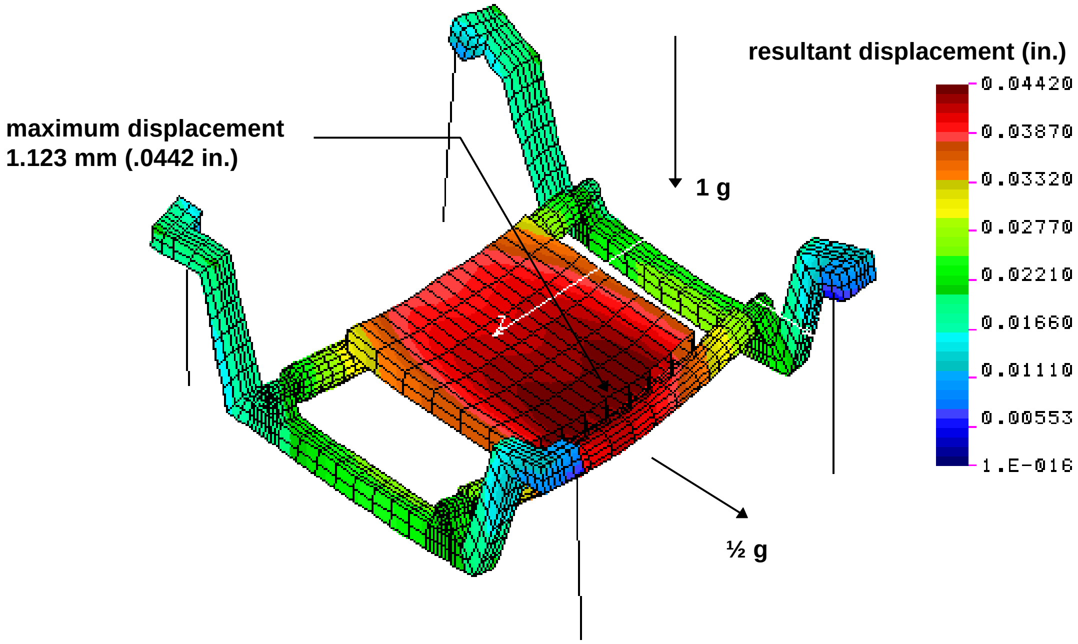


Figure 7. Deflections under pseudo earthquake loading - Case 1

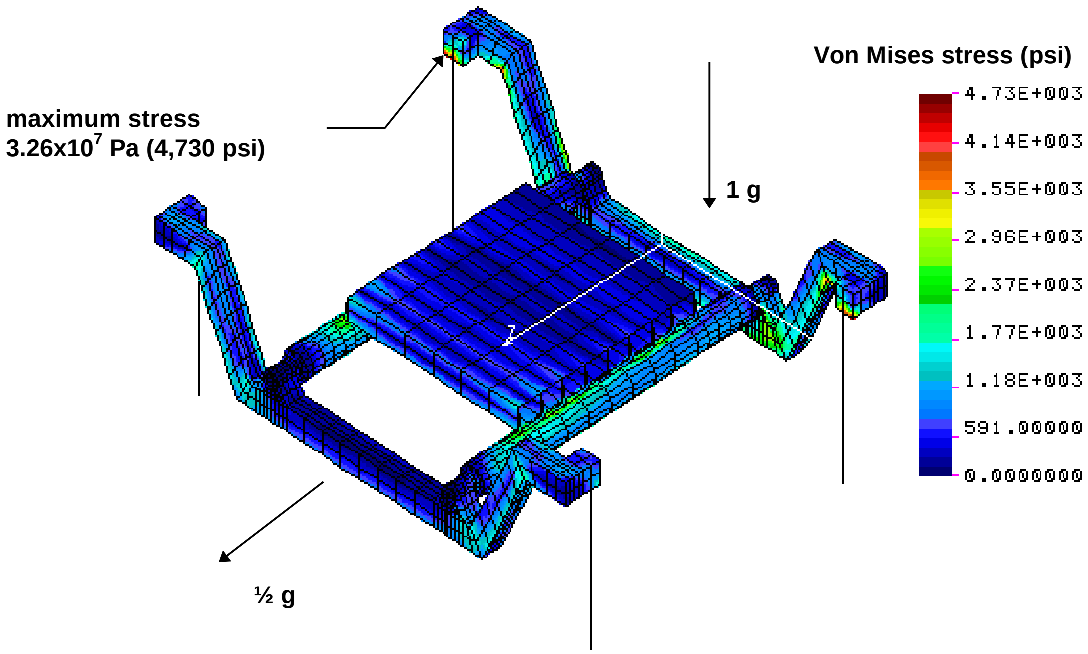


Figure 8. Stresses under pseudo earthquake loading - Case 2

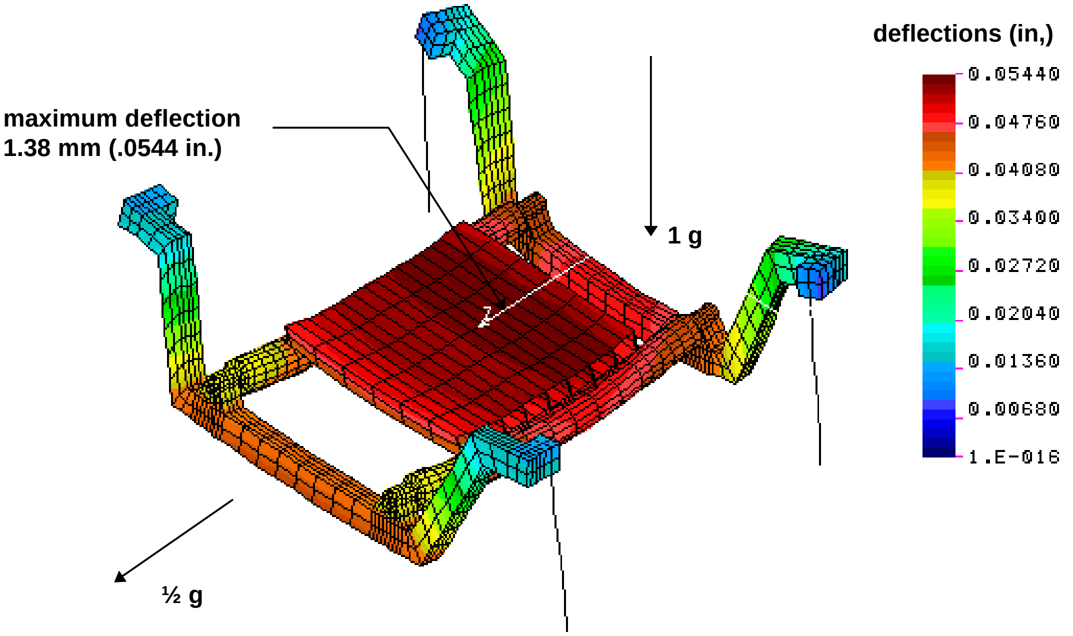


Figure 9. Deflections under pseudo earthquake loading - Case 2

3.3 Buckling

The model was loaded with vertical forces equal to 17,300N. This was equivalent to the forces generated by the weights of the stack, optics table and payload. The COSMOSM program calculated the buckling safety factor at 290. The top plate is removed in Figure 10. It shows that the lateral stiffeners are the weakest members in buckling.

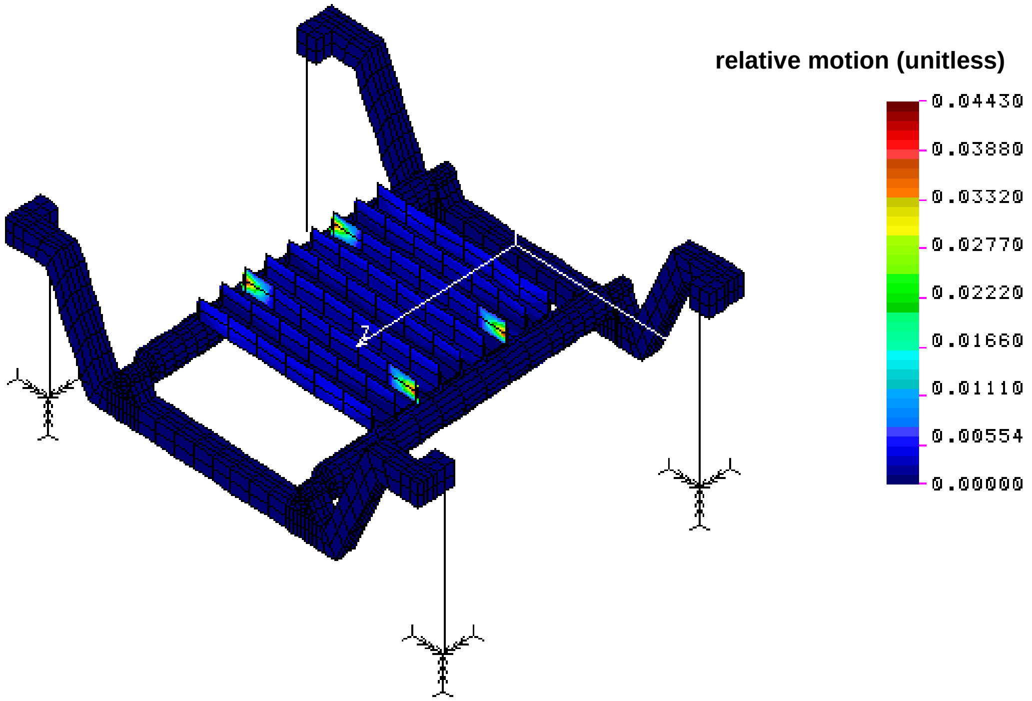


Figure 10. Buckling safety factor = 290
(top plate removed for clarity)

4. Conclusion

The low fundamental frequency is attributed to the gull wing design of the crossbeam. The gull wing design was required to accommodate the offset location of the support beams in the HAM pressure vessel relative to the location of the Z-drive. The problem is compounded by the lack of space, which restricts the stiffness of the crossbeam.

. However, the design is structurally sound. Stresses are well below the material yield points.

Note 1, Linda Turner, 09/03/99 11:39:09 AM
LIGO-T970237-00-D