KAGRA Leading-edge Research Infrastructure Program
Large-scale Cryogenic Gravitational Wave Telescope Project

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BS Installation Procedure (Test Hang Version)

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JGW-DCC

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of the KAGRA collaboration.

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Introduction

1.1 Purpose and Scope

Explains how to assemble the BS suspension

1.2 References

JGW-E1604817: BS Payload Assembly Procedure

1.3 Version history

1/25/2016: Pre-rev-v1 draft.

6/16/2016: -v1 for discussion at review

1.4 Dummy procedure step for cutting and pasting

1.5 Resources for editing

In lists of items, use [1], [2], etc for suspension parts, (1), (2) etc for screws, and {1}, {2} etc for other items.

2 Background Information

2.1 Location

The installation will be done on the Y-arm side of the BS tank. To minimize the angle the suspension needs to be rotated during installation, the side of the optic with the BS coating will face toward the MC area (-X). This is also the side with the flags and OSEMs (unlike the PRx which has the HR surface on the opposite side from the flags).

Figure 1: Cleanbooth First Floor

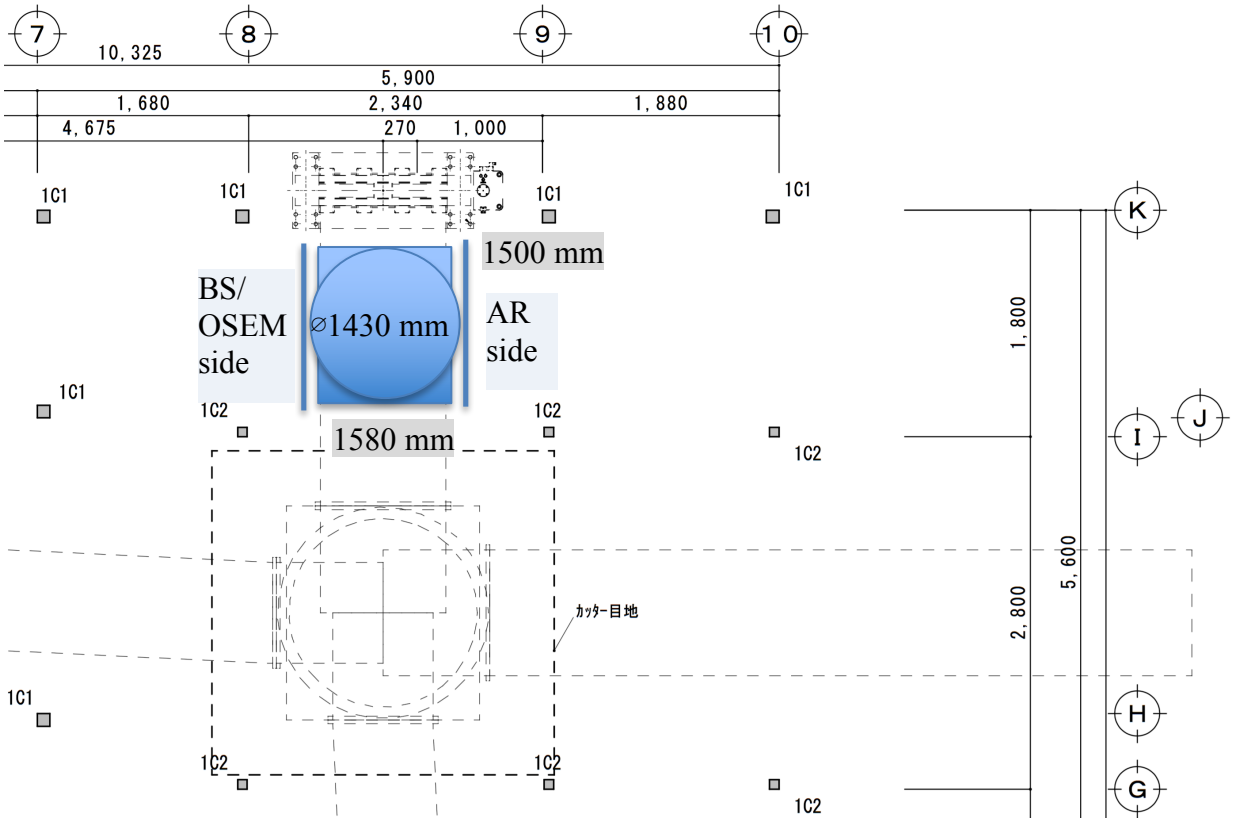


Figure 2: Cleanbooth Second Floor

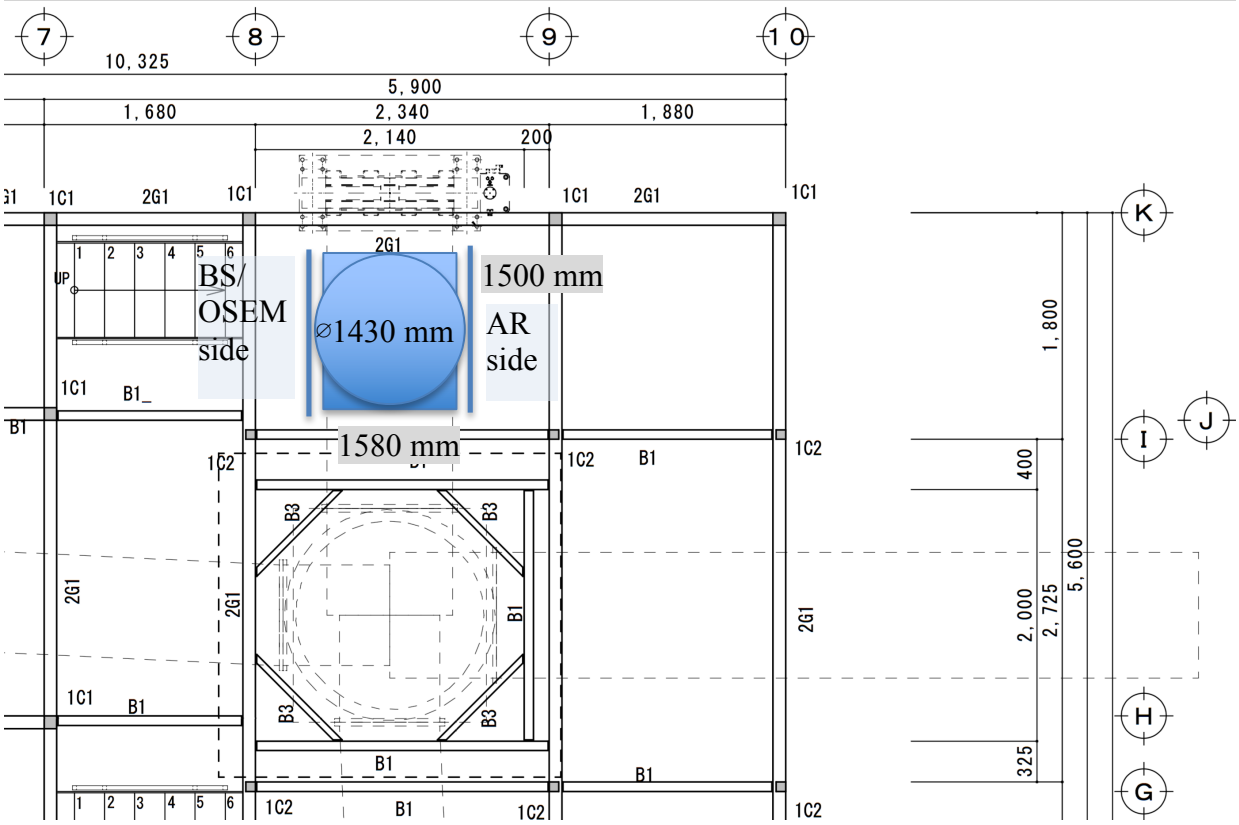
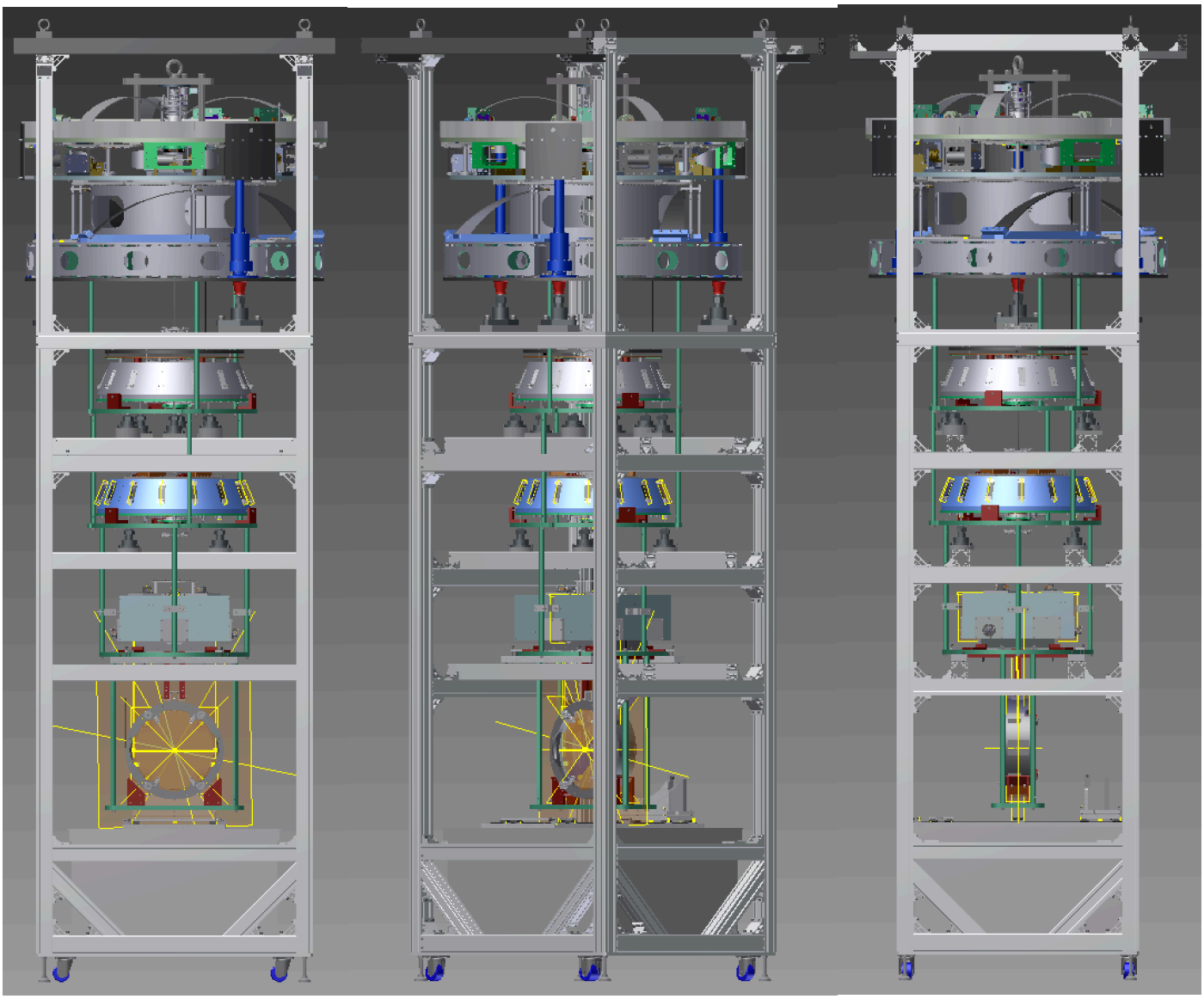


Figure 3: The suspension on the assembly frame as it will be constructed on the +Y side of the tank – views in the -X, -X/Y and -Y directions (towards the PR2, diagonal, towards the BS tank. (Top half will be rotated by 180° relative to these old pictures.)



3 Pre-Assembly

3.1 Optic

For the test hang, a dummy optic will be used. See JGW-D1604820.

Tatsumi-san will glue the flags and prisms on the optic or dummy optic. The flags go on the "front" of the optic, with the beamplitting coating. See JGW-E1504248.

3.2 Recoil Mass

See JGW-E1604817 by Fabian.

3.3 Intermediate Mass

See JGW-E1604817 by Fabian.

3.4 Bottom filter

[Hirata-san already did most of this. Add link to any procedure document.]

3.5 Standard filter

[Hirata-san already did most of this. Add link to any procedure document.]

3.6 Prepare space

Remove spool piece between Y-arm and BS chamber. Also remove spool pieces on ±X sides of chamber. Remove flooring above work area. If possible, remove only the section between pillars (8) and (9) in Figure 1 and Figure 2, and leave the section between (9) and (10). Wipe down all surfaces above or near work area, working from the top down. Clean floor, paying particular attention to small rocks and debris. Lay down SS sheet.	

3.7 Construct assembly frame and optical table - Mirapro

Construct the assembly frame according to Mirapro assembly VP6845, except put the supports for the SF cross bars 5 mm lower than indicated (502 mm below the PI level, not 497 mm).

Check that the crossbar supports at the various levels are the following distances below the underside of the PI level: 502 mm (SF), 1033 mm (BF), 1556 mm (IM). The

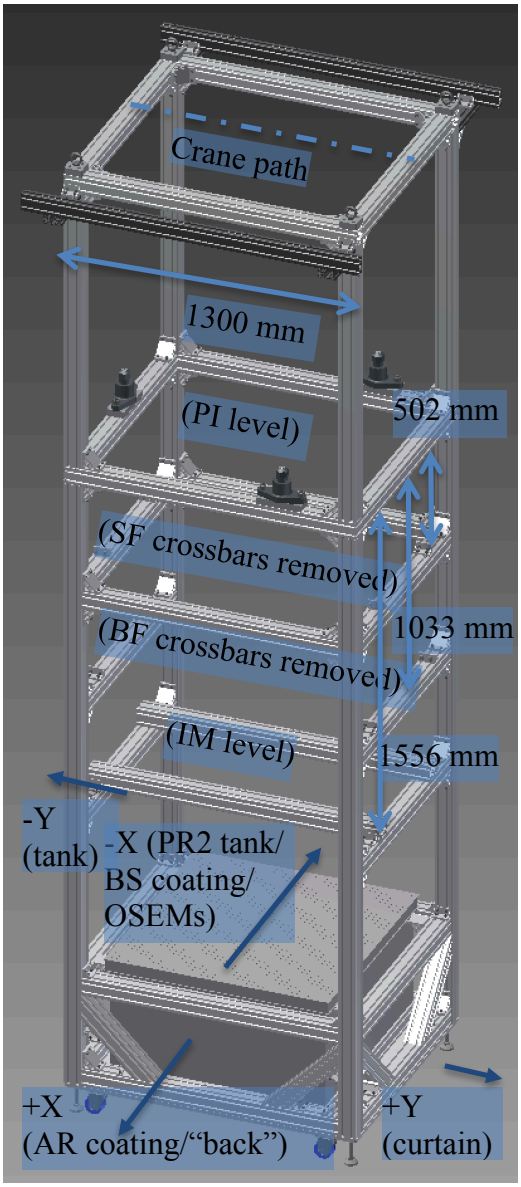
Move the frame into position on the +X side of the BS tank.

Position it directly under the line of the crane and midway between the (K) and (I) rows of pillars (see Figure 1), with the long axis aligned with Y and the side where the BS will be facing in the –X direction (towards the MC area).

There should be 1620 mm in the Y direction between the rows of pillars in the BS cleanbooth, and the frame is 1300 mm at the bottom (1500 mm at the cleanbag support bars), so there should be 160 mm clearance on the ±Y sides at the bottom (60 mm at the top).

Extend the feet of the frame until they support the weight and the uprights of the frame are as vertical as possible as measured by a bubble level.

Remove the internal crossbars at the BF and SF levels, wrap them in foil and store them in a clean place.



3.8 Install feedthroughs on assembly frame

[1]: 4 x **Kyocera ICF203+D-SUB 9 PIN X8 vacuum feedthrough**

(1) 8 x **M8 x 40**

(2) 20 x **M8 washer**

(3) 8 x **M8 T-Nut**

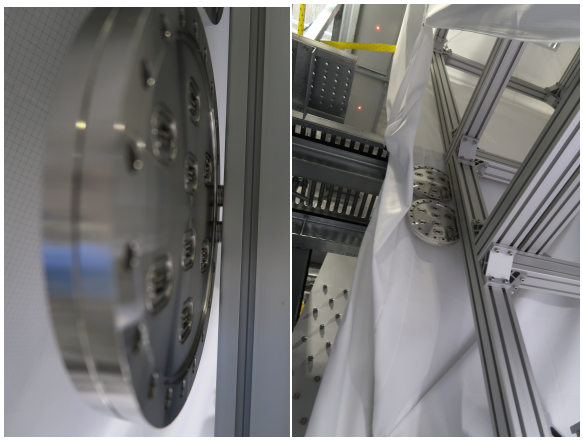
(4) 54 x **4-40 screw**

{1}: 27 x **anti-feedthrough adapters**

Attach four [1] feedthroughs, each with 8 D-Sub 9's, to the uprights of the assembly frame at convenient positions just below the second floor level. Secure each with 2 (1) screws, 5 (2) washers (between the flange and the upright) and 2 (3) T-Nuts (in the grooves of the upright).

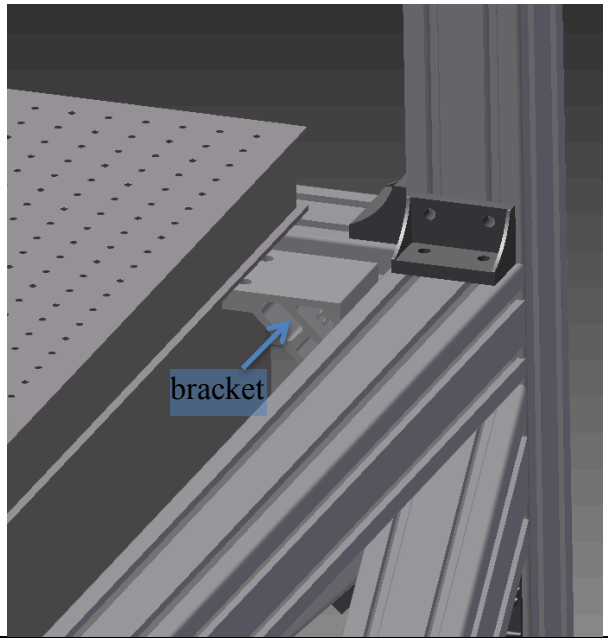
Use great caution to keep the vacuum-facing sides of the feedthroughs clean.

Put anti-feedthrough adapters on 27 of the outside connectors and secure each with 2 (4) jack screws.



3.9 Install optical table immobilization brackets

If it has not already been done, install the four brackets near the corners of the optical table using 2 M8 screws each to prevent it slipping off if there is an earthquake.



3.10 Adjust assembly frame crossbars for IM

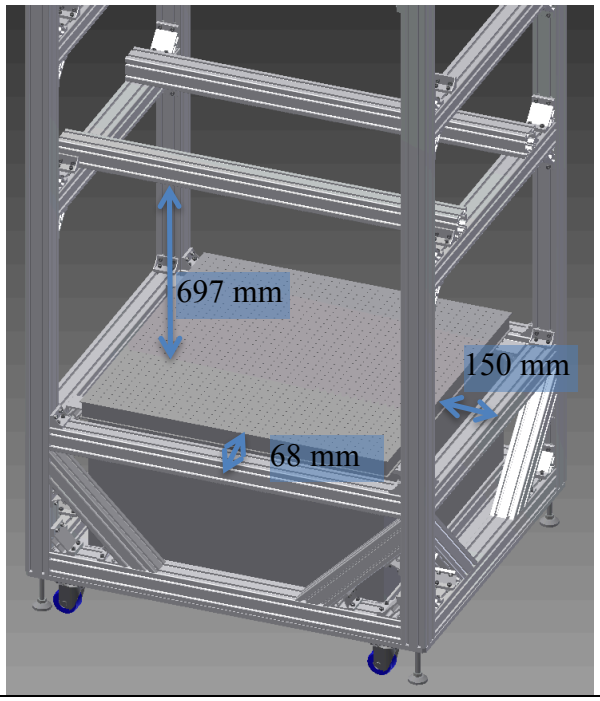
Set the legs of the optical table so that it is level as measured by a bubble level and there is 697 mm‡ to the underneath of the internal crossbars below the IM and level in both directions as measured by a bubble level. (This should mean that it is 500 mm tall.)

Center the optical table in the space. There should be 68 mm to the outside of the frame in the ±X direction and 150 mm to the outside of the frame in ±Y.

Double-check the levelness.

‡Version –v1 of this procedure had 694 mm but this didn't allow for raising the BS and RM by 3 mm during hanging.

Put the 4 base parts for the PI guides to lock the table in front/back direction



3.11 Install adapter bars, rails and trolleys

[1]: 2 x **adapter bars**

[2]: 4 x **dog clamps**

[1]: 8 x **M8 x ???**

(2): 8 x **M8 T-Nut**

(3): 4 x **locating pin**

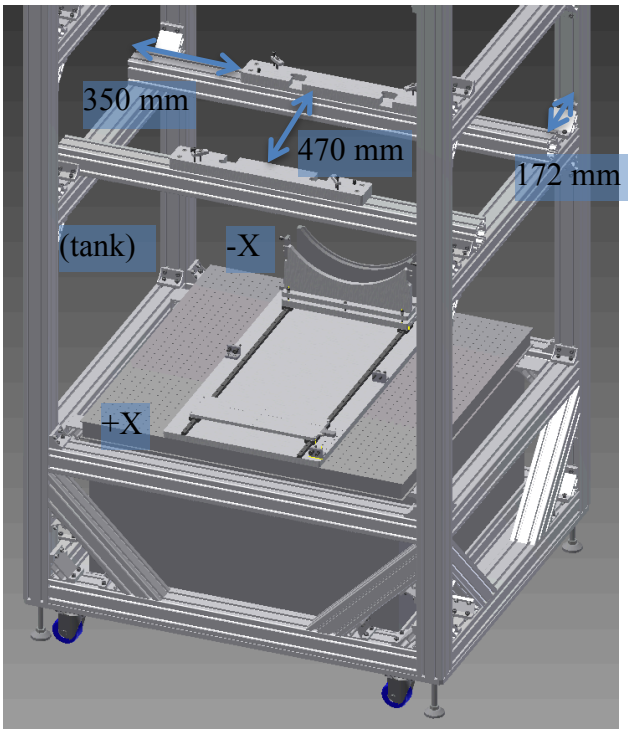
(4): 8 x **M6 x 35**

Set the internal crossbeams so that there is 172 mm from the outside of the crossbeam to the inside of the vertical pillar.

Install the two adapter bars on the internal crossbars using 8 (1) screws and 8 (2) T-nuts. Set them symmetrically so that there is 350 from the end of each bar to the outside of the frame. Check that the separation is 470 mm.

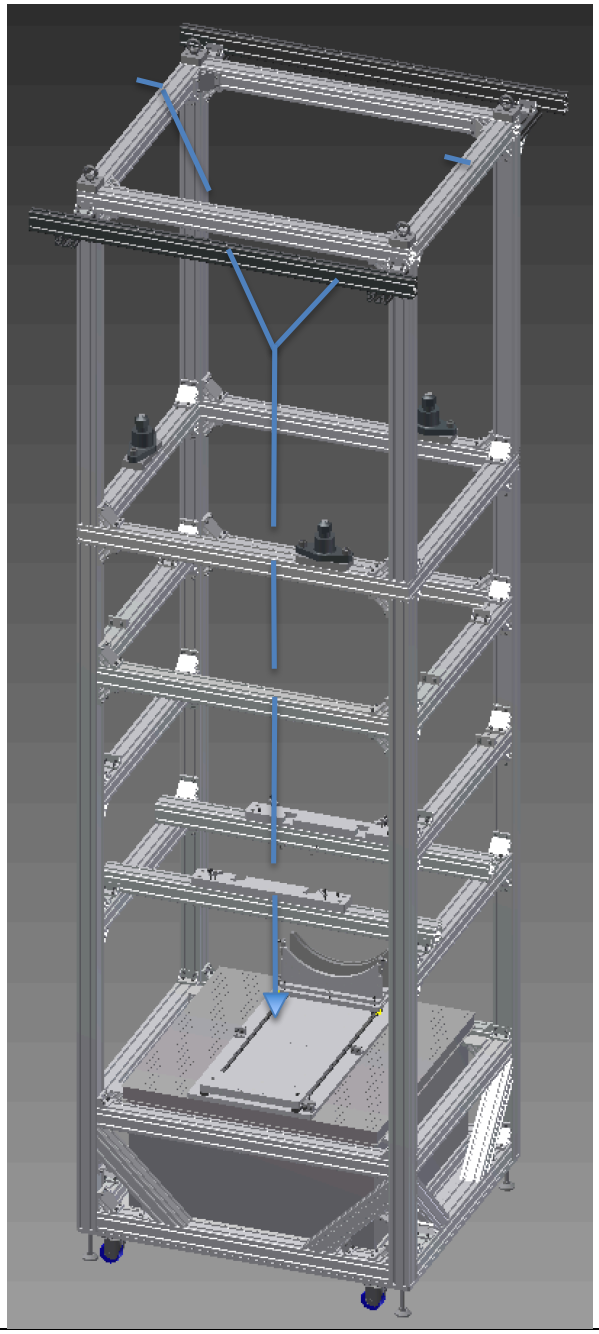
Insert the (4) locating pins in the adapter bars and loosely attach each [2] dog clamp with two (1) screws (one as pusher screw and one as puller screw).

Install the baseplate for the rails centrally on the optical table with 4 x ??? M6 screws. It



should be flush with the edge of the table at front and back and there should be 10 rows of visible holes on each side. Install the rails on the baseplate with ??? screws, leaving them very loose. Install the 4 stop brackets using 8 x ??? screws, leaving the screws loose. Install the stop screws in the brackets. Install the trolley baseplates on the carriages using TBD screws. The trolley for the RM goes at the –X end. Run the trolleys back and forth to ensure they run smoothly and the rails are parallel, then tighten the screws holding the rails. Install the stop bars on the sides of the trolleys. For each trolley and each stop bracket, move the trolley to the bracket, check that the puller screws enter the holes in the side bars properly, and tighten down the brackets.	

3.12 Double check vertical alignment

Suspend a plumb bob over the center of the table from the midpoints of the the two top crossbars as indicated, and check that it lines up with the scribe lines indicating the center of the rail system baseplate. If necessary, adjust the centering of the optical table and/or the verticality of the main frame. Repeat at 90°. (If preferred, this whole step can also be done earlier, before the baseplate is attached. In that case, note that there is an odd number of rows of holes, so the bob should be directly over a row.)	

4 Random stuff for filing

4.1 Set up electronics rack

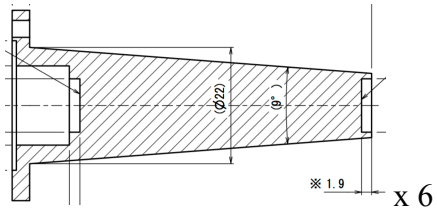
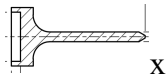
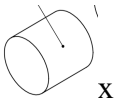
Set up the rack according to JGW-D1503600: BS Suspension Cabling, and JGW-E1605111: BS Suspension Electronic Items List. Measure the distances from the rack to the feedthrough positions on the vacuum tank. Also measure the distance to the feedthrough support rack.	

Determine the longest distance the cables will need to run and get 27 D-Sub 9 cables, JGW-D1402377: D-SUB cable specifications, of appropriate length from the AEL stock.	

4.2 Make anti-feedthrough adapters

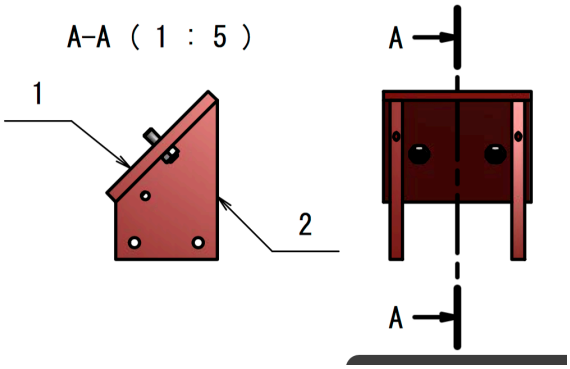
[1]: 27 x **Hirose (HRS) D-Sub 9 Male IDC Connector FDE-9P(05)** [2]: 27 x **Hirose (HRS) D-Sub 9 Female IDC Connector FDE-9S(05)** [3] 27 x **100-mm lengths of 9-conductor IDC ribbon cable** Crimp a [1] male at the top of each [3] cable, and a [2] female at the bottom, such that Pin 1 connects to Pin 5 and vice versa, per Sheets 1-8 of JGW-D1503600: BS Suspension Cabling. Fold the cable through 180° near each connector and apply a strain relief clip.	(a) After crimping. (b) After attaching strain relief clips. 

4.3 Make IM flag assemblies

Lay out 6 flag bases D1605088-1, 6 flag tips D1605088-3, 18 magnetic disks D1605088-2 and 12 magnets on UHV Al foil. Check the disks, the recesses in each end of the flag base, and the recess in the flag tip carefully for burrs or other irregularities. Check that the disks fit easily and squarely into the recesses. Remove the disks again. Make a small boat from UHV Al foil, and a glue applicator from clean Cu wire. Mix a sachet of EP30-2 adhesive, cut the sachet open and squeeze the tube into the boat. Use the Cu wire to apply ??? amount of glue to the. Press a disk into each recess on top of the glue and check that it is square. If necessary, wipe away any excess glue.	 x 6  x 6  x 18  x 12

Put away the flag bases, flag tips and the boat with the remaining glue in a clean place, and let the glue cure for 24 hours. Check that the glue in the boat has dried properly – it should be clear and brittle. Check the magnets for any dirt or magnetic particles, and wipe them firmly if necessary. Stick magnets to the disks at either end of the flag bases, with the N pole facing out at both ends. Stick the flag tips onto the magnets at the small ends of the bases.	

4.4 Assemble “security recoil mass” units

See JGW-D1605124. [1]: 2 x **JGW-D1605122-552 main plate** [2]: 4 x **JGW-D1605122-553 support main plate** (1): 8 x **??? [not called out in JGW-D1605124]** (2): 4 x **??? [not called out in JGW-D1605124]** For each [1] plate, connect 2 x [2] plate with 4 x (1). For each [1] plate, insert 2 x (2) stop screws from	

4.5 Pre-assemble optical bench blade units

Needed (for 3 units): [1]: 3 x **Part-52-base support blade** [2]: 3 x **Part-51-blade curve** [3]: 3 x **Part-53-clamp blade** [4]: 6 x **Part-56-column blade** [5]: 3 x **Part-57-retainer blade** [6]: 3 x **Part-54-orientation washer** [7]: 3 x **Part-55-orientation washer** [8]: 3 x **clamp_base_preisolator_3** [9]: 3 x **clamp_base_preisolator2** [10]: 54 x **clamp_on_TM_BS**	

(1): 6 x **ISO 4762 M8 x 45**

(2): 6 x **ISO 4762 M12 x 50**

(3): 6 x **ISO 4026 M12 x 50**

(4): 6 x **ISO 4026 M12 x 60**

(5): 9 x **ISO 4672 M10 x 30**

(6): 9 x **ISO 7093 A ST 10 – 140 HV – A**

(7): 9 x **UNI EN 24032 M12**

(8): 12 x **UNI EN 24032 M12**

(9): 30 x **ISO 4762 M6 x 16**

(10): 108 x **ISO 4672 M4 x 8**

For each assembly:

Insert 2 x (3) set screws into [1] base from below and screw in until flush.

Screw [4] column onto each (3) stud from above and tighten firmly with a hex wrench through the through-hole.

Screw a (4) set screw into the top end of each [4], until it won't go further or until only 44 mm is left sticking out, whichever is sooner.

Screw a (8) nut onto each (4) set screw until there is a gap of 11 mm between the top of [4] and the bottom of the (7).

Fix the [1] base to a clean work table by TBD method (e.g., C-clamp or the screws that are part of the assembly: 3 each of (5) screw, (6) washer and (7) nut (and if helpful, 2 of (1))).

By TBD method, hang TBD kg of mass [???: ≈(84+116)/3 = 67 kg] on the end of the [2] blade.

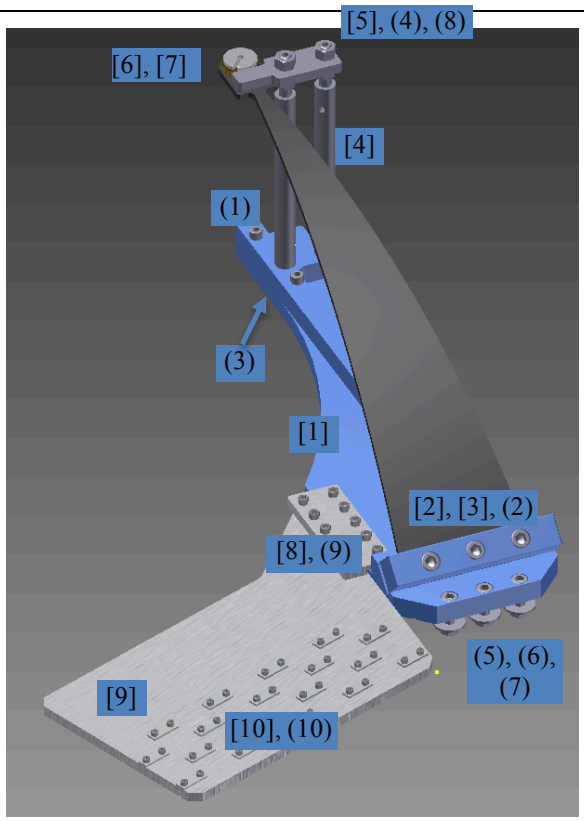
Place the [5] retainer over the two (4) set screws and secure with 2 more (8) nuts.

Remove the load mass and unfasten the [1] base from the work table.

Attach [8] joint to [9] clamp base with 5 of (9) screw.

Attach 18 of [10] to [9] clamp base with 36 of (10).

Wrap the two main sub-assemblies ([1]++ and [9]++) and the remaining parts and



fasteners ([6], [7], (5), (6), (7), remainder of (9)) and store for later.	

4.6 Check OSEMs with multimeter

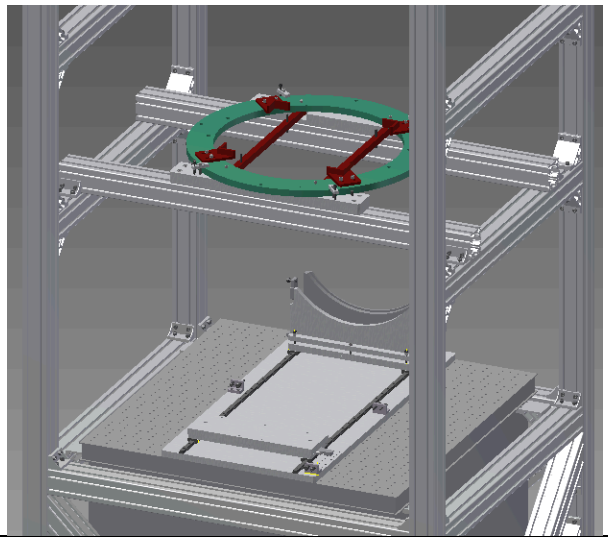
Check OSEM connections (per D1503600): LED – forward voltage 1.051 V At OSEM, red=anode=3, black=cathode=7 Elsewhere, red=anode=3, black=cathode=8 PD – forward voltage 0.47 V At OSEM, red=anode=9, black=cathode=5 Elsewhere, red=anode=6, black=cathode=1 Coil - ?? ohms At OSEM, 8 and 4 Elsewhere, 2 and 7	

4.7 Dummy procedure step for cutting and pasting

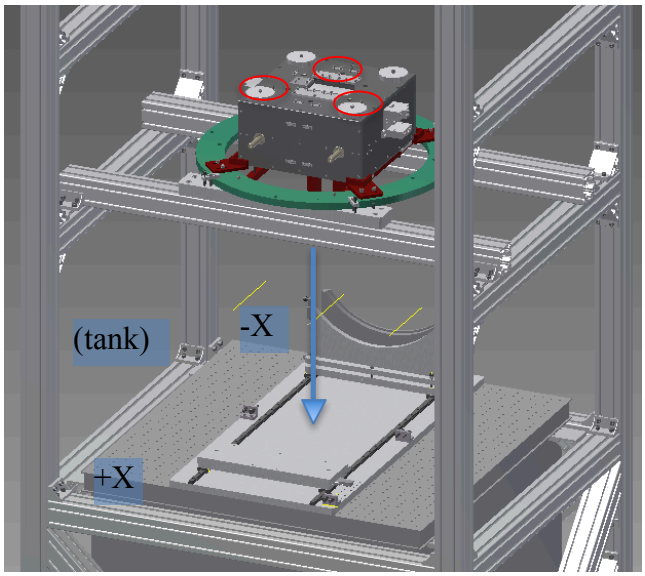
5 Install the IM

See Fabian's JGW-E1604817: BS Payload Assembly Procedure. The following section headings outline the main steps.

5.1 Install "green ring", "red bars" and brackets at below-IM level

5.2 Install, level and center IM

Adjust the 4 support screws in the red bars until the tips are 24 mm above the red bars or 4 mm above the green ring. Place the IM on the screws, facing so that the triangle formed by the top flag positions (circled in red in the picture) points in the –X direction. Attach a plumb-bob (下げふり) to the screw mount at the center of the bottom of the IM (originally intended for the damper). Adjust the horizontal position of the IM until the plumb-bob lines up with the scribe lines in the center of the rail system base plate. Check the levelness of the IM using a bubble level placed on top and adjust using the screws below. Move the mirror box trolley to the center, and double check that the plumb-bob lines up with the "X" on the trolley in the ±Y direction. Adjust the "pusher" stop screw so that when the trolley contacts the screw, the plumb-bob is also in line with the "X" in the ±X direction. Repeat the previous step with the RM trolley.	

5.3 Install winches

5.4 Mount mirror box with BS on trolley

[???: This section recycles text for the PRx, and may need editing for the BS.] Remove the screws holding the lid of the mirror box. Remove the lid. Remove the outer cylinder. Add hex bars to the corner of the base plate. Add the leg plate with TBD 2 screws. Add the foot with TBD 5 screws.	

Check the guide rods are tight. Move the trolley to the end of track on the =X side of the assembly frame and engage the side screw to immobilize. Working with an assistant (one person on each side) stand the mirror box up on the trolley Lift optic onto trolley, holding base and foot (two people). Secure the mirror box with TBD 3 screws. Release the side screw and move the trolley to the center. Engage the side screw to immobilize the trolley.	

5.5 Suspend BS

5.6 Setup optical lever

Note that the yellow optical fibre is permanently connected to light source. Leave the light source disconnected from AC to begin with. Fix the light source to the breadboard with dog clamps. Fix mirror mount 1 m from mirror, slightly off center horizontally. Pass the tail of the blue optical fibre into the mirror mount from the front, and carefully pull all fibre through. Mount the head of blue optical fibre in the mirror mount. Mount the optical fibre junction connector on the breadboard. One at a time, clean the ends of the optical fibre with the cleaner device and plug into the connector. Note that there is a bayonet fitting on each side to ensure correct alignment of the optical fibres in roll. Plug the light source into AC power. Aim the beam at the optic.	

Using a T-square or the like, measure the height of the middle of the diode aperture above the breadboard. Use the laser level to level the outgoing beam. Using the T-square, measure the height of the return beam.	

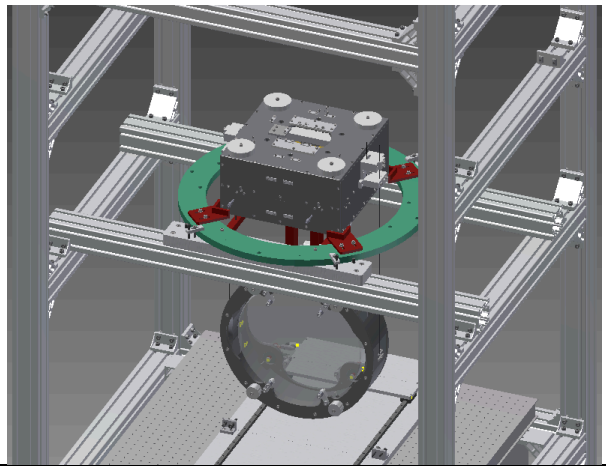
5.7 Align BS

5.8 Bring in RM back section on trolley

5.9 Attach front ring

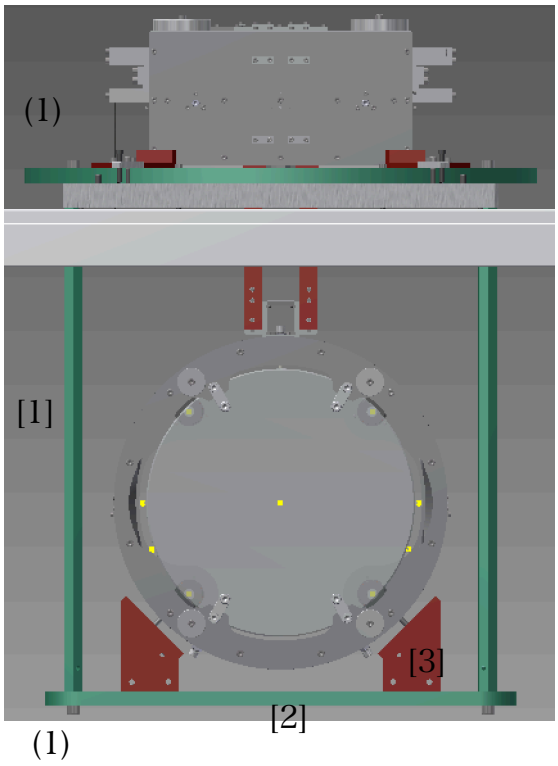
5.10 Route OSEM cables from RM up to IM

5.11 Suspend RM

5.12 Check BS alignment

5.13 Install Security Structure Lower Section

See JGW-D1605124. [1]: 4 x JGW-D1605122-550 hex rods [2]: 1 x JGW-D1605122-551 plate [3]: 2 x security recoilmass assembly (see 4.4) (1): 8 x ISO 4762 - M12 x 35 SDC (2): 8 x ISO 4762 - M5 x25 Insert 4 x (1) from the top through the holes in the ring under the IM. Screw 4 x [1] rods on to the (2) screws. Carefully bring in the [2] plate under the bottom of the rods, being careful not to bump the RM. (It may be convenient to put it on one of the trolleys and roll it in.) Lift the [2] plate and secure with another 4 x (1) screws. Slide in the 2 x [3] assemblies, being careful not to bump the RM, and secure with 8 x (2) screws inserted from underneath.	

5.14 Connect and test IM picomotors

Connect the IM picos to the feedthrough via cables: IM Pico Adapter Cable D1503901-03 BF to PI Motor Cable D1503901-14 TR to Flange Motor Cable D1503901-20 Continue to the rack via cables: Anti-Feedthrough D1503600-01 Generic D-Sub 9 Tank to Rack D1402377 Double Pico Splitter Cable D1503600-03 Newport Pico Driver 8742 (and joystick)	

6 Hang IM/RM/TM group

6.1 Tighten RM-to-BS stop screws

[???: Decide best order]	

6.2 Install the IM-RM Safety bar

See D1605127.

Required:

[1]: **2 x D1503444-16 Clamp safety joint**

(9): **4 x ISO 4762 - M5 x 16**. [???: Need to add these to the drawing]

[2]: **2 x D1503444-17 Safety joint mirror**

(5): **4 x ISO 4762 - M5 x 10**.

[3]: **2 x D1503444-26 Frontal lock aid**

(6): **6 x ISO 4762 – M6 x 25** [???: Need to add 2 extra of these to the drawing.]

(7): **2 x ISO 4762 - M6 x 35**

(8): **4 x ISO 7092 - ST 6 - 140 HV** [???: Need to add 2 extra of these to the drawing.]

[4]: **2 x D1503444-27 Spacer frontal lock**

Check the RM-to-BS stop screws are entered so as to immobilized the BS, per the previous step.

On each side of the bottom of the IM attach [1] with 2x(9). [???: Need to decide whether these can remain on IM permanently.]

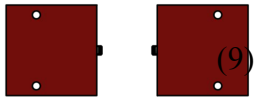
To each [1], attach a [2] using 2x(5).

In the outside channel of each [2], place a [3], aligned so the slot in [3] lines up with the hole at the back of the channel, and the side of [3] is flush with the side of the channel on the non-AR side of the RM - see figure (c). (The slot in [3] is placed asymmetrically, so you might have to rotate the part to get it on the right side.) Attach each [3] with 2x(6) screws inserted from the non-OSEM side but do not tighten yet.

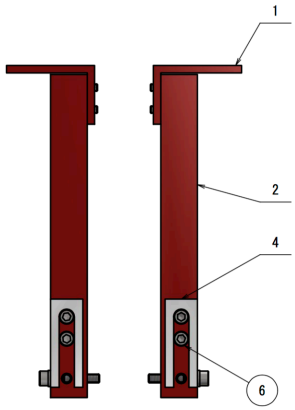
Very gently, from each of the ±Y sides, insert a (7) screw and (8) washer through [3] and [2] into the cube, but do not tighten yet.

Very gently, on each of the ±Y sides, lower a [4] over the screws (6) into the gap between the [2] and the “wings” on the cube.

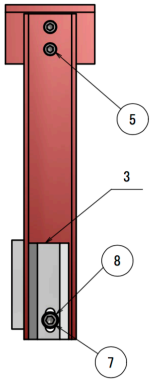
(a):

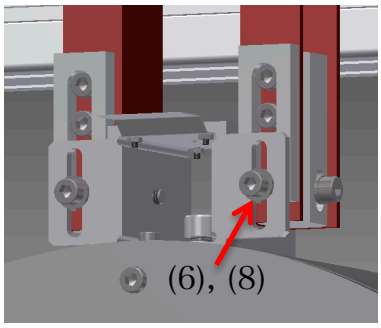


(b):



(c):

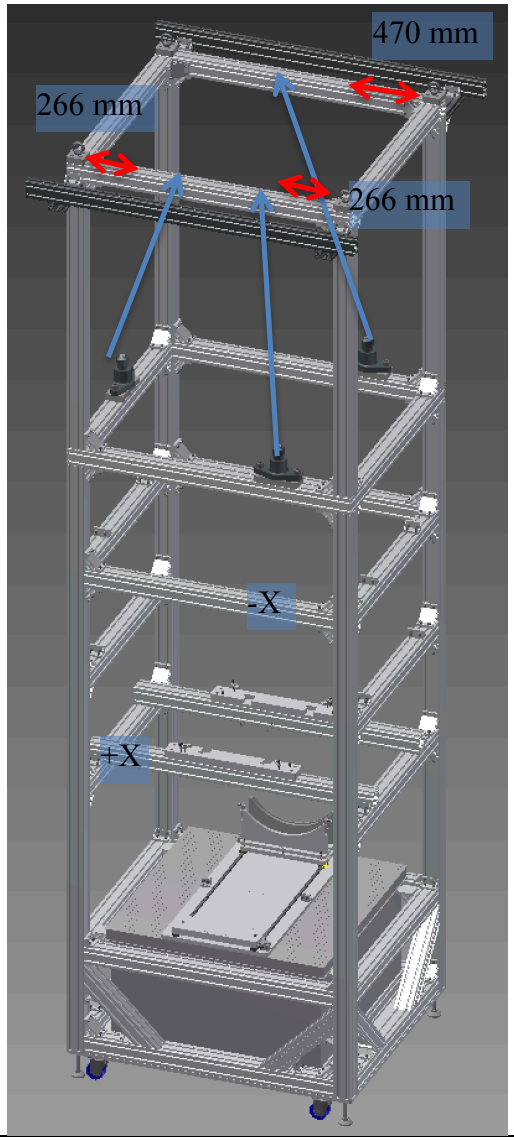




Very gently, on each of the ±Y sides, insert a (6) screw and an (8) washer from the non-OSEM side through the side wall of the [2] into the [3]. Gently tighten all screws until the RM is immobilized.	

6.3 Dummy procedure step for cutting and pasting

6.4 Install load gauge adapter and jacks

If the 3 NB-03 jacks are installed at the level under the PI, move them to the top level of the assembly frame at TBD positions. [???: check positions when design is finalized.] Crane the load gauge adapter onto the jacks.	

6.5 Weigh IM/RM/BS

Install the **IM-RM Safety bar, D1605127**, per 6.2. Retract the four **Part-15009-locking recoil mass**. Connect the load gauge adapter to the IM with TBD load gauge, TBD length adjuster, TBD maraging rod adapter, and maraging rod **Part-15006-wire intermediate-bottom filter**, and adjust the length until there is a small amount of tension. Have three assistants with 46 mm wrenches, slowly raise the load gauge adapter until the IM/RM/BS is suspended. Check the IM/RM/BS is level using a bubble level on top and diagnose/correct any large error. (The safety bar being present will reduce the effect of any mass imbalance.) Lower the load gauge adapter again until the IM/RM/BS touches down on the support screws.	

6.6 Trim payload assembly

Subtract the mass of the **IM-RM Safety bar, D1605127**, from the measured mass and compare to the rated load of the BF. Add/remove mass as appropriate.	

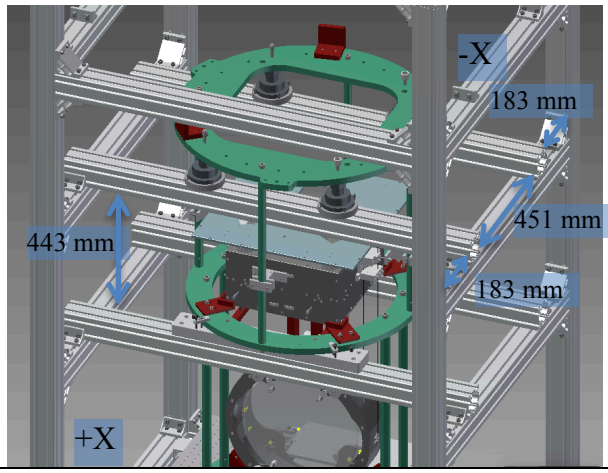
6.7 Remove load gauge adapter

Unhook the load gauge and chain block, and crane away the load gauge adapter. Leave the jacks in place for the next few steps.	

6.8 Dummy procedure step for cutting and pasting

6.9 Install assembly frame crossbars for under BF

Install the crossbars for under the BF. Set the height so that from the top side of the IM crossbars to the underside of the BF crossbars is 443 mm.



6.10 Install EQ structure parts up to ring under BF

See JGW-D1605124.

[1]: 4 x **D1605122-554 Rod suspension intermediate plate**

[2]: 1 x **D1605122-357 Safety disk bottom filter**

[3]: 3 x **D1605122-354 Stop for filter**

(1): 8 x **ISO 4762 - M12 x 35 SDC**

(2): 6 x **ISO 4762 - M6 x 35 Hexagon Socket Head Cap Screw**

(3): 3 x **ISO 4032 - M6 Hex Nut**

(4): 3 x **SSHH-SUS-M6-40 (Misumi)**

Identify the four holes for the [1] rods in the ring under the IM, which are at 12, 3, 6 and 9 o'clock as viewed looking in the –X direction.

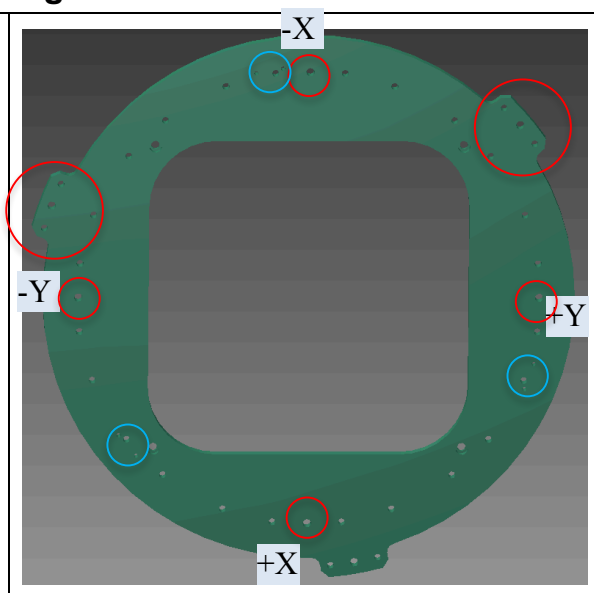
For each [1] rod, insert a (1) screw through the hole from underneath and into the end of the rod. Tighten gently for now.

Pick the ring up with the crane so that, viewed looking towards –X, the round-cornered rectangular hole is square in X and Y, and there are tabs at 5:30, 9:30 and 1:30.

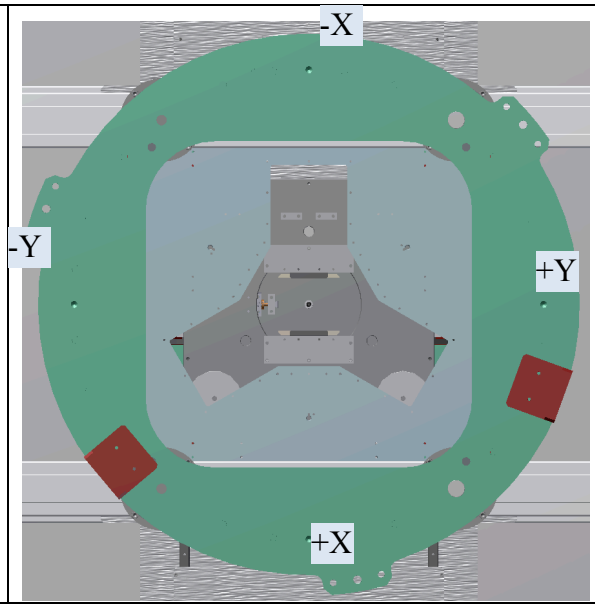
Crane the ring onto the top of the rods and secure with 4 more (2) screws. Tighten all 8 screws firmly.

Install 3 [3] stops, securing each with 2 x [2] screws from underneath through the ring.

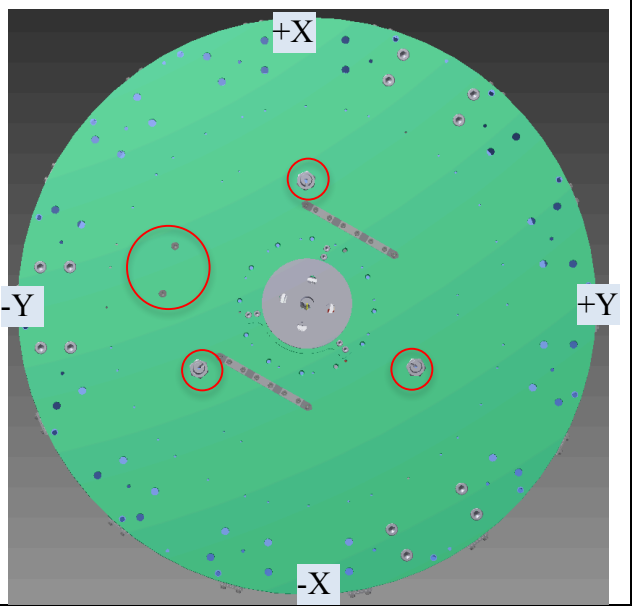
In each of the stops, install a (4) stop screw with a (3) lock nut on the outside.

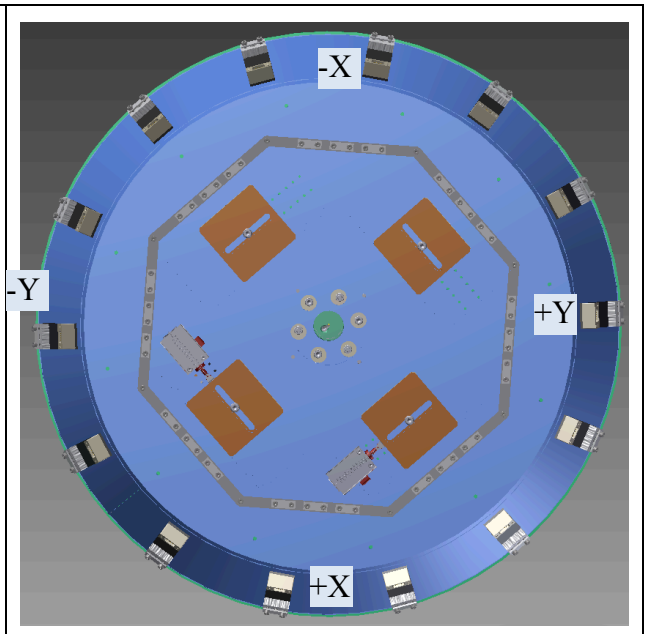


6.11 Install pushers and jacks at ring under BF

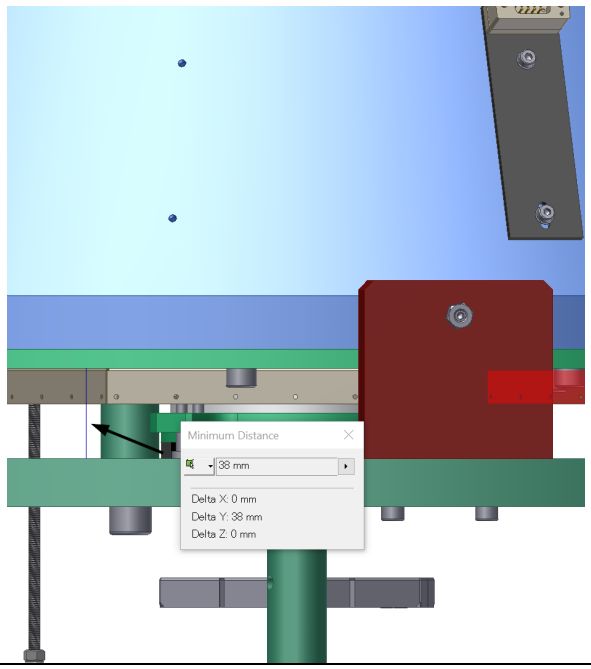
Put the pointy pushers on the –Y side and the cup pushers on the +Y side.	

6.12 Crane in BF

Pick up the BF with the maraging rod adapter attached to the crane with a sling and raise it just above head height. Stand on the +X side of it and rotate it so that the triangle of IRM support rod holders is pointing toward you and the screws for the fishing rod are at 10 o'clock. Crane the BF into the assembly frame in the same orientation. When the BF is about to touch down, guide the two screws above the cup-head pushrods into the cups.	Note: the real BF has many additional trim masses on the inside relative to the CAD, so most of the screw holes in the picture are occupied. 

6.13 Set height and level of BF

Adjust the jacks until the BF is level according to a bubble level, and there is a 38 mm gap from the top of the ring to the underside of the BF.	

6.14 Remove BF cap with crane

Remove 16 x ISO 4762 M8 x 25 screws from the bottom of the BF around the outside edge, and crane away the cap.	

6.15 Wire up BF yaw pico

[1] 1 x third conductor pair for **IM pico adapter JGW-E1503901-03** [2] vacuum-compatible heatshrink [3] UHV-clean Kapton-coated copper wire Plug the pins at the D-Sub end of the [1] extra conductor pair into positions 3 and 7 of the shell for the IM pico adapter cable IM pico adapter JGW-E1503901-03. Insert the pico end (the one with sockets) of the extra conductor pair through a hole in the base of the BF. Pull it through until there is just enough length on the outside to allow the D-Sub-9 connector on the outside to sit where the top of the BF cap will be (when it is added). On the inside, secure the conductor pair to one of the uprights of the keystone safety cage using a twist-tie made from a short length of [3] Cu wire. Use more twist-ties of Cu wire to secure the extra conductor to the BF base plate and to the other pairs of the adapter cable coming up from the IM. Put a TBD length of [2] heatshrink over each of the pico motor wires and slide them towards the pico until the pin on the end of the wire is exposed. Using an ohmmeter or otherwise, identify the conductor whose far end is position 3 at the D-Sub shell. Call this Conductor 3. The other is Conductor 7. Plug the pins on the end of the pico wires into the sockets on the extra conductor pair as follows: • Pico red wire = Conductor 3. • Pico white wire = Conductor 8. Slide the pieces of heatshrink over the pin-socket junctions to prevent shorting.	

6.16 Wire up BF fishing rod stepper

[1] 1 x **BF&SF Stepper adapter JGW-E1503901-05** [2] vacuum-compatible heatshrink	

[3] UHV-clean Kapton-coated copper wire Insert the stepper end (the one with sockets) of the [1] adapter cable through a hole in the base of the BF. Pull it through until there is just enough length on the outside to allow the D-Sub-9 connector on the outside to sit where the top of the BF cap will be (when it is added). Use twist-ties of Cu wire to secure the extra conductor to the BF base. Put a TBD length of [2] heatshrink over each of the stepper motor wires and slide them towards the stepper until the socket on the end of the wire is exposed. Using an ohmmeter or otherwise, identify the conductors whose far ends are position 1, 6, 2 and 7 at the D-Sub shell. Call these Conductor 1 through Conductor 7. Look for the small colored rings on the end of the four thick stepper motor wires. Ignore the two thin cables, which are for the limit switch. Plug the pins on the end of the cable into the sockets on the stepper motor wires as follows: • A1 = Green = Conductor 1 • A2 = Grey = Conductor 6 • B1 = Black = Conductor 2 • B2 = White = Conductor 7 Slide the pieces of heatshrink over the pin-socket junctions to prevent shorting.		

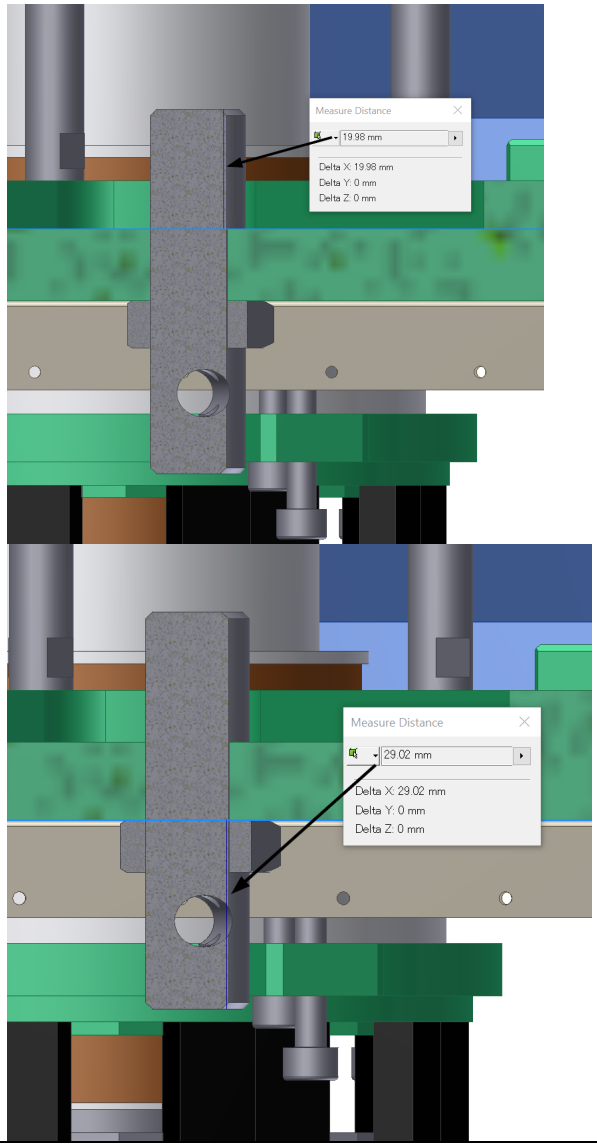
6.17 Wire up BF GAS LVDT

[1] 1 x **BF&SF LVDT adapter JGW-E1503901-06** [2] vacuum-compatible heatshrink Start at the pin end of the [1] adapter apart and pull apart the three conductor pairs for about 50 cm. Identify three adjacent small holes around the outside of the BF baseplate. Through each of the three holes, *carefully* insert the end of one of the pairs. It may help to wrap the pins and the ends of the wires in a small piece Al foil to give it some mechanical reinforcement. After the pins are through the hole, carefully peel off the foil. Pull all of the pairs through until there is just enough length on the outside to allow the D-Sub-9 connector		

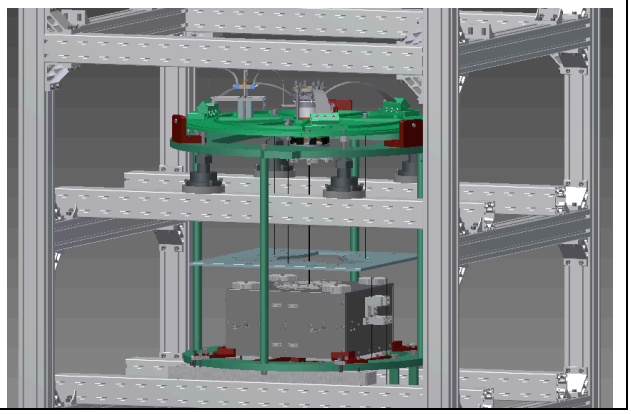
on the outside to sit where the top of the BF cap will be (when it is added). Put a TBD length of [2] heatshrink over each of the six LVDT wires and slide them towards the stepper until the socket on the end of the wire is exposed. Using an ohmmeter or otherwise, identify the conductors whose far ends are position 1, 6, 2, 7, 3 and 8 at the D-Sub shell. Call these Conductor 1 through Conductor 8. Using an ohmmeter, identify the three different coils and plug them in as follows: Single coil = "In" = ≈187 Ω = 1/6 Double Coil = "Out" = ≈78 Ω = 2/7 Force Coil = "Act" = ≈110 Ω = 3/8 (The polarity is not important because it's hard to set consistently in hardware but can easily be compensated for in software.) Slide the pieces of heatshrink over the pin-socket junctions to prevent shorting		

6.18 Route IM cables through IRM top plate up to BF

6.19 Adjust IRM rod holders

Adjust the IRM rod holders until there is 20 mm protruding at the top or 29 mm at the bottom.	

6.20 Suspend IM top plate with rods from BF

Bring in the top plate of the IRM and attach it to the rods. Adjust the upper rod holders slightly until the IRM top plate is level.	

6.21 Hook IM to BF

Put the hexagon cable clamp around the IM-BF maraging rod, but leave it loose. Insert the rod into the space above the IRM and hook it into the BF. Fix the cable clamp about halfway up the rod. (This will need some foil as a spacer to correct for a discrepancy between the collet and rod diameters.)	

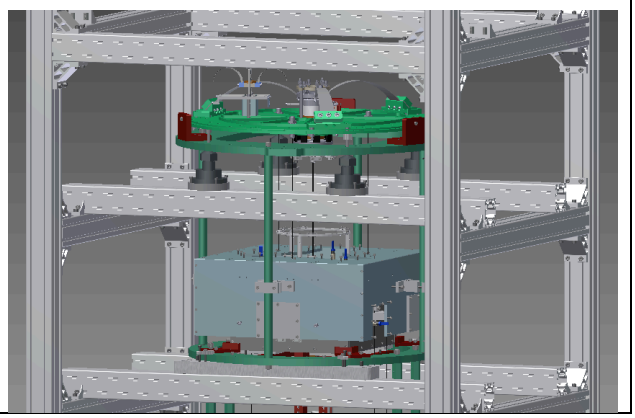
6.22 Remove security bar between IM and RM

6.23 Raise BF with jacks, test payload weight match

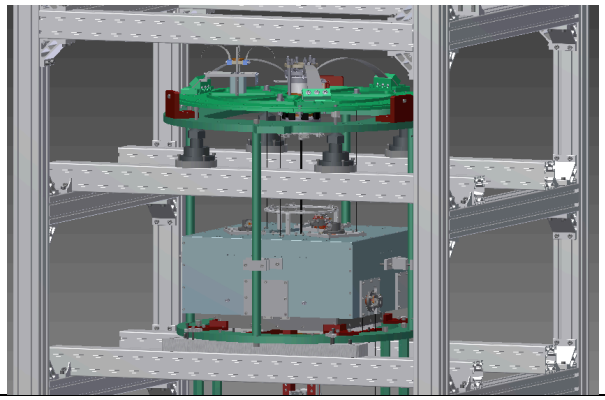
6.24 Level payload

7 Suspend IRM

7.1 Build IRM around IM

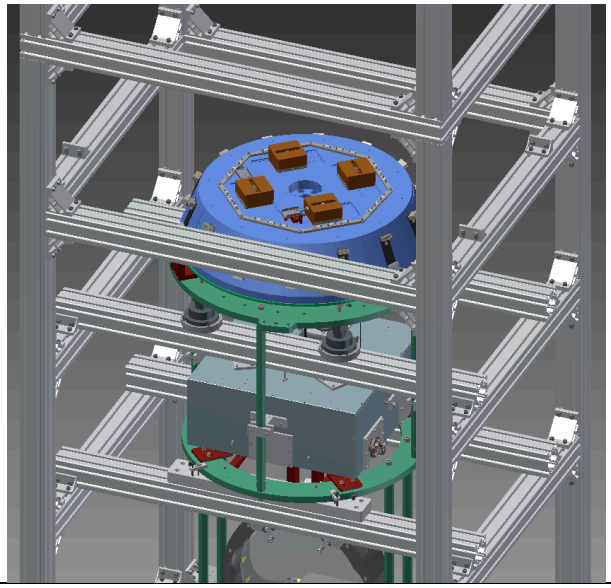
	

7.2 Attach OSEMs

7.3 Route OSEM cabling up to BF

7.4 Crane in BF cap

7.5 Connect payload cables to BF cap

8 Suspend BF + payload

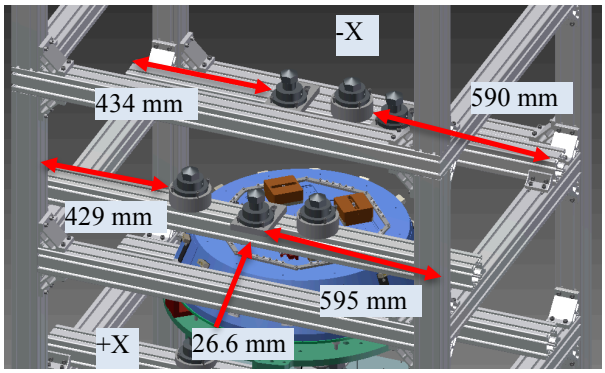
8.1 Install load gauge adapter

8.2 Weigh/trim/balance BF+payload

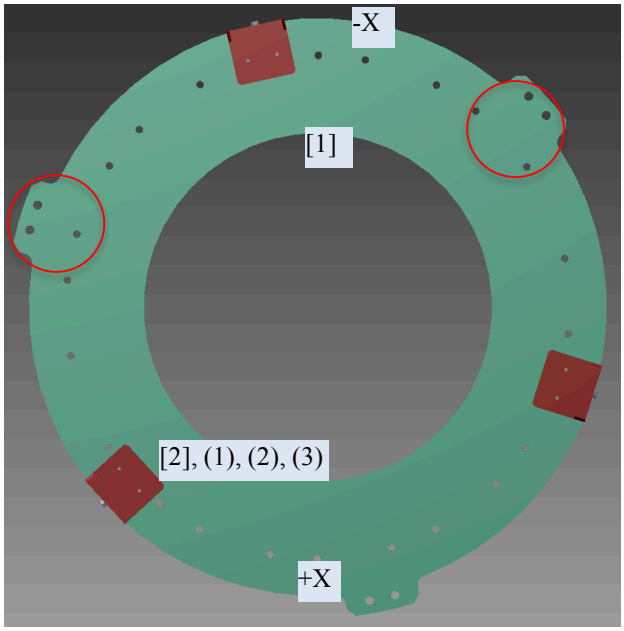
8.3 Remove load gauge adapter

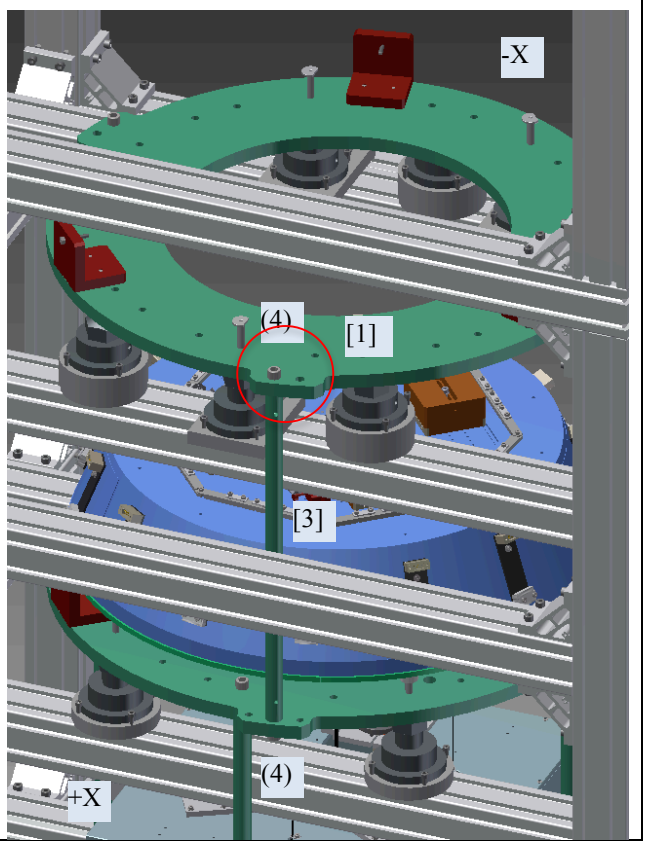
Unhook the load gauge and chain block, and crane away the load gauge adapter.	

8.4 Install crossbars for under SF

Install the crossbars for under the SF, running in the Y direction. There should be a gap of 120 mm from between the crossbar and the inside of the corner upright. Do not tighten the screws holding the brackets yet. Install the six jacks as shown, with a triangle of jacks on round bases and one of jacks on square bases. Note that the round bases have a diameter of 120 mm and the rectangular bases are 110 mm wide. Do not tighten the screws holding the bases to the crossbeams yet. [???: Double check that the jack positions are right, especially the ones on the outside – they seem to have changed in the Inventor.]	

8.5 Install EQ stop parts up to ring under SF

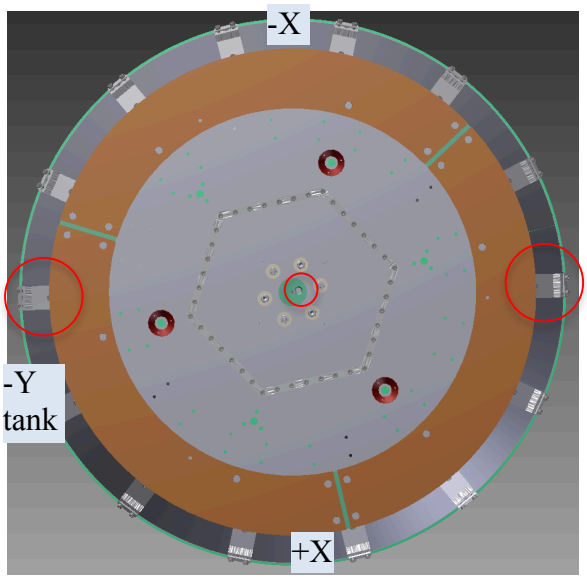
[1]: 1 x **JGW-D1605122-355 Safety disk filter with damper** [2]: 3 x **JGW-D1605122-354 Stop for filter** [3]: 3 x **JGW-D1605122-356 Rod suspension disk** (1): 6 x **ISO 4762 - M5 x25** (2): 3 x **ISO 4032 - M6 nut** (3): 3 x **SSHH-ST-M6-40** (4): 3 x **ISO 4762 - M6 x35** (5): 6 x **ISO 4762 - M12 x 35 SDC** Pick the [1] disk up with the crane and orient it so that, as viewed looking towards –X, the tab that is opposite a single hole is at 9:30, and the tab that is not opposite a hole is at 1:30 (see figure). Place 3 x [2] stops on the [1] ring with the upright parts to the outside. Secure with 6 x (1) screws inserted from below. Put a (2) locknut on each of 3 x (3) lock screws and insert the screws into the [2] stops from the outside.	

Through each of the central holes in the tabs around the edge of the ring under the BF, insert a (4) screw from underneath and attach a [3] rod. Crane the [1] ring on top of the [3] rods, positioning it so that each of the rods is underneath the leftmost hole in one of the tabs around the end. Secure the ring to the rods with 3 x (1) screws inserted from above.	

8.6 Install jacks and pushers at ring under SF

	[???: Need picture with Hirata-san's modified design.]

8.7 Crane in SF

[???: Crane away load gauge adapter] Pick up the SF with the crane. Orient the SF until, viewed looking from above in the –X direction, the keyhole for the maraging rod at the top is just above the 3 o'clock position and there are cable mounts at the 9 o'clock and 3 o'clock positions. [???: Is there a better way of specifying this? Unlike with the BS, the jacks do not precisely locate the SF.] Lower the SF onto the jacks and adjust to be central. There should be 25 mm from the outside of the SF bottom plate (radius 365 mm) to the outside of the main part of the ring (radius 390 mm), or 10 mm to the inside of the restraint brackets.	

8.8 Remove SF cap with crane

Remove 16 x **ISO 4762 M8 x 25** on the bottom of the SF around the outside edge, and crane away the cap.	

8.9 Wire up SF stepper, LVDT

[1]: parts for **BF&SF Stepper Adapter, D1503901/05** [2]: parts for **BF&SF LVDT Adapter, D1503901/06** [3]: **SF-PI Motor Cable D1503901/15** [4]: **SF-PI Signal Cable D1503901/08** [5]: **TR-Flange Motor Cable D1503901/20** [6]: **TR-Flange Signal Cable D1503901/19** [7]: **feedthrough** [8]: 2 x **feedthrough adapter** [9]: 2 x **Generic D-Sub 9 Cable M-F** Cut 5 cm [???: or TBD] lengths of UHV heat-shrink tubing, and place over all the pins of both the LVDT and stepper motor. For each of the [1] and [2] adapters, take a long section of the appropriate cable, and feed the free end into the SF [???: where?]. Crimp the appropriate pins on the end the cable. Plug the pins into the ones from the LVDT or stepper, and adjust the heat-shrink to cover the connection. [???: Shrink the heat-shrink?] Route the cable to the edge of the SF and cut the cable at a suitable point about 10 cm [???: or TBD] beyond. Attach a D-Sub 9 connector to the cut end. Secure the cable to the **hexagon_bottom_plate_SF_assembly** on the bottom of the SF. Connect up the rest of the cables to the rack per D1503600, and test.	

8.10 Replace SF cap with crane

8.11 Route cables from BF up to SF

8.12 Hook BF+payload to SF and raise SF to suspend BF+payload

[1]:	

8.13 Install load gauge adapter

[1]: **small hexagon assembly** {1}: **short test rod for SF filter (from ATF)** Check that the jacks are in position on the top level of the assembly frame, and if necessary position per 6.4. Crane the load gauge adapter onto the blocks. Hang chain block, load gauge, maraging rod adapter and {1} test rod from the load gauge adapter.	

8.14 Weigh/trim/balance SF+BF+payload

Install the **IM-RM Safety bar, D1605127**, per 6.2. Retract the 4 x **Part-15009-locking recoil mass** around the IM, and the 6 x **Part-10024-clamp filter** around the BF and SF. Hook the test rod into the SF, and then adjust the length of the chain until there is some tension. Using 46 mm wrenches, adjust the jacks to raise the SF+BF+payload until it is suspended. Note the load gauge reading. Adjust the jacks to lower the SF+BF+payload until the SF is sitting on the jacks as before. Subtract the mass of the **IM-RM Safety bar** from the load gauge reading and compare to the rated load of the PI top filter. If necessary, add/subtract trim mass to/from the SF.	

8.15 Remove load gauge adapter

Unhook the load gauge and chain block, and crane away the load gauge adapter.	

8.16 Place damper ring

NOTE: The following was the original plan when we were going to use the full Cu damper. With only two segments in use, the Cu ring is probably too fragile to risk stacking the magnet ring on top of it temporarily. Instead, the magnet ring will be connected to the PI just after the PI has been picked up with the crane to bring it in.

Required:

[1]: 1 x **Part-76-damping plate with magnets**

[2]: 3 x **Part-77-fasten wire damper**

[3]: TBD x **magnet**

(1): 6 x **ISO 4672 M5 x 20**

(2): 3 x **ISO 4672 M6 x 40**

{1} 1 x **magnet template**

{2} 3 x **spacers ≈20 mm thick**

Attach 3 x [2] holders to the top of the [1] ring with 6 x (1) screws. Also insert 3 x (2) screws from above.

Place the [1] ring upside down on a clean non-magnetic surface, with the {1} template on top.

Attach TBD number of [3] magnets to the [1] ring through the holes in the template, placing them in a symmetrical pattern with alternating polarities. Leave gaps for the spacers.

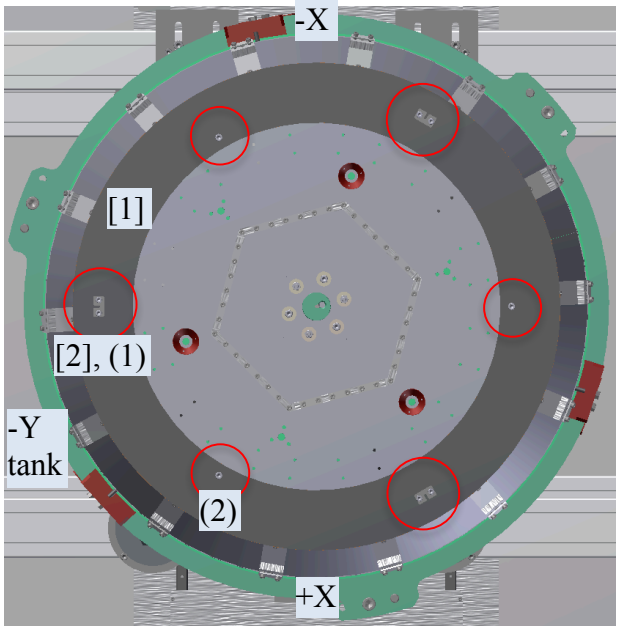
Remove the {1} template, turn the [1] ring right-side-up, and sling it from the crane using appropriate slings.

Lower the [1] ring until it is just above the SF, with the [2] holders at 9, 1 and 5 o'clock (looking towards the –X direction). Put 3 x {2} spacers on the Cu ring of the SF in line with the gaps between the magnets.

Adjust the position and angle until the (2) screws line up with the holes in the Cu ring.

Lower the [1] ring onto the spacers and tighten the (2) screws.

Disconnect the crane.



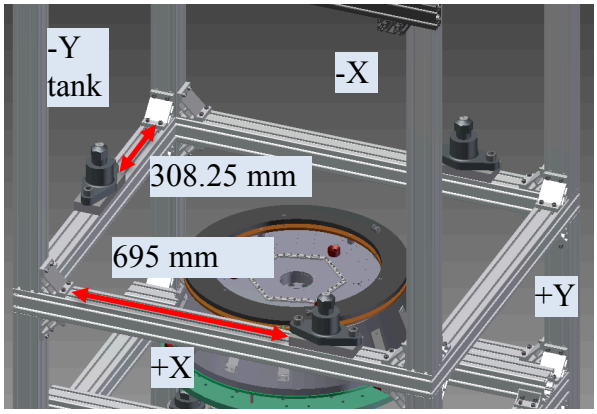
8.17 Reposition top jacks

Move the 3 NB-03 jacks from the top level down to the crossbars under the PI.

Place the jack on the tank side of the frame symmetrically (there should be 308.25 mm from the jack adapter block to the nearest point on the right angle brackets).

Place jacks on the ±X sides with 695 mm between the jack adapter block to the nearest point on the right angle brackets at the tank end.

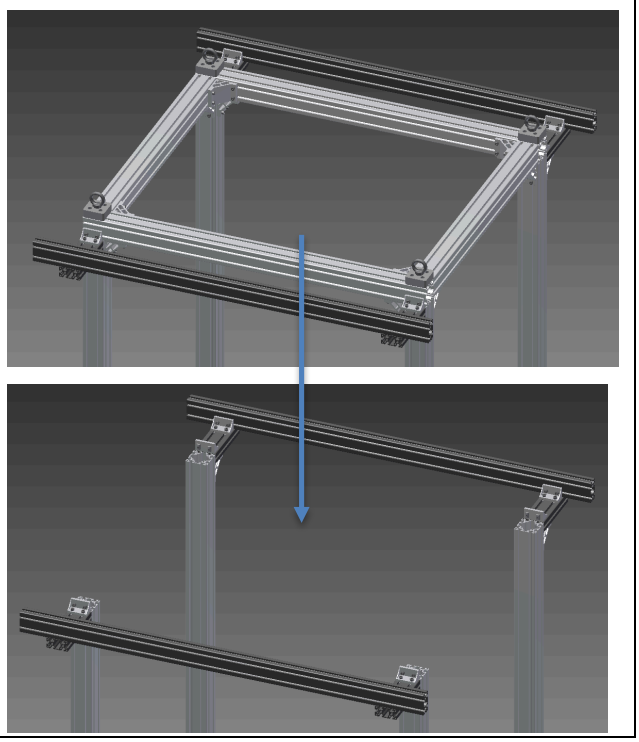
Set the jacks to 200 mm high from the base of the adapter block to the tip of the rotating section (nominal height).



8.18 Remove top crossbars

Remove the lifting eyes, the top outside crossbars on all four sides, the brackets on the inside corners and the brackets that supported the crossbars from underneath.

If the extension bars are wobbly, lower them a few centimeters until the upper right-angle brackets are connected.



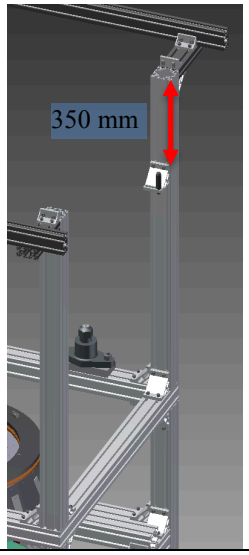
8.19 Attach crane adapter

8.20 Install PI Guides

{1}: 4 x **PI Guide**

Install 4 x {1} guides on the uprights, opposite the brackets for the clean bag extension and 350 mm below the top.

Adjust the rod part of the guide to the outside (so as not to interfere with the PI when it first comes down).



8.21 Insert screws for security structure

Identify the M12 threaded holes for the security structure screws, in the bottom plate of the PI accessible through the cutouts immediately clockwise of each IP leg.

Plan A:

(1): 3 x **ISO 4762 M12 x 35 treated**

For each hole, insert a (1) screw *from above*, screw it in as far as it will go, and tighten moderately.

Plan B:

(1): 3 x **TBD M12-M10 adapters**

(2): 3 x **ISO 7093 A ST 10 – 140 HV – A**

(3): 3 x **UNI EN 24032 M10**

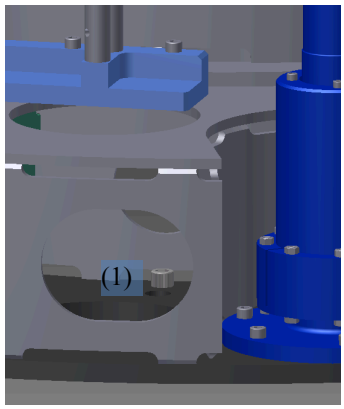
For each of the hole, insert the M10 end of a (1) adapter *from below* and secure with a (2) washer and a (3) on top. Leave the nut very loose.

Plan C:

(1): 3 x **ISO 4762 M10 x 35 treated**

(2): 3 x **ISO 7093 A ST 10 – 140 HV – A**

For each of the holes, insert a (1) screw with a (2) washer *from above* and just leave them sitting in the M12 hole.



8.22 Crane in PI

Move the PI to TBD position on the line of the crane with the forklift.

Attach the crane adapter to the PI per 8.19.

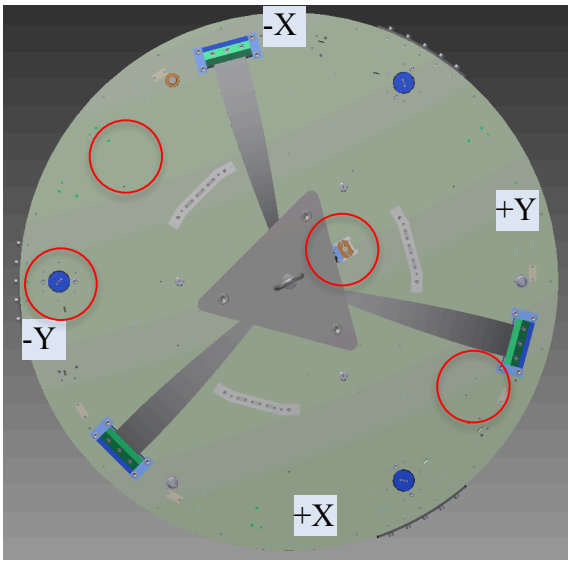
Lift the PI with the crane and move it into the cleanbooth if it isn't already.

Remove any remaining wrapping material.

Rotate the PI on the crane so that, as viewed looking towards –X, there is an IP leg at 9 o'clock, the fishing rod slot is at 2 o'clock, and the M4 holes for the magic wands are at 10 o'clock and 4 o'clock.

Check the levelness of the PI in both directions with a bubble level and, if necessary, readjust the slings and/or put weights on one side so that it hangs straight.

[???: Maybe hook maraging rods into PI here – currently 8.28.]

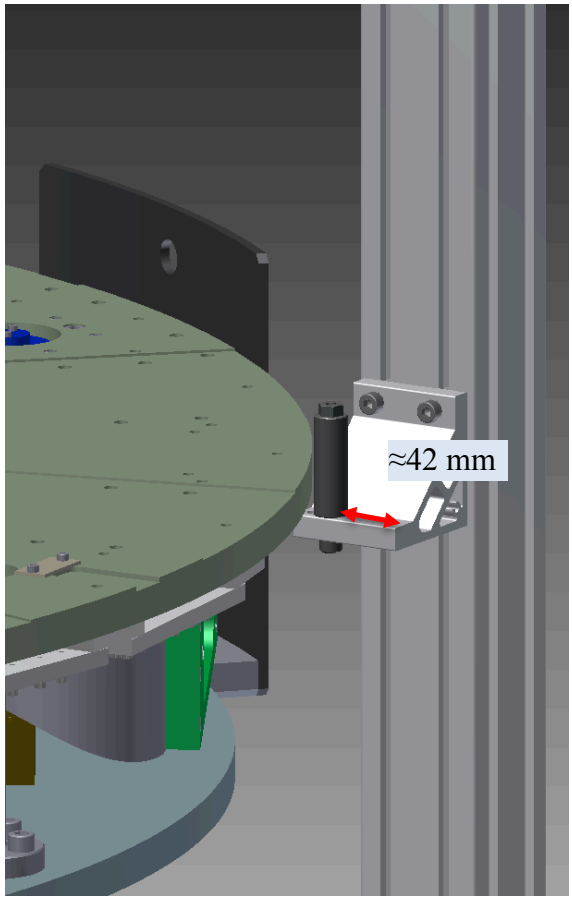


8.23 Adjust PI Guides

Lower the PI with the crane until it is about 90 mm above the jacks (leaving room for a 78 mm tall **adapter_conical_bellows**). Adjust the position and angle until each IP leg is directly above a jack.

[???: Need to add some extra checks that PI is centered.]

Adjust the rods on the PI Guides inwards to capture the PI horizontally. There should be approximately 42 mm from the outside of the bracket to the outside of the cylinder. If necessary adjust the height of the PI Guides until the top filter plate touches near the top of the rods (to allow room for lowering).



(This picture has the PI at its final, low position. In reality, at this step, it will be further up.)

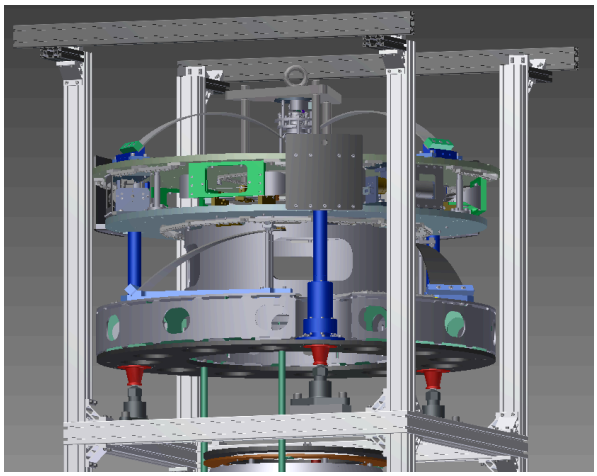
8.24 Insert conical bellows

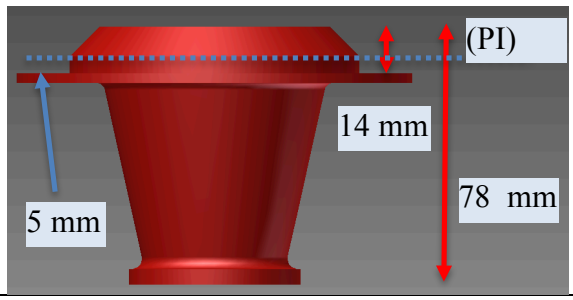
[1]: 3 x **adapter_conical_bellows**

{1}: 3 x **Newport_PS-0_125_additional_machining**

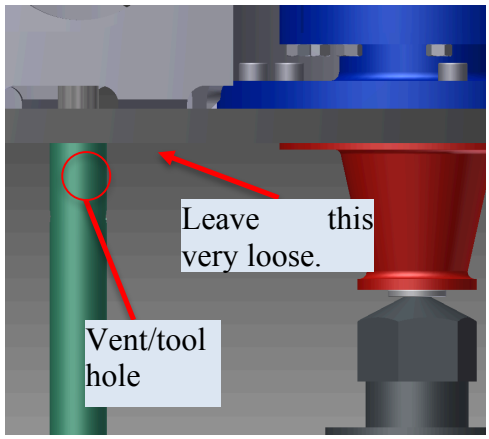
Below each IP leg, insert a [1] bellows from below into the large hole in the base of the PI. Support the [1] bellows and insert a {1} disc between the bottom of the bellows and the tip of the NB-03 jack.

While supporting the [1] bellows, lower the PI very gradually with the crane until there is about a 5 mm gap between the shoulder of the [1] bellows and the bottom of the PI, so that the [1] bellows are captured at the top

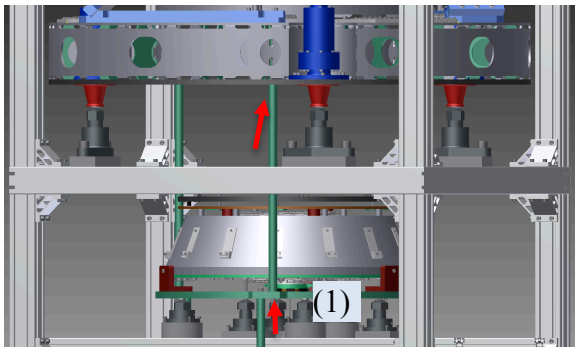


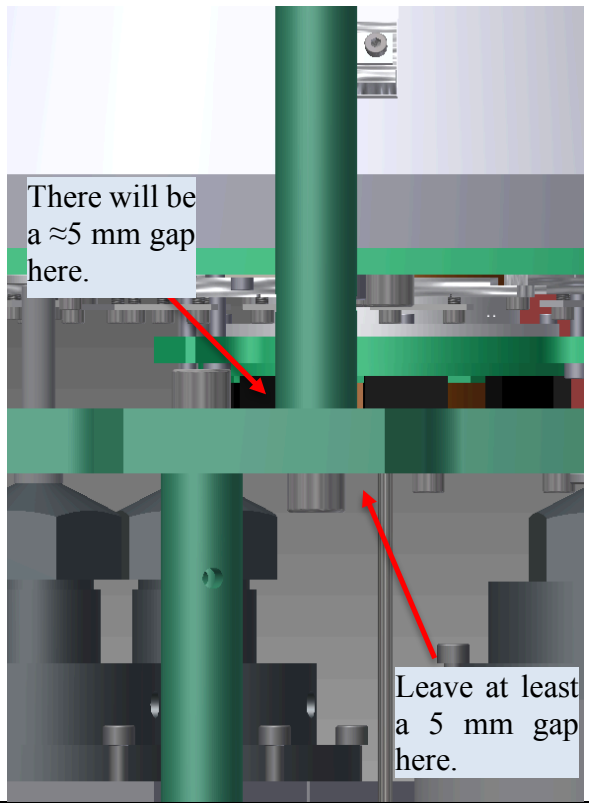
and cannot fall off the jacks but are still not supporting the weight of the PI.	

8.25 Attach SS rods to PI

[1]: 3 x **Part-10005-rod security structure 602** (regular, or modified with M10 hole at top, depending on choice of plan in the previous step, 8.20) Screw 3 x [1] rods around the ends of the screws from step 8.20, but leave them very loose so that it easy to back them off again. If the rod is too stiff to turn, insert a hex wrench or similar tool into one of the vent holes about 30 mm from each end of the rod and use it as a lever.	

8.26 Connect SS rods to ring below SF

(1): 3 x **ISO 4762 M12 x 35 treated** Check whether the rods line up with the holes in the security structure ring below the SF and make adjustments to the position/angle of the PI as needed. Insert the 3 x (1) screws from below, through the security structure ring, and into the ends of the rods. In small increments, gradually screw the (1) screws further into the bottom of the rods. After each round of adjustment, check the position/angle of the PI and the alignment of the rods. Stop if anything gets so stiff that it indicates an alignment problem between the PI and the ring. Also stop when there is a gap of about 5 mm between the screw heads and the bottom of the disk.	

There will naturally be a gap of about 5 mm between the bottom of the rods and the top of the ring – don't worry about this.	

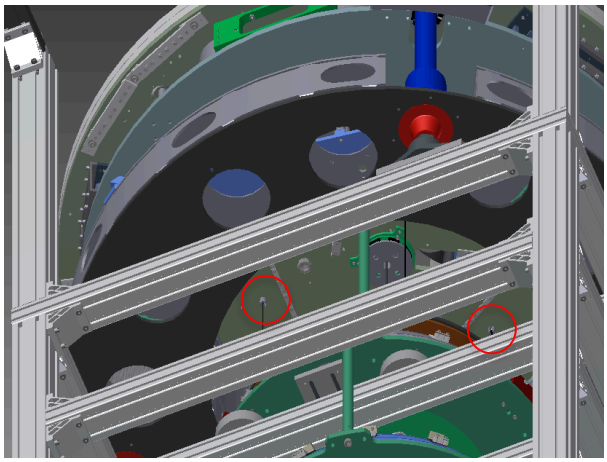
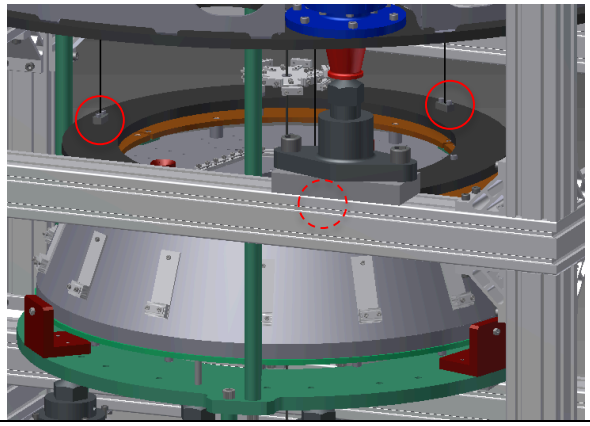
8.27 Raise jacks to support PI

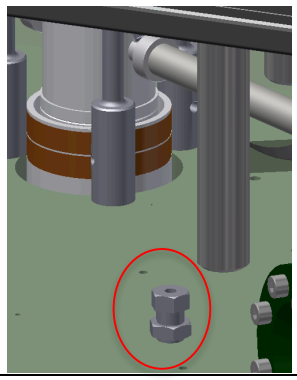
Raise all the jacks in parallel by 1/6 of a turn at a time until at least one of the conical bellows has its flange against the underside of the PI (approximately 5 mm / 2 mm/turn = 2.5 turns). Ideally they should all touch after the same number of turns. Recheck that the top of the PI is level. If the flanges are not all touching, diagnose the problem and decide how to proceed. Otherwise, raise all the jacks in parallel by steps of 1/6 turn for another 1-2 turns, or until the whole weight of the PI is on the jacks. If more than 2 turns are required, back off the screws at the bottom of the rods (from the previous step, 8.26) so that the ring below the SF is not lifted. When the weight is completely on the jacks, disconnect the crane. Then, lower all the jacks in parallel by steps of 1/6 turn for around 5 turns, until the rods are about to touch down on the ring under the SF. Continue to lower the jacks in parallel by smaller steps until one rod does touch down.	

Recheck that the top of the PI and the ring are both level. If there is any visible gap between the bottom of the other rods and the ring, screw them down until they touch. Screw in the 3 x (1) screws from 8.26 and tighten firmly.	

8.28 Suspend SF damper ring

NOTE: The following was the original plan when we were going to use the full Cu damper. With only two segments in use, the Cu ring is probably too fragile to risk stacking the magnet ring on top of it temporarily.

[1]: 1 x **Part-43-Half-wire d 3.5** [2]: 2 x **small hexagon assembly** [3]: 3 x **Part-10031-wire damping filter standard** [???: Might have to hook wires at top end before PI is placed - 8.22.] Attach 2 x [2] wire clamp assemblies to the [1] maraging rod. Pass the [1] rod into the assembly frame and hook the top end to the keystone of the top filter. Pass the 3 x [3] rods for the damper into the assembly frame and hook the top ends into the receiving parts (**Part-36-regulation magnet's plate**).	
Lift the damper ring and hook the 3 x [3] rods so that the ring is suspended.	

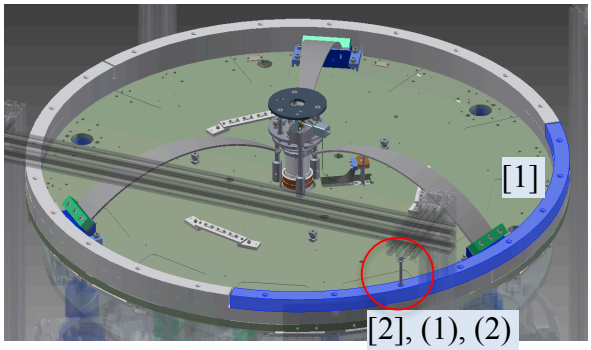
Adjust the nuts on the rod receiving parts on the top side of the top filter until the gap between the damper ring (not counting magnets) and the Cu ring is 13.7 mm or TBD at all points.	

8.29 Route cables up to PI

8.30 Wire up LVDTs, picos, steppers

Required: [1]: 4 x **TR-Flange Signal Cable D1503901-19** [1']: (if needed) 4 x **Signal Cable Extension D1503901-10** [2]: 1 x **PI Stepper Adapter D1503901-24** [3]: 4 x **TR-Flange Motor Cable D1503901-20** [3']: (if needed) 4 x **Motor Cable Extension D1503901-16** [???: need to check existing wiring to see if correct length, gender]	

8.31 Place PI ballast

Required: [1]: approx. 6-9 x **Arc_weight_IP_t38_n3** [2]: 6 x **Part-51-tie rod** (1): 6 x **ISO 7093 A ST 8 – 140 HV – A** (2): 6 x **UNI EN 24032 M8** Install 6 x [2] tie rods at evenly spaced intervals around the edge of the top filter. Install a first layer of 3 x [1] weights. Install a second layer of 3 x [1], starting from a different point on the rim so that the weights in the two layers are staggered. Secure the weights with a (1) washer and (2) nut on each [2] tie rod.	

8.32 Install magic wands

Required:

[1]: 2 x **Assembling balance** units less items below

[2]: 2 x blade assemblies

[3]: 2 x **B-part-49-clamp** (9.5 mm, for keystone)

[4]: 2 x **B-part-48-clamp** (12 mm, for wand)

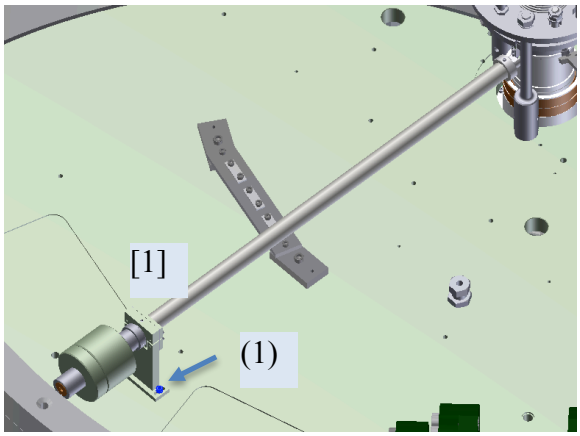
(1): 4 x **ISO 4762 M4 x 20**

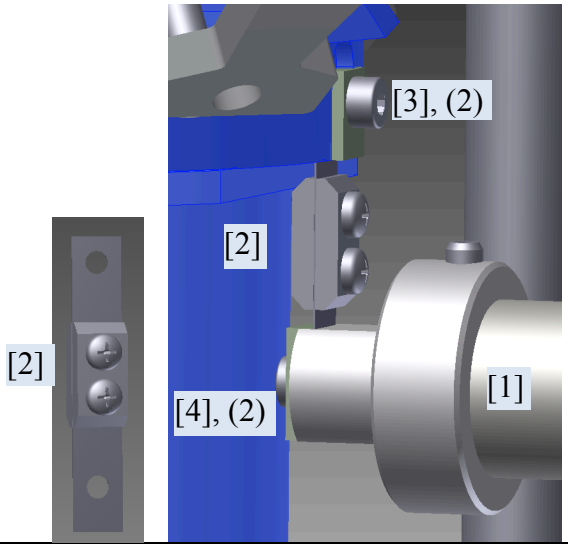
(2): 4 x **ISO 4762 M4 x 6**

For each [1] wand, attach to the top filter with 2 x (1) screws. [???: At TAMA, the outer end of the wand fouled on the ballast mass – need to check this is fixed.]

Identify the top and bottom ends of the blade assembly: there is screw hole at each end of the blade, but the hole at the top end is nearer to the tip than at the bottom.

For each [1] wand, install a [2] blade assembly between the keystone and the end of the wand using [3]+(2) at the top and [4]+2 at the bottom.





8.33 Install geophones

Required:

[1]: 3 x **geophones in pods**

[2]: 3 x **geophone interface**

[3]: 3 x **geophone cable, D1503901 Sheet 07**

(1): 12 x **ISO 4762 M8 x 25**

(2): 12 x **ISO 4762 M10 x 20 treated**

Handle the geophones with the **connector end down** whenever possible.

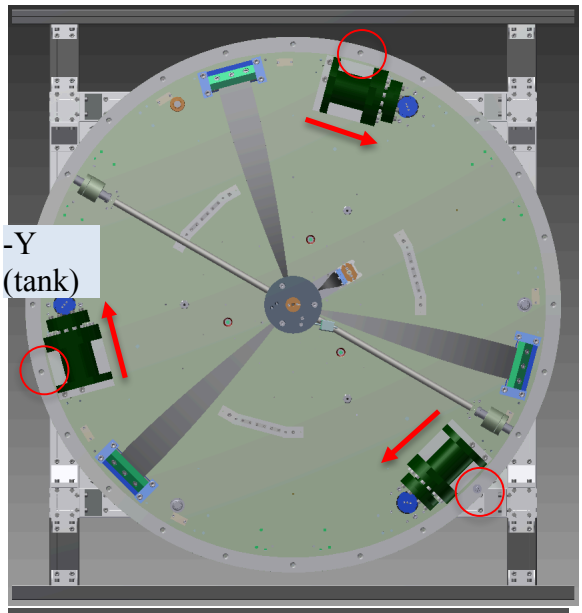
Identify the geophone locations: three positions on the top of the top filter, 30° clockwise from each spring base (clock positions 12:30, 04:30 and 08:30 as viewed looking in –X direction).

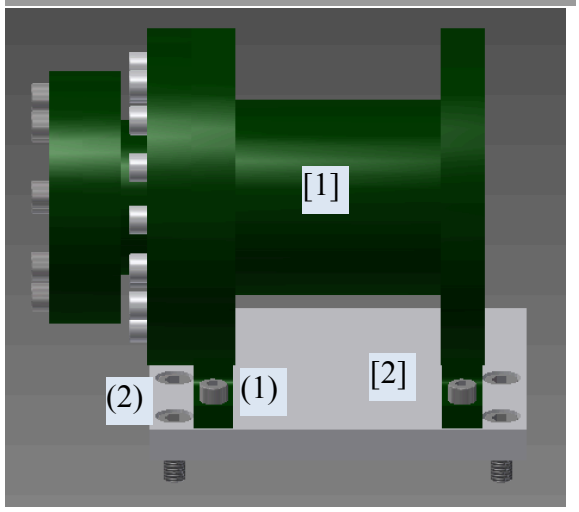
Fix a [2] geophone interface plate in each position on the top filter using 4 x (2).

Very slowly and carefully, carry each [1] geophone to the PI and lay it down to a horizontal position on a [2] geophone interface, with the connector end pointing clockwise around the rim of the top filter.

Attach each [1] geophone to its [2] interface using 3 x (1) screws. (There are four holes but the one at the connector end on the outside near the arc weights is inaccessible.) Record in the logbook which geophone is used in each position. (The geophones are identified by numeric punch marks on the top of the flange. [??: Need to sort out which position will be #0, #1, #2 with the flipped PI.])

[???: Mass of geophones is ≈32 kg per VI elog 4/16/2015]





8.34 Hook SF+BF+payload and lower SF to suspend SF+BF+payload

8.35 Level, center, tune PI

9 Prepare LBB

9.1 Set up KOACH filters

9.2 Remove flange covers

9.3 Lay down blocks

9.4 Pass halves of Cu-support ring into tank

9.5 Join halves of Cu-support ring

9.6 Install Cu segments on top of Cu-support ring

9.7 Pass halves of magnet ring into tank

9.8 Join halves of magnet ring

9.9 Thread slings to make loops around rings

9.10 Crane rings up

9.11 Attach end stops, hook magnet ring, attach locking pliers

9.12 Remove slings

9.13 Dummy procedure step for cutting and pasting

9.14

10 Install in Tank

10.1 Install crane adapter

See Install crane adapter.

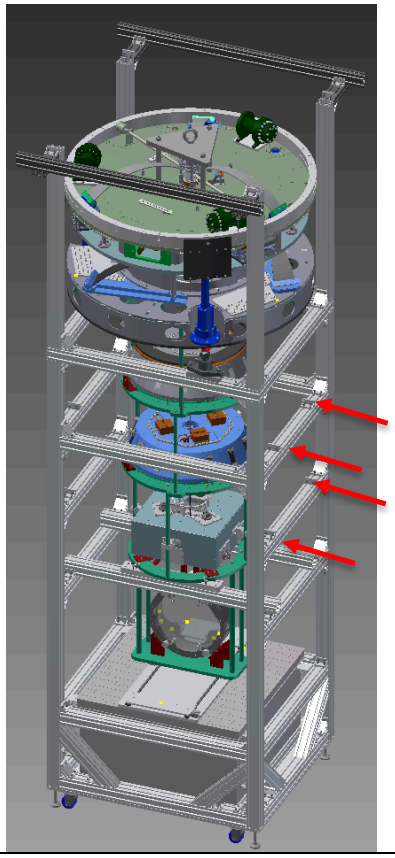
10.2 Attach security transport plates

See Attach security transport plates.

10.3 Disconnect cables from feedthroughs

Disconnect all the in-vacuum cables from the vacuum feedthroughs, coil them neatly and place the coils on top of the lower section of the PI, near the LBB blade units.	

10.4 Remove lower crossbars from assembly frame

Lower the jacks below the SF, the SF ring, and the BF. Remove the jacks and cantilever plates (where applicable) from the crossbars. Remove the internal crossbars that supported the jacks.	

10.5 Dummy procedure step for cutting and pasting

10.6 Prepare pallet (or pallets?) for receiving tank lid

10.7 Unbolt tank lid

10.8 Crane tank lid onto pallet(s)

11 Generic steps

11.1 Attach security transport plates

Required (see D1605179):

[1]: 3 **Part-34-security transport**

[2]: 3 **Part-35-security transport**

(1): 3 **ISO 4672 M8 x 16 treated**

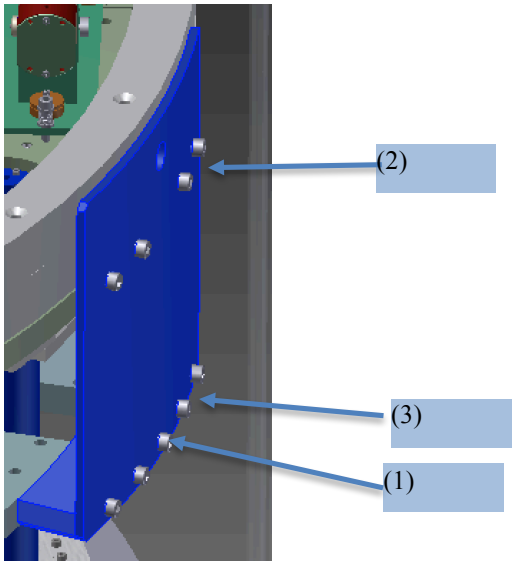
(2): 4 **ISO 4762 M8 x 25 treated**

(3): 4 **ISO 4762 M8 x 60 treated**

Assemble 3 x [1] and 3 x [2] with 3 x (1), leaving the screws slightly loose.

At three places around the PI (near each leg), attach [1]+[2] using 4 x (2) at the top and 4 x (3) at the bottom.

Tighten all the screws.



11.2 Install crane adapter

Install the three vertical pillars for the crane adapter.

Remove the top ring of the keystone, including the yaw picomotor.

Install the top triangle of the lifting plate.

NOTE: The final crane adapter has a different lifting ring from the illustration, with a swivel bearing and a much larger eye.