LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

*LIGO Laboratory / LIGO Scientific Collaboration*

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# Available Height above the HAM Optics Table

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**Abstract**

Advanced LIGO configurations will employ multiple pendulum suspensions which have a greater vertical extent than the single suspensions in the initial LIGO configuration. The available height above the optics table in the HAM (Horizontal Access Module) chambers, in particular, may constrain the length of the multiple pendulum designs for the input mode cleaner, output mode cleaner, power recycling and signal recycling suspensions. The elevation view for the initial LIGO optomechanical in-chamber layout drawing, D970309, gives a non-precise indication of the height available. This technical note documents the available height above the HAM optics table, as a function of the elevation of the HAM optics, (which at the time of this report is a variable parameter for advanced LIGO configurations). It is anticipated that this information will be used to make a decision on the proper elevation of the HAM optics tables, on the appropriate length(s) of the multiple pendulums in the HAM chambers and the elevation of the laser beam centerline.

Revision 01: Corrected the elevation of the HAM chamber nozzle 'A' centerline and all figures as a result (as well as some other miscellaneous minor clarifications). Included a statement of the minimum elevation of the optics table for the "stiff" HAM SEI.

# 1 HAM Chamber Geometry

The geometry of the HAM shell is basically the intersection of two cylindrical shells:

- a 84.25" ID cylinder with an axis set perpendicular to the laser beam axis and 300 mm below the global x-y plane
- a 60.50" ID cylinder with an axis set parallel to the laser beam axis and 100 mm below the global x-y plane

However, there are internal attachment brackets welded to the interior of the 84.25" ID shell every 30 degrees. A conservative approach is to assume a shell, which is reduced in radius by the depth of these brackets, i.e. 1.5" In addition there are two 10" nozzles and one 14" nozzle on the top of the chamber, which add small niches, but I would advise against attempts to use this space as well.

The coordinate system used in this note is parallel to the LIGO global coordinate axes but centered horizontally in the HAM chamber. The global x-y plane is defined as a best fit to the centerline of the beam tubes:

- LIGO-1 HAM tables are 200 mm below the global x-y plane
- LIGO-1 BSC tables are 500 mm above the global x-y plane
- BSC chambers have their door nozzle centers in the global x-y plane
- HAM chamber "laser beam" nozzles have centers which are 100 mm below the global x-y plane

The HAM Chambers dimensions are taken from the following PSI Drawings:

V049-4-128, HAM Shell Weldment

V049-4-002, HAM Assembly

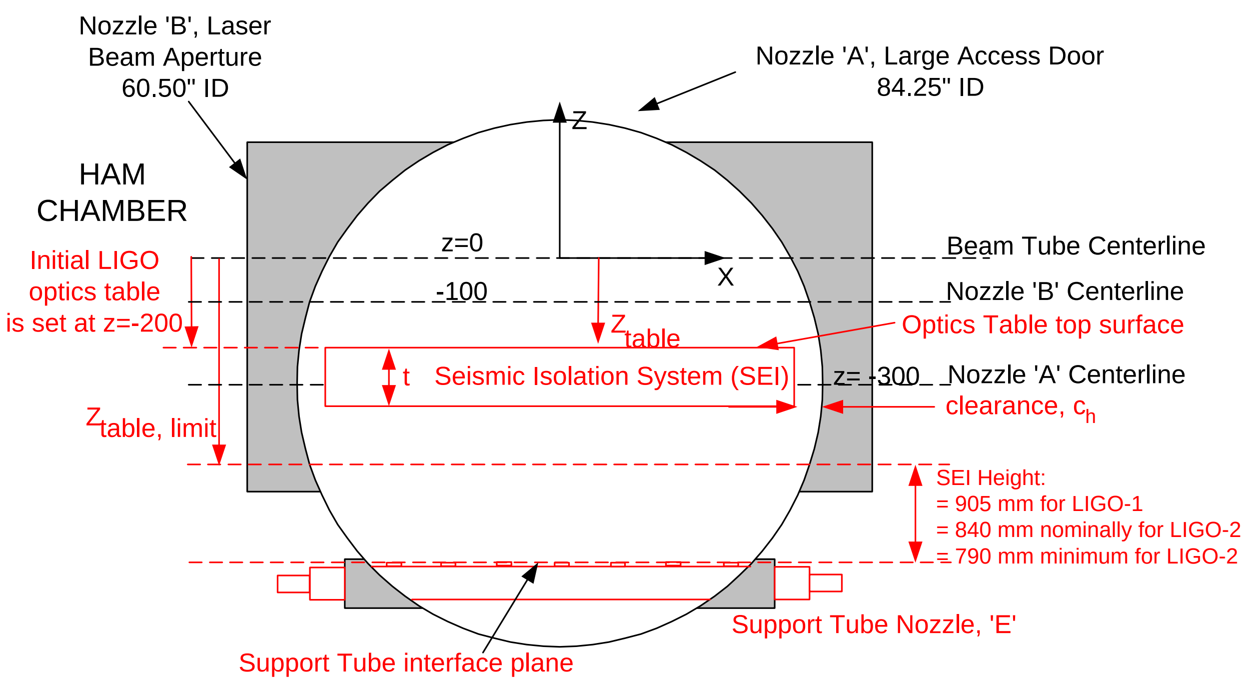
The HAM Seismic Isolation (SEI) optics table will mate to the existing HAM Support Tube (D972610-G, HAM Support Tube Weldment). The current LIGO-2 SEI HAM design has a height (the distance between the interface with the HAM support tube welded inserts and the optics table top surface) of 84 cm. The SEI group has indicated that the height could be reduced by 5 cm without any concerns (to 79 cm). The current LIGO-1 HAM optics table height (same feature references) is 90.5 cm, so the nominal LIGO-2 HAM SEI system is shorter than the LIGO-1 SEI system by 6.5 cm (which can be increased to 11.5 cm).

In order to establish a reasonable bound on the x-direction width of the optics table for advanced LIGO configurations, the thickness of the initial LIGO optics table (D972710), 13.25", was assumed to be representative: In addition a minimum clearance between the side of the optics table and the flange of the HAM chamber access port of $c_h$ =12 mm, on each side, was assumed.

The HAM Chamber and optics table geometry is shown schematically in Figure 1.

**Figure 1 HAM Chamber and Optics Table Geometry**

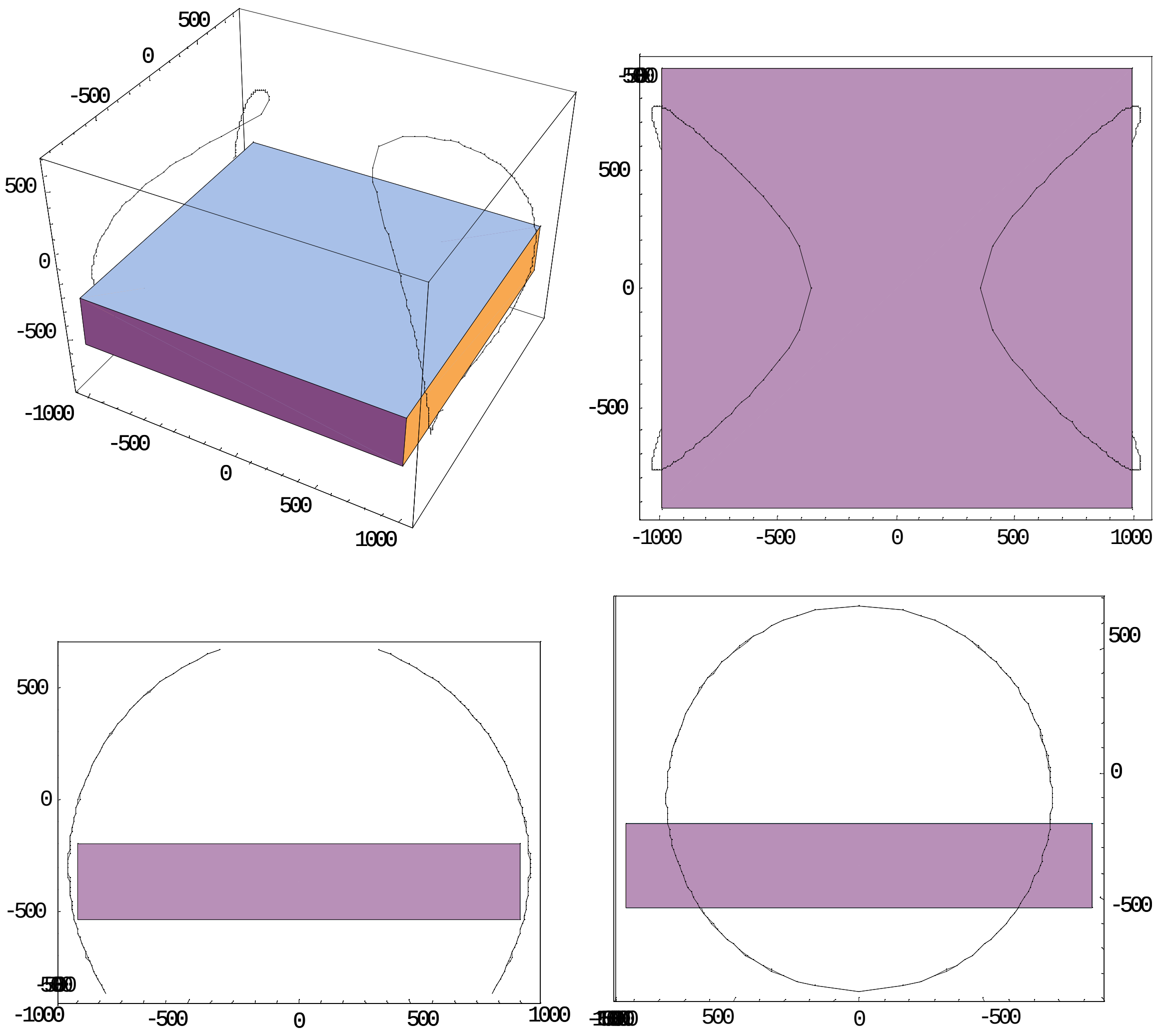
All dimensions in mm, unless otherwise noted
Assumed (subject to review), minimum optics table elevation, $Z_{table,limit}$ = -315
Optics Table assumed thickness, t = 336 mm (LIGO-1 table thickness)
Horizontal clearance, $c_h$ = 12 mm




## 2 Height Contours

Due to the intersection of the two principal shells (Figure 2), uniform headroom is not available above the optics table, as indicated in the height contour plot of Figure 3. The contours form a region on the table in the form of a cross, whose dimensions (indicated in Figure 4) are dependent upon the elevation of the optics table and the desired height above the optics table for the multiple pendulum suspensions. The variation in the parameters which define the layout area, with table elevation and desired height above the table, are given in Figures 5, 6 and 7.

**Figure 2 HAM Optics Table and HAM Shell Intersection Curves**
(dimensions in mm)




Lower left quadrant curve for the intersection of the two shells:

$$\{x,y\} = \left\{-0.125\sqrt{6.2385\times 10^{7} - 38400.\,z - 64.\,z^{2}},\ -0.000183107\sqrt{1.73098\times 10^{13} - 5.96516\times 10^{9}\,z - 2.98258\times 10^{7}\,z^{2}}\right\}$$

where z is the elevation in the global coordinate system. All dimensions in mm

**Figure 3 HAM Optics Table Exclusion Zone Contours**

dimensions in mm
The contours on the left are for the entire optics table; The contours on the right (with a scale) are for the lower left quadrant (-x, -y) The elevation contours on the right are:
8200, 250, 300, 350, 400, 450, 500, 550, 600, 650, 700<
These contours are of the elevations of the interior of the HAM shell (reduced by the depth of the internal welded brackets); The contours are independent of the optics table elevation.

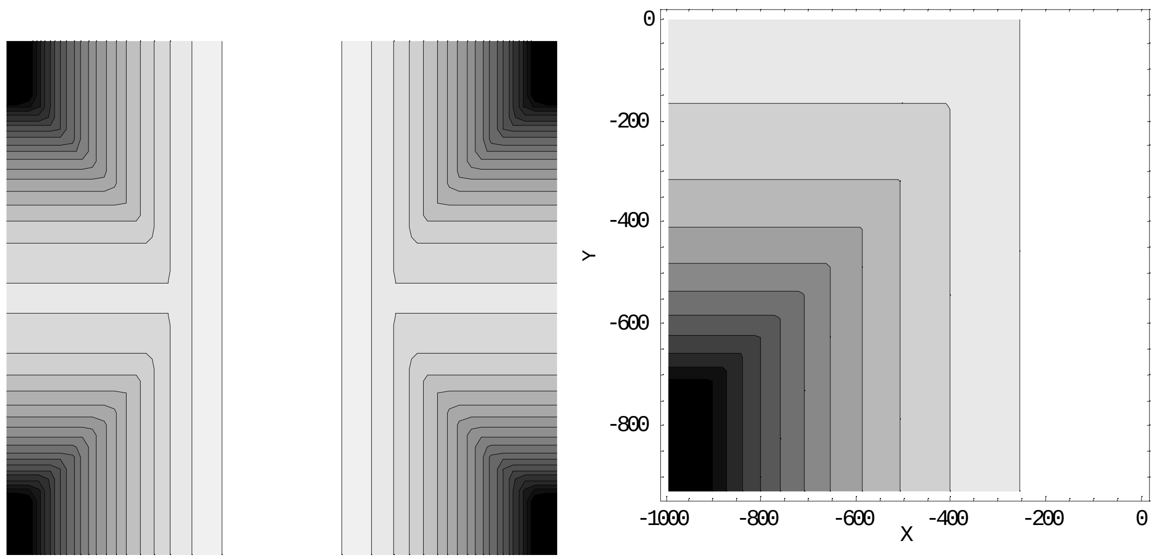


**Figure 4 HAM Optics Table Exclusion Zone Geometry**

See also Figure 1 for variable definitions
$Y_{table}$ = Nozzle 'A' Flange-to-Flange length less clearance of 50 mm = 1855 mm
(Note: Initial LIGO $Y_{table}$ = 1702 mm)
$X_{table}$ = function($Z_{table}$, t, $c_h$)
$W_x$ = function(Z, $Z_{table}$); See Figure 5
$W_y$ = function(Z, $Z_{table}$); See Figure 6

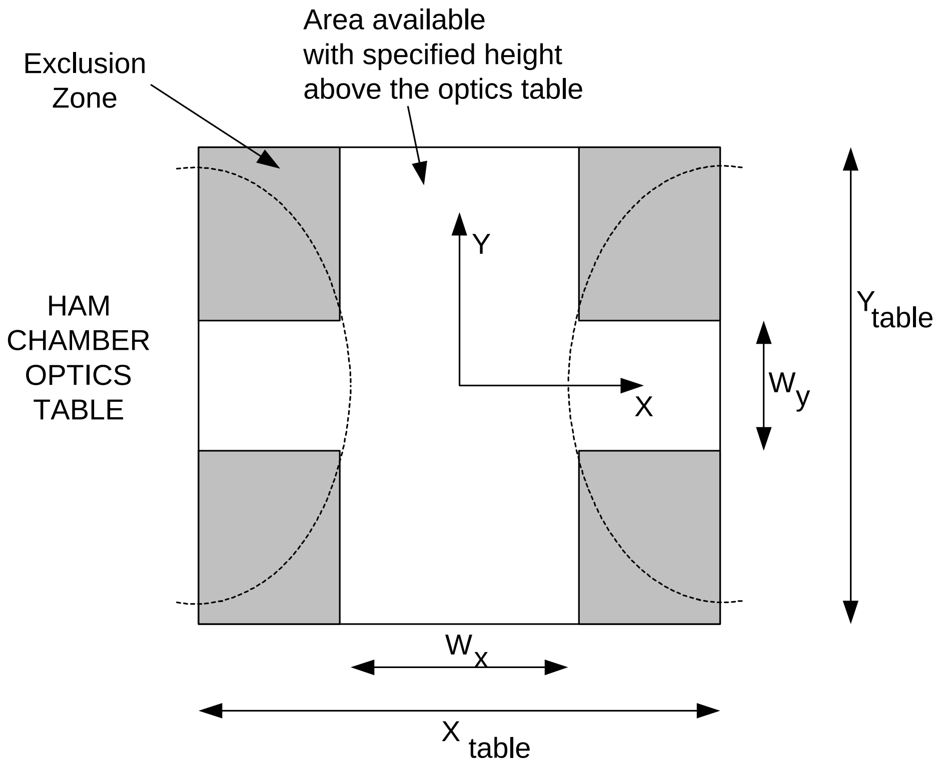
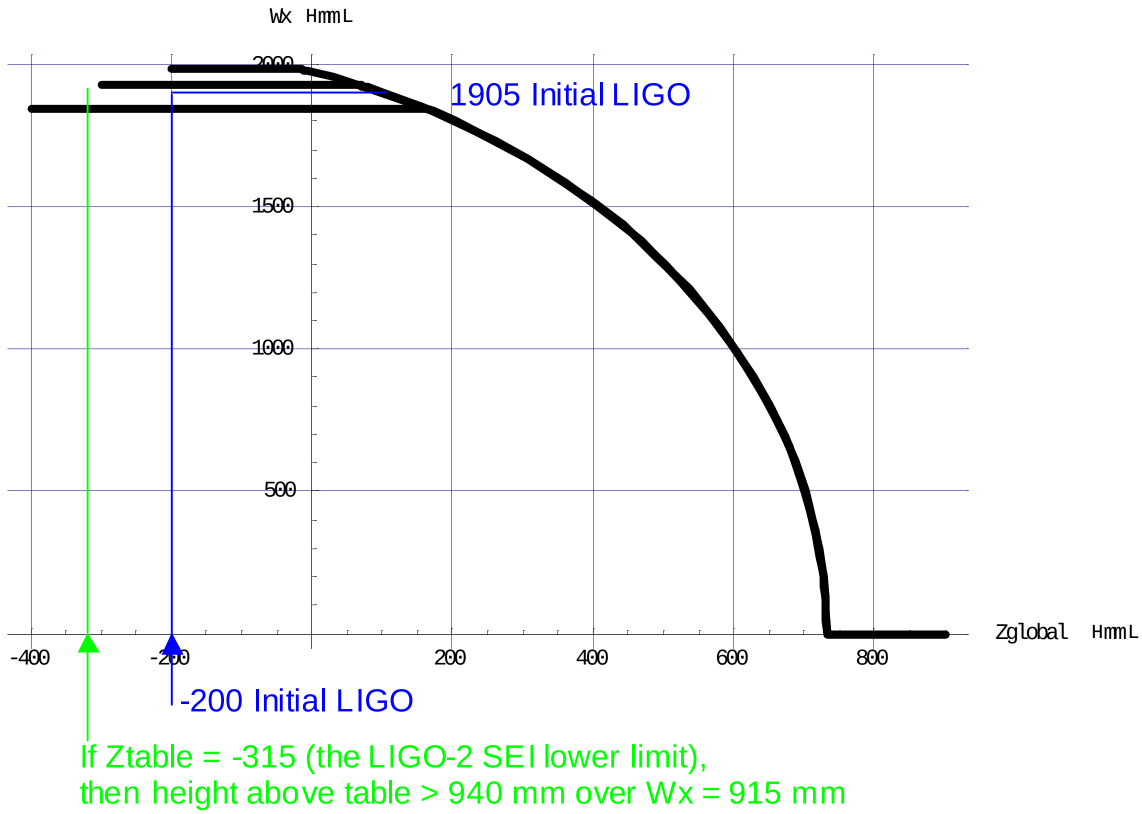


**Figure 4 $W_x$ as a function of Elevation above the Optics Table and Parameterized by Optics Table Elevation**

**[**Top line is for $Z_{table}$ = -200 mm. Each succeeding line is for the table set lower by 100 mm, so that the bottom, 3rd line is at an elevation of -400mm]



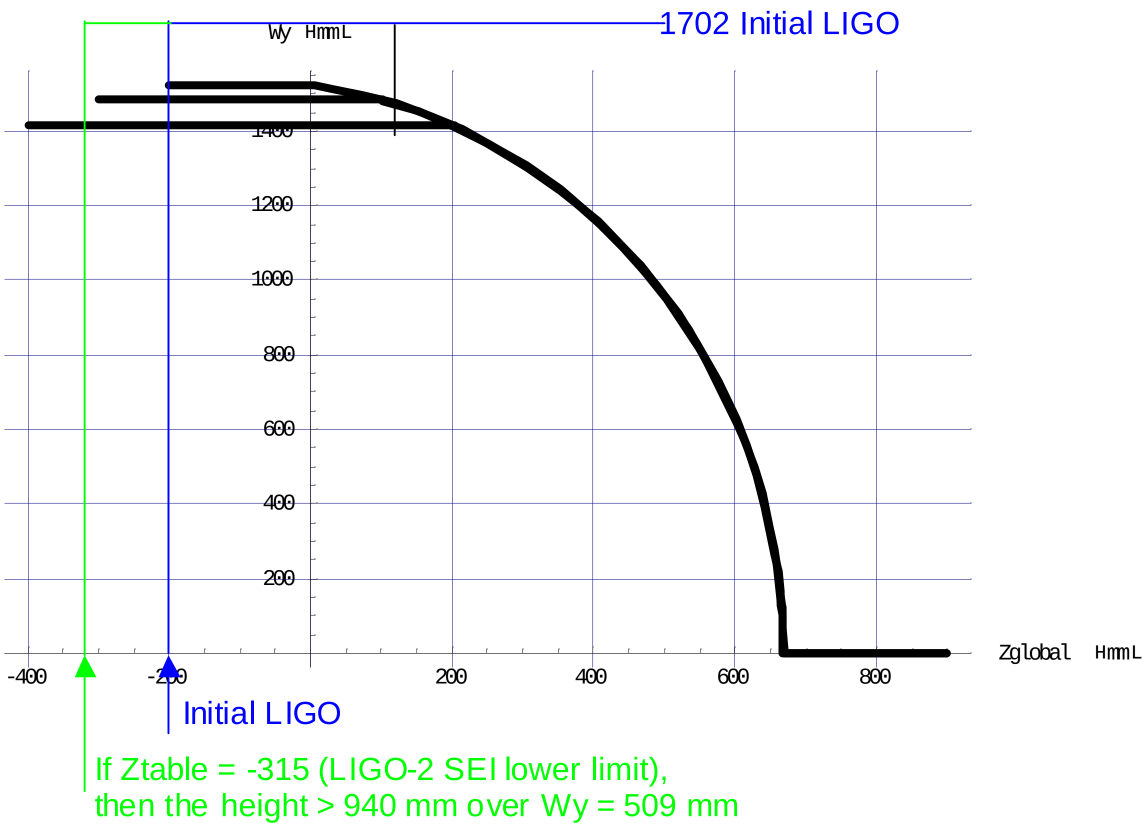

$W_x[zz] = \text{If}[zz \le 731.875,\ 2\sqrt{r1^2 - (zz - zo1)^2},\ 0]$

where

r1 = 1031.9 mm
zo1 = -300 mm
(as long as Wx <$X_{limit}$)

**Figure 5 $W_y$ as a function of Elevation above the Optics Table and Parameterized by Optics Table Elevation**

**[**Top line is for $Z_{table}$ = -200 mm. Each succeeding line is for the table set lower by 100 mm, so that the bottom, 3rd line is at an elevation of -400mm]



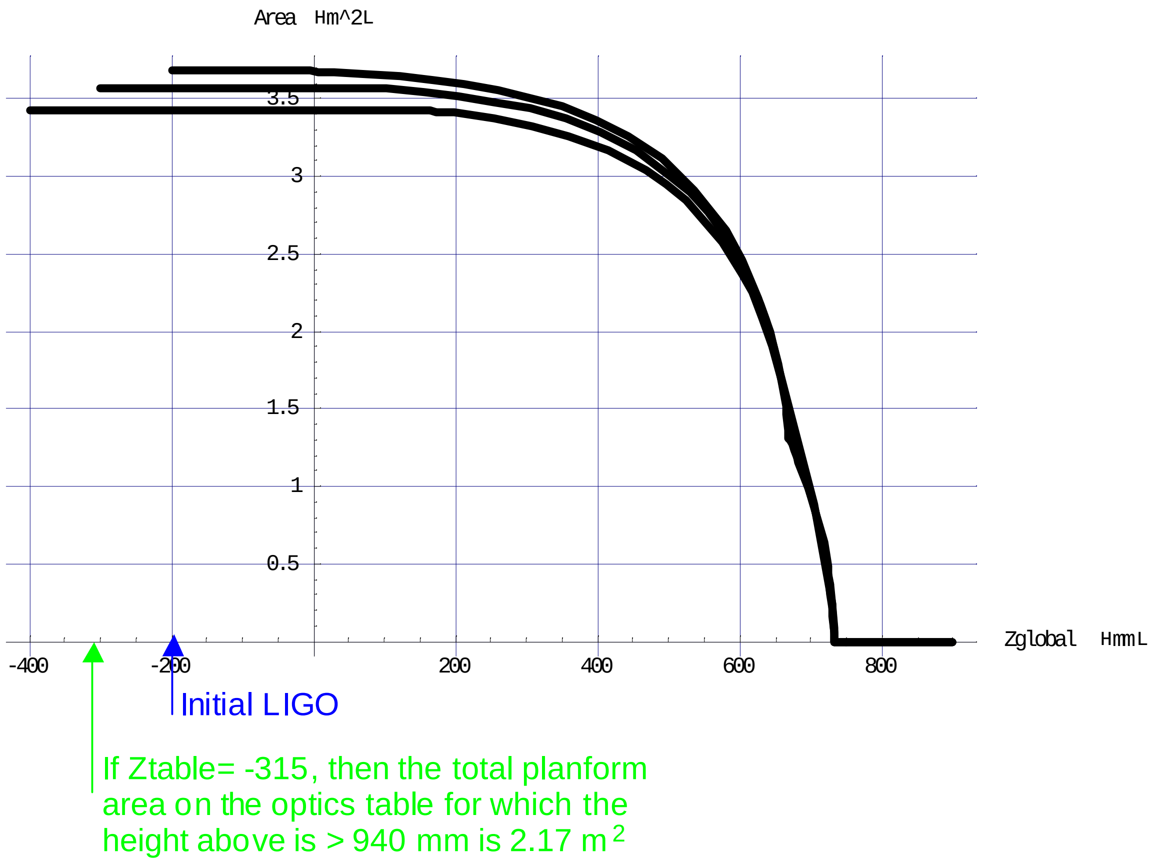

Wy[zz] = $\text{If}[zz \le 668.35,\ 2\sqrt{r2^2 - (zz - zo2)^2},\ 0]$

Where

r2 = 768.4 mm
zo2 = -100 mm
(as long as Wy <$Y_{limit}$)

**Figure 6 Layout Area ($m^2$)as a function of Elevation above the Optics Table and Parameterized by Optics Table Elevation**

**[**Top line is for $Z_{table}$ = -200 mm. Each succeeding line is for the table set lower by 100 mm, so that the bottom, 3rd line is at an elevation of -400mm]




## 3 Tolerances and Installation Height Clearance

The LIGO vacuum chamber shell inner diameter dimensions are not tightly controlled dimensions. It is reasonable to expect variations of ± 5 mm on the radius. In addition, there needs to be some allowance for installation clearance and potentially access to the top of the suspension pendulum structures. As a minimum, a clearance of 20 mm should be used in determining acceptable table elevations and suspension heights.