T1400750 - aLIGO Mechanical design considerations for a larger Beamsplitter optic

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2 Introduction

2.1 Background:

Norna Robertson outlines first thoughts for a larger Beamsplitter suspension in T1400296, and this includes a proposed set of updated parameters which were discussed between Norna and Joe O'Dell at Rutherford Appleton Laboratory on 15th September.

For full conclusion to this discussion, see afore mentioned document.

This document outlines mechanical considerations and recommendations for an updated Beamsplitter design. Here the intention is to outline a conceptual design for the updated parameter set, to identify the following:

- Nature and scale of the modifications including a detailed summary of;
  - Parts that require modification
  - Parts that need to be re-made
  - Parts that are new
- Identification of key features and components where modification should be avoided

Summary of relevant parameters (altered parameters marked in red):

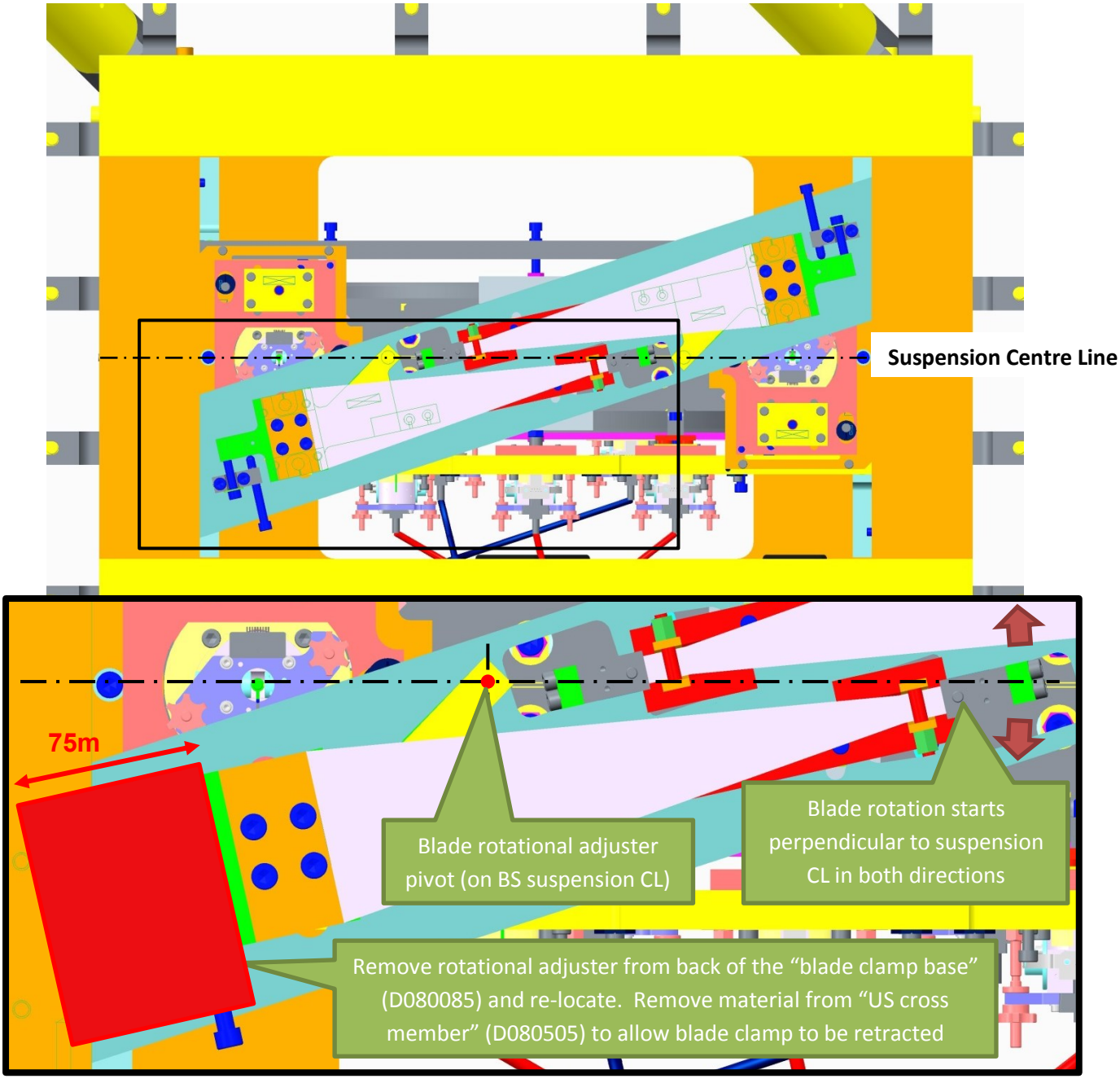
	Current	New
M1	1.2630e+001	1.2630e+001
M2	1.3575e+001	1.3575e+001
M3	1.4168e+001	2.0983e+001
N0	7.7000e-002	7.7000e-002
N1	1.3000e-001	1.3000e-001
N2	6.0000e-002	4.0000e-002
N3	1.9150e-001	1.9150e-001 (check)
N4	1.8650e-001	2.3750e-001
N5	1.8650e-001	2.3750e-001
ir	1.8500e-001	1.8500e-001
tr	1.8500e-001	2.2500e-001

2.2 Design philosophy:

- Attempt to modify the parameters outlined in T1400296, whilst avoiding altering others
- Re-use as many of the original components as possible
- Increase MOI numbers for suspended masses as little as possible
- Take the opportunity to make design improvements to existing parts, where it can be done economically

3 Top stage conceptual modifications:

3.1 Existing design features:



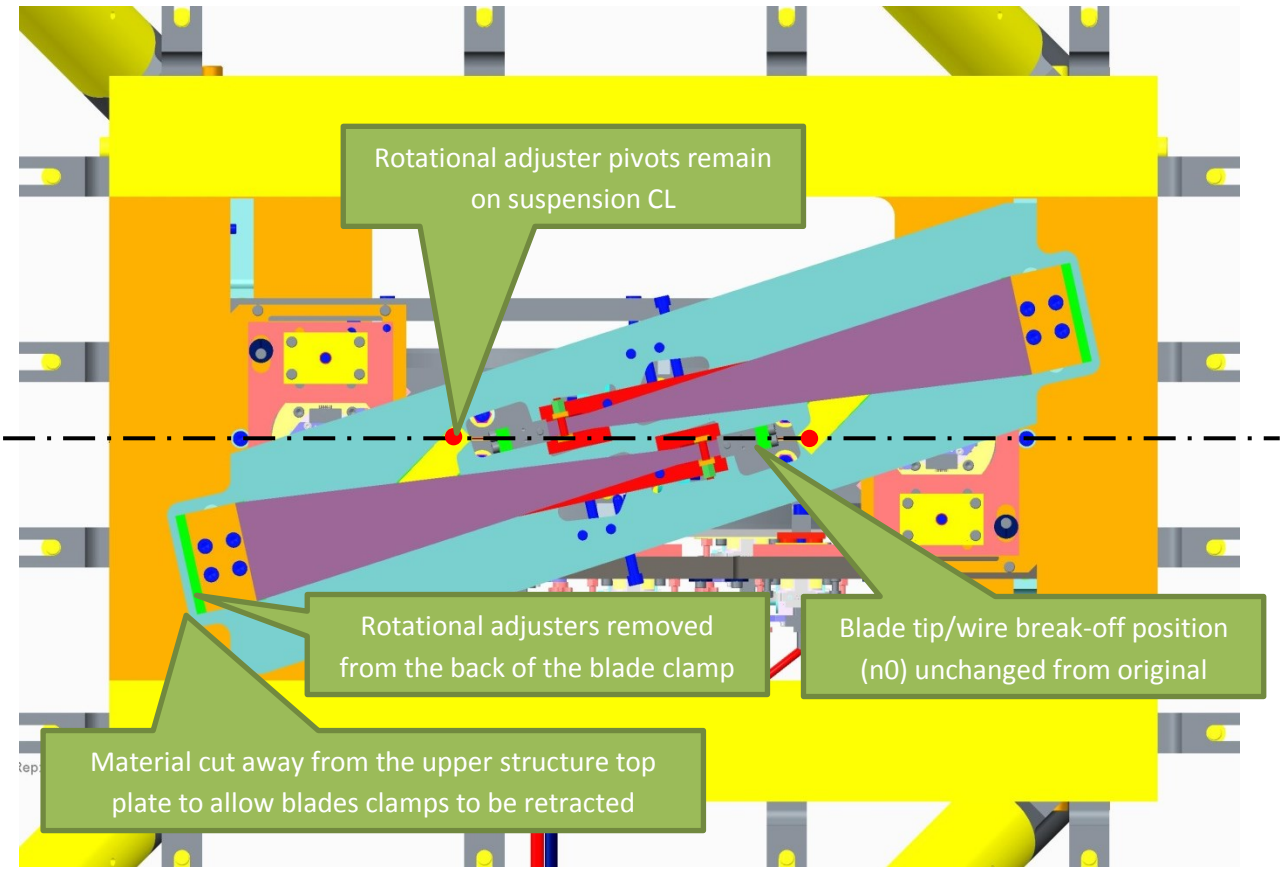
3.2 Design intent for design modifications

- Increase length of blades by 75mm
- Maintain position of rotational adjuster pivot on optic centre line (this minimises coupling of yaw adjustment with lateral shift, and also maximises linearity of adjustment)
- Maintain existing value of n0 without changing the blade angle by pushing blade roots away from suspension Centre line

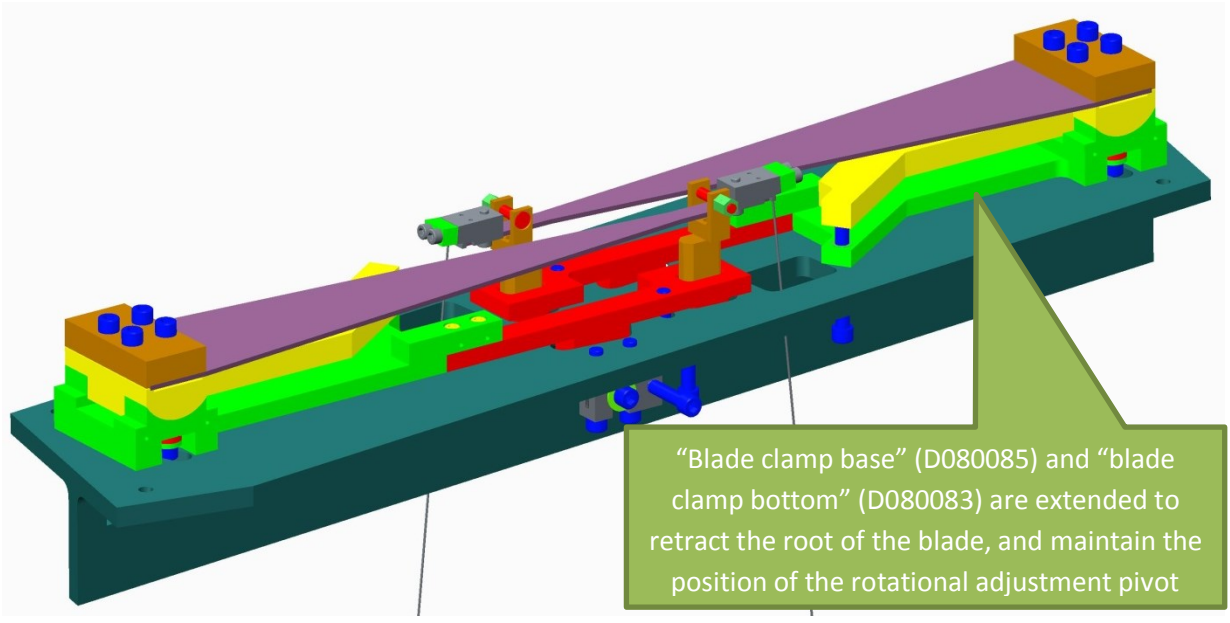
- Relocate all adjustment screws to below the base of the top stage to ease adjustment

3.3 Top stage proposed changes:

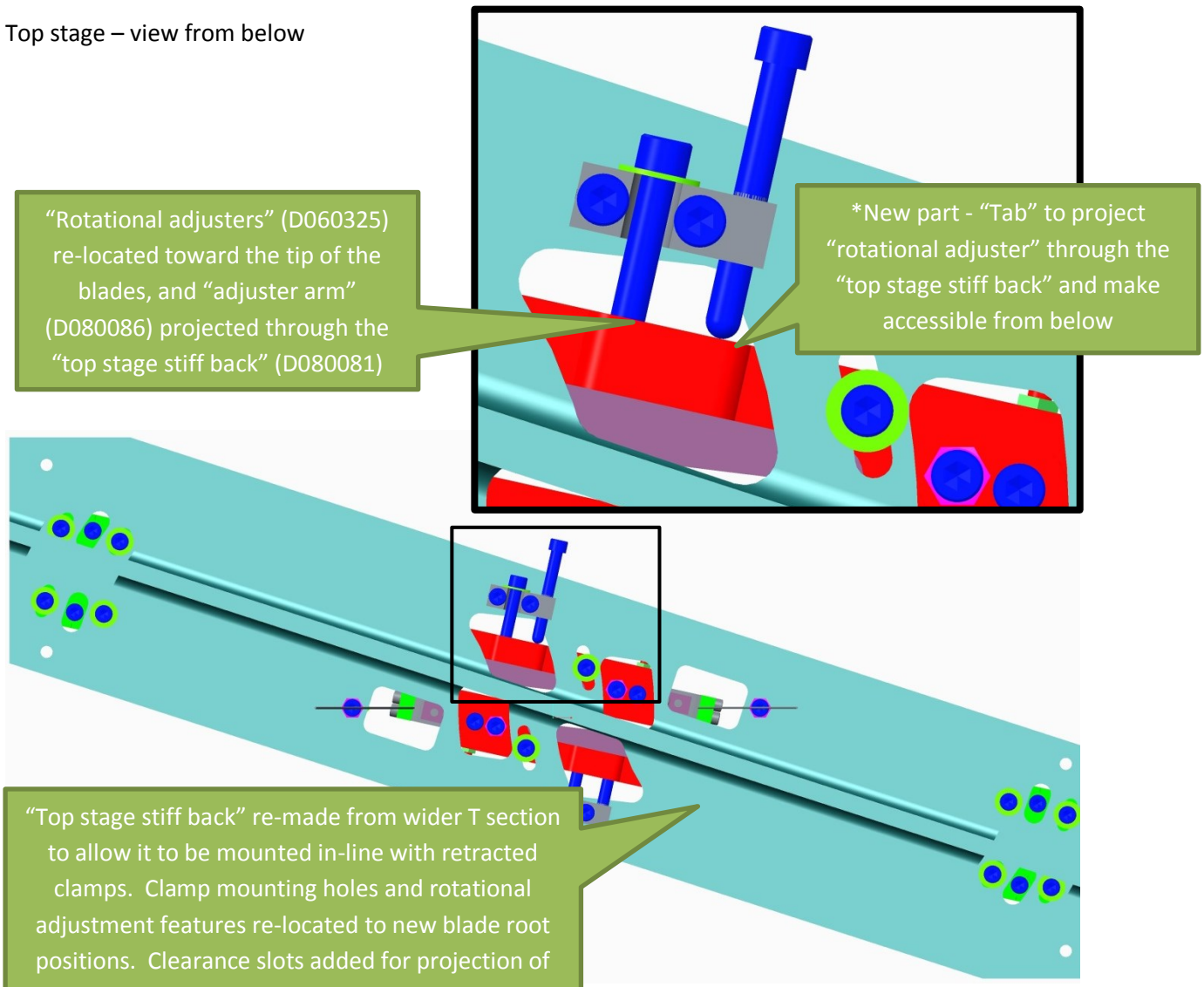
View from above – top stage in upper structure.



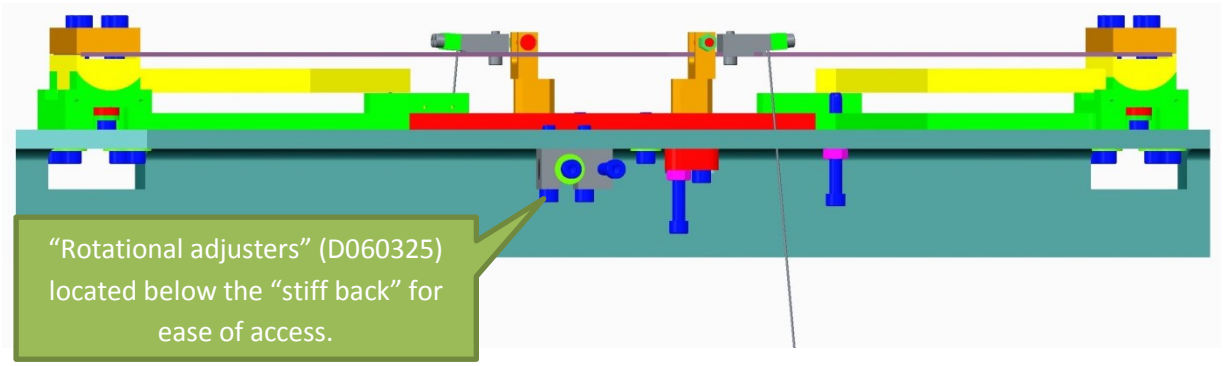
3D view – upper structure omitted for clarity



Top stage – view from below

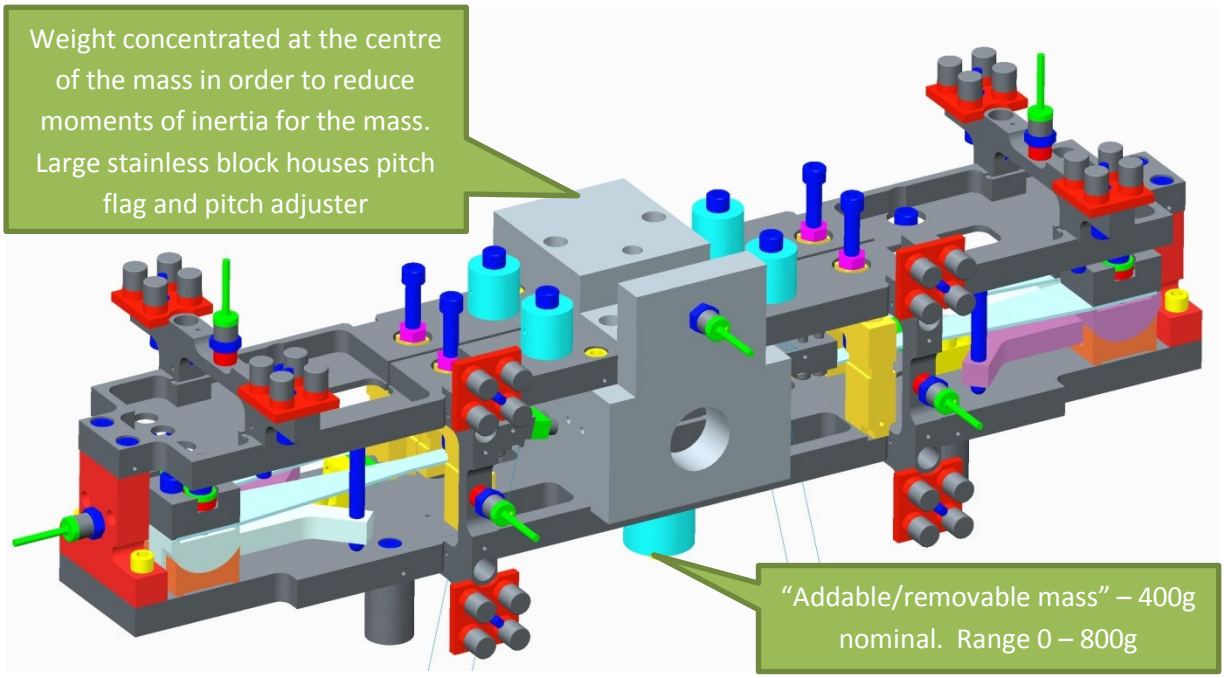


Top stage – side view



4 Top mass conceptual modifications:

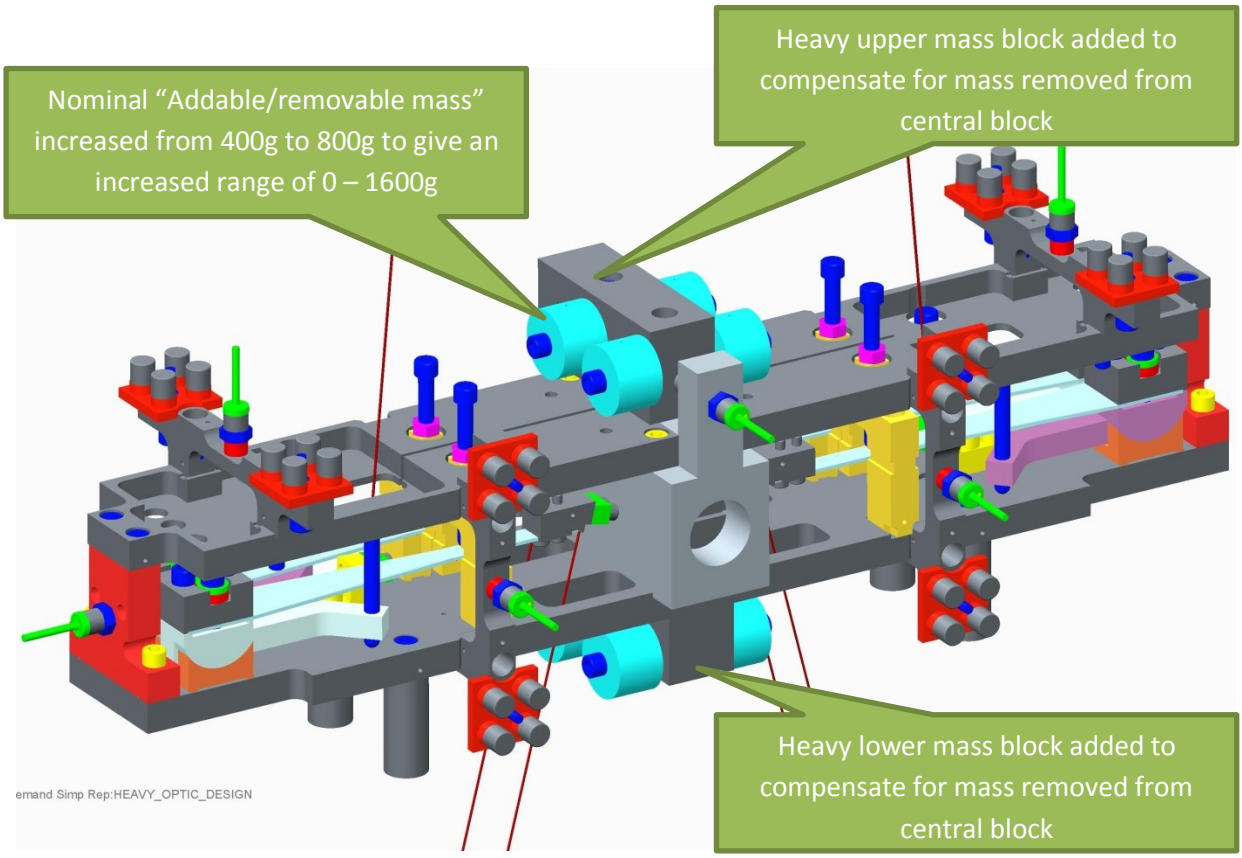
4.1 Existing design features

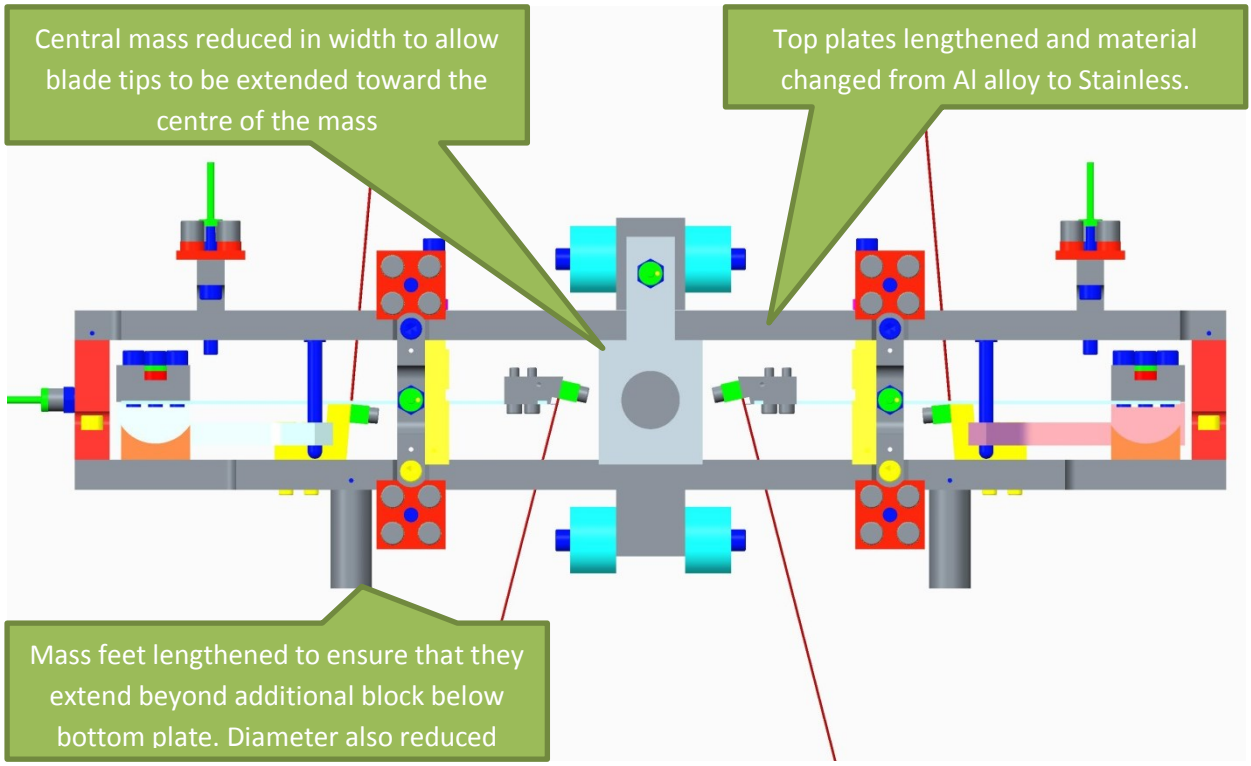


4.2 Design intent for modifications

- Increase length of top blades by 20mm
- Keep moments of inertia as low as possible – double that of the existing design has been identified by Norna as a limit.
- Increase adjustment range for mass by incorporating more "addable/removable mass"
- Maintain line of sight onto blade tips for ease of measurements and trouble shooting.
- Maintain all other functionality including flag positions and blade height adjustment

4.3 Top mass proposed changes





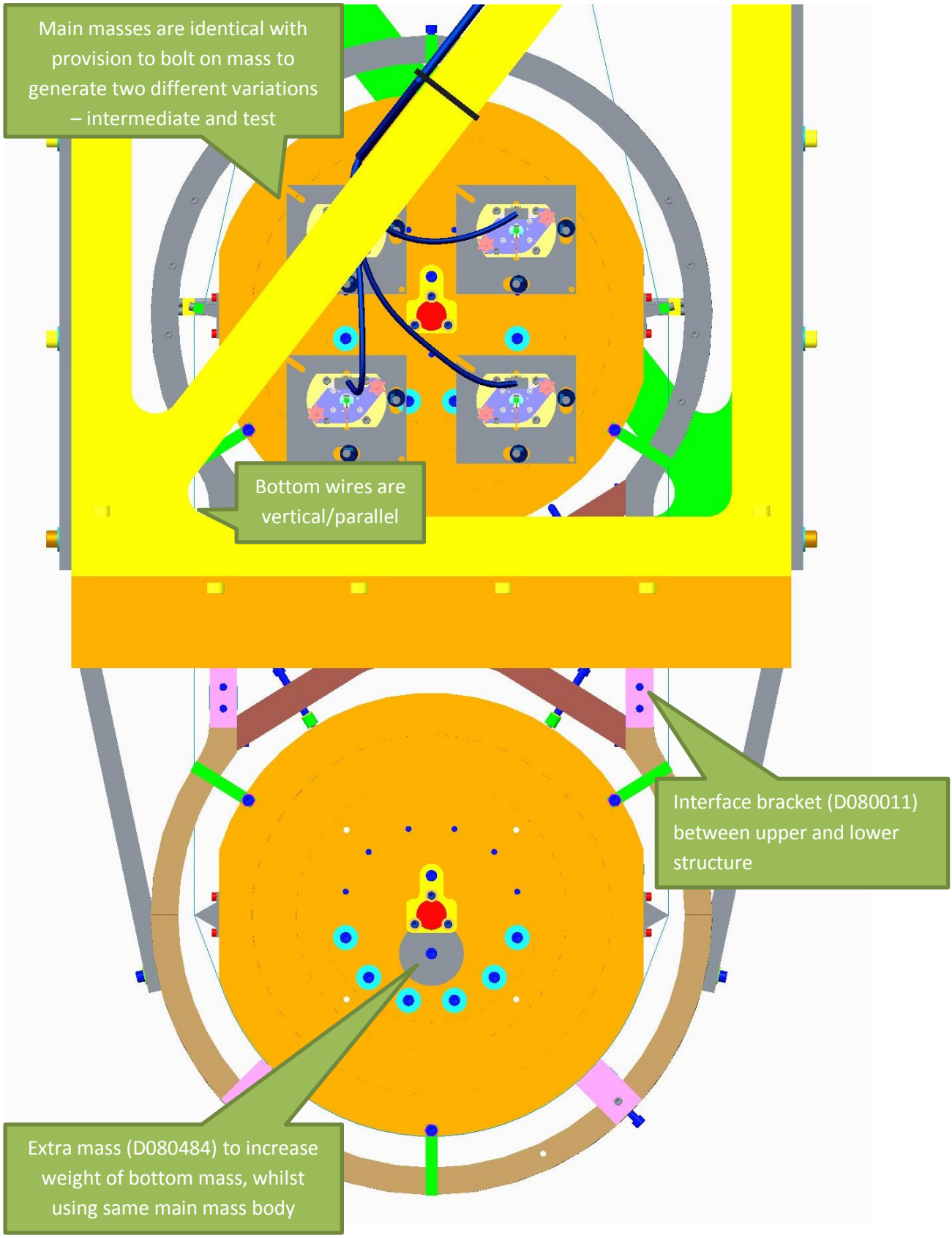
4.4 Comparison of top mass dynamics (existing vs new)

	Existing	New conceptual	% increase
I1x	1.6593E-01	**1.8934E-01**	14.11%
I1y	2.4732E-02	**2.7037E-02**	9.32%
I1z	1.6432E-01	**1.8123E-01**	10.29%

Note: Mass C of G and overall weight remain unchanged.

5 Round masses:

5.1 Existing design features (lower tablecloth omitted for clarity)



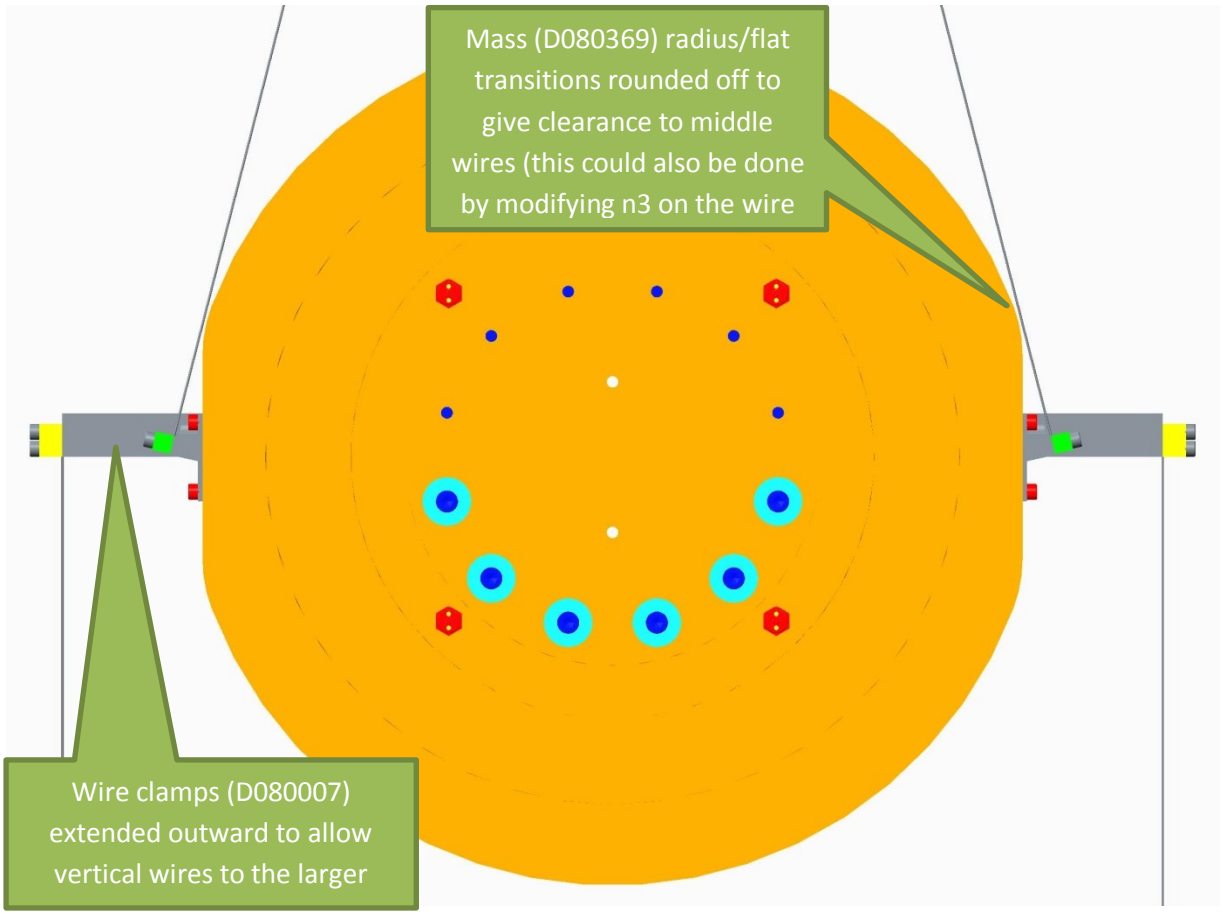
6 Intermediate mass conceptual design modifications

6.1 Design intent for modifications:

- Maintain existing weight of middle mass
- Maintain vertical/parallel orientation of bottom wires
- Use existing structure parts where possible i.e. wires exit lower structure from existing holes

6.2 Intermediate mass proposed changes

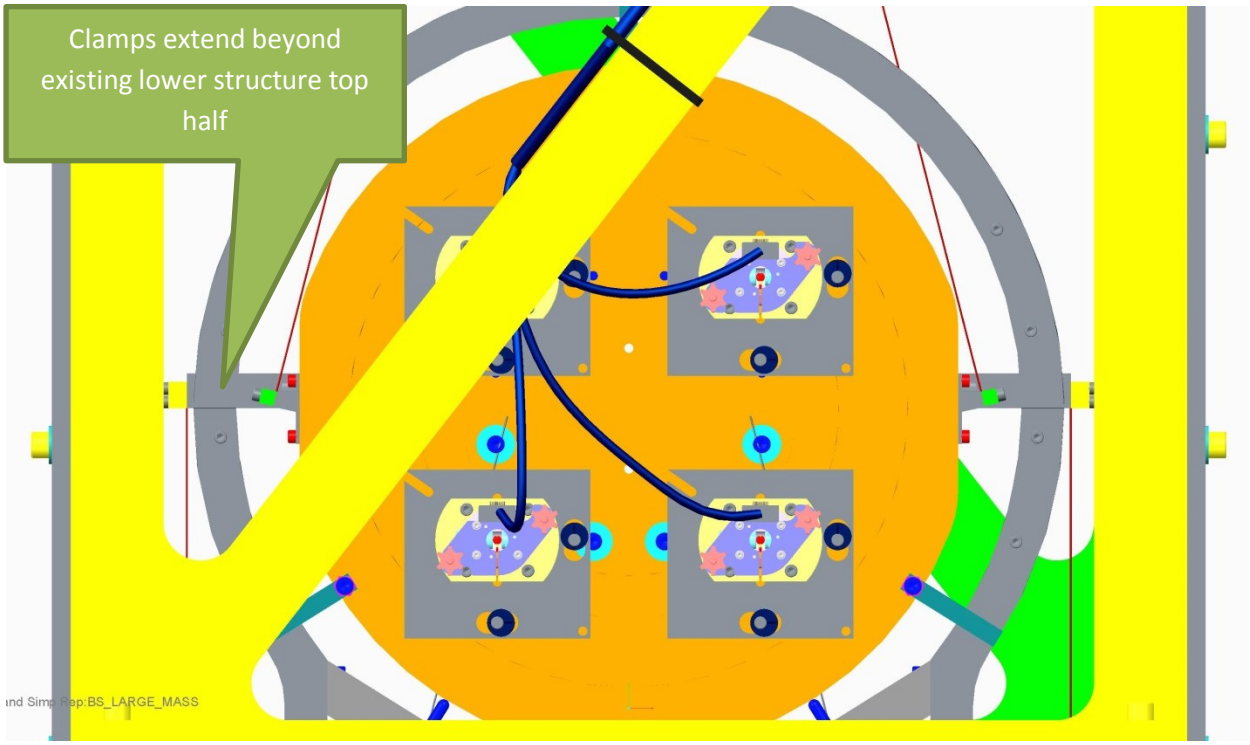
Intermediate mass with structures omitted:



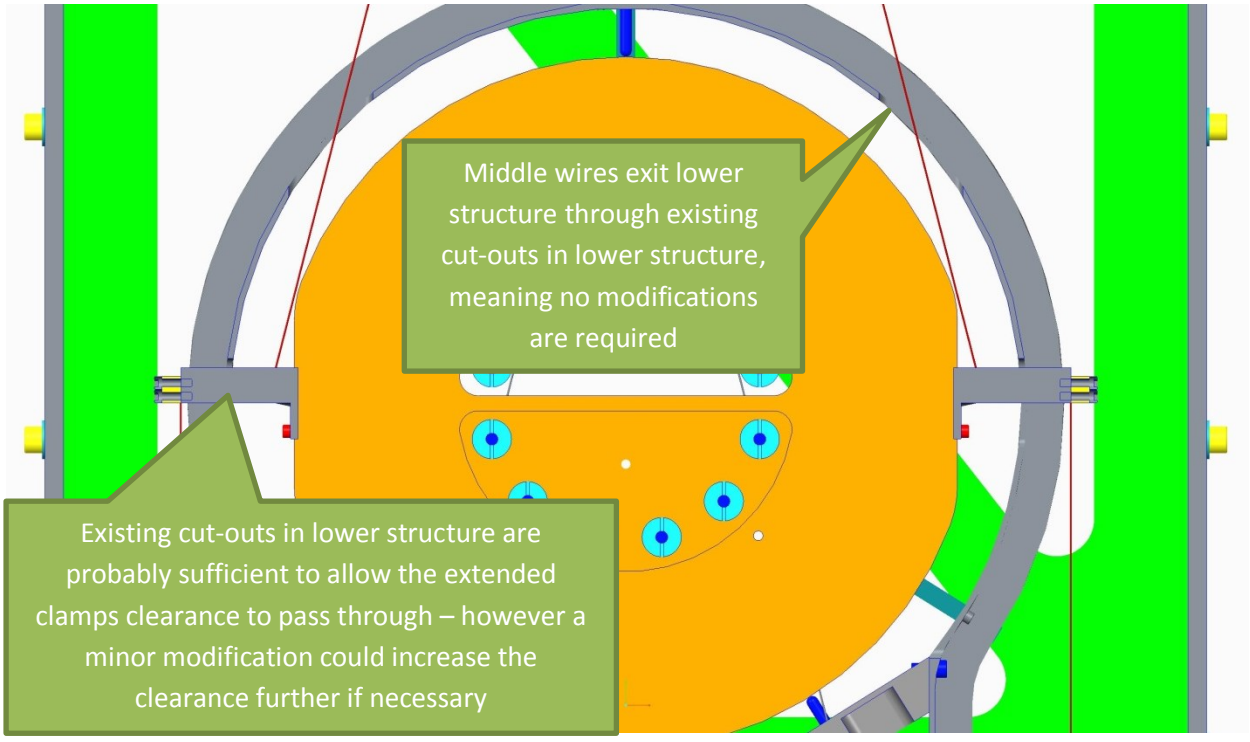
Note:

Changes to mass dynamics are thought to be negligible

Intermediate mass shown with upper/lower structures



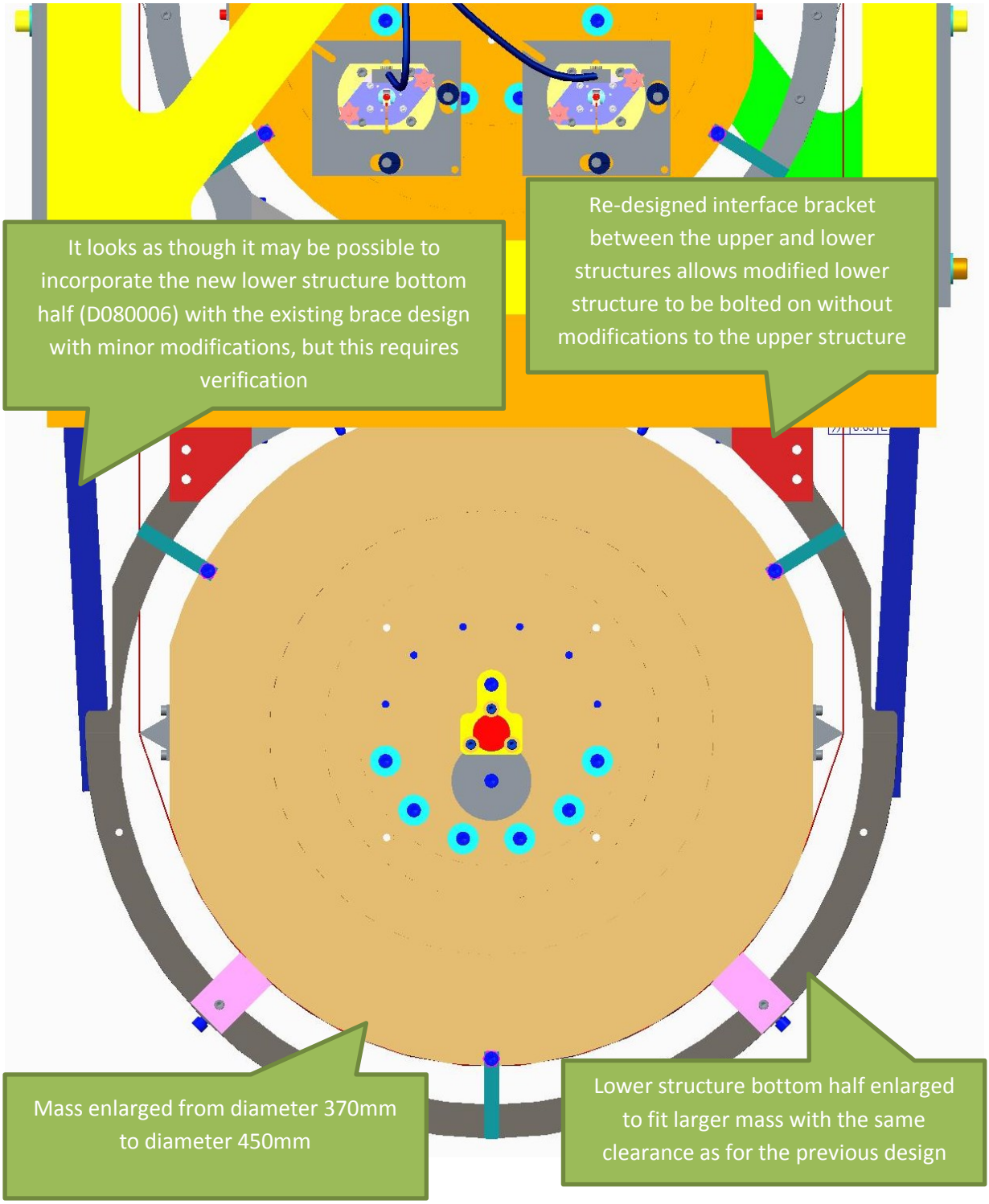
Intermediate mass shown with upper/lower structures – section view through CL



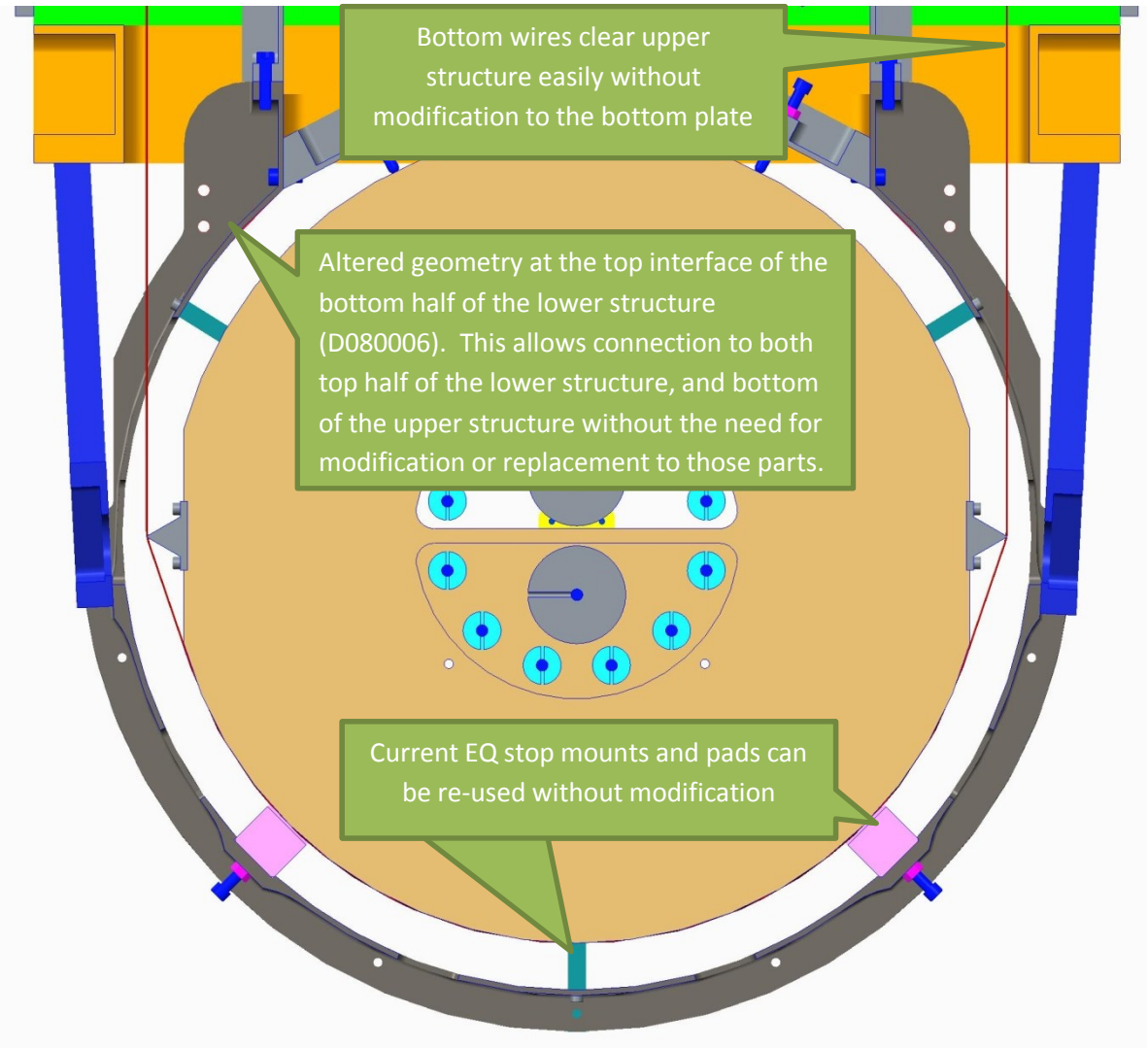
7 Test mass dummy

7.1 Design intent for modifications:

- It is clear that changes to the lower half of the lower structure are unavoidable, but it is the intention to maintain the original interfaces to all mating parts.
- Avoid modification to the Upper structure
- Use same EQ stops and support pads

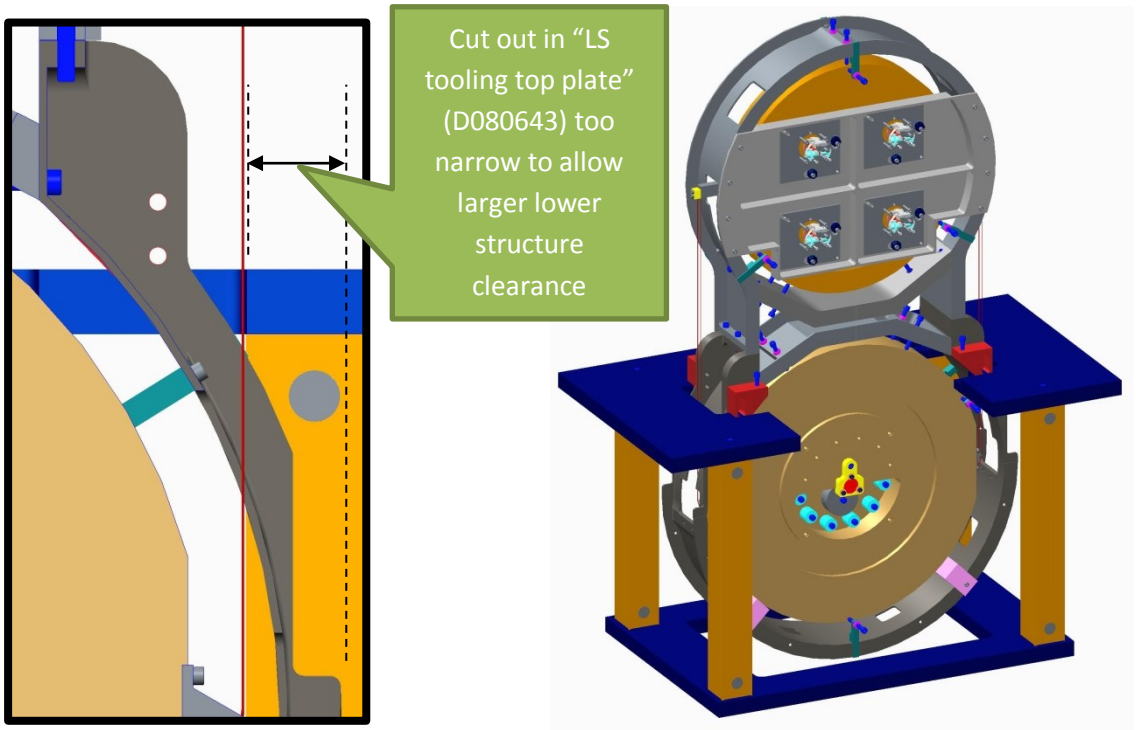


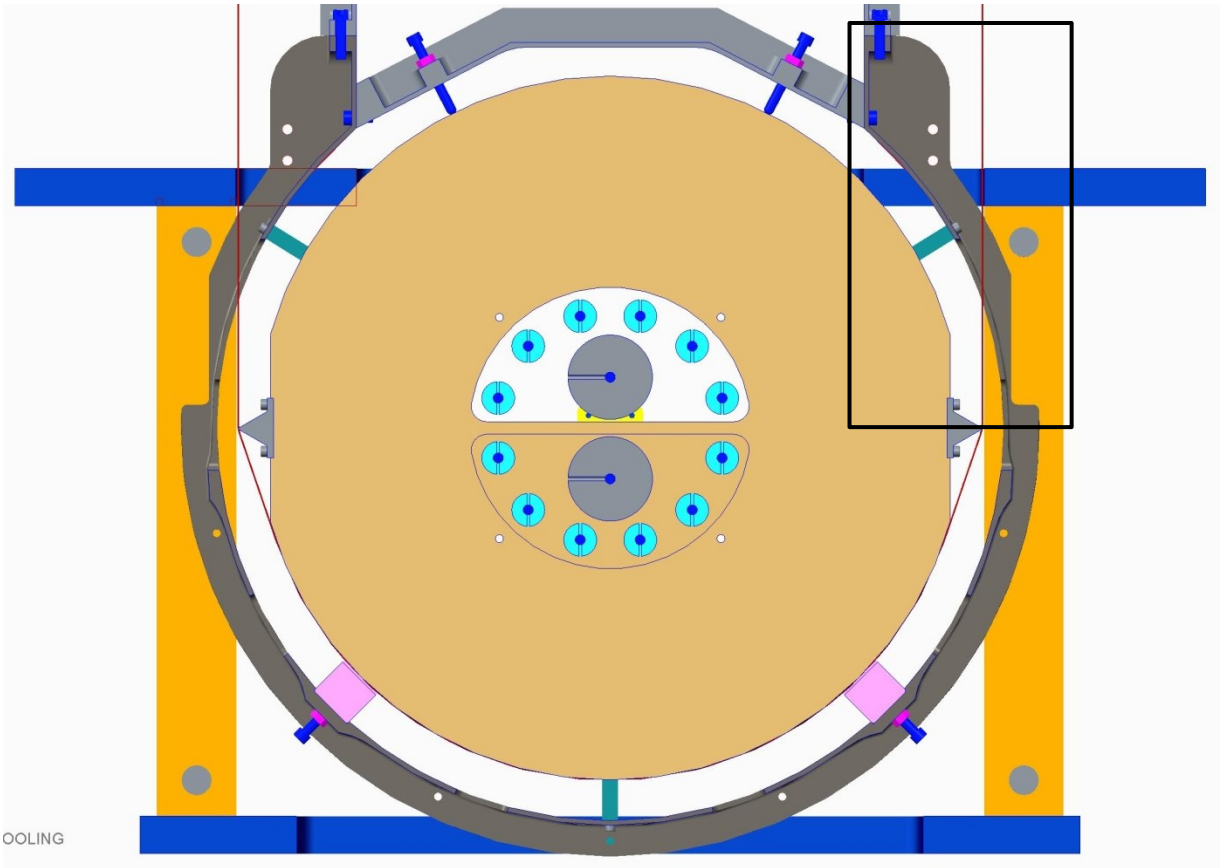
Bottom mass dummy – section view through CL

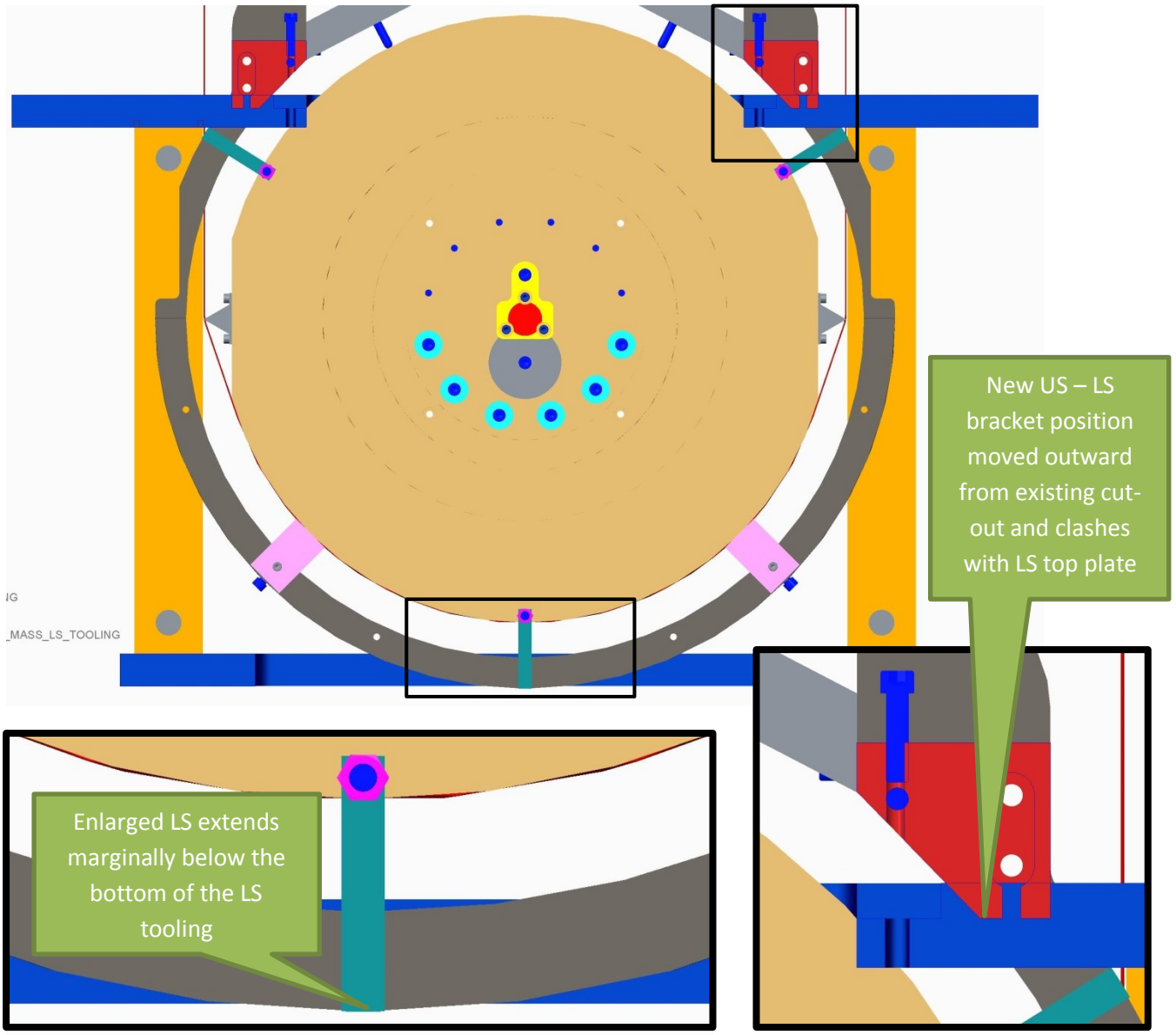


8 LS Tooling

8.1 Issues with modified lower structure in existing LS tooling.







8.2 Recommendations for modifications to LS tooling:

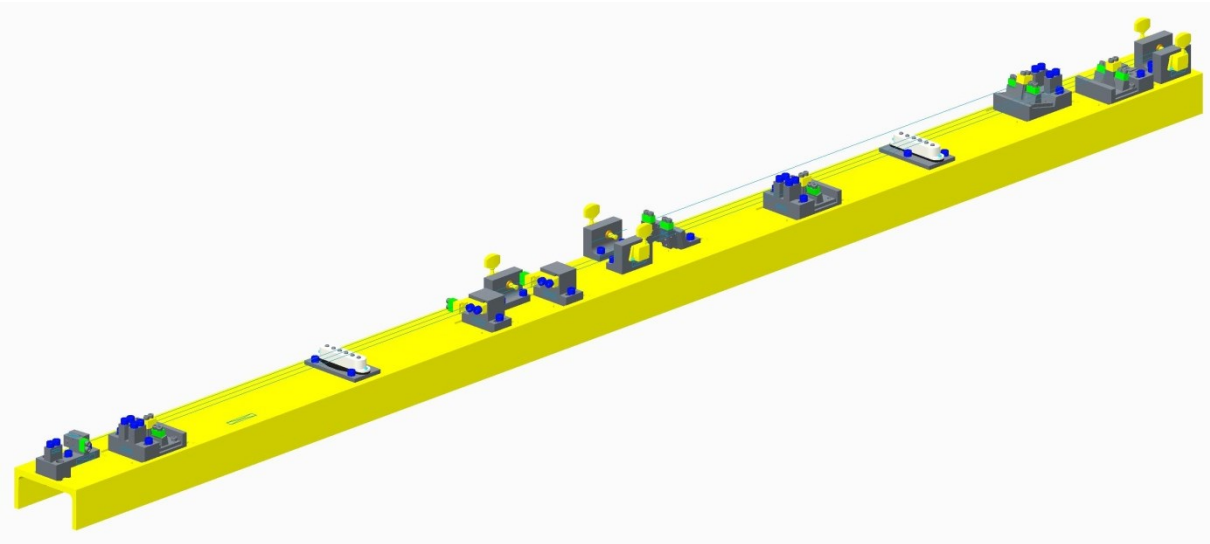
Modify the "LS tooling top plate" (D080643) with the following alterations:

- Widen the cut-out to allow the LS bottom half to slide through it without interference
- Machine new recesses for the location of the "US – LS brackets"
- Reduce the depth of the new recesses in order to raise the "US – LS bracket" so that the LS bottom half does not protrude below the base of the LS tooling.

Note – these modifications can be made to the existing plate without the need to re-make. It is believed that the modifications described to the existing plate above are the only modifications required to the LS tooling.

9 Wire jig

Here the wire lengths for the conceptual design for the larger mass are considered relative to the existing wire jig tooling pictured below:



The table below shows the new wire lengths in comparison to the nominal wire lengths on the wire jig. The wire jig is capable of making wires of length "nominal" +/- 20mm.

	Wire length		Wire jig settings		Notes
	Wire jig nominal	New conceptual	Offset	Spacer total (range 0 - 40mm)	
Top wire	612	612	0	20	Within range of wire jig
Middle wire	600	604.5	4.5	24.5	Within range of wire jig
Bottom wire	1586.9	1711.9	125	145	Out of range of wire jig

9.1 Proposed wire jig modifications:

The top wire is unchanged, and can therefore be made with the existing wire jig and spacers per assembly drawings D080133. The Middle wire changes slightly in length, but is still well within the range that the wire jig is capable of. The new bottom wires for the larger mass design are increased in length by approximately 145mm. This takes them well outside of the range that the existing wire jig is capable of, and this means that the wire jig base plate (D080147) requires re-make with an increased length.

10 Summary of proposed changes

All of the conceptual design changes discussed previously have been summarised below in terms of three categories:

- **Modifications of existing parts**

Parts could be kept and modifications made by machining new features into them

- **Re-make parts**

Parts that have been changed significantly and require remake

- **New parts**

New parts that have been identified that are additional to the existing parts

10.1 Modification of existing parts

Upper structure:

- D080505 - Upper structure cross member

Lower structure:

- LS stiffening brace (part number not known)

Top stage:

- D080086 - Top stage adjuster arm

Intermediate mass:

- D080369 - BS round mass body

10.2 Re-make parts

Top Stage

- D080081 - Top stage stiff back
- D080083 - Top stage blade clamp bottom
- D080085 - Top stage blade clamp base
- D080513 - Top blade spring

Top mass

- D070417 - Bottom blade spring
- D070422 - Top mass baseplate
- D070430 - Top mass top plate
- D070423 - Top mass pitch adjuster and mass
- D070434 - Top mass stability leg

Intermediate mass

- D080560 - D clamp body

Lower structure

- D080006 - Lower structure bottom half
- D080011 - Lower structure – upper structure interface bracket

Lower structure tooling

- D080643 - LS tooling top plate

Wire jig

- D080147 - wire jig base plate

10.3 New parts

Top stage

- Rotational adjustment extension tab

Top mass

- Heavy upper mass block
- Heavy lower mass block

Test mass dummy

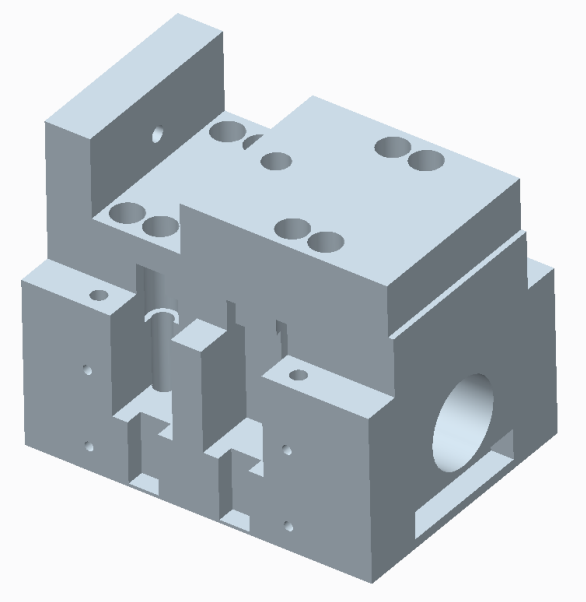
- Test mass dummy body

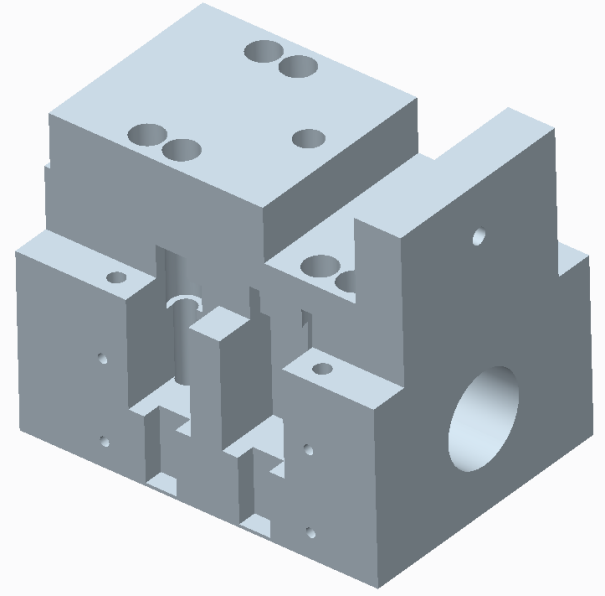
Appendix A - Alternative top mass modification

The following is a study that was carried out previously to consider whether the BS top mass could be modified for the longer blades, without increasing the MOIs, and with only modifications to existing parts without the need to re-make parts.

This approach is not recommended, but has been included for reference as a possible option for reducing the work required to make these modifications. It could also be referred to in the future if requirements on MOIs became more stringent than currently supposed.

The current central mass has been modified to include further machining that will allow it to be reused with the proposed larger blade springs. This now includes new holes for mounting it to the main chassis, as the position of the bolts in the current position would clash with the blade tips. There are large sections taken out for the blade tips to be located in their extended positions, with the assembly order being accounted for. There is also a slot machined out just below the central hole to reduce the moments of inertia to the same order as that of the previous design. Figures 1 and 2 show the new central mass from two opposite angles.





The centre of mass and the moments of inertia of the previous and new designs are shown below:

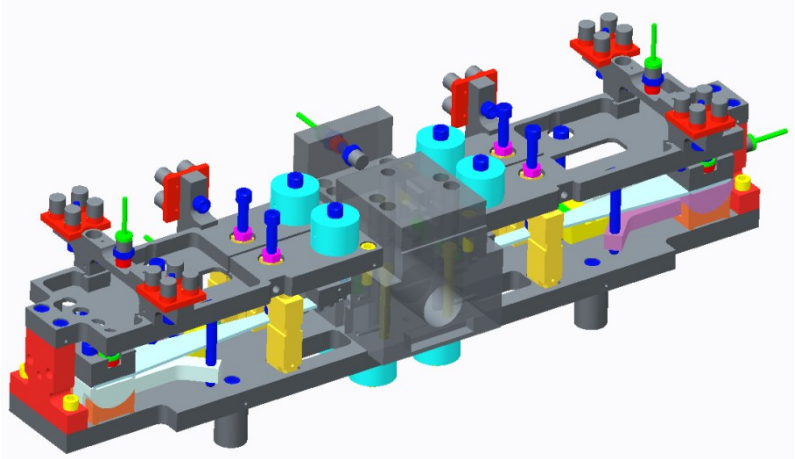
Previous Design

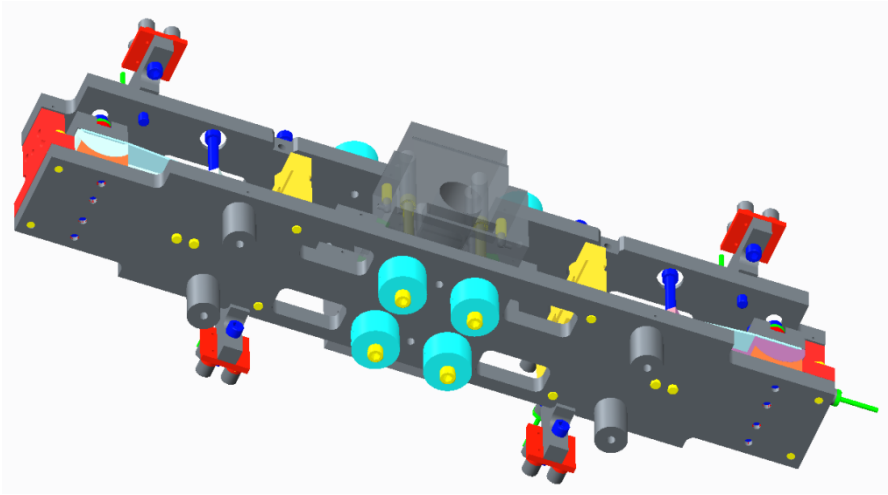
COG	X	Y	Z
	3.69E-01	-2.77E-01	2.29E-01
I Tensor	**1.62E+05**	0	5.76E+00
	0	**2.39E+04**	2.32E-01
	5.76E+00	2.32E-01	**1.61E+05**

New Design

COG	X	Y	Z
	8.01E-04	-2.85E-01	1.31E-01
I Tensor	**1.63E+05**	-2.48E-01	-5.17E-01
	-2.48E-01	**2.40E+04**	2.32E-01
	-5.17E-01	2.32E-01	**1.61E+05**

These numbers show that the centre of mass has been maintained. The most significant moments of inertia (Ixx, Iyy and Izz) are of the same order of magnitude and value as that of the previous design, whilst the other inertias also stay close to their former values. With further work it may be possible to bring these down to smaller numbers if necessary, but for the purpose of providing a conceptual design is to show that the larger blades can be introduced to the suspension system with modifications to the central mass, and also the addition of more balancing masses. Figures 3 and 4 show the middle suspension system from above and below respectively.





The main advantage of this concept is that the mass dynamics are maintained, and there is a minimum of modification work involved.

The main disadvantage of this concept is that the blade tips are hidden by the pitch adjuster/mass block, which will make diagnosis work on the BS more difficult.