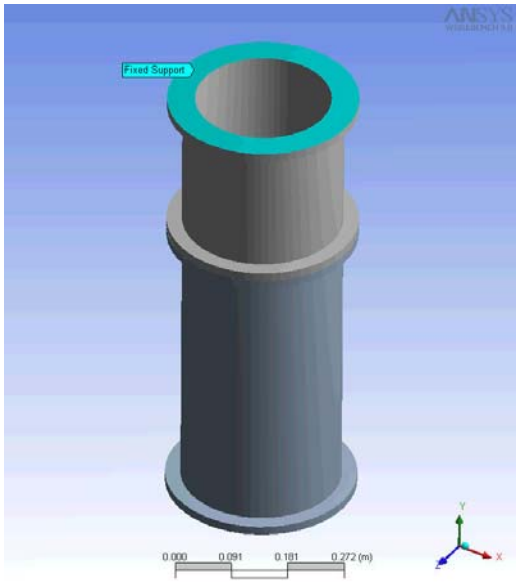
Frequency analysis of quad noise prototype

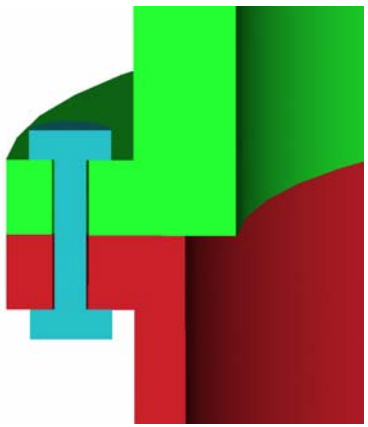
Justin Greenhalgh summarising work of Tim Hayler
and others in T060059-00-K

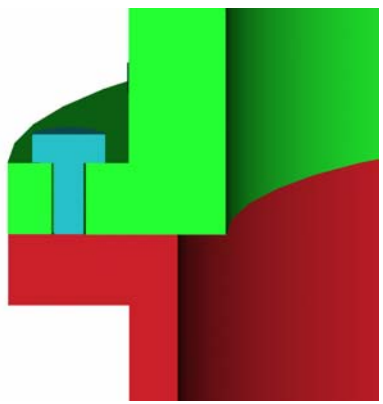
LSC Meeting, LHO, March 2006

LIGO-G060107-00-K

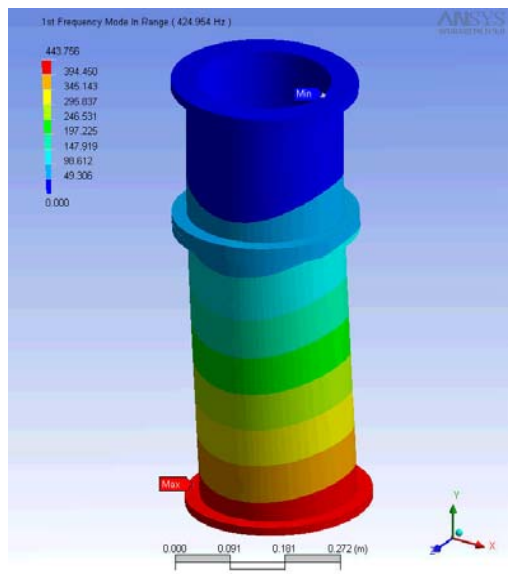
Simple bolted structure







Screws



Simple bolted structure

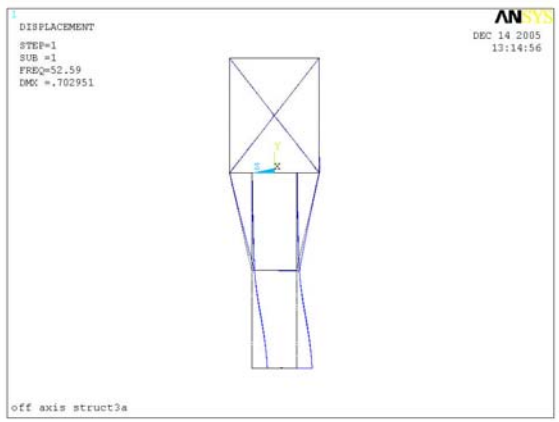
Fasteners	Contact surface stiffness	Fastener modulus	Hz
bonded	Program controlled	NA	424
"	0.01	"	402
"	0.001	"	328
Bolts	suppressed	2E11 Pa	224
"	"	2E15Pa	356
Screws	suppressed	2E11 Pa	298
"	"	2E15Pa	350
Bolts	frictionless	2E15Pa	405
screws	"	2E15Pa	408

Simple bolted structure – conclusions

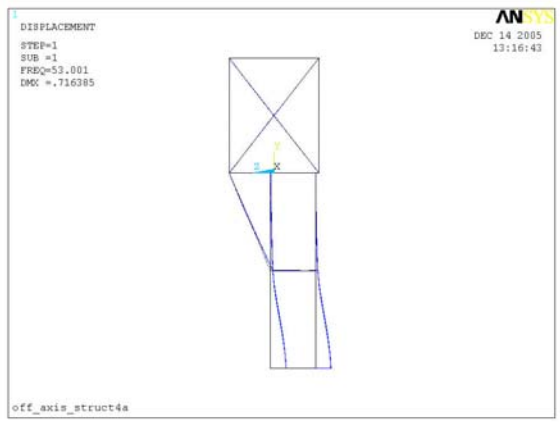
- Plenty of opportunity to vary the result with different representation of bolts/screws etc.

Asymmetric structure

- Idea: outriggers on one side are at a better angle
  - Downside is that the outriggers at the other side are ineffective – not clear if the benefits will outweigh the disadvantages
- Result – did not improve things



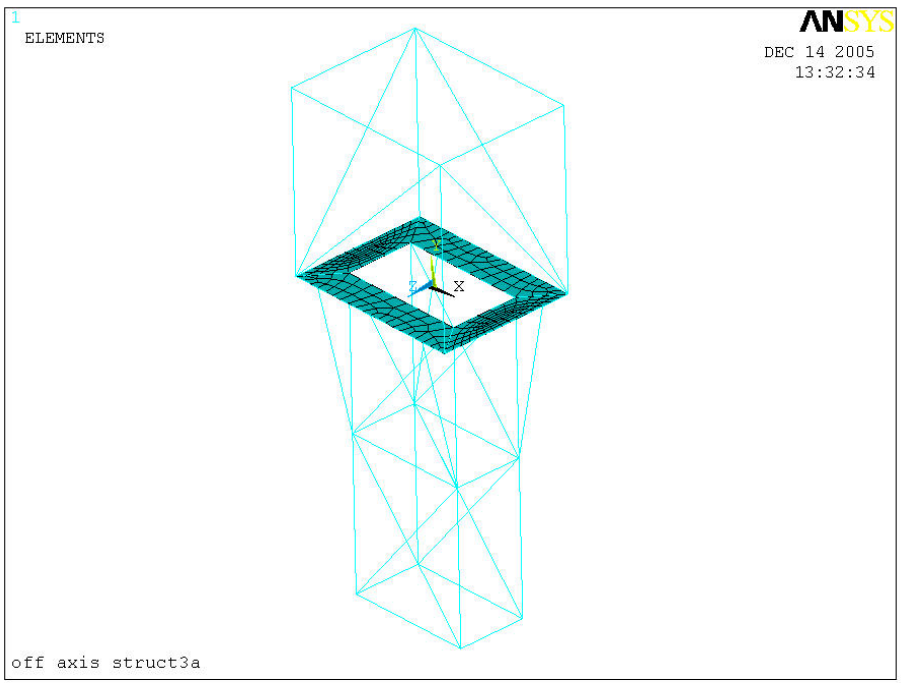
52.5Hz



53Hz

Change thickness of top plate

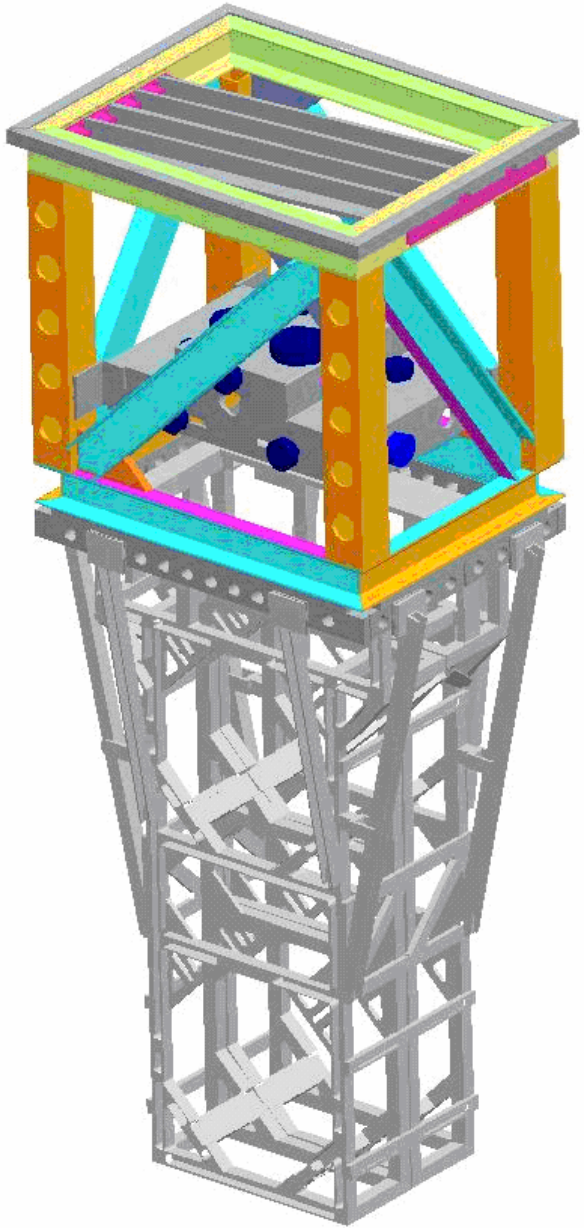
- Extra stiffness and extra mass – did not help

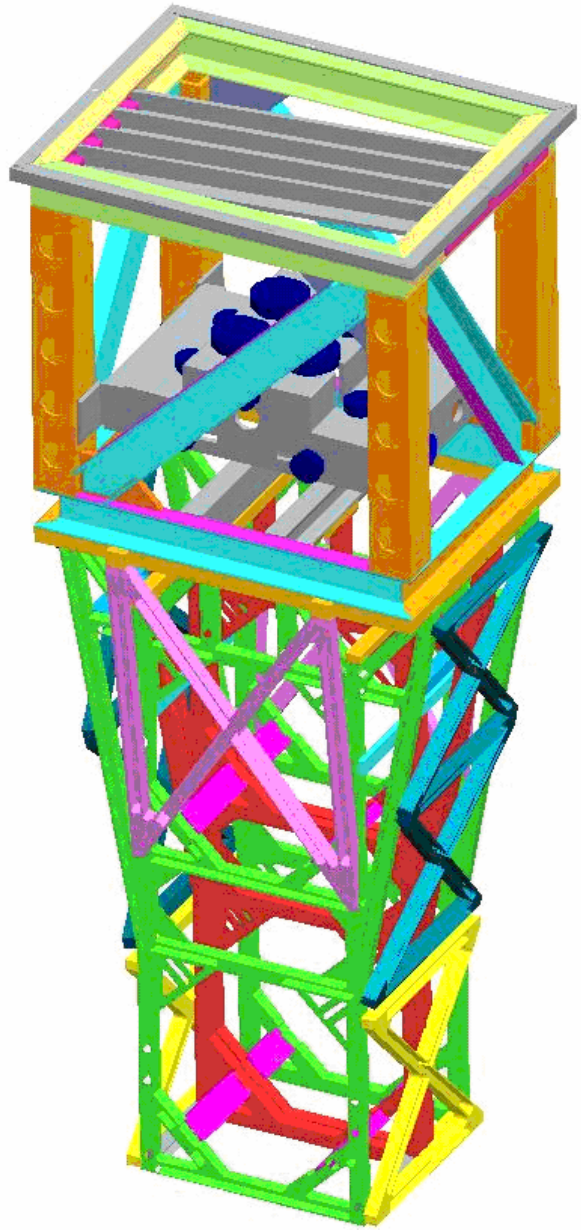


Modify bracing arrangement and reduce mass of implementation ring

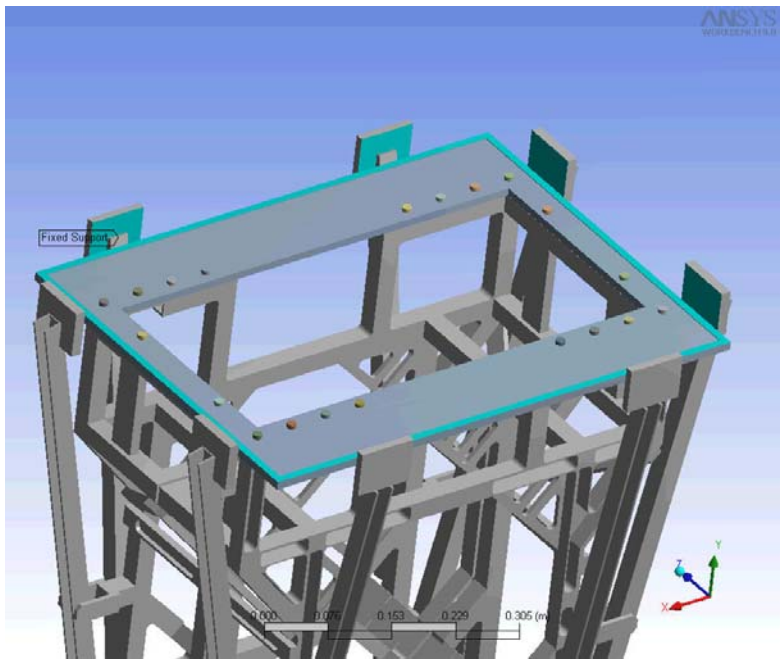
- Reduce from three rings of bolts to one ring of bolts at implementation ring
  - But bolts not in the model, so not surprising this did not help the results
- Modify bracing (outriggers) by looking at load paths and trying to straighten them
  - Probably we did not put enough mass into the outriggers – but even so it's a surprise that it did not help at all
- Bottom line result:
  - Before = 77.8 Hz
  - After = 77.8 Hz

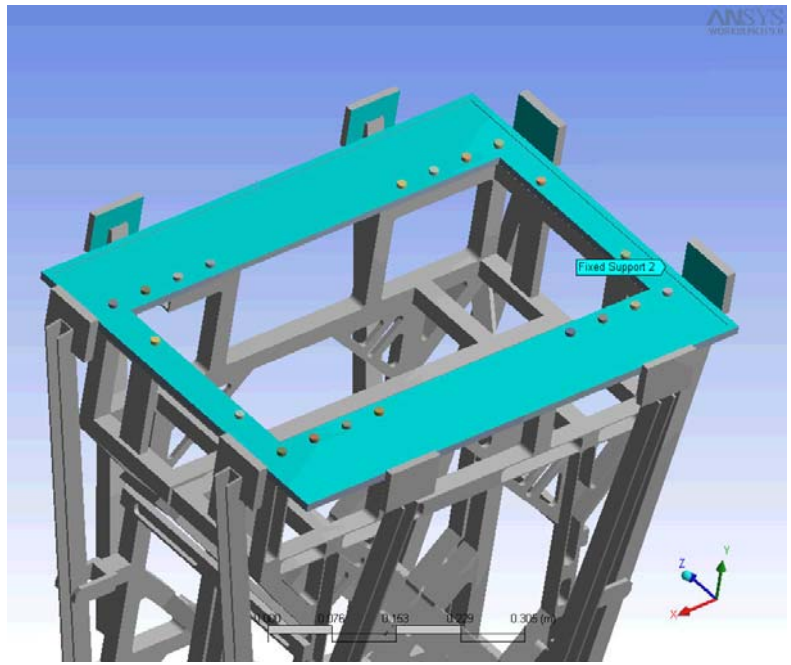
Modify bracing arrangement and reduce mass of nentation





Varying the clamping method on the top plate





case one. Fixed supports are maintained on the outriggers assembly pads to the implementation ring (implementation ring not included in model) and around the perimeter of the top plate.

case two. Fixed supports are maintained on the outriggers assembly pads to the implementation ring (implementation ring not included in the model) and on the entire surface of the top plate.

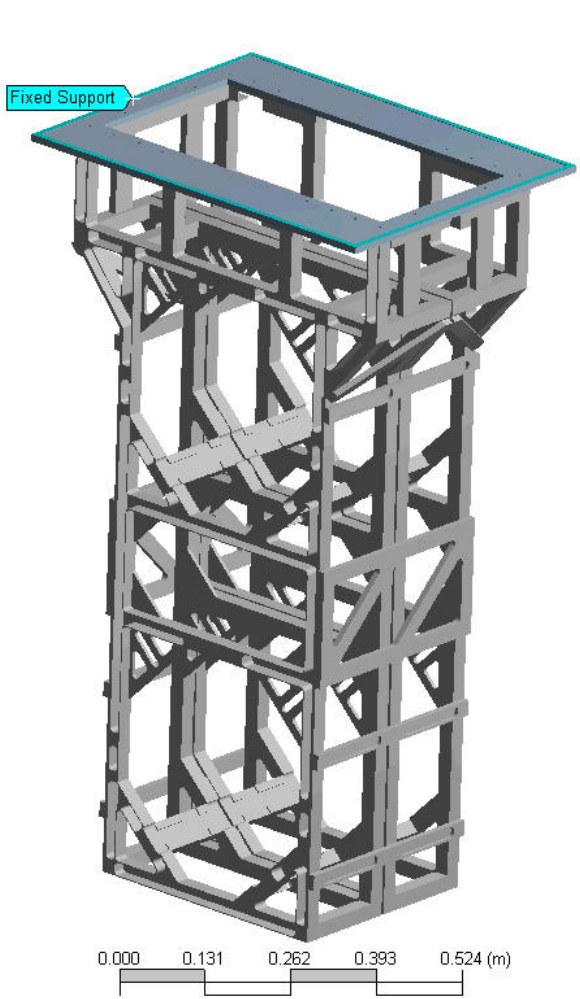
Varying the clamping method on the top plate

Case	Top plate joined to face plates by	contact	Frequency Hz			
One	Bonded		111.6	114	138	218
One	screws	frictionless	110.5	113.5	137	216
one	screws	none	107*	112.7	137	213
two	screws	frictionless	113.5	114	139	221.5
one	screws	1mm gap	106.8*	112.7	137.4	213
two	screws	1mm gap	110.5	113.7	138	220

Varying the clamping method on the top plate

- Conclusions:
  - Varying the style of clamping of the top plate does not make much difference
  - So the plate is not “panting” to a significant effect
  - Varying the style of the bolting model does not make much difference either
  - Disappointing because these were obvious candidates for improving things

Analysis of differences in CIT tests



Typical CIT test configuration

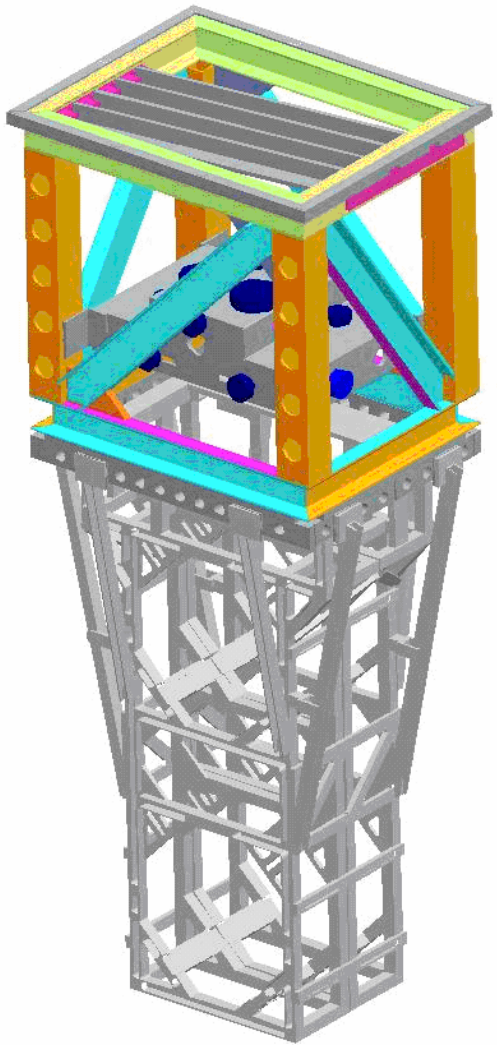
Analysis of differences in CIT tests

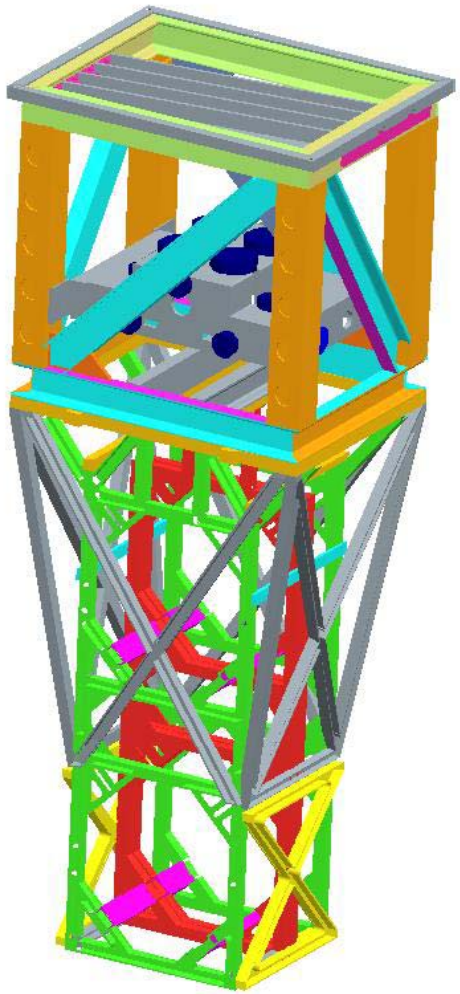
	Calum's clean room results Hz	Δ	FEA results Hz	Δ
Implementation ring, Top plate and outriggers.	56		114	
		45		40
Top plate no outriggers.	31		69	
		33		61
Top plate no outriggers and no plates on the side.	21		27	
		19		19
Top Plate and one half of the structure.	17		22	

Analysis of differences in CIT tests

- Conclusion:
  - The side plates don't change things nearly as much in the real world as the FEA suggests – so maybe it's the way THEY are bolted that we should look at.

“X-brace” idea to make the outriggers work harder

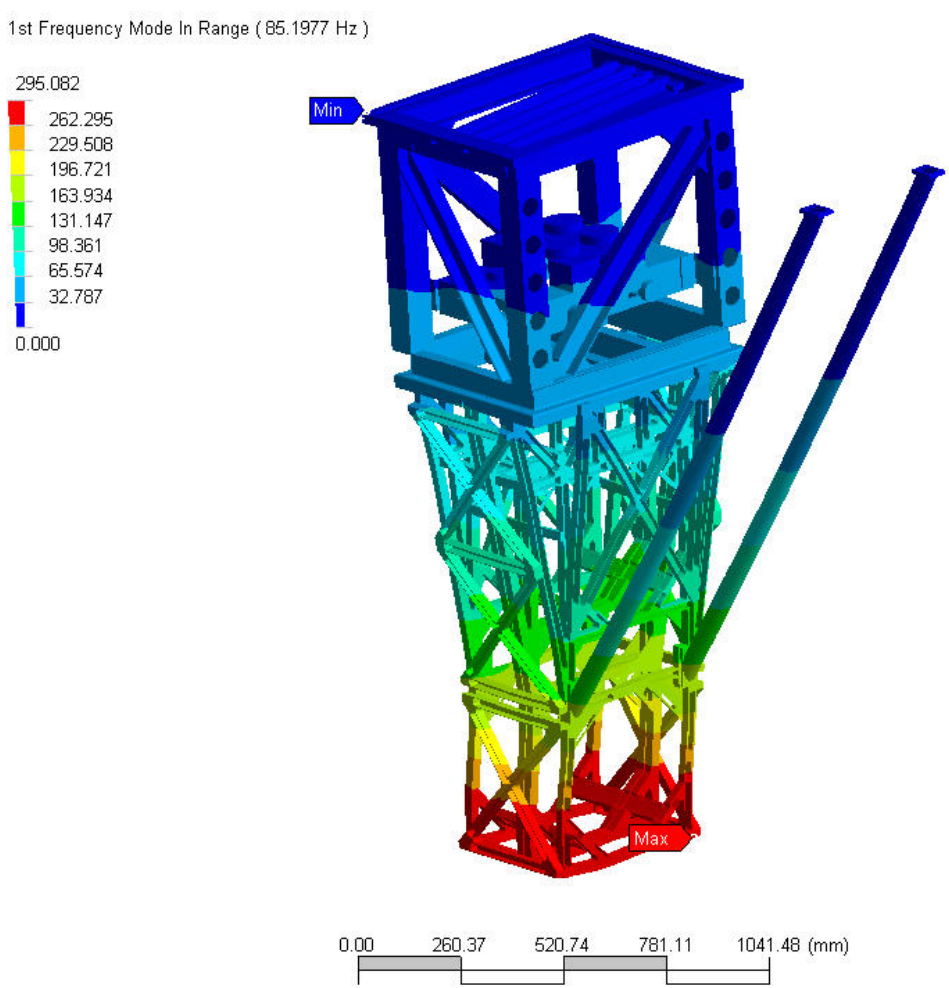




“X-brace”

- Theory:
  - Create “hard points” at the tops of the X-braces.
  - X-braces extend the “triangles” idea used successfully in the top structure
- Result:
  - No change in frequency
  - Maybe because the X-braces are not meaty enough compared to the side plates they are trying to stiffen

Struts



- Break the envelope
- But give good results
- 50od 40id
- ~1.8m long
- 35 degrees to vertical

Struts

mode	Frequency Hz	Comment
1st	75	Internal mode in brace
2nd	78	“
3rd	80	“
4th	80	“
5th	85	Lateral mode not improved by brace
6th	129	THIS IS THE ONE

Struts

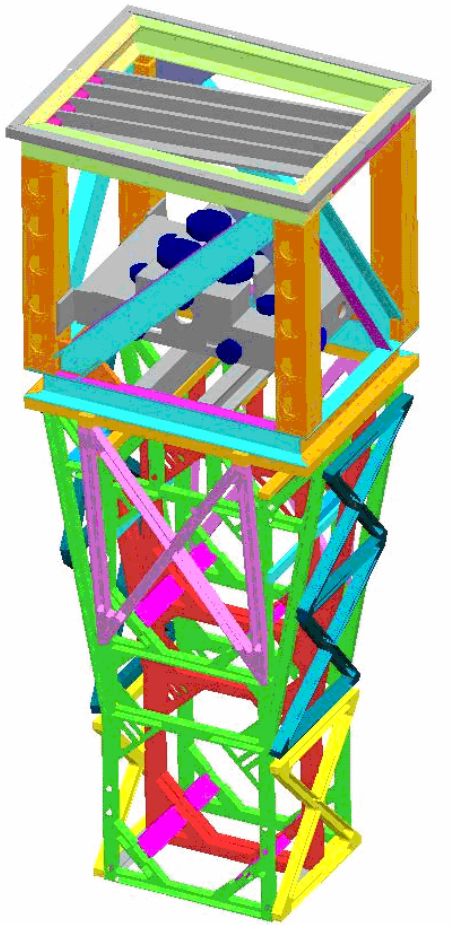
- Use braces with no density to remove internal modes:

mode	Frequency Hz	
1st	85	
2nd	129	Was ~77 Hz
3rd	169	
4th	192	
5th	197	
6th	227	

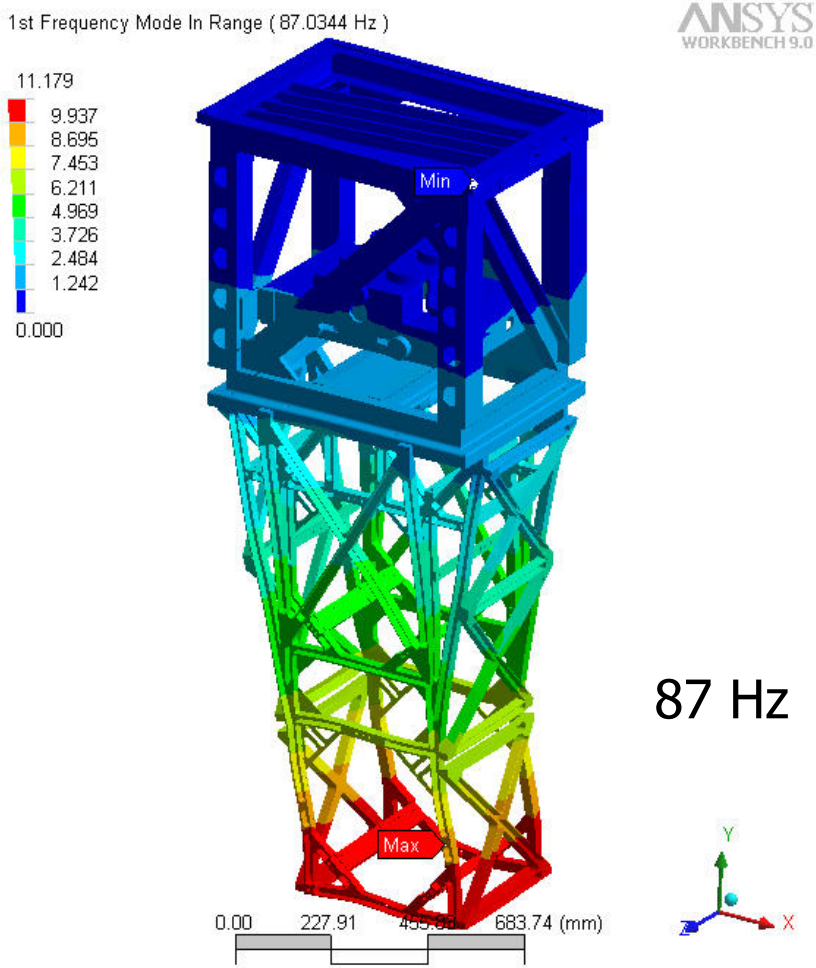
Removal of central side-plates

- SIMPLE experiment, simply suppressed some parts of the structure
- Improved primary beam modes by ~10 Hz
  - Modes were 77 & 86 Hz
  - Became 87 & 94 hz

Removal of central side-plates



77 Hz



87 Hz

Conclusions so far

- Modelling bolts has the potential to build a model that matches the tests with a credible rationale
  - And hence making things better by use of modified bolted joints eg in compression/tension rather than shear.
- Making the structure asymmetric did not help
- Initial ideas did not help
  - Modify thickness of top plate, minor mods to outriggers
- Reducing number of bolted joints in implementation ring may help
  - Need to figure out how to model bolted joints to assess this
- Changes to clamping of top plate and modified bolting between side plates and top plate did not help
- More radical change to outriggers (X-braces) did not help
  - But we think they will help if we trade mass into them
- Struts outside the envelope helped a lot
  - But introduce internal modes of their own that would need fixing
  - This should only be a fallback
- Removing the central plates helped ~10Hz
  - But introduces issues with assembly and potentially a big issue with welding

Options for the structure

- Improve performance of structure
  - Tweaks to make better use of mass
  - Understand and then fix bolted joints
- Strut to improve stiffness
- Damping in control system
  - Electronic
  - Mechanical (strut or tuned-mass)

- If we introduce a strut would we rather have better stiffness or better damping? (cannot do both)
- And what about parasitic modes that come with the strut?