ETM STRUCTURAL DESIGN SUMMARY

FEA OF PROPOSED ETM STRUCTURE

ANSYS Workbench (ANSYS University Advanced) version 9.0
LIGO-G050187-00-Z

Information also covered in LIGO-T040214-DRAFT

March 22nd 2005

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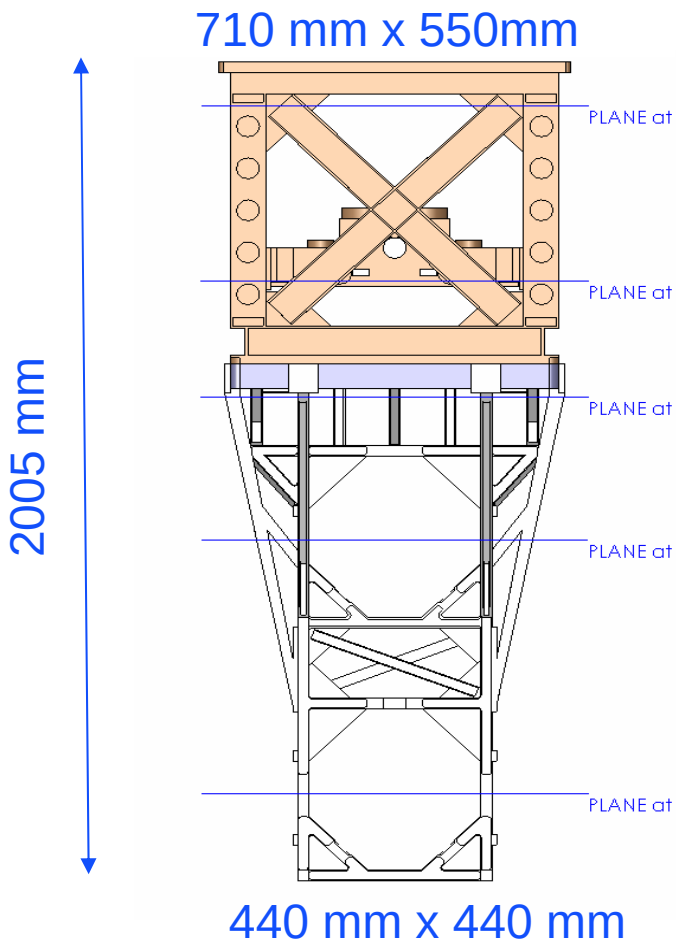
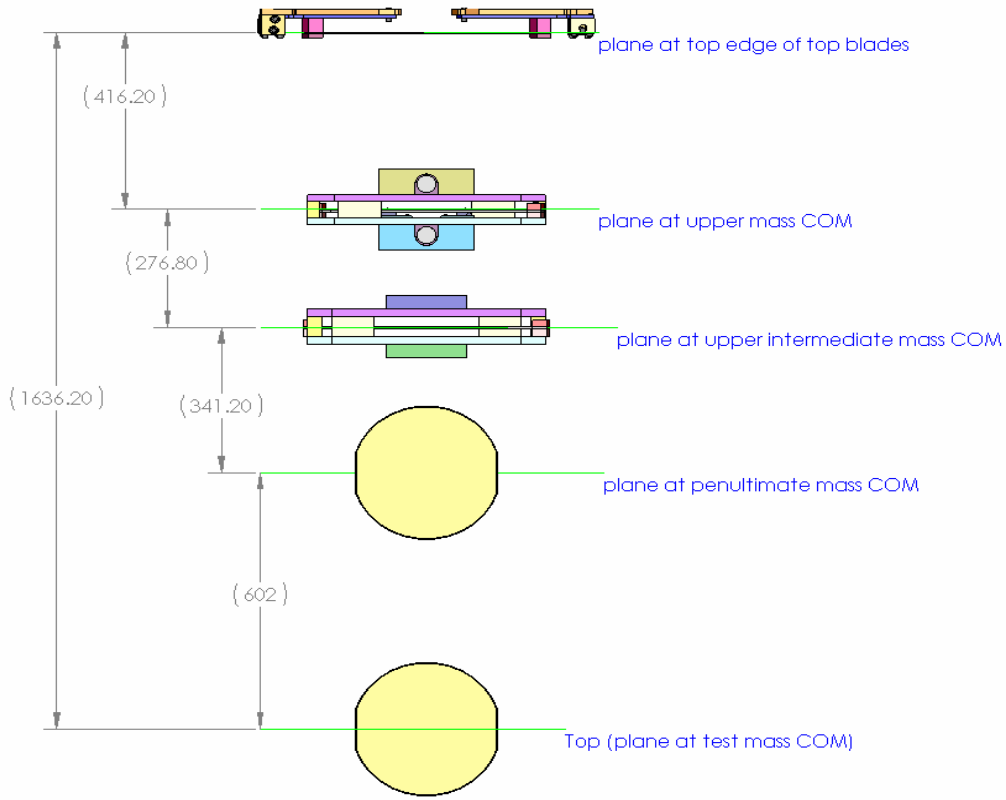
Layout of the Controls prototype





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REQUIREMENTS

The first resonance limits, including structural and non structural mass, and assuming a perfectly rigid support:

- > 200 Hz first resonance for the upper structure
- > 100 Hz Lower structure
- > 100 Hz combined upper and lower structure

Initially confirmed by FEA with a 15% contingency, later confirmed by prototype testing.

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Cf. 418 kg from LIGO-T030137

MASS BUDGET

- UPPER

TOP MASS, 22 kg x 2 (S)		= 44 kg
» Tablecloth etc … (NS)	15 kg + 25 % C	= 19 kg
» Top Stage (NS)	24 kg + 25 % C	= 30 kg
» Ring (NS)	5 kg + 100 % C	= 10 kg
» UPPER STRUCTURE	37 kg + 25 % C	= 46 kg

- LOWER

» UI MASS, 22 kg x 2 (S)		= 44 kg
» PEN MASSES, 40 jg x 2 (S)		= 80 kg
» TEST MASSES, 40 kg * 2 (S)		= 80 kg
» CLAMPING etc, 23 + 25 % C (NS)		= 29 kg removable ?
» Ring (NS) 5 kg + 100%		= 10 kg
» Lower Structure (NS),23 kg + 25% C		= 29 kg
	TOTAL	**= 422 kg**

OVERALL NON-SUSPENDED MASS inc. STRUCTURE ~ 140 kg

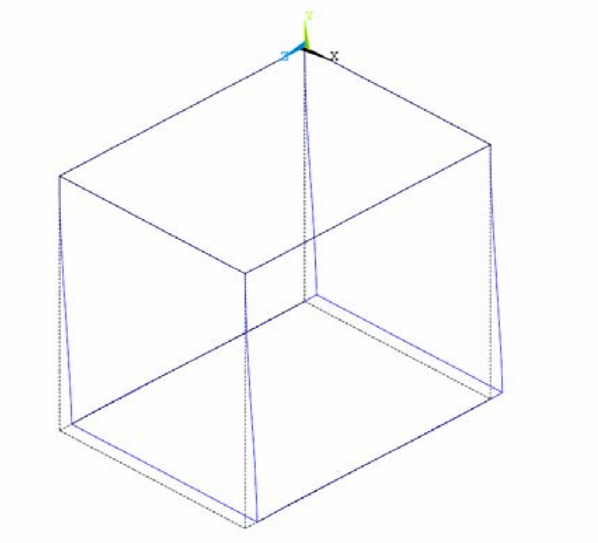
Actual Non-suspended mass inc. Structure ~ 133 kg

Designing for vacuum

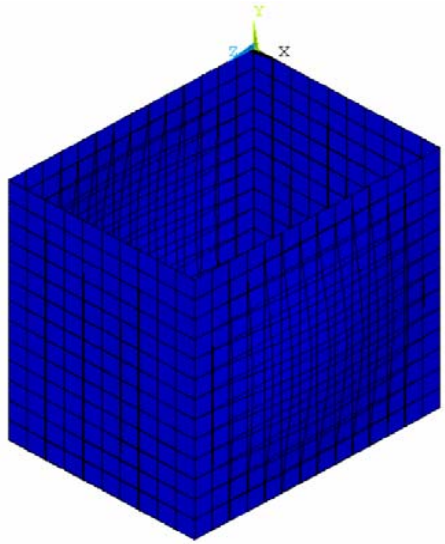
- Full penetration welds, avoids trapped volumes.
- No mating surface areas that trap residue from cleaning process.
- Welding method TIG, full penetration welds requires back gassing technique, labour intensive. Looking into possibility of dip brazing.
- Nitronic 60 thread inserts to inhibit wear, dust and galling.

  All holes to be through holes, LIGO-T040111-00-D
- Grade of Aluminium 6061-T6 is acceptable with respect to out-gassing requirements, reference LIGO vacuum compatible materials list, LIGO-E960050-B-E.

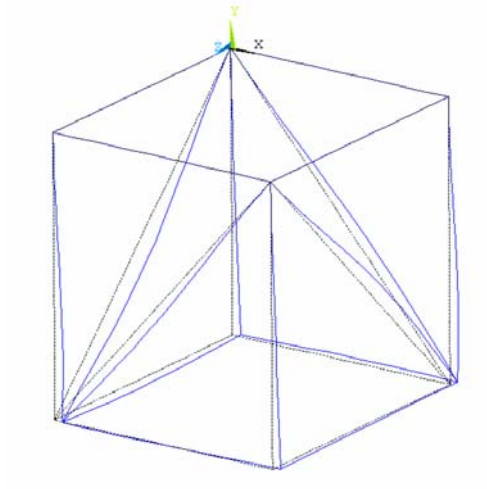
Beams and Shells
Upper structure example



Box structure,
1st mode 90 Hz.

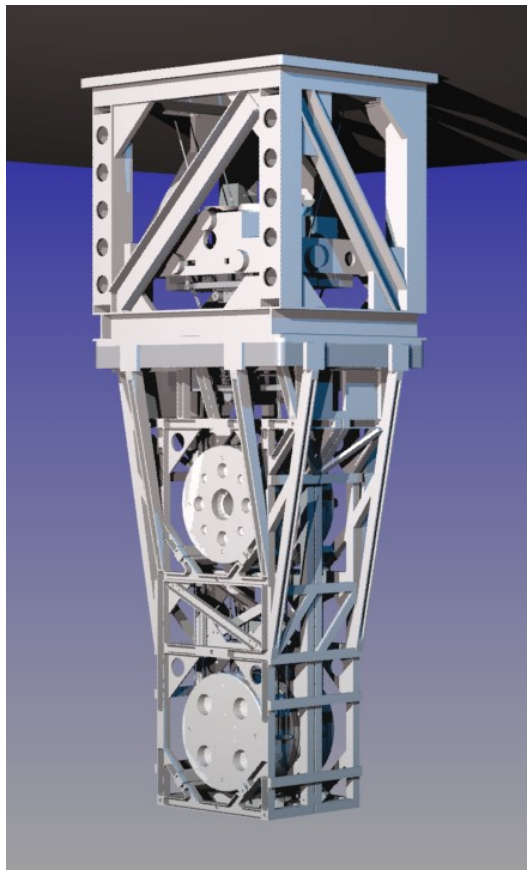


Box structure
with plates,
1st mode 118 Hz.



Truss structure,
1st mode 240 Hz

ETM STRUCTURES
CAD MODELS

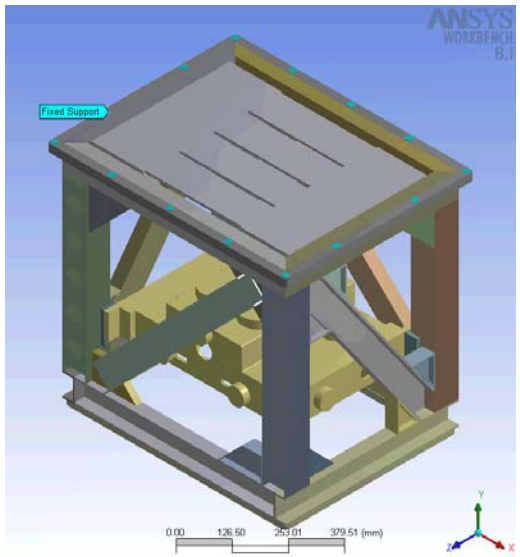


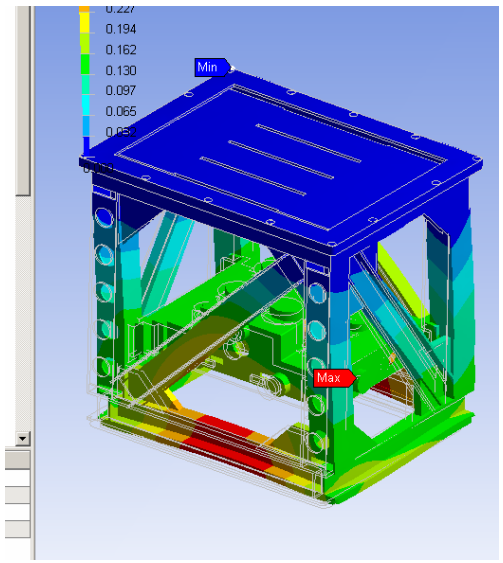
Solid model FEA
Clamping, Meshing, Convergence & Comparison

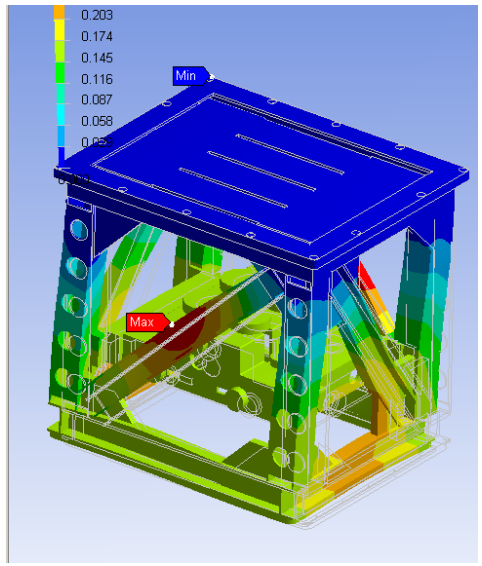
- CLAMPING
  - » Surface fixed — 235 Hz and 252 Hz
  - » 10-14 point locations — 215 Hz and 228 Hz
  - » 4 corners — 188 Hz and 202 Hz
- MESH
  - » in general basic mesh with ~ 50,000 elements. Had to use ~ 120,000 elements for overall structure. Assumes complete connectivity, welded structure. Defeaturing the model such as rounds and holes.
- CONVERGENCE
  - Increase number of elements until solution converges
  - » work in process to cover this using reference LIGO-T030044
- COMPARISON
  - Solid model with beams and shells model
  - ALGOR and ANSYS Comparative analysis

GOAL: - 200 Hz + 15% contingency

UPPER STRUCTURE







14 fixed supports around the ledge.

1st mode = 214 Hz

2nd mode = 217 Hz

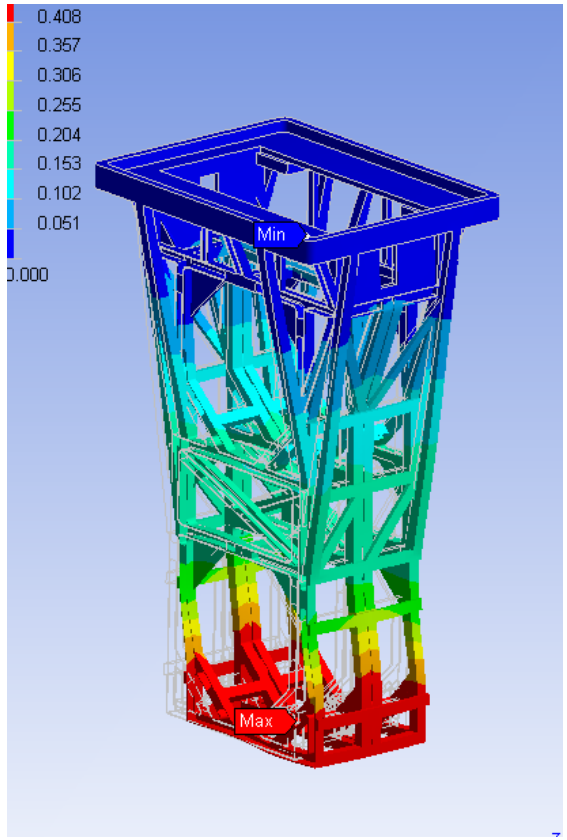
Mass = 84 kg; # of elements = 26,000; clamping at 14 points, same as the overall structure.

NOTE: - Comparative analysis done in ALGOR!

GOAL: - 100 Hz + 15% contingency

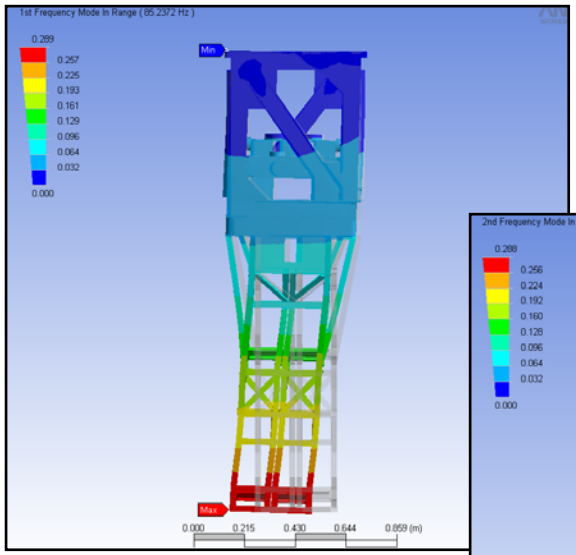
LOWER STRUCTURE

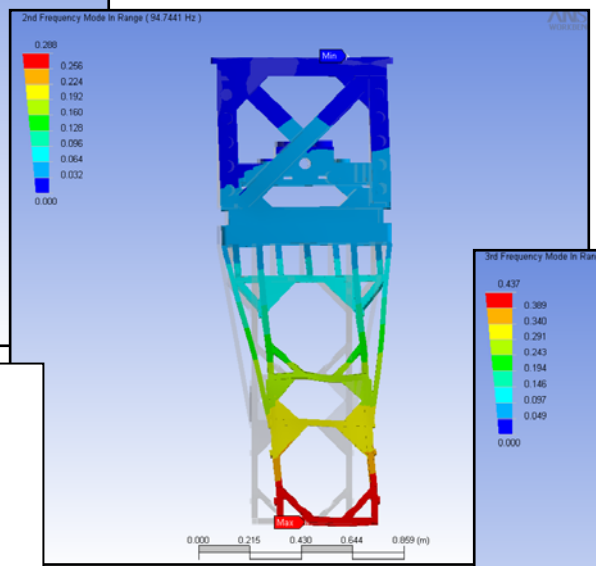
- # of elements = 45,000
- Clamping method, fixed support on ring surface.
- 1st mode = 130 Hz
- 2nd mode = 131 Hz
- Mass = 50 kg

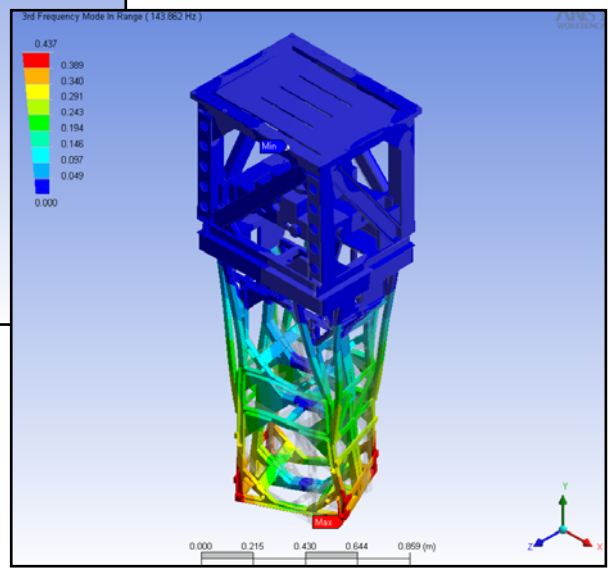


NOTE: - Comparative analysis done in ALGOR!

Overall Structure Modeling





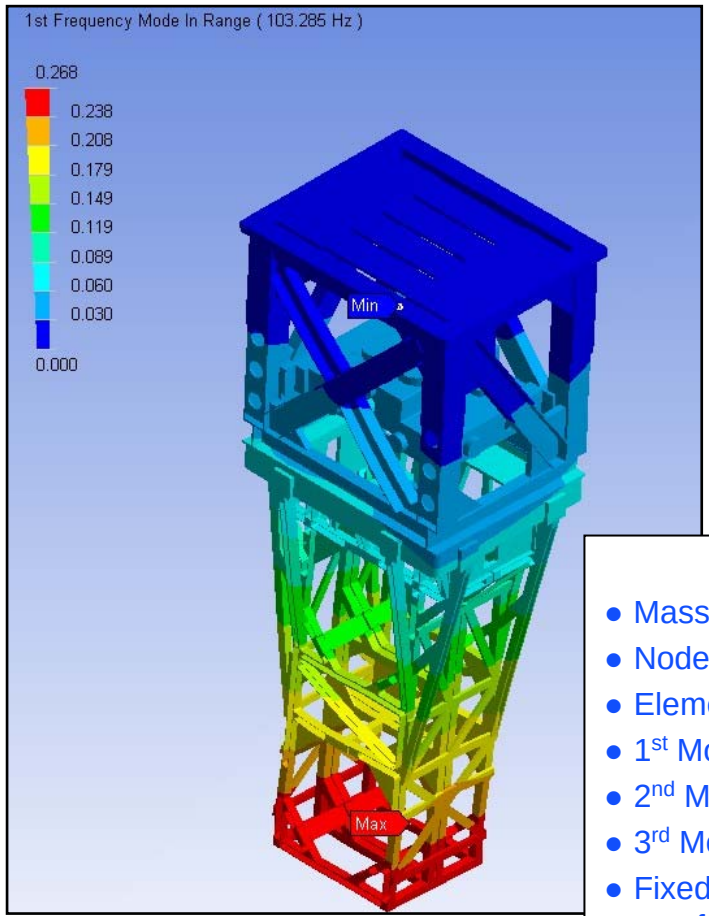


Model Notes

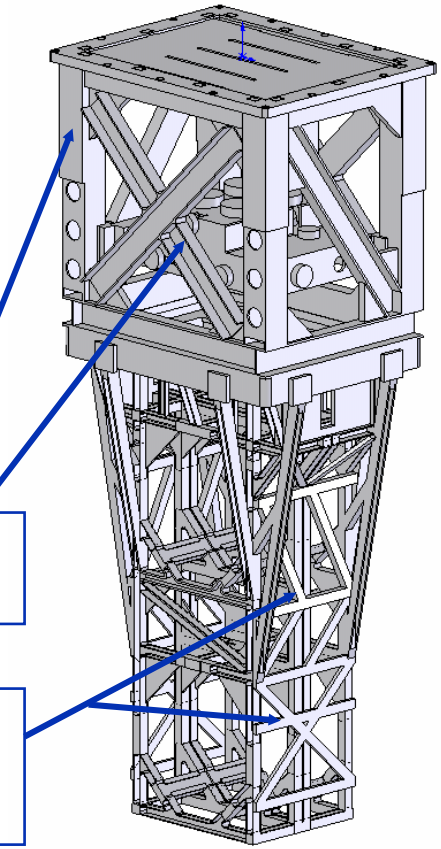
- Mass = **133 kg**
- Nodes = 115,000
- Elements = 57,000
- 1st Mode = **85 Hz** (long.)
- 2nd Mode = **94 Hz** (trans.)
- 3rd Mode = **144 Hz** (tors.)
- Fixed at 14 points around the top of the structure

• Tying together the Upper and Lower structure models we have a structure below the requirement of the mass budget with a 1st resonance of 85 Hz.

Potential Improvements



- By adding more stiffening members to both the Upper and Lower Structure we have been able to increase the first mode to above 100Hz, however we now are over the mass budget requirement.



Model Notes

- Mass = **140 kg**
- Nodes = 125,000
- Elements = 62, 000
- 1st Mode = **103 Hz** (long.)
- 2nd Mode = **108 Hz** (trans.)
- 3rd Mode = **178 Hz** (tors.)
- Fixed at 14 points around the top of the structure

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Future Plans

TWO STRUCTURES

- CONTROLS PROTOTYPE for CALTECH and MIT.

  Both will be made by Caltech Machine shop.

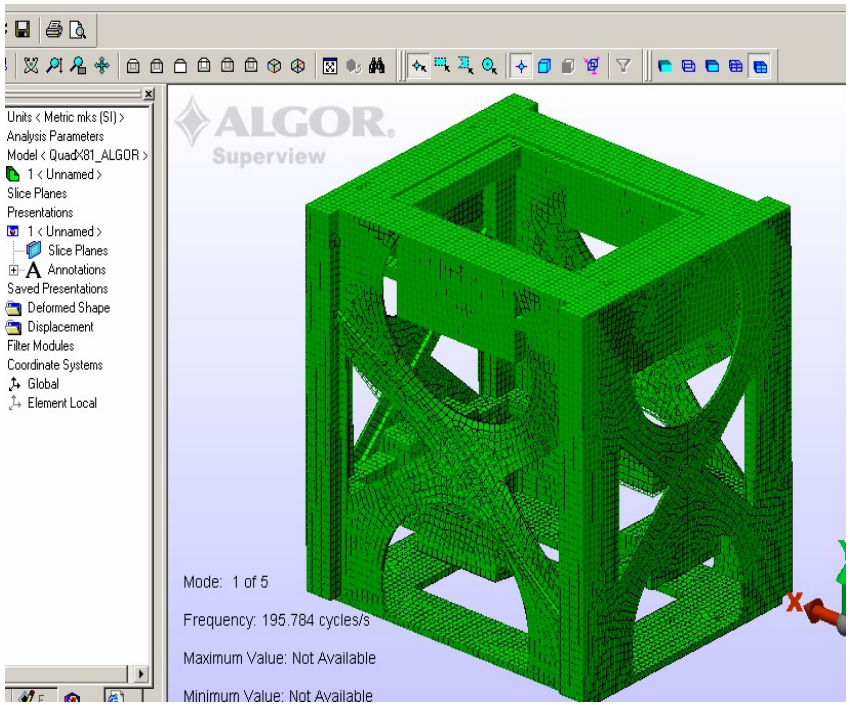
Piece parts being made at CALTECH now for the upper structure.

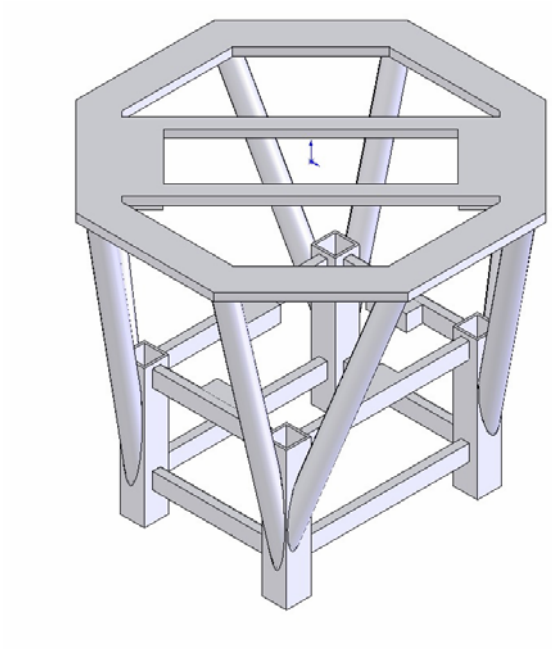
Lower structure will be in the CALTECH Machine shop by the end of the month.

- RESONANCE TESTS at STANFORD

  - Stanford transfer function tests will be done with the Seismic technology demonstrator.

History: Other Examples



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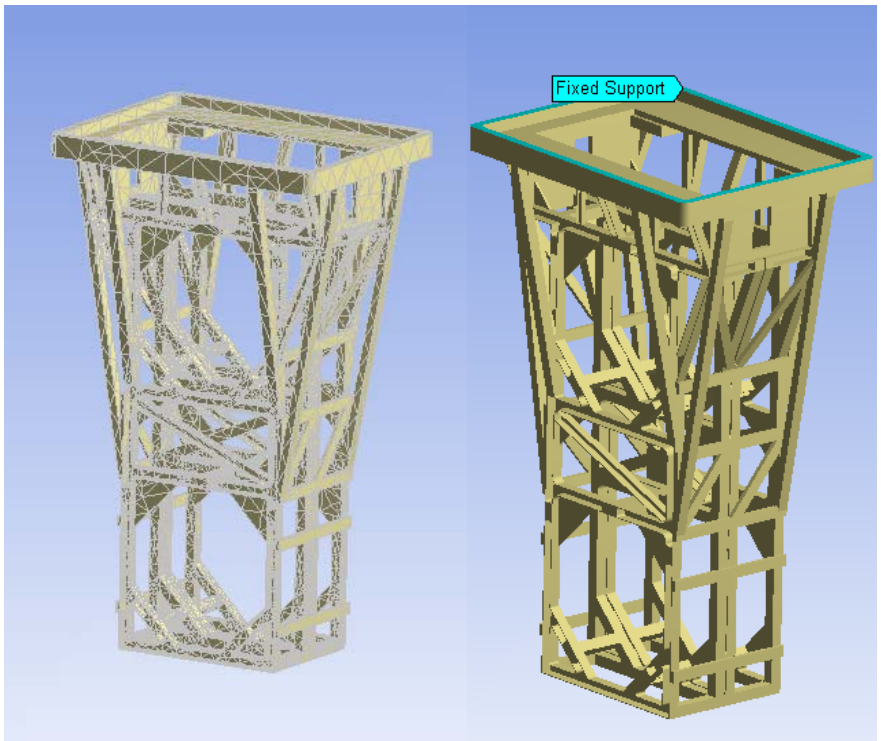
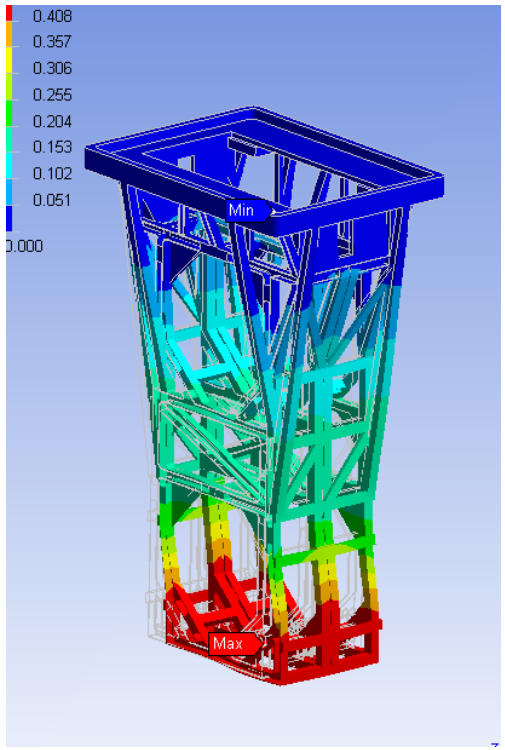
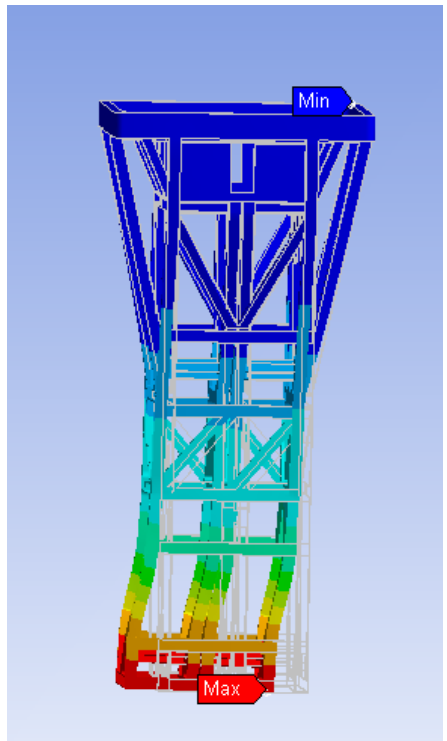
GOAL: - 100 Hz + 15% contingency

LOWER STRUCTURE - JAN







# of nodes = 127,000

# of elements 66250

Mass= 44 kg

Fixed Support

(for comparison only!)

1st mode = 146 Hz

Transverse

2nd mode 157 Hz

Longitudinal

NOTE: - Comparative analysis done in ALGOR!

GOAL: - 100 Hz + 15% contingency

OVERALL STRUCTURE - JAN

Mesh with 124,084 Nodes

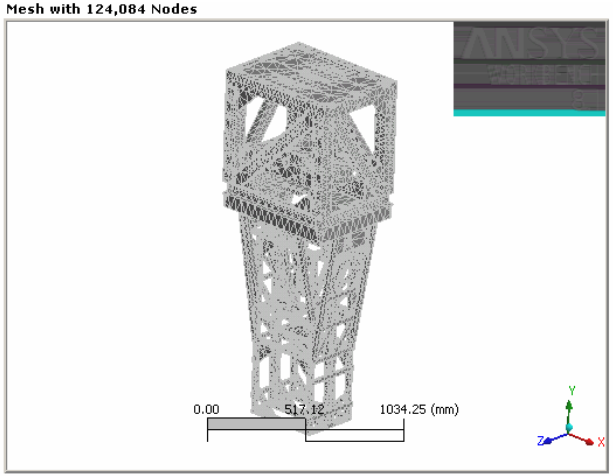


Figure A1.3. *"2nd Frequency Mode In Range"* Contours
Mode Shape 2

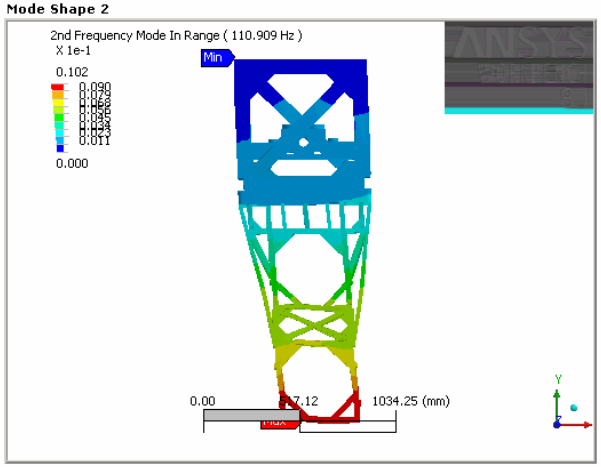


Figure A1.2. *"1st Frequency Mode In Range"* Contours
Mode Shape 1

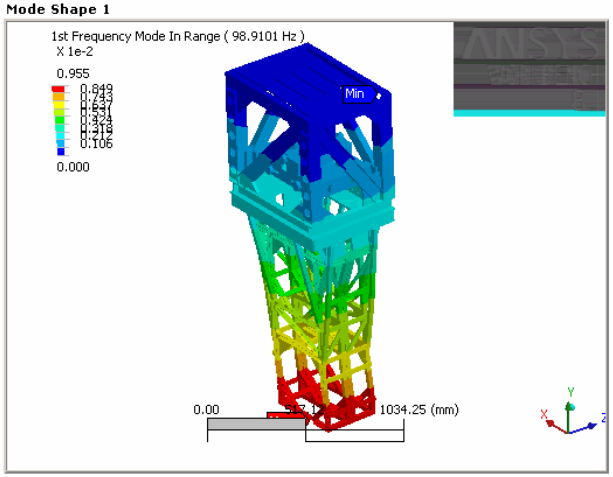
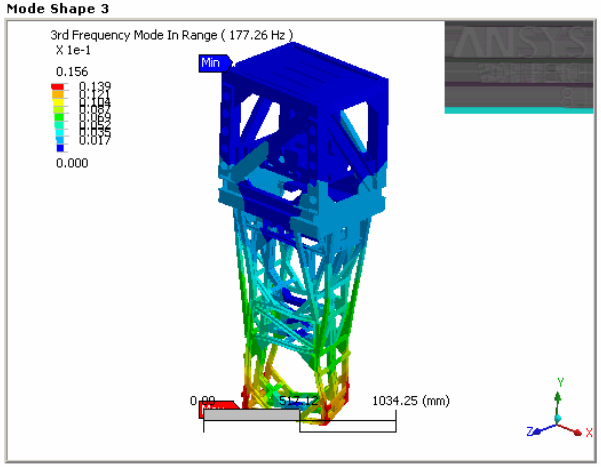


Figure A1.4. *"3rd Frequency Mode In Range"* Contours
Mode Shape 3



Mass 121 kg

f1 = 99 Hz

f2 = 111 Hz

f3 = 177 Hz

# of nodes = 124,000

# of elements = 62,021

Clamped at 14 fixed points

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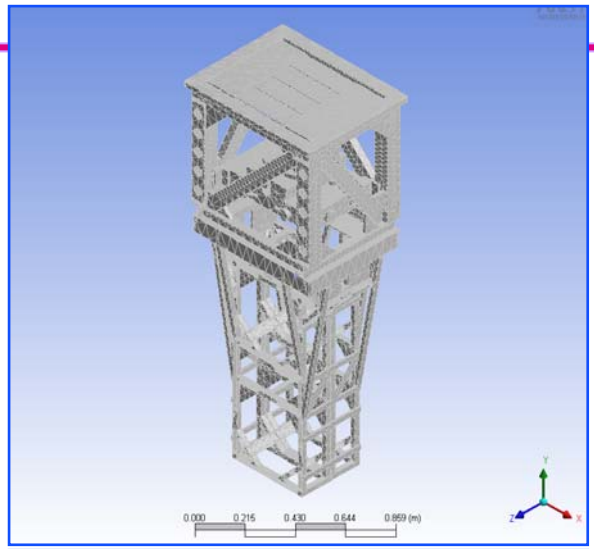
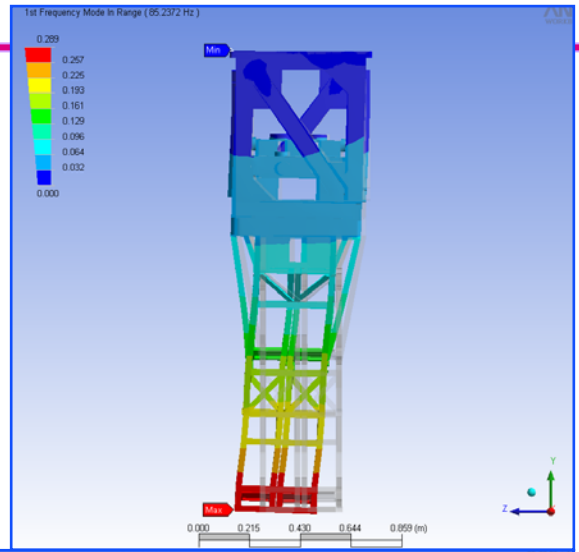
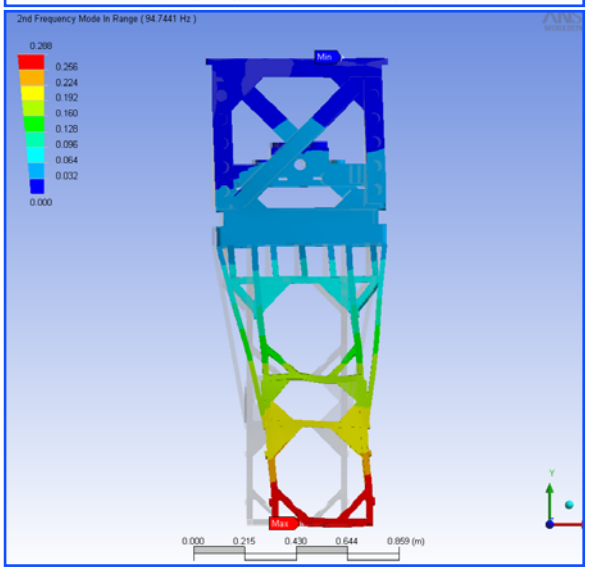
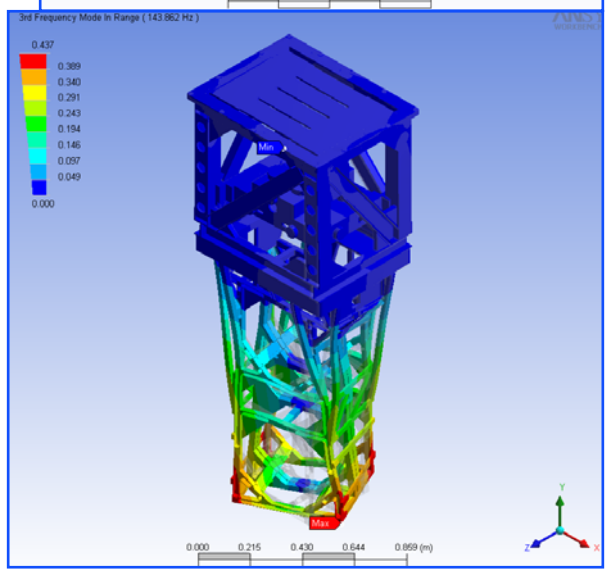
GOAL: - 100 Hz + 15% contingency

OVERALL STRUCTURE - FEB









Latest Model

Mass = 133 kg

Nodes = 115,000

Elements = 57,000

1st Mode = 85 Hz (long.)

2nd Mode = 94 Hz (trans.)

3rd Mode = 144 Hz (tors.)