LIGO Laboratory / LIGO Scientific Collaboration

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Finite Element Analysis of Advanced LIGO SUS ETM structures using ANSYS workbench

Tim Hayler, Mark Barton, Caroline Cantley, Dennis Coyne, Justin Greenhalgh, Russell Jones, M Perreur-Lloyd, Joe O'Dell, Norna Robertson, Janeen Hazel Romie, Ken Strain, Calum Torrie, Ian Wilmut.

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This is an internal working note
of the Advanced LIGO Project, prepared by members of the UK team.

Institute for Gravitational Research
University of Glasgow
University Avenue, Glasgow G12 8QQ,
Scotland UK

+44 (0) 131 440 5880

Department of Physics
University of Birmingham

+44 (0) 121 414 6447

Engineering Department
CCLRC Rutherford Appleton Laboratory
Chilton, Didcot, Oxon OX12 0NA
Phone +44 (0) 1235 44 5297
Fax +44 (0) 1235 445843

Particle Physics and Astronomy Research Council (PPARC)

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http://www.eng-external.rl.ac.uk/advligo/papers_public/ALUK_Homepage.htm.

1. INTRODUCTION

This document continues on from the analysis work done in document LIGO-T060087-00-K which looks at trends for a new design of the noise prototype structure. In the new design the lower structure has a comparatively stiff outer sleeve with “x” bracing; the internal functional part is a similar light weight version of the previous design. The development of the design is shown here using Pro-Engineer CAD models and the finite element package, ANSYS workbench.

2. OUTRIGGERS WITH “X” BRACING

The design, shown in figure 1, makes use of outriggers with “x”-bracing; its first two frequencies are 77 and 86 Hz. In the document LIGO-T060059-00-K we saw how this design did not improve the frequency from previous designs and the reasons why.

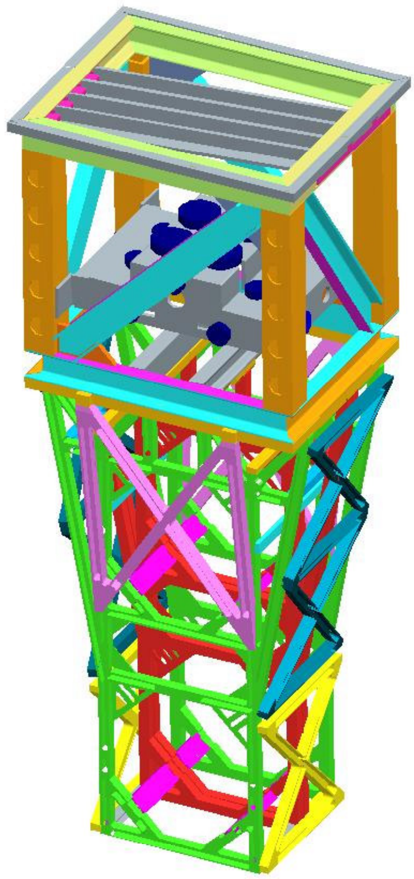

Fig 1. Current design 1st and 2nd frequencies 77, 86 Hz

3. VERIFICATION OF BEAM MODELS

The first model shown in figure 2 verifies the work done with beam models in document LIGO-T060087-00-K. Table 1 compares the values from the beam models with the solid model.

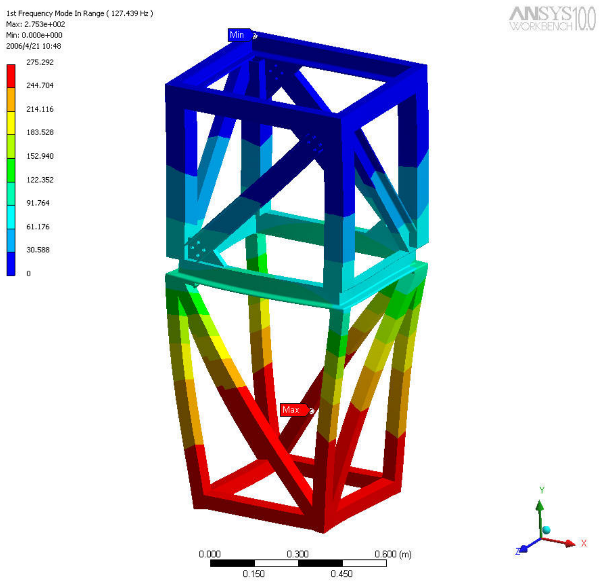

Fig 2. Simple structure with the same geometry as the beam model, 1st and 2nd frequencies 127, 146 Hz.

Table 1. Comparison between ANSYS workbench and beam model solutions.

Mode	Mode shapes workbench versus classic beam model	ANSYS workbench solution Hz	ANSYS beam model solution Hz
1st	same	127	126
2nd	same	146	149

The values in the table compare favourably giving confidence in the design intent.

4. DEVELOPMENT OF DESIGN

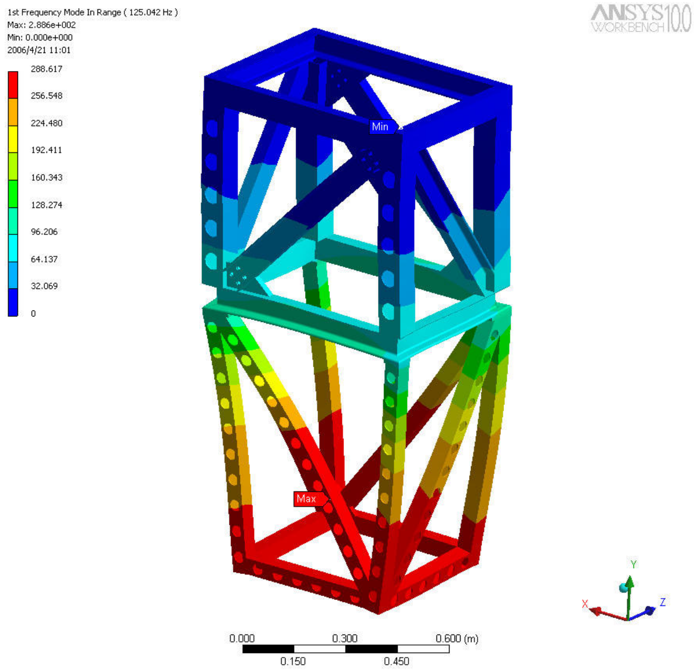

Fig 3. Simple structure with holes for cleaning access, 1st and 2nd frequencies 125, 147 Hz.

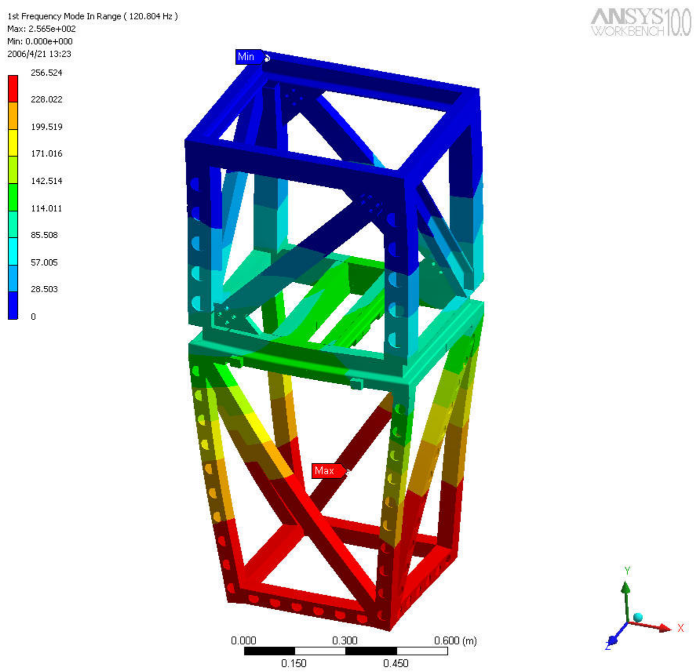

Fig 4. Simple structure with two additional cross members in the upper structure and the implementation ring, 1st and 2nd frequencies 120, 144 Hz.

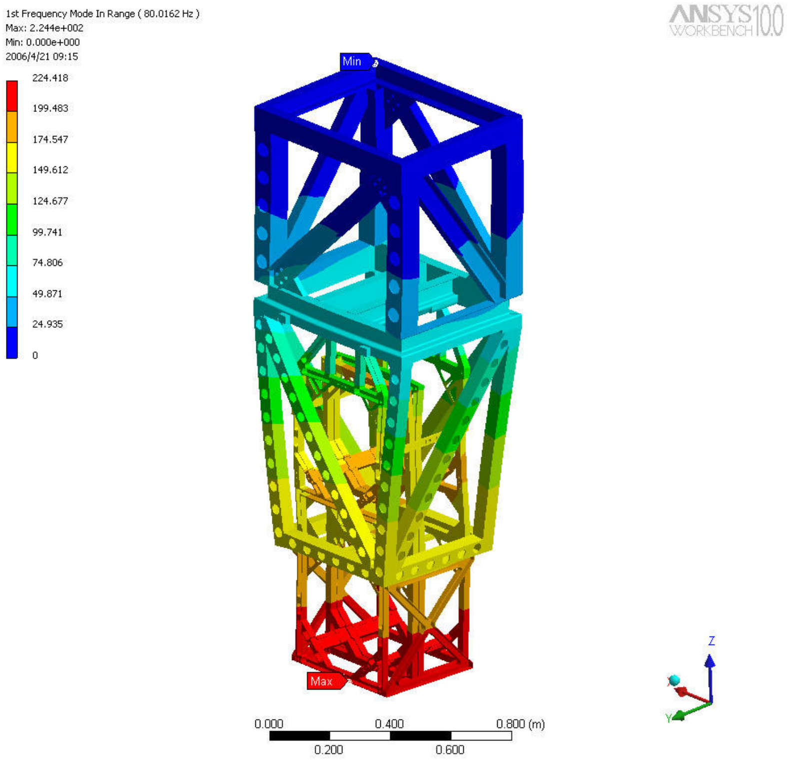

Fig 5. Stiff lower structure with original face plates, 1st frequency 80 Hz

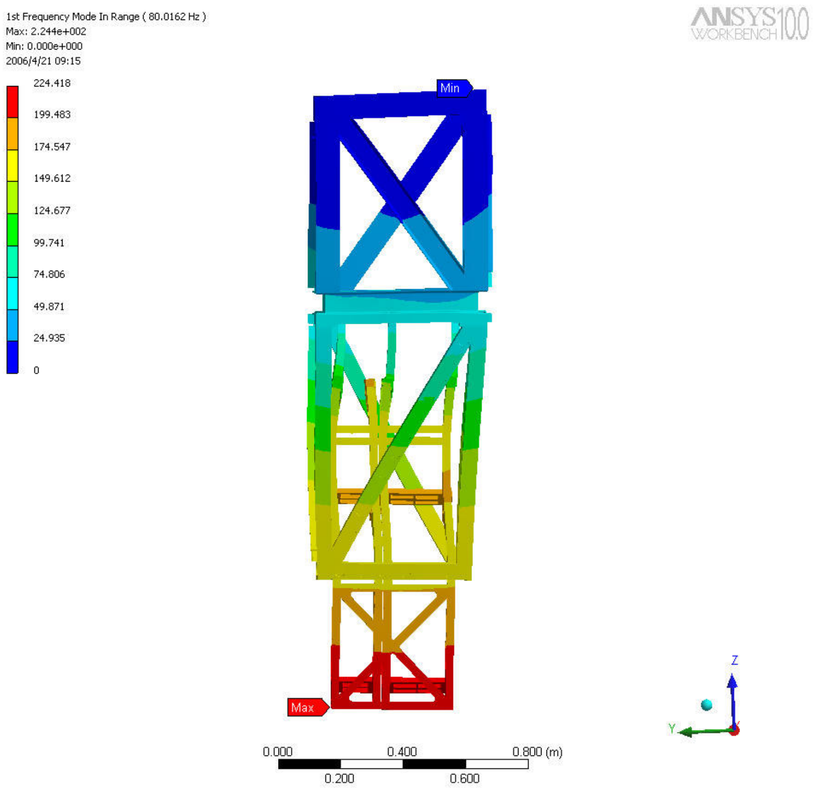

Fig 6. Stiff lower structure with original face plates, 1st frequency 80 Hz. Face plates are badly connected together.

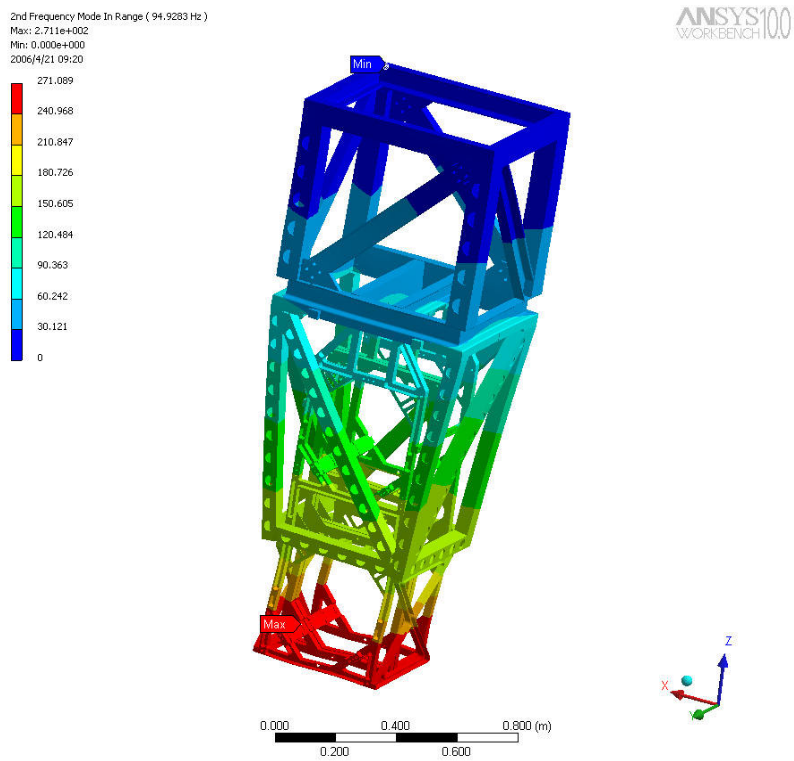

Fig 7. Stiff lower structure with original face plates, 2nd frequency 95 Hz

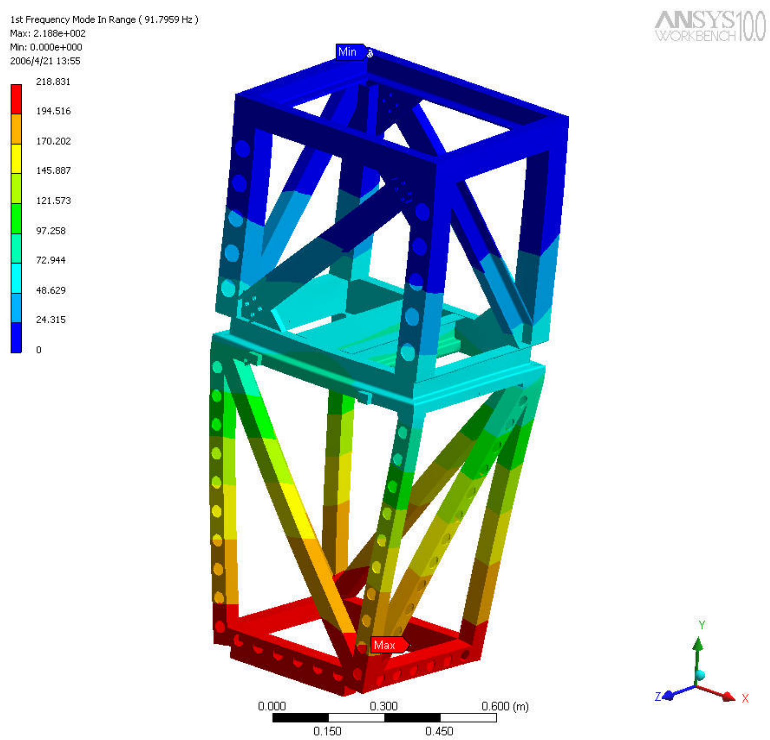

Fig 8. Simple structure with two additional cross members in the upper structure, the implementation ring and 10kg of extra mass at the extreme bottom, 1st and 2nd frequencies 92, 112 Hz

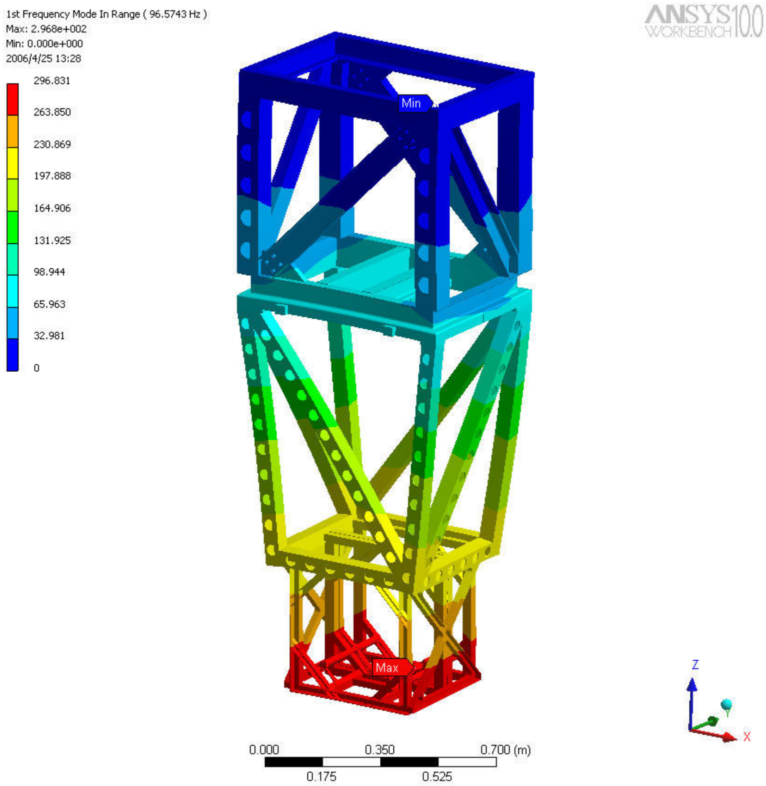

Fig 9. Simple structure with two additional cross members in the upper structure, the implementation ring and the test mass part of the face plates. 1st and 2nd frequencies 97 and 114 Hz.

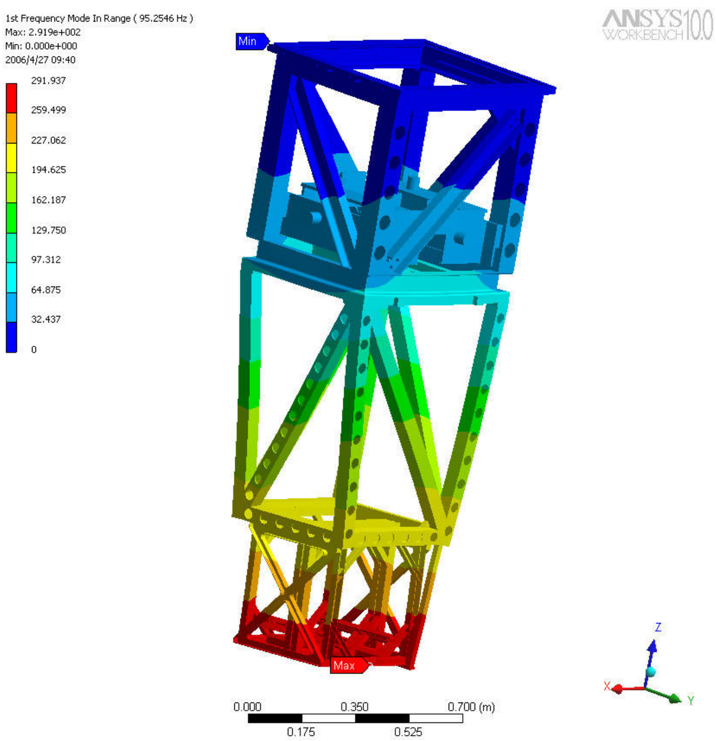

Fig 10. Simple structure with two additional cross members in the upper structure, the implementation ring, tablecloth and the test mass part of the face plates. This structure has an extra beam at the bottom to retain the face plates. 1st frequency 95.3 Hz.

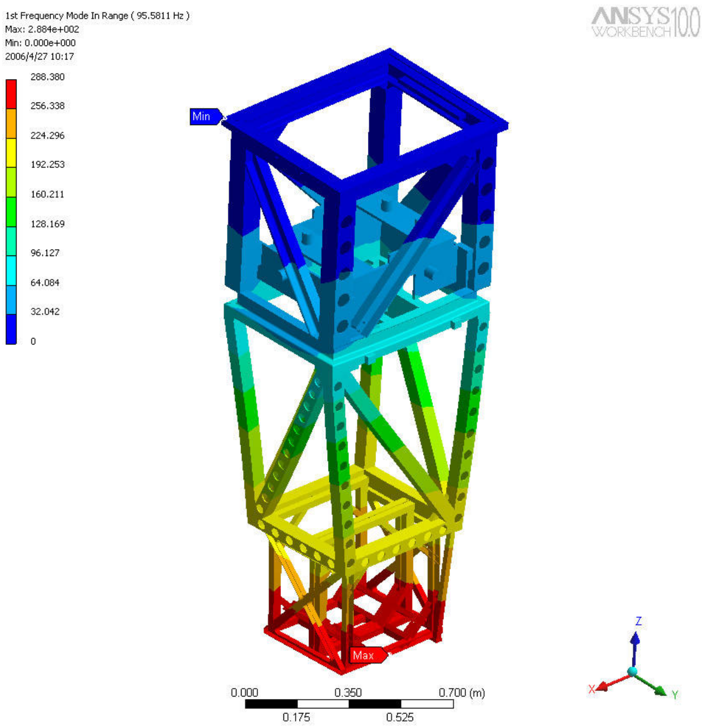

Fig 11. Simple structure with two additional cross members in the upper structure, the implementation ring, tablecloth and the test mass part of the face plates. This structure has an extra beam with an infinite stiffness at the bottom to retain the face plates. 1st frequency 95.6 Hz.

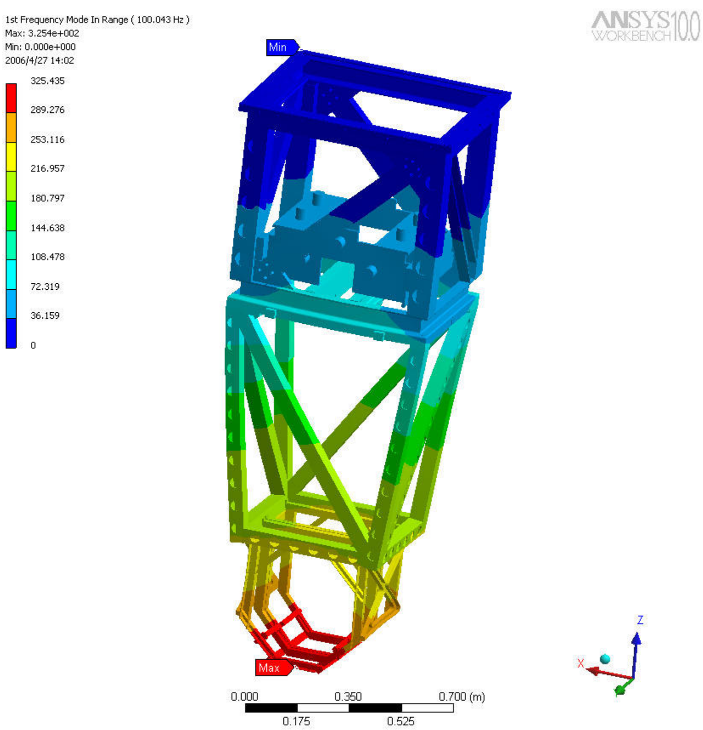

Fig 12. Simple structure with two additional cross members in the upper structure, the implementation ring, tablecloth and the light weighted test mass parts of the face plates. 1st and 2nd frequencies 100, 118 Hz.

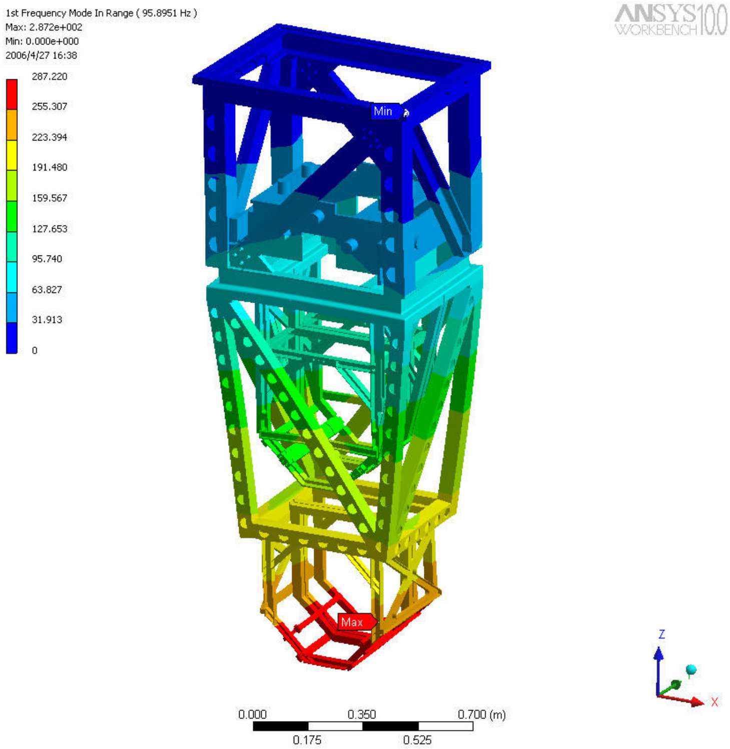

Fig 13. Simple structure with two additional cross members in the upper structure, the implementation ring, tablecloth and the complete light weighted face plates split into two separate units. 1st and 2nd frequencies 96, 112 Hz

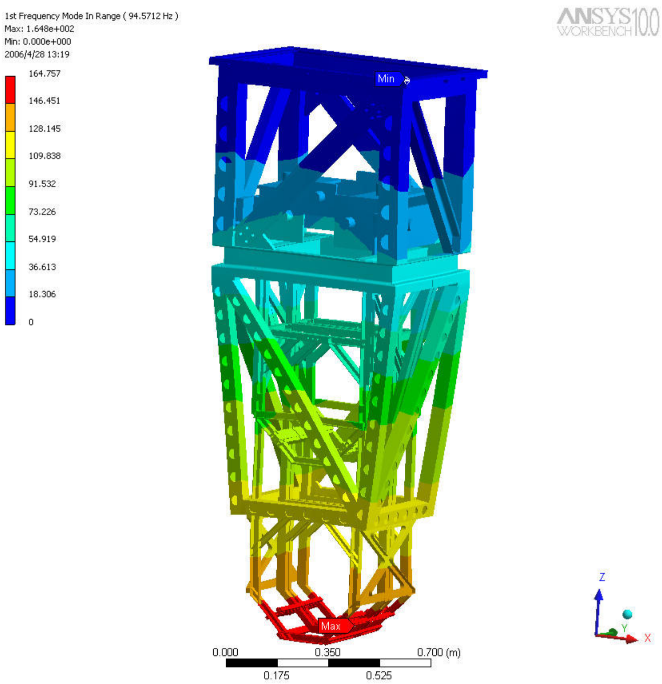

Fig 14. Simple structure with two additional cross members in the upper structure, the implementation ring, tablecloth and the light weighted face plates in one complete unit. 1st and 2nd frequencies 95, 112 Hz.

CONCLUSION

Table 2 shows the performance of the SUS ETM structures. The first three rows demonstrate the discrepancy between predicted and measured frequencies for the overall controls, upper and lower structures taken from the document LIGO-T050237-03-D; Frequency analysis of the quadruple Pendulum Controls Prototype Structure. The third row suggests a fantasy figure for the discrepancy between the predicted and measured values for the noise structure design.

The table shows that the overall controls structure has a large discrepancy of 35% between predicted and measured values for the frequency. Given that the controls structure is made up of the upper and lower structures, by examining the table we can seek to understand where this large discrepancy comes from; the upper structure discrepancy is small at 15% where as the lower structure discrepancy is large at 40%. A possible explanation for this lies in the construction of the two structures. The upper structure discrepancy is small, most probably due to its simple welded construction and the lower structure discrepancy is large, possibly due to its multiple bolted connections; this has been explored in T060059-00-K.
In the noise design there is a dominant sleeve like structure that dictates the behaviour of the lower structure, shown mounted to the upper structure in figure 2. Because the design of this structure is similar in construction to the upper structure and bypasses the effect of the multiple bolted connections, we anticipate the discrepancy for the noise structure to be better than the controls structure. A reasonable figure for the discrepancy is then 25%. Working back from this figure the final row in the table indicates that the frequency of the overall structure has increased from 54 to 72Hz

Table 2. Performance of the SUS ETM structures.

Structure	Predicted frequency [Hz]	Measured frequency [Hz]	Discrepancy [%]
Controls	84	**54**	35
Upper	230	200	15
Lower	120	72	40
Noise	95	**72** (fantasy)	25 (fantasy)