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Concept for Addition/Subtraction of 500g to/from the Recycling Mirror Intermediate Mass

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INTRODUCTION

The document displays a concept for adding mass to or removing mass from the Recycling Mirror Intermediate Mass. Due to the unpredictability of the cantilever blades and small differences between the actual weight of the suspended masses compared to that calculated by Solidworks, we cannot guarantee that the lower mass of the Recycling Mirror Suspension will be at the exact height that it was designed to be. It is therefore very useful to be able to add or remove mass accordingly to adjust the height during assembly.

Norna Robertson has confirmed[1] through the MATLAB Triple Suspension model that, with a range of up to +/-1kg, the dynamics of the recycling mirror suspension remain within the limits set out in the design requirements document. We have chosen initially to model with a +/-500g range as this is more like what we believe will be required to alter the height of the 36kg suspension. At the time of writing the range of +/-500g is purely an assumption of the amount of mass required to raise or lower the suspension sufficiently. Although this is an assumption, the starting figure of + or – 500g is based upon the effect seen when proportionally smaller masses were added to the mode cleaner suspension[2]. The assumption will be backed up through experimental and mathematical modelling in due course.

On previous suspensions, for example those used in GEO 600 and early LASTI Mode Cleaner designs, this consideration was made as an afterthought and mass has had to be added or removed from existing manufactured parts. With the current recycling mirror design, overleaf, not yet manufactured we have the luxury to incorporate adjustability now.

[1] See email from NAR to MPL and CIT on 7/28/03
[2] Refer to Document T030147, EXCEL Calculation, Maintaining the centre of mass of D020534.
The Mode Cleaner upper mass has an allowable added mass of +200g.

EXISTING DESIGN

The current design for the Recycling Mirror Intermediate Mass is shown below.

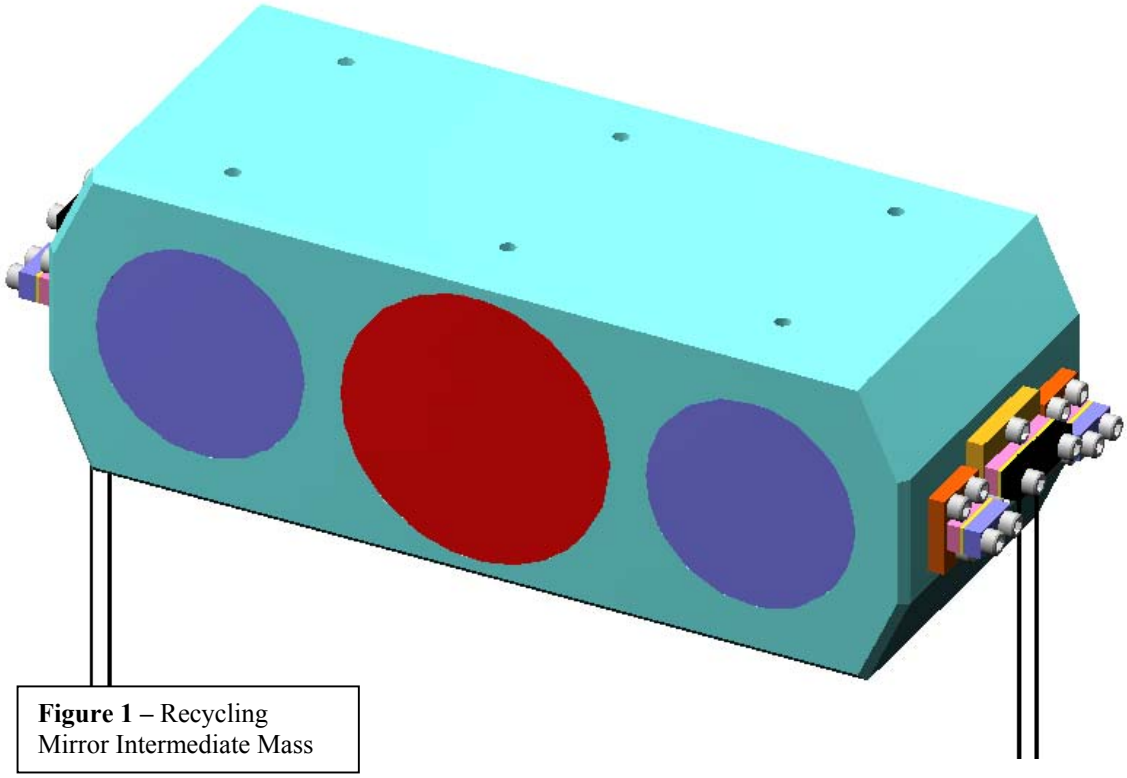


Figure 1 – Recycling Mirror Intermediate Mass

The main body of the mass (light blue) is manufactured from Stainless Steel and the three cylindrical inserts (red and two blue) are manufactured from Aluminium. The reason for the mass being designed using this combination of materials is to ensure that the mass and moments of inertia are matched as accurately as possible to those from the MATLAB triple suspension model. At this point the intermediate mass model we have matches the MATLAB very well, however we have not yet incorporated the facility to add or remove mass easily.

+/- 500G CONCEPT

As we have already designed the Intermediate Mass to ensure that the mass, centre of mass and moments of inertia replicate the MATLAB triple suspension model (see figure 1). We now need to incorporate adjustability without drastically altering these characteristics.

In past suspensions added mass was placed on the top and bottom of the mass. The size of these added masses were calculated to ensure that the centre of mass remained the same. However, as a consequence, the moments of inertia were altered somewhat by their addition. These greater moments of inertia that these added masses created were, however, still in keeping with those specified by the MATLAB model[3].

To keep the centre of mass and the moments of inertia values relatively close to that at which they start it seemed sensible that we add or remove mass as close to the centre of mass as possible. Fortunately, with the Recycling Mirror Intermediate Mass we have an opportunity to do this, as currently the mass has a cylindrical core that lies symmetrically (along the x-axis) through the centre of the mass and is removable. It is important to note that this addition is relevant to both the Recycling Mirror controls prototypes and noise prototypes as in this suspension design the lower stages are always manufactured from aluminium or stainless steel.

The following design has been developed to make best use of this opportunity. The design involves machining of the central Aluminium cylinder to leave a dumbbell that weighs 500g less than before. Then by adding collars of Aluminium or Stainless steel we can incrementally increase the mass from – 500g to +500g.

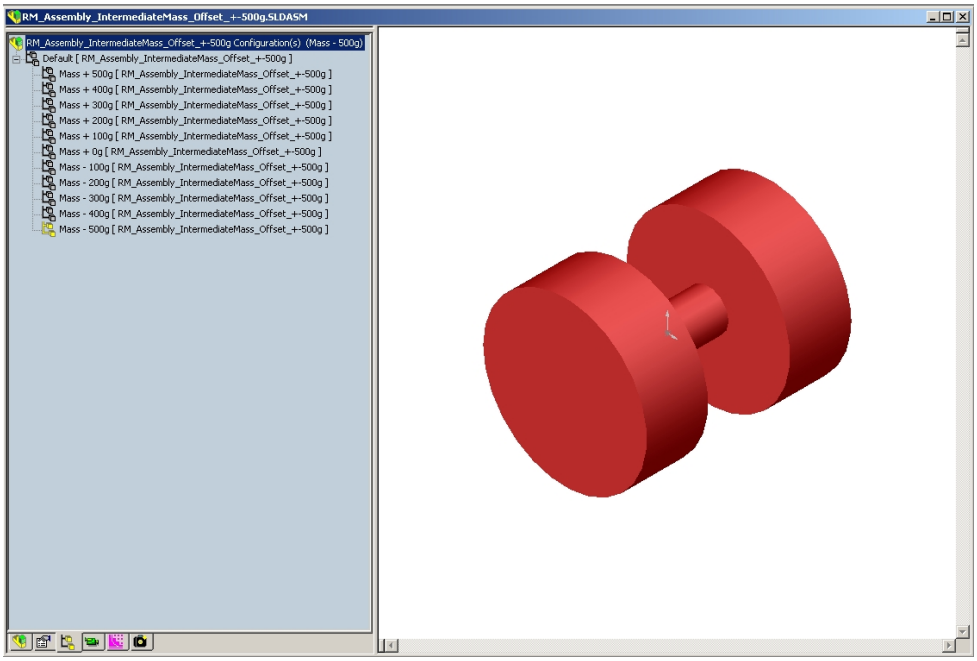


Figure 2 - The above screenshot shows the basic re-machined aluminium central core (previously a solid cylinder of diameter 80mm and length 100mm). Notice the list of configurations of this assembly from –500g to +500g in the left hand column of the screen.

[3] Refer to Document T030147, EXCEL Calculation, Maintaining the centre of mass of D020534.

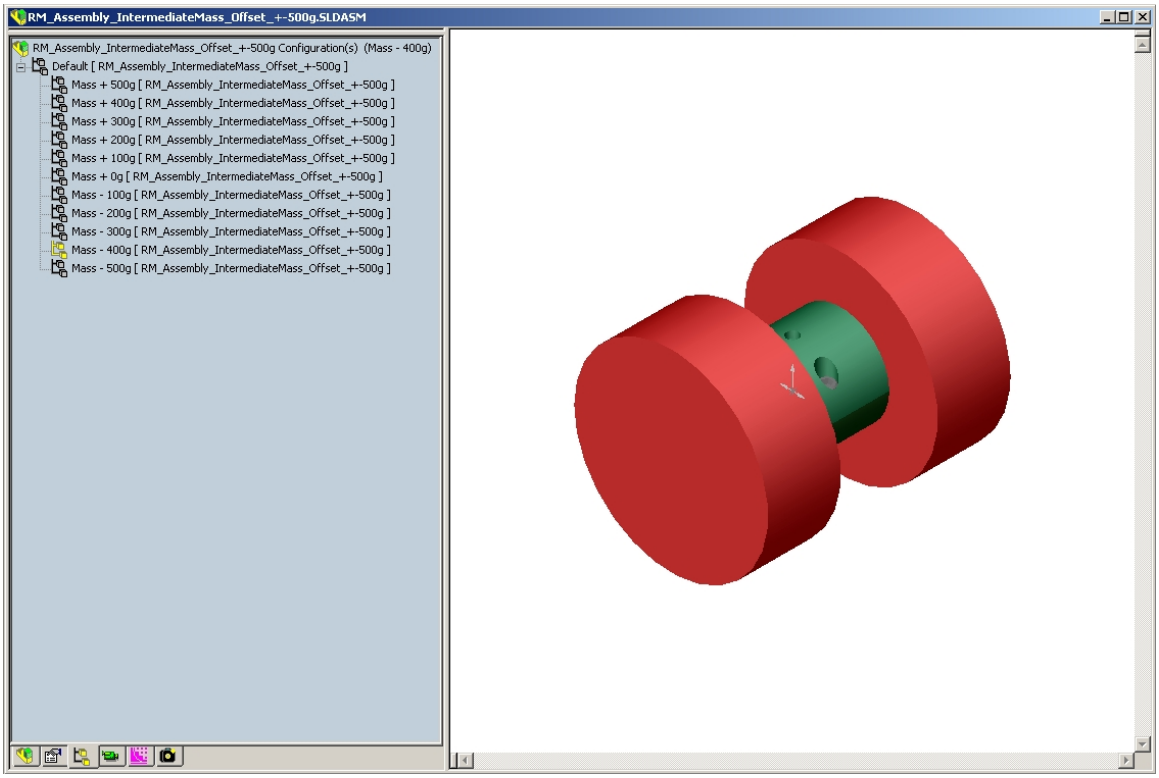


Figure 3 - The above screenshot shows the original dumbbell with an aluminium collar attached. The collar is manufactured as two semi-cylindrical sections that bolt together around the dumbbell with a grub screw to tightly fasten the collar to the dumbbell. This particular screenshot shows the configuration for a mass –400g (i.e. collar weighs 100g)

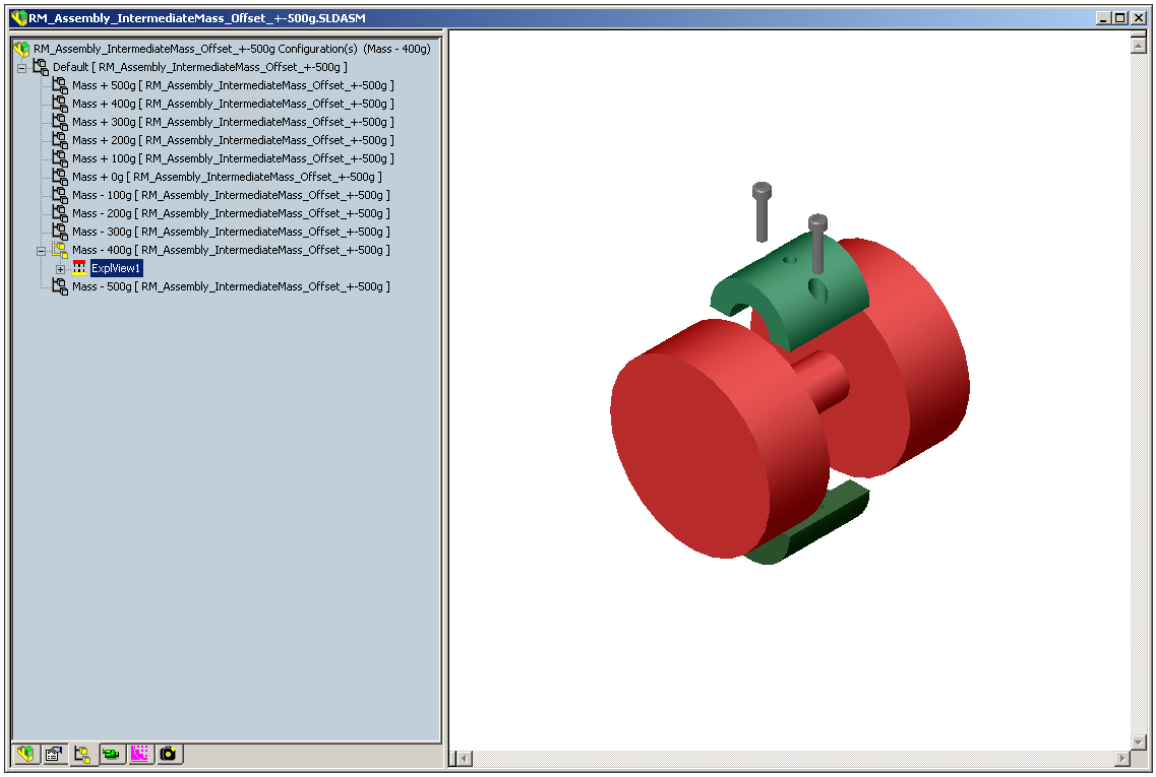


Figure 4 – The –400g configuration exploded. The green/dark green semi-cylinders along with the dumbbell are aluminium.

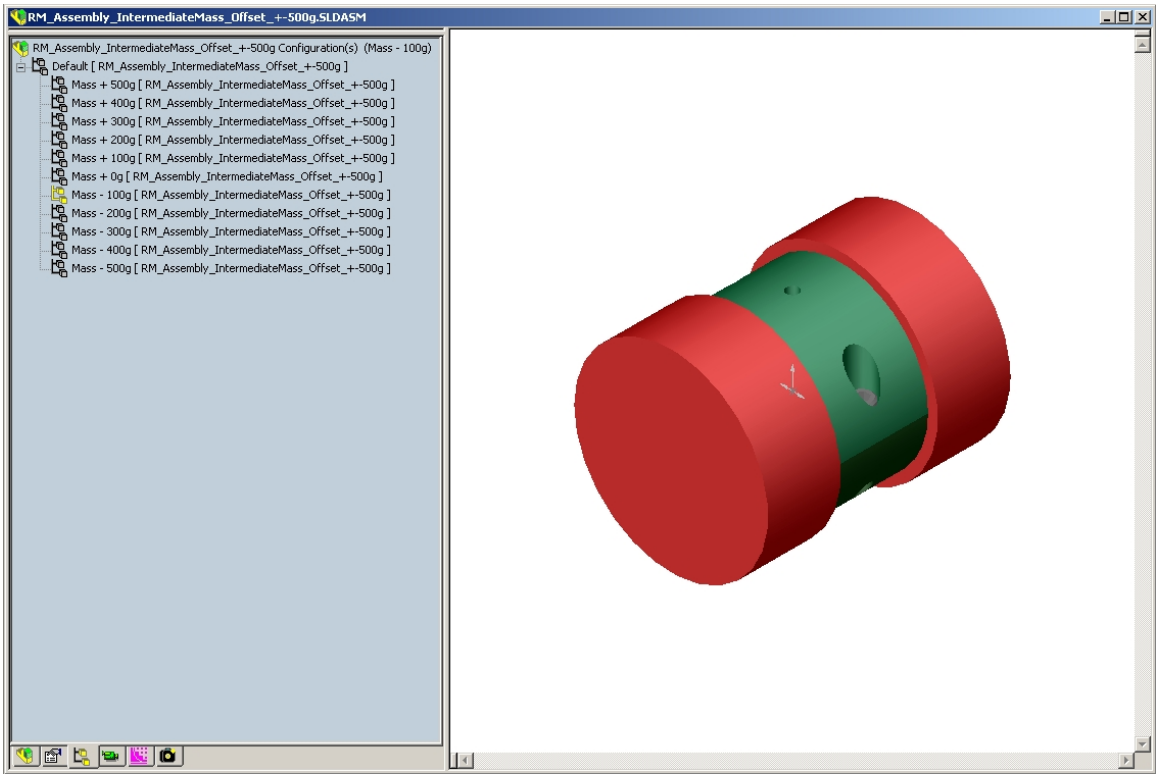


Figure 5 – The above screenshot shows the largest aluminium collar. This particular configuration is for the mass –100g. It was not possible to make the mass at its default setting (+0g) solely out of aluminium, as there would be the risk that the assembly would not fit into the hole in the intermediate mass. The intermediate mass has a hole with a tolerance specified as a smooth running fit.

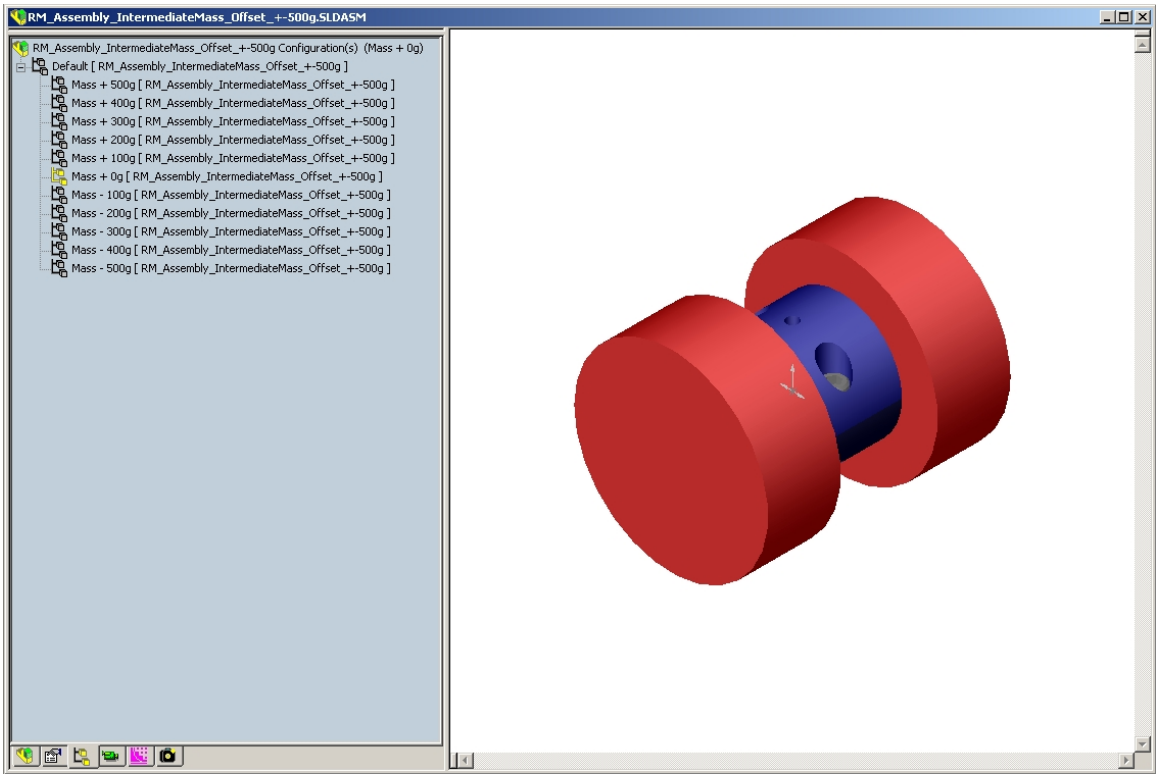


Figure 6 (above) – shows the +0g configuration with a stainless steel collar attached.

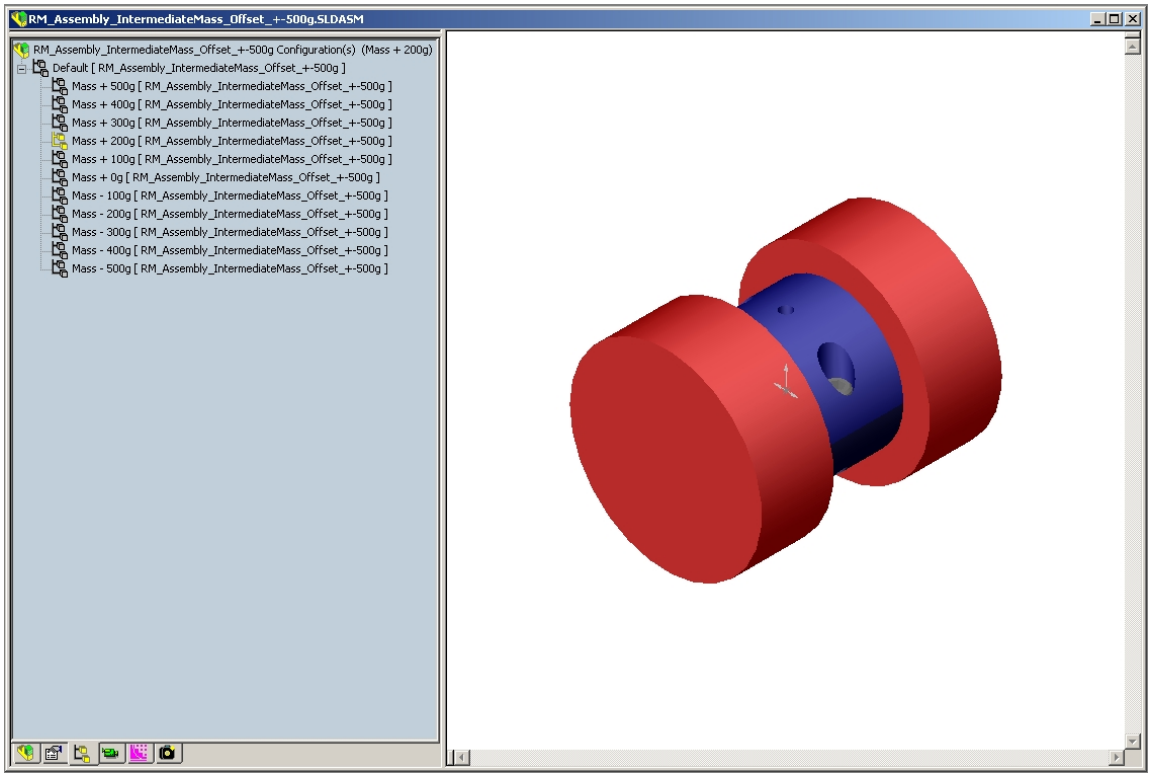


Figure 7 – The above screenshot shows the +200g configuration. As stated previously these configurations exist from –500g to +500g in 100g increments.

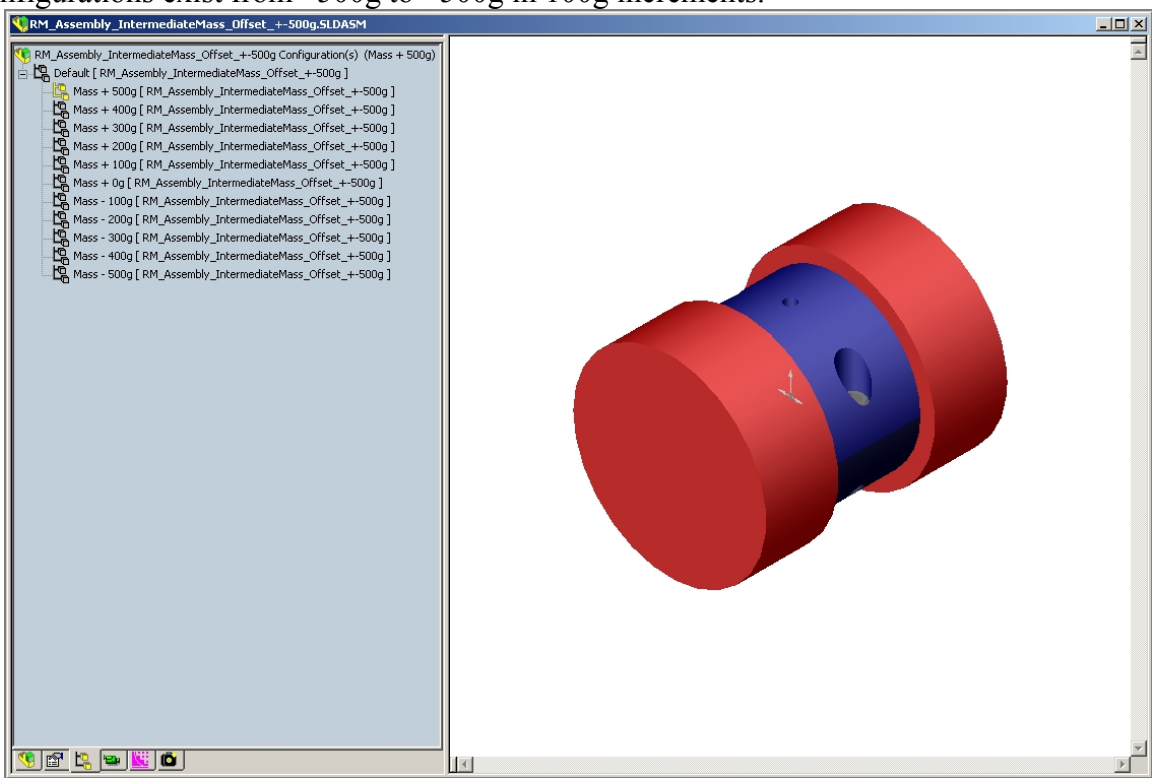


Figure 8 – The above screenshot shows the largest (+500g) configuration for the Intermediate Mass. Again the collar is manufactured from stainless steel with two bolts to join the semi-cylinders and a grub screw to fasten to the dumbbell.

CONCLUSION

This document has presented a concept for the addition or subtraction of 500 grams of mass to the Recycling Mirror Intermediate Mass. At the time of modelling this concept, we have not yet determined the range of vertical displacement required for this suspension and whether the + or -500g proposed is either sufficient or excessive[4].

To predict the amount of vertical displacement at the Recycling Mirror lower mass, that each increment of 100 grams will give us, it is possible to run an experiment on the RM cantilever blades that will replicate this situation. At this time the RM blades are not manufactured however it would be advisable that this testing is undertaken once the manufacture of the blades is completed. We can also estimate the deflection of a cantilever blade (when increments of 100g are added) mathematically by utilising an Excel program, written by Calum Torrie, which represents a set of blade equations supplied by Mike Plissi.

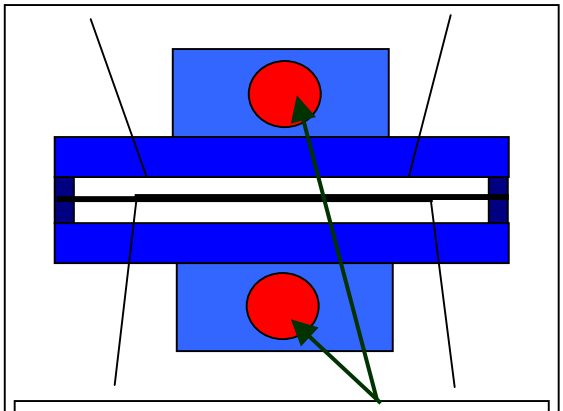
It is important to note, however, that this document is not written to solve the aforementioned problem it is written primarily to present a concept that can be easily incorporated in to the existing design and that can be adapted to cover smaller or larger increments and ranges if necessary.

NEXT STEPS

- Calum Torrie has begun calculations that will hopefully simulate the effect of adding or removing 500 grams of mass. As described earlier, this is done by manipulating an Excel program. The results of these calculations will be published when complete - See Appendix 1.

- On manufacture of the Recycling mirror blades we can double-check these results through experimental testing.

- Added Mass Concepts for a quad suspension will need to be considered. Concepts for a quad will be more akin to the Mode Cleaner seeing as it is constructed from two 'sandwich' upper masses and two Silica or Sapphire lower masses. However, it is still feasible that a concept similar to that proposed above could be adapted for use in the top and bottom t-sections of the quad upper masses.



Example of added mass adjustment in a Quad Upper Mass design

[4] see Appendix 1

APPENDIX 1

Experimental Measurements to simulate the effect of adding/subtracting mass to/from the Recycling Mirror Intermediate Mass

The steps taken by Calum Torrie in calculating the range of added mass required by the Recycling Mirror Intermediate Mass are detailed below. The excerpt was taken from an email written by Calum to MPL on 12th December 2003.

"Okay now for my analysis of blades and how I came up with the numbers for the amount of adjustment for the RM blade: -

1) I measured a MC upper blade on the bench and found that for + ~ 100g the blade tip moved ~ 4mm.
2) I then measured a mode cleaner suspension and found that for + ~ 100g the suspension moved ~ 2mm.
3) Using the blade equations I verified that this relationship was approx linear and that I would obtain similar numbers to those obtained above
4) I then estimated sets of masses that could be added to the MC, not relevant here!
5) Using the info gather from 1,2 and 3 I used the blade equations to estimate how much mass and in what size of increments this mass should be in order to adjust a RM suspension by +/- 2mm in 0.5 mm increments. I calculated that mass of +/- 680g in 170g increments would provide ~ +/- 2mm of adjustment."

NOTE:

It is clear from this calculation (done after the modelling of the +/-500g concept) that it will be necessary to increase the range of the added mass and the increment size. As this document presents only a concept it will be easy to adapt the design prior to production.