Noise prototype Assembly procedure

1. INTRODUCTION/NOTES

HISTORY

T060040-01 2 page procedure; briefly discussed at LSC, March 06.
T060040-02 6 page procedure; worked out by JG, TH, JO & IW on 17th May 06
T060040-03 7 page procedure; Glasgow University on 25th May 06, CIET, RJ, CAC, IW, JG,IO,TH,SA
T060040-04 7 page procedure; as 03 but bulked out for PDR-03 by IW

NOTES

References to controls assembly procedure T060039 marked in square brackets.

2. DIRTY METAL ASSEMBLY

NOTES

- We have elected to assemble the upper structure on the gazebo offering up in parts in order. We will also have a manual fork truck available so we can re-visit this decision and elect to assemble on the bench if we prefer.
- This assembly procedure makes many attempts to minimise the necessary range in the implementation ring. In discussion with UK team it was felt that provision should be made for "unforeseen" factors in assembly that will require a greater than anticipated Implementation ring range. It is proposed that the noise prototype use large range ~28mm, we hope top then reduce this range in the final item based upon our experiences with the Noise prototype.

PREREQUISITES OF DIRTY METAL ASSEMBLY

- Ensure that the metal masses to be used have the same mass as the non-metal masses they are to replace.
- The Blades will have been matched as per the controls prototype procedures (ref T040299-10 for examples) and then the matched blade sets will have undergone an initial creep bake as per T040108-03.
- Ensure by trial fit that the upper and lower structure correctly interface to the sleeve.
- Assemble all helicoiled parts with over-long helicoils to facilitate removal. This is to allow their removal prior to cleaning to allow clean helicoils to be installed for the clean assembly.

INFERSTRUCTURE REQUIRED

For the dirty metal assembly the following will be available:

Gazebo:	Similar to the Caltech gazebo but more rigid.
Manual fork truck:	Similar to Caltech Genie
Bench:	Maybe an optics bench but this is not mandatory
Tools:	All the appropriate hand tools and measuring devices
Masses:	These will be necessary to load blades flat. Note: this is not part of this procedure

2.1 Upper structure build [2.2]

TOP STAGE

1. Install empty upper structure on the gazebo [2.2.2.1 changed plan to avoid adjustment at 2.2.2.2 by making castellated piece as part of upper structure or similar] [2.3.1.2][2.3.1.3]
2. Install all four top stages in place. Add the dowels to ensure the tips are central. [2.2.2.3]
3. Ensure all blade tips are held well down with blade stops. Target is that the tips are 2mm below nominal. This means the blade will be over deflected by ~ 2% [2.2.2.4 changed]

TABLE CLOTH AND TOP MASS

4. Assemble the tablecloth side plates and back plate in place with no OSEMs/ECD assemblies. Install all the dowels to locate it nominally WRT to the structure. [2.2.2.5 changed]
5. Add the two top masses and position nominally in x and y using dowels and approximately 10mm too high in z [2.2.2.9] (do this by inserting the stops too far). The masses should have their top plates and outer blade stops omitted. In this configuration the mass will be very stable if suspended by mistake. [2.2.2.8 changed]
6. Connect the top two masses to the top stage by hooking the top wires into the top blades (drum end wires) or by bolting the wire clamps to the blade tip (traditional wires). [2.2.2.9]
7. Add the front plate to the tablecloth omitting the ECD and OSEM mounts. [2.2.2.7]
8. Lower top two masses to nominal position. [2.2.2.10]

[2.2.2.6, 2.2.2.12, 2.2.2.13] no longer applicable due to design changes. [2.2.2.11] now comes later.

2.2 Lower structure

TOOLING REQUIRED [2.1.1]:

- Scissor table with optics bench top, with twin roller rails (lazy Susan) supporting carriages that support each lower structure half. The carriages will reinforce the lower structure halves allowing all the masses to be safely installed.
- Frame work to abandon half a lower structure on (mini gazebo).
- Ergo arm (modified to take a non-glass mass)
- Tooling to set "glass" masses roll.
- Wire jig
- Test mass jack
- Inter chain transport stops
- Autocollimator (or two); and /or theodolite. Note all metal dummy masses need autocollimator reflector.

1. Assemble both lower structures onto carriages on lazy Susan (separate by ~100mm)

REACTION CHAIN

2. Add the reaction UI mass into place on fully retracted vertical stops, this puts the masses 10mm below nominal. Note: OSEMS should be in place. [2.1.3.1] Note the UI mass has both the middle and bottom wires attached during its pre-assembly.

3. Add the Penultimate reaction mass in to a position in its nominal position WRT lower structure (on fixed PFA440HP[1] pads); set roll. Note: OSEMS should be present and in place. [2.1.3.2 removed by design change] [2.1.3.3]
4. Add the penultimate – test wire loops to the reaction chain. Note that the wire loop will need to be unique in order to accommodate different angles on the barrels of the penultimate masses that allows the 5mm separation gap to be uniform, and allows the penRe mass the be horizontal WRT the structure. [no equivalent]
5. Attach the wires from the UI to Penultimate reaction mass. [2.1.3.3]
6. Add the reaction test mass ~3mm above nominal onto the test mass jack using ergo arm [2.1.3.4]; set roll using roll tooling [2.1.3.5]. Note provision needs to be made to either restrain the wire loops to allow the re test mass to be installed, or the re test mass to be installed first.
7. Hook the wire loops into the groves on the test reaction mass. [2.1.3.8] Note recommendation of allowing good access to grooves during installation of loops.
8. Lower test reaction mass by adjusting the "test mass jack" to its nominal position, using the test mass jack. [2.1.3.8] [2.1.3.11] Note; it is suggested that the test mass jack has an open clamping face to allow hands access to the wire grooves.
9. Add the inter chain transport stops (main chain absent at this point).
10. Raise the UI mass to its nominal position on the vertical stops taking care to keep it horizontal. [2.1.3.10]
11. Raise the penultimate mass and remove its PFA440HP pads. Lower the penultimate mass suspending it. [2.1.3.10] Note to selves; at some stage around here we will need to wire the ESD during the clean glass assy.
12. Lock all three masses in their nominal positions (leaving the wires all in tension).
13. Check pitch and yaw of all masses [2.1.4] and fix.

TEST CHAIN

For the initial noise assembly of the test chain it is proposed to duplicate the reaction chain procedure as closely as possible as follows:

14. Add the reaction UI mass into place on partially retracted vertical stops (23mm is the full range), this puts the masses 10mm below nominal. Note: magnets should be absent. [2.1.3.1] Note the UI mass has the middle wire attached during its pre-assembly.
15. Attach the bottom wire loops to the UI mass. Consider notes above.
16. Add the Penultimate reaction mass in to a position in its nominal position WRT lower structure with magnets omitted (on fixed PFA440HP pads); set roll. [2.1.3.3]
17. Lift the UI mass, tensioning wires to 25% load.
18. [2.1.3.2] "route the wire loops of the penultimate mass wire assembly into the groove on the penultimate"
19. Add the test mass 9mm above nominal using ergo arm [2.1.3.4].
20. Add the final wire assemblies

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[1] PFA440HP has not been approved for Advanced LIGO vacuum, however these pads are tooling only and will never be put under vacuum.

21. Suspend test mass by progressively lowering stops. Once suspended verify that that pitch and roll are acceptable. Rehearse using lever arm clamp to overload wires (will later be ribbons), make sure that the stops are never a long way from the mass as the wires are overloaded.
22. Add the inter chain transport stops (reaction chain distant at this point). [2.1.5.2]
23. Remove lever arm clamp.
24. Raise the UI mass to its nominal position on the vertical stops taking care to keep it horizontal. [2.1.3.10]
25. Raise the penultimate mass and remove its PFA440HP pads. Lower the penultimate mass suspending it. [2.1.3.10].
26. Lock all three masses in their nominal positions (leaving the wires all in tension). [2.1.5.1]

FINAL LOWER STRUCTURE ASSEMBLY

27. Un-clamp carriages on the lazy Susan to allow them to move.
28. Push the two halves of the lower structure together. [2.5.1.3]
29. Bolt two halves of the lower structure together, adding "Z" plates etc…
30. Unlock test and penultimate masses in both chains and verify that the penultimate masses are parallel, and that the test reaction mass is hanging at the correct angle, Note to selves this may be horizontal. [2.1.4] Also verify that there is no differential yaw in each chain.

2.3 3 in 1 assembly [2.3]

1. Clamp both lower structure carriages to trolley. [2.1.5.1] [2.1.5.5]
2. Wheel trolley under upper structure in gazebo.[2.3.2.1] Note, it is recommended to switch the combined lower structure to the 5 axis table at this point with a "genie".
3. Raise lower structure as far as it will go (~28mm above nominal). If desired at this point rehearse use of 5 axis trolley, get this in place by taking lower structure weight temporarily on upper structure and removing lazy Susan trolley. [2.3.2.5]
4. "use the slack in the UI wires to connect to them to the top masses"[2.3.2.6]. Note that the top masses are in their nominal positions WRT the upper structure and the UI masses are in their nominal position WRT the lower structure. We are planning to use straight wire so that *in principle* only the wire stretch of 2mm need be accommodated by the implementation shim. If necessary lower the blades on top mass using the stops in order to allow the wires to be connected. We intend to test that overloads of up to 10mm do not compromise blade performance.
5. Add top plate etc to top mass, add the top plates to the tablecloth omitting the ECD and OSEM mounts [2.2.2.11]. Note that on global controls there are no magnets or flags at the moment but the OSEMs are present.
6. Let down the Lower structure into its nominal position. [2.3.2.8]
7. Insert implementation shim and connect lower and upper structures.[2.3.2.8]
8. Ensure reaction top mass is horizontal and in its correct position.
9. Release test reaction mass and then pen re mass and then UI reaction mass [2.4.1.1]
10. Release test mass and then pen test mass, and then UI test mass [2.4.1.1]
11. Retract top stage blade stops.Taking great care release top masses, watch for pitch etc at all times [2.3.2.7]

12. Solve the unknown problems.

2.4 Completion

1. Balance and align the quad to the point where both chains are at the correct height and are correctly pitched, and yawed. Note; alignment of the OSEMs will effect the pitch.
2. Fit the sleeve, add the removable member if present.
3. Before dismantling ensure complete records of serial numbers of all parts, also note positions of any adjustments made, a checklist/record sheet should be used at this point to ensure firmal record keeping.
4. Remove all helicoils.

3. CLEAN METAL AT RAL

Clean metal assembly at RAL is identical to the dirty metal assembly with the following exceptions.

- New wire and clamp assemblies.
- All tooling class B clean
- Assembly area is a cleanroom (proposed class 10000)
- Full cleanroom precautions
- Silver plated screws in SS where galling may be an issue.
- Start by helicoiling with correct length (rather than over length) helicoils; remove tangs.
- No need to remove helicols at end.
- Check all serial numbers to ensure the same parts go in their previous positions.
- Blades must be cleaned and baked at 120 C for 48 hours.
- After assembly of Top, and UI mass and the top stage these assemblies must be baked at 120 C for 1 Week to remove creep and creak effects. After this bake the blades must not be un-loaded.
- It may be prudent to cable and test the OSEMs and electronics. (maybe align the OSEMs, using procedure below). SA
- Leave whole suspension for 3 days minimum to verify alignment has not changed.
- Prior to shipping the suspension will be shipped down to the level of mass assemblies and individual structures (upper, lower, sleeve).

4. CLEAN METAL AT LASTI

Repeat the “clean metal at RAL” procedure excluding helicoil fitting. We must certainly fit all OSEMs, wireing and electronics and align and verify function.

4.1 Mass and OSEM alignment procedure. (Clean metal at LASTI) [2.5]

Note: this procedure will need to be repeated once the real masses have been installed but is being rehearsed at this stage before the most delicate components are present.

At this point it would be premature to wright an alignmemnt procedure for the quad. It is proposed that the noise procedure will be based upon controls procedure, and will be updated with lessons learned.

5. CLEAN GLASS (OUTLINE PROPOSAL FOR WIDER DISCUSSION)

Need to define when and where we do ESD tabs. See doc from BT & CIET

Strip down of clean metal

1. Lock all masses
2. Lock and overload blade tips to desired position.
3. Remove sleeve.
4. Offer up tooling with carriages and remove implementation shim lowering lower structure slightly.
5. Raise lower structure
6. Disconnect UI-Pen mass wires
7. Disconnect electrical wiring to lower structure.
8. Remove lower structure
9. Separate halves of lower structure
10. Wheel structure to non-metal mass assembly area.

Real clean glass assy

Note: We must double check at this point that all the metal masses we will be removing at this point are identical in mass to the glass being installed. If discrepancies are found corrections should be made to metal masses and re alignment of metal masses trial assembly.

11. Unclamp dummy reaction test mass and remove with ergo arm; replace with glass.
12. Wire in the ESD and cable to top of reaction chain lower structure.
13. Abandon reaction chain on stand.
14. Unclamp dummy test mass and remove with ergo arm. Ref T050213 section 4 to be removed, section 5 to be updated.
15. Lower test UI mass to release tension in Bottom wires OR overload blades in UI mass.
16. Unclamp and remove dummy test penultimate mass with ergo arm.
17. install lever arm clamp, test mass jack, and assembly stops, with high position welding spacers in place.
18. Add the Penultimate test mass into loops from UI mass; set roll. Note: Magnets should be absent, they will be added later.
19. Lift the UI mass, tensioning wires to 25% load. Ensure loops on Pen mass are correctly in grooves.
20. Add the test mass 8mm above nominal; set roll.
21. Wheel assembly to welding rig and bolt in position. Note trolley will require turntable and z adjustment to allow structure to be adjusted for welding.
22. Prepare structure for welding operations, add baffles etc… [Section 5 of T050213]
23. Weld ribbons.
24. Lower test mass ~1mm to allow for stress relief reheat on ribbons.

25. Suspend test mass by progressively lowering the jack. Once suspended verify that that pitch and roll are acceptable. Use lever arm clamp to proof test of ribbons, make sure that the stops are never a long way from the mass as the ribbons are overloaded.
26. Lock test mass in position.
27. Remove lever arm clamp. Raise main UI mass to nominal position suspending the two masses below.
28. Lock all the masses in their nominal positions. (Note to selves the test mass barrel may not be horizontal this will be allowed for in the design of the stops depending on wedges etc…)
29.
30. Note 32 on needs notes above to be incorporated in to below
31.
32. Raise test mass with test mass jack, and remove welding spacers. Fit stretching spacers
33. Lower test mass ~1mm hard against stretching spacers and relieve stress on ribbons.
34. Use test mass jack to lift the test mass and remove the stretching spacers.
35. Fit overload spacers.
36. Suspend test mass by progressively lowering test mass jack. Once suspended verify that that pitch and roll are acceptable.
37. Use lever arm clamp to overload fibres, make sure that the test mass jack is never a long way from the mass as the fibres are overloaded.
38. Release the load on test mass, raising the jack at the same time.
39. Remove the spacers and fit the transport stops. Note to selves, we need to remove these at some point.
40. Remove lever arm clamp and test mass jack.
41. Raise main UI mass to nominal position.
42. Stop UI mass blade tips down form nominal.
43. Add jack and raise test mass to 1mm below slack fibre position ~12.5% tension.
44. Lock all glass masses down with UHV polymer stops.
45. Separate lazy Susan/lower structure from welding table and return structure to mass assembly area.
46. Recombine structures, as above. Note test mass is too high and test mass must be lowered prior to suspending masses.
47. Re-connect all wiring including ESD, and tidy pig tales.
48. Final alignment of OSEMs and masses, (based on controls procedure).
49. Fit final stops.

6. INSTALL INTO TANK

This will need to be worked on in conjunction with LASTI closer to the time. It should be noted that we know that all parts of the quad can be fitted into the tank through the door where ever the quad is on the optics table so no significant problems are imagined.

7. REPAIR SENARIOS

These repair scenarios are not intended as a step by step repair guide (that will come with the final article). They are more "broad brush" concepts intend to convey the potential to make the repair rather the exact detail.

Failure	Repair description
Ribbon snaps/ ear bond fails	• Open tank • Lock ALL masses and the blade tips in present positions (many will be in the wrong places) • Remove the sleeve • Extract or retract the OSEM cans in the Pen Re mass • Remove the ESD cabling • Add the lower structure support tooling and take the weight of the lower structure (this may be on the articulated arm) • Remove the implementation ring • Lift the lower structure and disconnect the bottom wires from the UI mass • Lower the lower structure until it is free from the upper. • Remove the lower structure from the tank • Raise the reaction test mass with the mass jack • Lower the UI masses to 10mm below nominal • Lift the masses one by one and swap in the appropriate stops, do so in the following order: Test mass, reaction test mass, penultimate mass, Pen Re mass • Inspect all masses for damage • Inspect all stops for damage and replace as required • Check all OSEMs and ECDs at all stages for damage (theoretically impossible but good practice) • Rebuild lower structure as described above.
Replace a local control OSEM	• Open the tank • Find the appropriate OSEM and rack it back as far as possible (off the end of the screws). • Unplug the pig tail • Remove the faulty OSEM body • Put in the replacement OSEM body • Advance it forward • Plug in pig-tail • Align It is likely that it will be felt blasé that the chain has not been locked. We are not touching either suspended chain throughout this operation however and the risk of damage should be weighed against the risk of damage from locking down and

	unlocking the two chains.
Replace a global control OSEM (UI mass)	• Open the tank • Find the failed OSEM and photograph the position of the flags within all four OSEMs on the mass. • Lock down the reaction and test UI masses. (We may find the this should say "lock down both chains" as we work with the noise prototype) • Check you have not moved the mass by cross referencing the four photos just taken with what you now see. If there is a sufficient discrepancy release the UI masses and repeat. • Unplug the OSEM • Rack back the flag on the test chain UI mass • Remove the flag on the test chain UI mass • Unbolt the OSEM mount bracket from the UI mass. • Swap the new OSEM onto the mount bracket • Replace the OSEM and bracket to the UI mass. • Connect the OSEM and wind in the flag • Check the OSEM is still aligned as per the photograph • Release the chains (carefully checking from problems)
Replace a global control OSEM (Pen Re mass)	• Open the tank • Find the failed OSEM and photograph the position of the flags within all four OSEMs on the mass. • Lock down the Pen re and Pen masses. (We may find the this should say "lock down both chains" as we work with the noise prototype) • Check you have not moved the mass by cross referencing the four photos just taken with what you now see. If there is a sufficient discrepancy release the Pen masses and repeat. • Unplug the OSEM • Unbolt the OSEM can from the pen re mass • Slide out the OSEM can from the pen re mass • Dismantling the can as much as is required replace the OSEM taking care not to adjust the z,y adjuster. • Slide the OSEM can back into the pen re mass looking through the back of the OSEM and checking the magnet at all times. • Check the OSEM is still aligned as per the photograph • Release the chains (carefully checking from problems)
Wire replacement (any wire, generic	Since there are a lot of different wires in a suspension each with a subtly different replacement scenario it is very hard to write a generic procedure. What is written below is more a declaration of intent rather than a outline procedure, and in some cases will be a very long winded way of replacing a wire. It is intended to show that

procedure)	it is possible rather than to be a procedure to follow. • Open the tank • Lock all the masses and blade tips down in their present positions starting at the bottom and taking care not to make anything worse. • Remove the sleeve • Remove or retract all OSEMs and flags • Following the ribbon repair scenario remove the lower structure from the tank • Return all masses to their nominal positions in the safest way possible • Work back through the assembly procedure to get enough slack in the damaged wire to allow the installation of the replacement • Install the new wire • Rebuild the suspension as per the assembly procedure, take care that the new wire clamps have not affected the trim etc • Re-install the lower structure and final align optics and OSEMs.