GEMINI
OBSERVATORY

MCAO Adaptive Optics Module Finite Element Analysis Modeling

MCAO Preliminary Design Review Material

Prepared By: Eric James

Contributors: Kei Szeto and Joeleff Fitzsimmons

April 2001

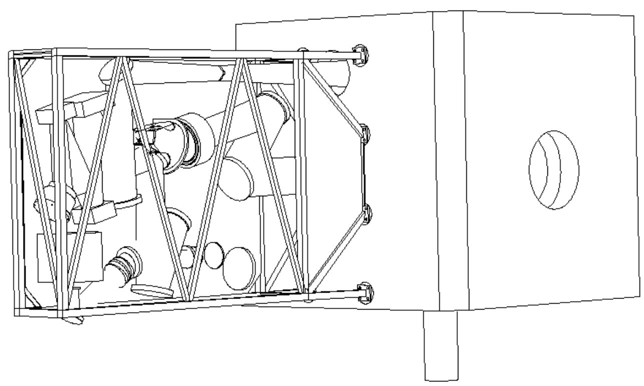
Version: Final

Summary

Structural and flexure analyses, both static and dynamic, were done using I-DEAS 8 software from SDRC. As a check, a separate analysis was done of the static deflections by Kei Szeto and Joeleff Fitzsimmons at the Herzberg Institute of Astrophysics in Victoria, B.C., Canada, using Algor software. The two analyses agree within acceptable margins. The frames for the electronics enclosures do not contact the optical bench and thus do not increase or decrease the optical bench flexure for static analyses.

Gravity Orientations.

The static analysis was done using a number of load cases. The first was with the telescope at zenith. In this orientation, the AO module is in its "rest" position. Since it will be aligned in this same orientation, any displacements due to static flexure will be removed during the alignment process. The actual flexure will, of course, still be there and needs to be accounted for in the subsequent studies at other orientations. The optical bench, mounted on the ISS, looks like this with the telescope at zenith:

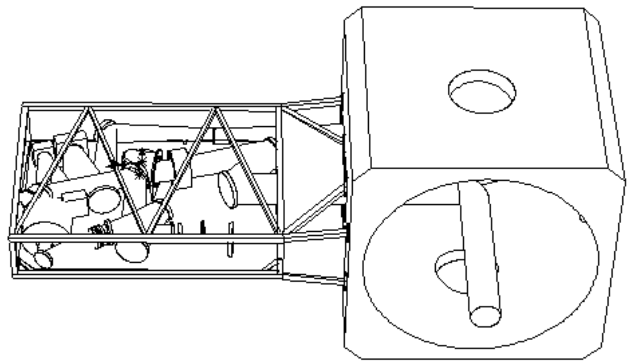


Telescope at Zenith

The gravity vector here is straight down, parallel to the optical table. The geometry dictates that the bench is the stiffest in this orientation and one would expect the flexure to be at a minimum.

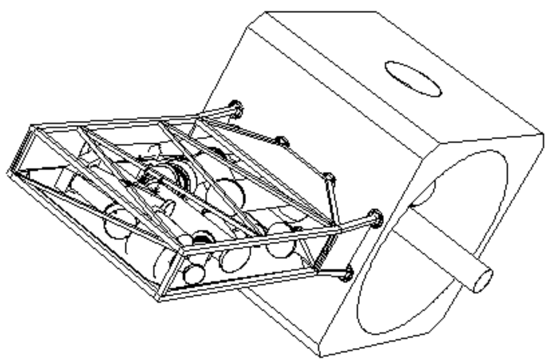
The greatest angle that the AO module will be used is 60° from zenith. At this angle, the image quality must still be reasonably maintained. Firm performance specifications, however, must only be maintained down to a maximum of 45° from zenith.

The Cassegrain rotator adds a second degree of freedom to the AO module orientation. In addition to zenith angle, the bench can rotate about the telescope optical axis. The orientation designated "west" is at the 9 o'clock position when observed from behind the telescope. The west orientation looks like this:



AO Module at "west" rotation

One would expect the maximum flexure at the greatest zenith angle (60°) and either the west or east rotation. 60 degrees west looks like this:

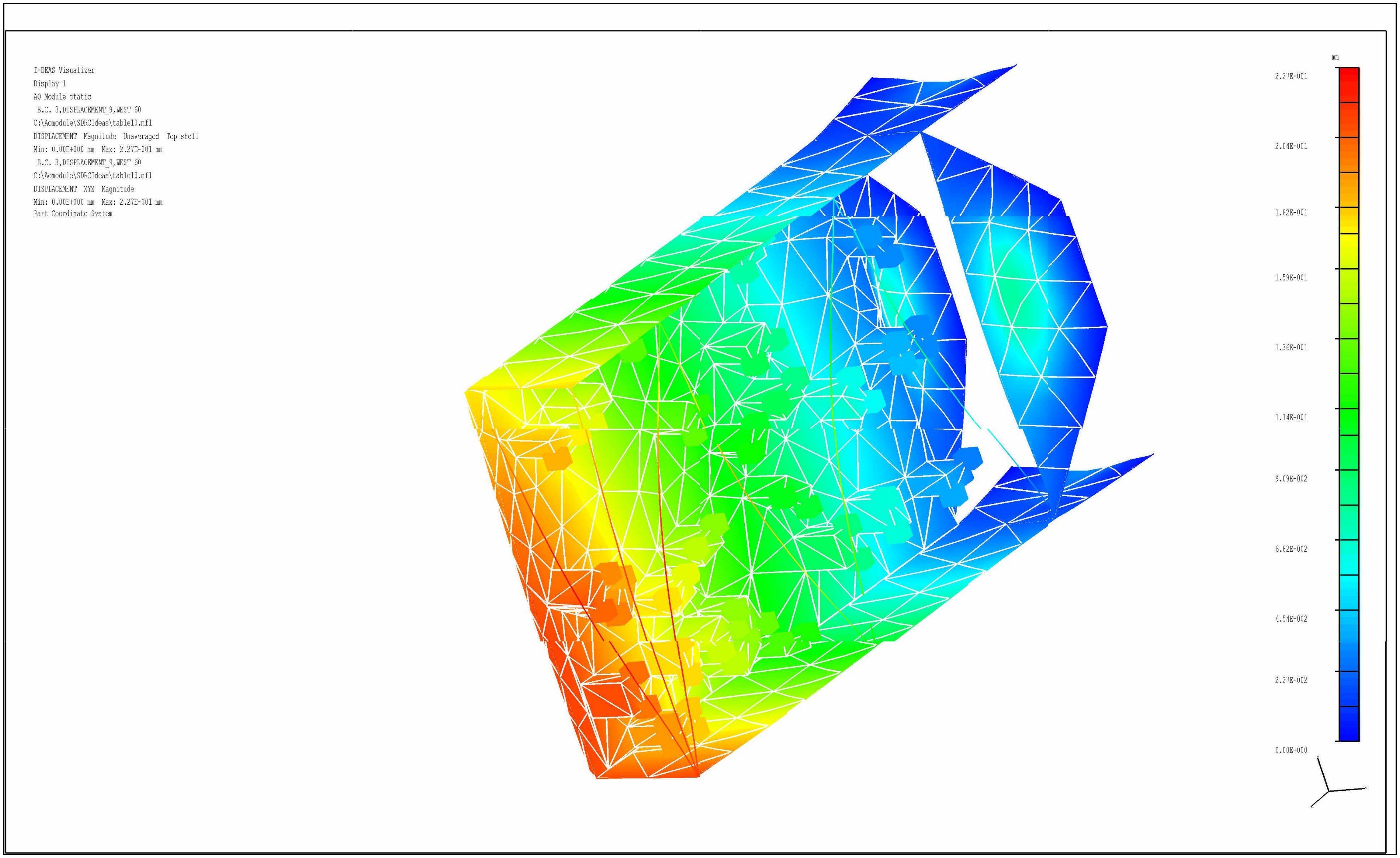


AO Module at 60° zenith angle

At this orientation, the gravity is mostly perpendicular to the structure and is loading it in its weakest direction.

<u>Finite Element Analysis Results - Static.</u>

The following diagram shows the static flexure at 60° west.

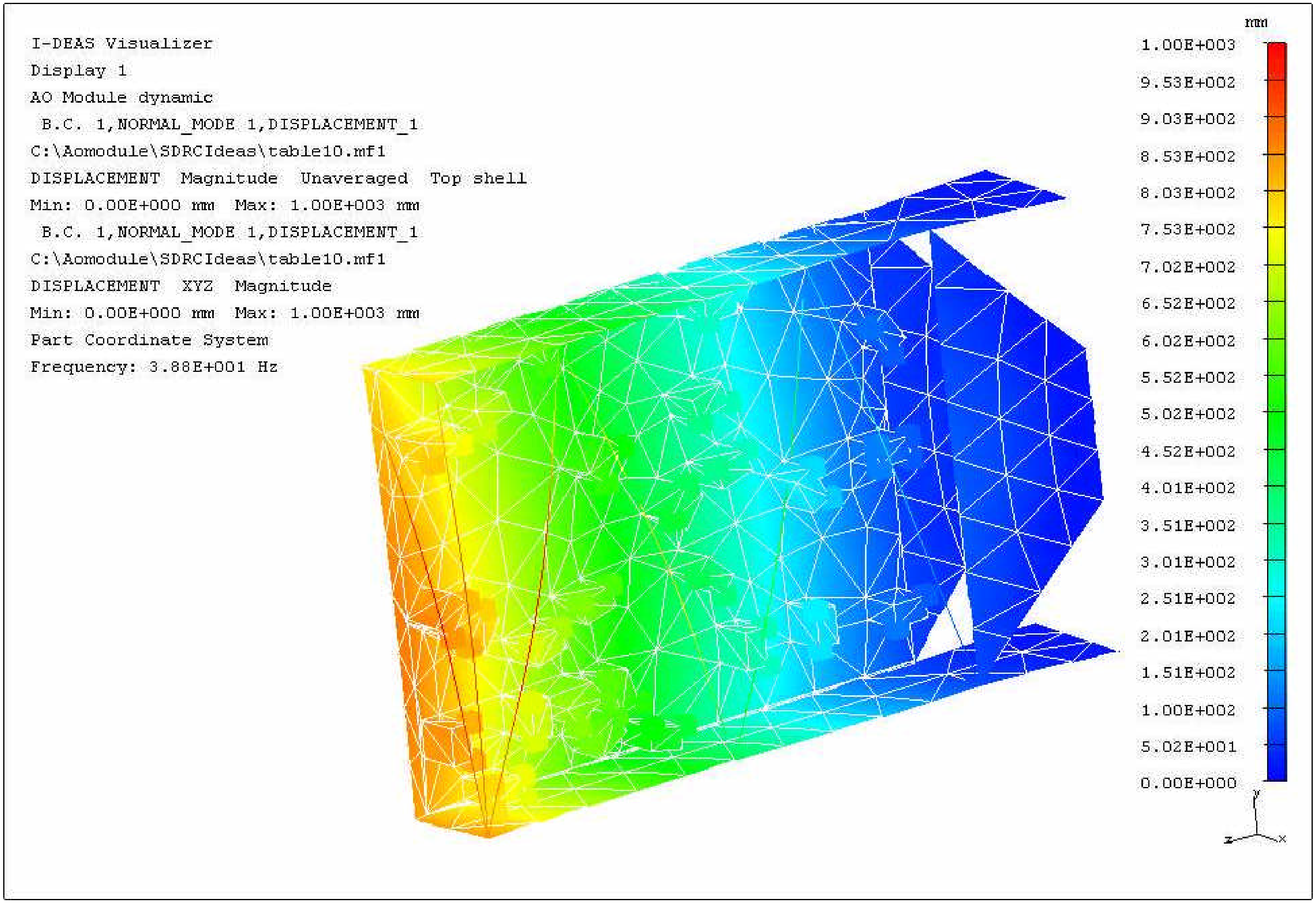

I-DEAS Visualizer
Display 1
AO Module static
B.C. 3,DISPLACEMENT_9,WEST 60
C:\Aomodule\SDRCIdeas\table10.mf1
DISPLACEMENT Magnitude Unaveraged Top shell
Min: 0.00E+000 mm Max: 2.27E-001 mm
B.C. 3,DISPLACEMENT_9,WEST 60
C:\Aomodule\SDRCIdeas\table10.mf1
DISPLACEMENT XYZ Magnitude
Min: 0.00E+000 mm Max: 2.27E-001 mm
Part Coordinate Svstem
mm
2.27E-001
2.04E-001
1.82E-001
1.59E-001
1.36E-001
1.14E-001
9.09E-002
6.82E-002
4.54E-002
2.27E-002
0.00E+000

The red areas show the maximum deflection of about 220 microns. Although this is the total deflection, most of the movement is perpendicular to the optical table. The individual displacements in all six degrees of freedom were obtained from the analysis results at representative nodes for each optical element. These were used for the static flexure component in the sensitivity analysis.

Finite Element Analysis Results – Dynamic.

The dynamic flexure is obtained from the same I-DEAS software using the same FEA model but solving for dynamic responses. The results are not as sensitive to gravity orientation but have multiple results – one for each dynamic mode. Since the AO system can compensate for some flexure below about 20 hertz, the lowest natural frequency is critical only as an indicator of the maximum amplitude. The lowest natural frequency (mode #1) is about 39 hertz. Whereas the frequency can be readily calculated from the FEA model, amplitude is also a function of the input energy from the telescope structure. This has not yet been measured. The diagram from I-DEAS for the first mode is on the following page. The motion is a side-to-side “fishtailing” motion. The first ten modes were studied. Higher modes show various modal shapes such as drumming of flat panels, vibrations of the long, thin struts, and one torsional motion of the entire bench. All of these have natural frequencies in the 70 to 90 hertz range.

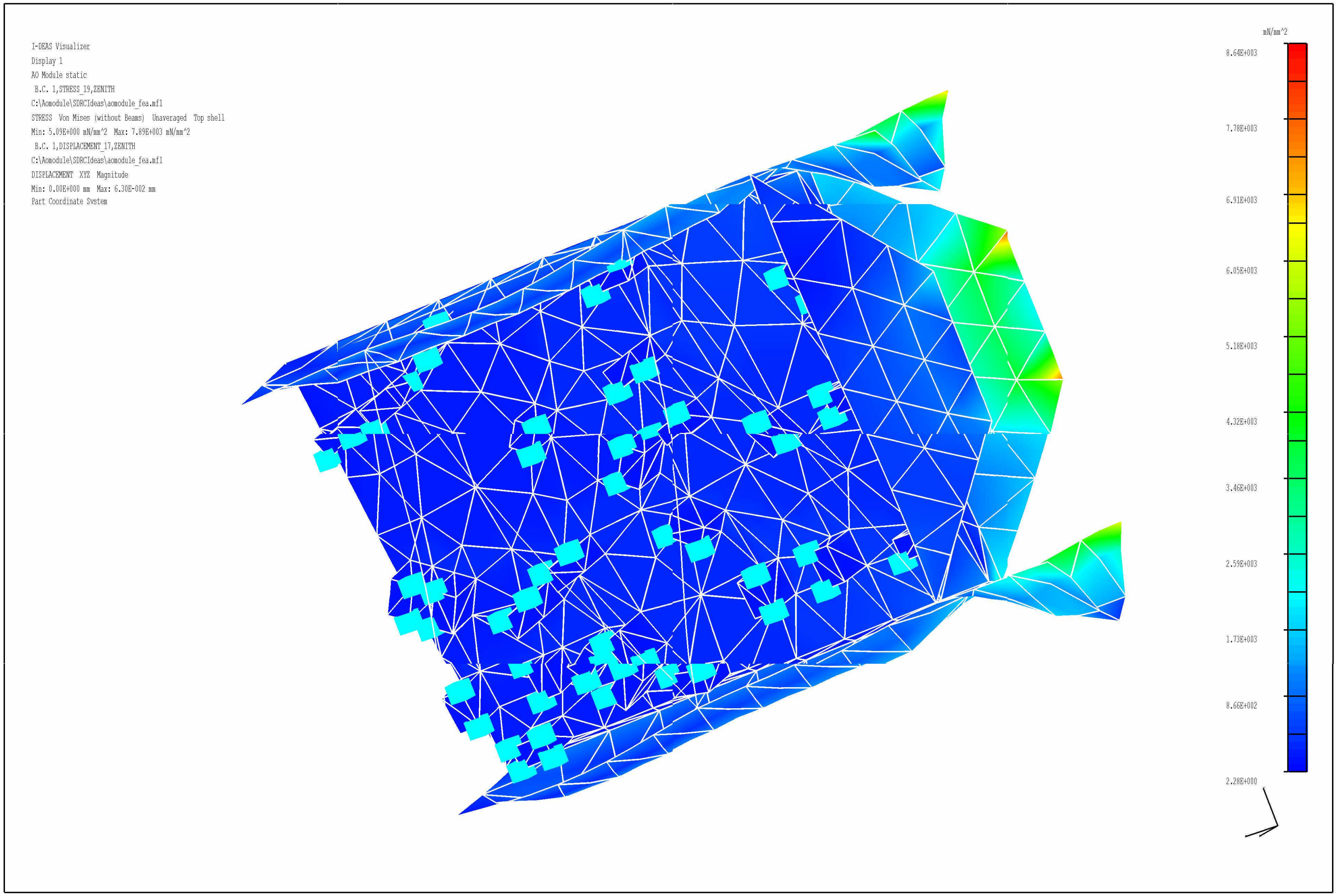
The diagram for the dynamic results, mode 1, is on the next page.


I-DEAS Visualizer
Display 1
AO Module dynamic
B.C. 1,NORMAL_MODE 1,DISPLACEMENT_1
C:\Aomodule\SDRCIdeas\table10.mf1
DISPLACEMENT Magnitude Unaveraged Top shell
Min: 0.00E+000 mm Max: 1.00E+003 mm
B.C. 1,NORMAL_MODE 1,DISPLACEMENT_1
C:\Aomodule\SDRCIdeas\table10.mf1
DISPLACEMENT XYZ Magnitude
Min: 0.00E+000 mm Max: 1.00E+003 mm
Part Coordinate System
Frequency: 3.88E+001 Hz
mm
1.00E+003
9.53E+002
9.03E+002
8.53E+002
8.03E+002
7.53E+002
7.02E+002
6.52E+002
6.02E+002
5.52E+002
5.02E+002
4.52E+002
4.01E+002
3.51E+002
3.01E+002
2.51E+002
2.01E+002
1.51E+002
1.00E+002
5.02E+001
0.00E+000
Y
Z
X

Finite Element Analysis Results – Seismic.

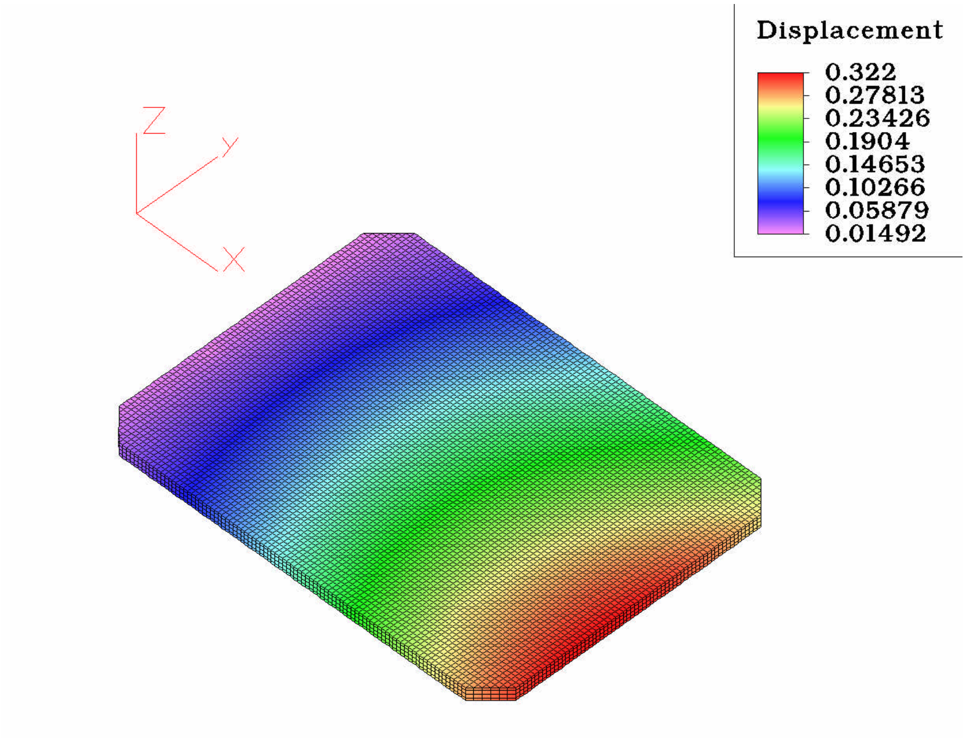
The seismic analysis is modeled as a static load case with an acceleration of 2 g's applied perpendicular to the bench. The maximum stress, located near the the base of the bench, is 7.89×10^3 mN/mm^2 (7.89 megaPascals).

The FEA diagram is shown on the following page.


I-DEAS Visualizer
Display 1
AO Module static
B.C. 1,STRESS_19,ZENITH
C:\Aomodule\SDRCIdeas\aomodule_fea.mf1
STRESS Von Mises (without Beams) Unaveraged Top shell
Min: 5.09E+000 mN/mm^2 Max: 7.89E+003 mN/mm^2
B.C. 1,DISPLACEMENT_17,ZENITH
C:\Aomodule\SDRCIdeas\aomodule_fea.mf1
DISPLACEMENT XYZ Magnitude
Min: 0.00E+000 mm Max: 6.30E-002 mm
Part Coordinate Svstem
mN/mm^2
8.64E+003
7.78E+003
6.91E+003
6.05E+003
5.18E+003
4.32E+003
3.46E+003
2.59E+003
1.73E+003
8.66E+002
2.28E+000

HIA static results.

The results obtained at HIA are as shown below:



This shows a maximum diplacement of 322 microns. However, this is for a load case of gravity perpendicular to the table, a condition that the AO module will not see during operation. The maximum angle of gravity with respect to the table is 60 degrees. Multiplying the 322 microns by the sine of 60° = .866 we have a maximum diplacement of 278 microns, reasonably close to the 220 microns predicted by the I-DEAS model.

The HIA study did not include a dynamic analysis.