ALIGO INITIAL ALIGNMENT PROCEDURE

LBSC3 As Built

AUTHOR(S)	DATE	Document Change Notice, Release or Approval
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Instructions on the use of this document:

1) Use, and complete, this document on a computer while the work is proceeding. When operating in a cleanroom, use a cleanroom compatible computer. This procedure must be available at all times during the alignment process. In addition, all of the applicable documents must also be available for reference during the procedure from the laptop computer.

2) Use this alignment procedure as a check list for preparation and during the alignment; As each step is completed, enter the name of the person completing the work (or approving or checking the step), as well as the date and any comments or notes. In particular, note any discrepancies or deviations and augment with any missing definition. ALL NOTES MUST BE RECORDED IN THE COMPLETED VERSION OF THIS DOCUMENT (NOT IN OTHER NOTEBOOKS OR FILES). If the additional notes are too cumbersome to include within the body of this completed procedure, then electronically attach them to the completed procedure.

3) Once completed, file the document in the LIGO Document Control Center (DCC) as the next highest version of the procedure and add a note that this is a completed/finished procedure.

4) File any significant notes or data from the completed procedure in the electronic logbook (such as any deviations); as a minimum note in the electronic logbook that the alignment was completed in accordance with this procedure (cite document number and revision).

Contents

1 SCOPE

The scope of this procedure is alignment of the optical elements of the LBSC3 chamber, which includes alignment of the following optical elements:

1) L1 ITMx (part of the quad suspension assembly, D0901346-v9)
2) Arm Cavity Baffle (ACB; D0901376)

This procedure starts with the preliminary alignment of the optical payload elements of the LBSC3 chamber in the "cartridge assembly" and then proceeds to the alignment of these same optical payload elements within the LBSC3 chamber. The "cartridge assembly" is comprised of the BSC ISI system with all payload elements, which are capable of fitting onto the test stand, integrated onto the optics table and the stage 0 structure of the BSC-ISI. The cartridge assembly is integrated and aligned while on the BSC mechanical test stand. The cartridge is then lifted, flown to the chamber and lowered into position onto the BSC support tubes.

This procedure does not cover the procedures for installing assemblies onto the BSC-ISI platform or for balancing and leveling the BSC-ISI optics table; these procedures are defined in separate documentation.

2 APPLICABLE DOCUMENTS

Listed below are all of the applicable and referenced documents for the initial alignment procedures. This list gives the latest revisions of the documents; within the alignment steps, only the document number (and not the revision) is quoted.

Document No.	Document Title
E0900047	LIGO Contamination Control Plan
T1000230	AOS Initial Alignment Requirements Final Design Document
T080307	Initial Alignment System Design Requirements Document
T1000446	Flow Chart AOS/IAS H1 & L1 ITMx Alignment
D1101050	SUS Alignment Template Assembly
D1200869	aLIGO IAS LLO Monuments
T1100318	Total Station modifications for stabilizing unit when Laser Autocollimator is Attached
T080230	Quad Pendulum Structure Pushers
E0900357	aLIGO BSC-ISI, General Assembly Procedure
E1200822	Quad "GAP" Setting Procedural Check List L1 – ITMx - Specific

3 COORDINATE SYSTEMS/REFERENCES

3.1 BSC Chamber

The local BSC chamber coordinate system origin is the point where the horizontal, cylindrical axes of the main access portals meet. The local BSC chamber coordinate system axes are aligned to the local gravity vector. Z is vertical (+Z is up). X and Y are both horizontal and approximately aligned to the global coordinate axes (as defined in T980044). The local BSC chamber coordinate system origin is nominally located 65.421 in [1661.7 mm] below the BSC-ISI optics table surface.

3.2 Mechanical Test Stand

The local mechanical test stand coordinate system origin is located 65.421 in [1661.7 mm] below the BSC-ISI optics table surface and centered between the row of mounting holes which interface to the BSC-ISI stage-0 structure (and represent the support tubes installed into the BSC chambers). The local mechanical test stand coordinate system system axes are aligned to the local gravity vector. Z is vertical (+Z is up). X and Y are both horizontal and approximately aligned to the global coordinate axes.

4 PREREQUISITES FOR CARTRIDGE ALIGNMENT

- The BSC mechanical test stand must be set so that the interface plane with the BSC-ISI stage 0 is horizontal.
- The features of the BSC mechanical test stand which interface to the BSC-ISI platform shall be used to establish a centerline and two offset lines with alignment monuments/references in the floor, as depicted in the D1200869 (see also Figure 2).
- An appropriate clean room should be installed over the test stand. For this procedure we are using BSC Test Stand #2 (see Figure 1)

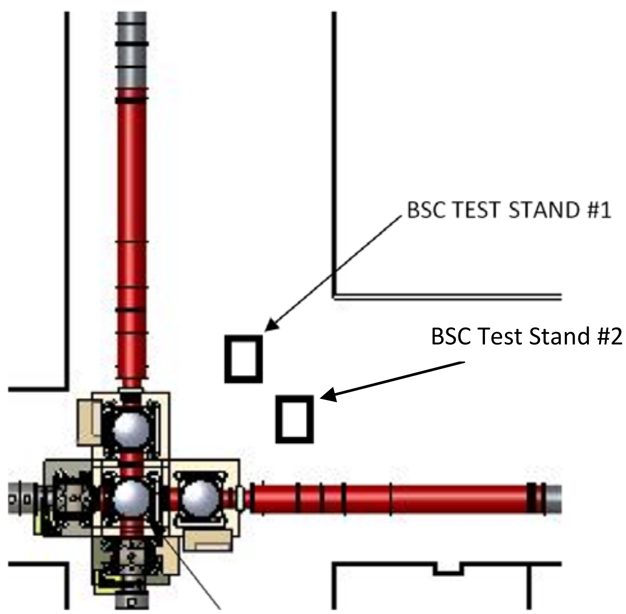

Figure 1: LLO LVEA Test Stand Layout

- All payload assemblies must be acceptance tested (to the extent possible and planned) prior to integration into the cartridge assembly.
- The ITMx suspension must be capable of being electronically damped while on the test stand and later when in the chamber.

- All IAS operations on the cartridge assembly are to be made with the BSC ISI in its locked mode. Verify that the ISI is locked.

5 REQUIRED EQUIPMENT LIST

- Total station (either a Sokkia Set2BII or a Sokkia SetX1 modified per T1100318) with tripod stand
- Laser autocollimator (Newport LDS Vector and LDS1000 controller)
- Optical level (Sokkia B2o AutoLevel with micrometer option, or equivalent) with tripod stand
- Precision bubble level
- Optical Transit Square (Brunson model 75-H) with stand
- Mechanical locating templates for ITMx suspension (D1101050 -11 through -12, cleaned to Class B per E0900047 and E960022)
- Precision pushers (D060052, cleaned to Class B per E0900047 and E960022)
- Retro reflector assembly (D1101340, cleaned to Class B per E0900047 and E960022)
- Depth Gauge
- BSC table height target (D1101611)
- Various optical or tripod stands

6 PROCEDURE FOR CARTRIDGE ASSEMBLY ALLIGNMENT

The reference monuments for the cartridge assembly on test stand 2 are given in D1200869 and in Figure 2 for convenience.

The LBSC3 cartridge assembly is depicted in Figure 3. The major optics assemblies integrated into the LBSC3 cartridge are the X Input Test Mass (ITMx) and Compensation Plate (CPx), both parts of the suspension assembly (D0900495). The other SLC baffles interfere with the test stand.

There is no need (other than practice) to perform these initial alignment steps on the metal-mass versions of the suspensions as installed on the BSC-ISI optics table on the mechanical test stand. These procedure starts when all optics have been installed into the suspensions on the BSC-ISI platform on the mechanical test stand.

N.B.: The Arm Cavity Baffle (ACB) should be available for the initial LBSC3 installation. However, the ACB is not installed as part of the cartridge assembly. In this document we address the alignment of all elements of a complete LBSC3 installation for completeness. In the event that some of these elements are missing for the initial installation, this should be noted in the completed installation notes/comments fields in this document.

LBSC3 As Built

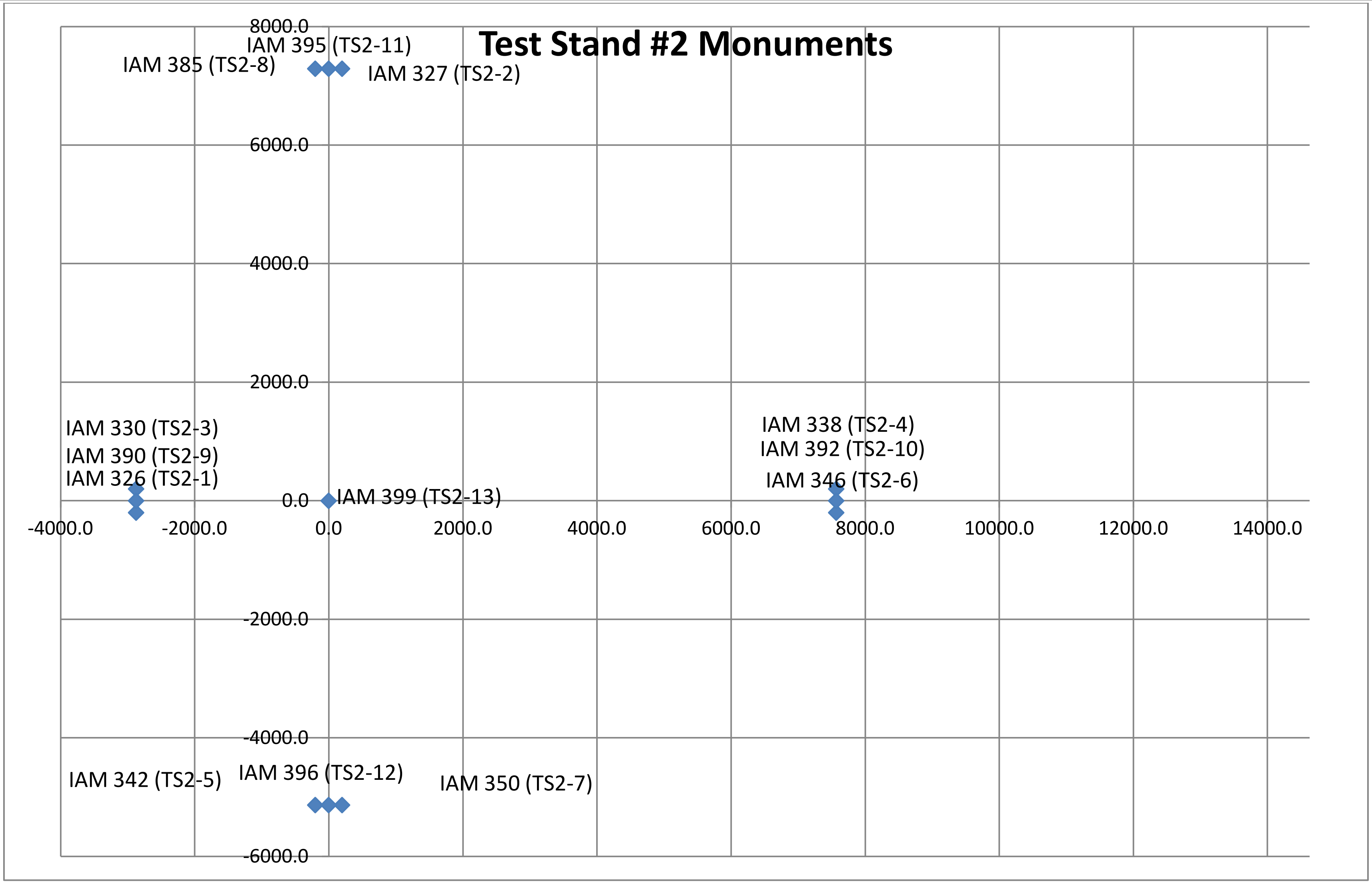

Figure 2: Monument Layout for Test Stand #2 (from D1200869)

LBSC3 As Built

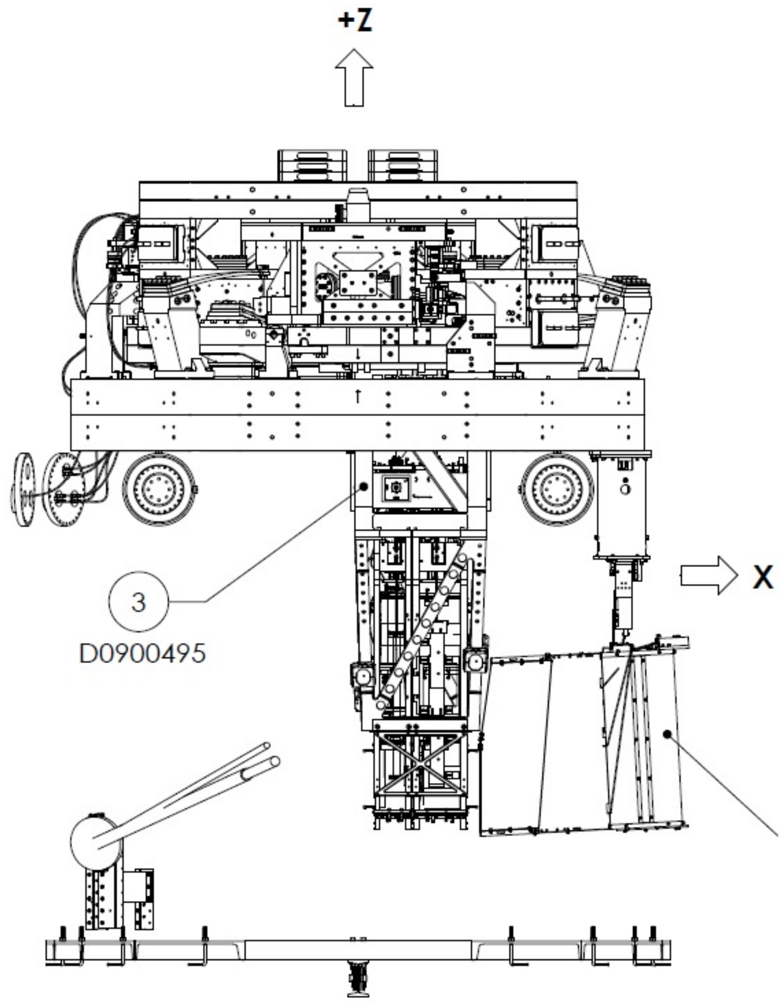

Figure 3: The LBSC3 cartridge assembly (D0900492)

6.1 Cartridge set-up

6.1.1 Check optics table level on the BSC mechanical test stand

Datum: Local gravity

Equipment: Optical level on tall tripod and targets on invar rods suspended from the optics table

Accuracy: ± 100 microrad (0.1 mm differential height)

Procedure:

- ☐ Attach 3 invar rods with targets to the table (equal lengths sufficient to be seen by optical level on tripod). Position the rods so that all 3 can be observed from a single optical level position.
- ☐ Place optical level on a tall tripod and sight the relative difference in target heights to determine tip and tilt of optics table.
- ☐ Adjust ISI trim/balance mass per E0900357 (v20, section 1.84)
- ☐ Record table levelness:

Tip (rotation about x)	microrad
Tilt (rotation about y)	microrad

6.1.2 Approximately align the Cartridge Assembly elements with the templates.

Datum: Bolt holes in optical table per D0900495

Equipment: Alignment templates (D1101050). Each suspension has two sets of templates. Either set may be used but not both.

Accuracy: Clearance in bolt holes

Procedure:

- ☐ Install D1101050-11 or D11050-12 template per D0900495
- ☐ If needed, install precision pushers (D060052) per T080230 adjacent to the ITM structure opposite of the templates.
- ☐ Push ITM structure to contact the templates per T080230.
- ☐ Lock down suspension structures.
- ☐ Remove all templates.

6.2 L1 ITMx

N.B.: Some of the data from the cartridge alignment is missing, so is not reported here; if the data is found this document will be updated accordingly.

6.2.1 Setup the ITM Retro-reflector Assembly

Datum: Optical axis of the test mass.

Equipment: Retro-reflector assembly, Depth Gauge

Accuracy: ± 0.2 mm

Procedure:

- ☐ Attach the retro-reflector assembly to the quad structure in front of the ITM HR face.
- ☐ Use the depth gauge to measure the offset distance from the retro-reflector assembly reference plate (square plate behind corner cube retro-reflector) to the ITM HR face. Do this on the right and left side of the plate and average two values to get the offset distance.
  ⚠Take care to clean the depth gauge, especially the contact feature. Contact the optic either on the outer perimeter of the HR face where there is no First Contact ™ film or in the interior but only on the First Contact™ film and be sure to contact very gently.
- ☐ Record the Offset (Y-distance).

Offset: distance from the ITM HR face to the Reflecting Plane of the Retro-reflector	mm

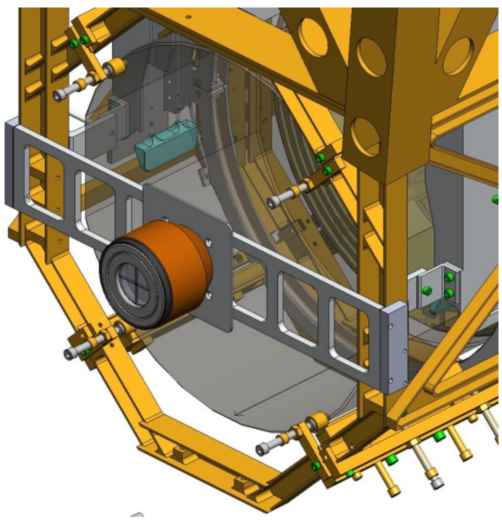

Figure 4: Retro-reflector Assembly attached to Quad Suspension Structure

6.2.2 Setup Total Station and Laser Autocollimator

Datum: Monuments TS2-6, TS2-1 – axis 200 mm shifted from the centerline; Height target is placed on the precision length rod (D1101611) to set target to optic height below the optics table.

Equipment: Total station, Newport Laser Autocollimator (mounted on top of Total Station), height target (D1101611)

Accuracy: ±1 mm

Procedure:

- ☐ Set the total station to approximately 977 mm above the floor
- ☐ Set the total station on TS2-6 and sight TS2-1
- ☐ Attach the height target to the optics table on a centerline hole near the table edge toward the total station.
- ☐ Yaw the total station to sight the height target and adjust total station height to match height target. The total station is now at the height of the test mass (i.e. -80 mm Z)

6.2.3 Set the ITM longitudinal position

Datum: Total station EDM, Retro-reflector and offsets to the HR face (determined in section 6.2.1)

Equipment: Total station, retro-reflector

Accuracy: ±3 mm

Procedure:

- ☐ Use total station EDM to set position to L = 9856 mm (remember to account for the offset distance from the retro-reflector to the optic HR face)
- ☐ Record position.

	Trial 1	Trial 2	Trial 3
Retroreflector to HR face offset	mm	mm	mm
EDM Distance	mm	mm	mm
Sum = L (ITM HR longitudinal distance)	9855.5 mm	mm	mm

6.2.4 Set the ITM horizontal position

Datum: Optical axis as established by the total station.

Equipment: Total Station, Pusher Assemblies (D060052), Slider/Mover Assemblies (D1100018)

Accuracy: ±1 mm

Procedure:

- ☐ With the Total Station at zero elevation angle, sight the left edge of the optic. Record the yaw angle difference (left optic edge = 360 – angle sighted)
- ☐ Sight the right edge of the optic. Record the yaw angle (right optic edge = angle sighted)
- ☐ Calculate the Center Error Distance (formula given in table below)

	Trial 1	Trial 2	Trial 3
Left optic edge (A)	mrad	mrad	mrad
Right optic edge (B)	mrad	mrad	mrad
Center error angle E = (B-A)/2	microrad	microrad	microrad
Center error distance L * E	mm	mm	mm

- ☐ Use the "slider/supports" and "pusher assemblies" (D060052) to shift the lateral position of the quad structure as needed, so that the center error distance falls within the required accuracy

6.2.5 Coarse Align the ITM Yaw

Datum: Optical axis as established by the total station.

Equipment: Laser autocollimator

Accuracy: ±1 milliradians goal (limited by the repeatability in the pusher and clamping method)

Procedure:

- ☐ Insure that the optics and masses, of the main suspension chain, are free (not clamped or on the mechanical or earthquake stops)
- ☐ Use the laser autocollimator to measure the TM optic yaw angle.
- ☐ Use the pusher assemblies to reduce the yaw angle to as close to zero as possible (< 1 mrad), using the SUS procedures. Note that the optics and masses should be clamped before attempting to move the Suspension frame/assembly on the optics table.
- ☐ Record residual yaw error.

	Trial 1	Trial 2	Trial 3
ITM yaw error	0.34 millirad CCW	millirad	millirad

6.2.6 Iterate/re-Check

Datum: Local gravity, optical axis as established by the total station.

Equipment: Optical level on tall tripod and targets on invar rods suspended from the optics table, total station

Accuracy: levelness: ±100 microrad (0.1 mm differential height)

lateral position: ±1 mm

longitudinal position: ±3mm

yaw: ±1 milliradian

Procedure:

- Re-check table level
- Re-check the lateral & longitudinal position and yaw and iterate until all are within required accuracy (coarse accuracy for the yaw).
- Remove the retroreflector and mount assembly from the ITM

Once this step has been completed, the ITM "frame" has been set; all further adjustments to the ITM are on the suspension chains.

6.2.7 Check the ITM vertical position

Datum: Optical axis as established by the total station.

Equipment: Total Station

Accuracy: ±1 mm

Procedure:

- With the Total Station at zero yaw angle, sight the bottom edge of the optic. Record the pitch angle (bottom optic edge = angle sighted – 90)
- Sight the top edge of the optic. Record the pitch angle (top optic edge = 90 – angle sighted)
- Calculate the Center Error Distance (formula given in table below)

	Trial 1	Trial 2	Trial 3
Bottom optic edge (A)	mrad	mrad	mrad
Top optic edge (B)	mrad	mrad	mrad
Center error angle E = (B-A)/2	microrad	microrad	microrad
Center error distance L * E	+0.1 mm	mm	mm

- The optic height was set during the SUS assembly and should be correct. However, if it is out of tolerance then use the SUS procedures to adjust the test mass height until it is within the required accuracy

6.2.8 Fine Align the ITM Yaw

Datum: Optical axis as established by the total station.

Equipment: Laser autocollimator

Accuracy: ±100 microradians (limited by air buffeting in the test stand/cleanroom environment)

Procedure:

- Ensure that the optics and masses of the main suspension chain are free (not clamped or on mechanical or earthquake stops)
- Use the top blade adjusters to reduce the residual error further, using SUS procedures
- Record the yaw error

	Trial 1	Trial 2	Trial 3
ITM yaw error	millirad	millirad	millirad

6.2.9 Align the ITM pitch

Datum: Optical axis as established by the total station.

Equipment: Total station

Accuracy: ±100 microradians (limited by air buffeting in the test stand/cleanroom environment)

Procedure:

- ☐ Set the total station pitch to 312 microradians (0° 1' 4") up (this is necessary to pitch the ITM down). Using the LAC, measure the pitch error.

Initial ITM pitch error	microradians

- ☐ If the pitch error is < 100 microradians, record
- ☐ If > 100 microradians, then adjust the upper intermediate mass pitch balance per SUS procedures

Final ITM pitch error	15 microradians down

6.2.10 Check the CP to ITMx Gap

Datum: The ITMx AR face and the opposing face of the CP.

Equipment: Keyance System and Davidson Autocollimator

Accuracy: ±0.25 mm average/center distance, and ±1.4 milliradians parallelism (corresponding to ±0.238 mm over the diameter of the optic)

N.B.: The gap spec is driven by the EQ stops on the CP (see T080128). The parallelism spec is driven by a combination of the EQ stops (since the parallelism will affect the gap spacing) and the avoidance of back reflections. The EQ stops mandate a gap setting tolerance of ±0.25mm, which leads to a parallelism spec of ±1.47 mrad. Back reflection avoidance leads to a spec of ±0.08° (per T1200452), or ±1.4 mrad; since the back reflection is the smaller spec, this is what we are adhering to. It must be noted though that the parallelism will affect the gap. What this means is that if both the gap and parallelism are at the edge of tolerance, there will be spots between the ITM and CP that are out of spec. Therefore both gap and parallelism should be adjusted as close to their targets as possible, not just "good enough." For a step-by-step guide to performing this portion of the alignment see E1200822.

Procedure:

- ☐ Measure & record the gap distance between the ITMx AR face and the opposing face of the CPx with the Keyance System. This should be done as close to the center of the ITM as possible.
- ☐ If the gap is not within the allowed tolerance of the nominal 20 mm, then adjust per SUS procedures

- ☐ Measure the parallelism between the surfaces and if not within the allowed tolerance, then adjust per SUS procedures
- ☐ Record the final gap parameters

Gap Distance	19.81 mm	
Gap Parallelism	Pitch	0.044 milliradians
	Yaw	0.044 milliradians

7 ALIGN THE CARTRIDGE ASSEMBLY IN THE BSC CHAMBER

Once in the chamber, IAS must align:

- the ITMx Optic in {x,y,z, yaw} by moving the entire cartridge assembly with HEPI as a rigid body
- the ITMx Optic in pitch, by adjusting the suspension
- the ITMx Arm Cavity Baffle

7.1 In Chamber Alignment

7.1.1 Level the Optics Table

Datum: Local gravity, BSC-ISI capacitive position sensors

Equipment: Optical Level, 3 metering rods, BSC-ISI capacitive position sensors.

Accuracy: 100 microradians (0.1 mm differential height)

Procedure:

- ☐ Make sure all payload and balance/ballast weight is on the BSC-ISI Assembly
- ☐ Attach 3 metering rods onto the Optics Table so that all 3 can be viewed from a single Optical Level position, on a tall tripod, through the open BSC door.
- ☐ Check the Optics Table levelness optically before unlocking BSC-ISI.
- ☐ If needed, adjust the table to be level using HEPI static adjustment per procedure E040011, “HEPI Assembly and Installation Procedures”
- ☐ Unlock the BSC-ISI and compare the capacitive position sensors offset values to the offsets measured on the cartridge test stand. If necessary, adjust the balance mass to get the same capacitive position sensor offsets as achieved on the test stand.
- ☐ Confirm the Optics Table levelness (again) with the Optical Level

7.1.2 Setup the Total Station and Laser Autocollimator

Datum:

a) Monuments L1 IAM 381, IAM 76, IAM 87 – axis 200 mm shifted in the -Y direction from the X centerline

b) Elevation mark Y-10

Equipment: Total Station; Newport Electronic Visible Laser Autocollimator (LAC); Initial Alignment Tooling Stand (D980429 through D980434); Brunson Optical Square; Metering Rods/Targets; 8” diameter Flat Mirror on a Newport Gimbal Mount and Tripod.

Accuracy: ±1 mm, ±40 microradians rss, alignment reference transfer (see T1000230-v6, section 17)

Procedure:

- ☐ Remove the LBE-1A Spool (on the X arm just past the LGV2 Gate Valve) per procedure M1000357, “Spool Manifold Removal Procedure”
- ☐ Set the Initial Alignment Tooling Stand in the space vacated by the Spool, over monument IAM 76
- ☐ Setup the Brunson Optical Square
  - o Set the Brunson directly over monument L1 IAM 381
  - o Sight elevation mark Y-10 and set the height to +69.5 mm (local coordinate system)
  - o Sight monument IAM 87 to get alignment parallel to the X global axis
- ☐ Set up the Sokkia SET1X total station
  - o Setup the SET1X on the Initial Alignment Tooling Stand at approximately 1810 mm above the floor directly over IAM 76
  - o Mount the LAC to the top of the Total Station
  - o Sight elevation mark Y-10 and set the SET1X/LAC height to -83.5 mm (local coordinate system)
  - o Setup the large Flat Mirror with gimbal mount/tripod with an unobstructed view of, and a few meters from, the SET1X/LAC
  - o Bore sight the SET1X and LAC using the Flat Mirror
- ☐ Set the SET1X to be square to the Brunson Optical Square using the LAC
- ☐ Zero the yaw reference on the SET1X
- ☐ Yaw the SET1X precisely +90° 0’ 0”
- ☐ Pitch the Total Station up by 312 microradians (0° 1’ 4”, total station reading of 89° 58’ 56”). The Total Station is now pointing to the desired location of the center of the ITMx HR face

7.1.3 Measure Axial Position Error of ITMx

Datum: Monument IAM 76

Equipment: Retro-Reflector Assembly (D1101340), Total Station, Depth Gauge

Accuracy: ±3 mm

Procedure:

- ☐ Mount the Retro-Reflector Assembly to the ITMx Suspension Assembly structure
- ☐ Measure the distance from the Retro-Reflector reference plane to the ITM HR face using a depth gauge

  ⚠Take care to clean the measurement tool, especially the contact feature, (b) contact the optic either on the outer perimeter of the HR face where there is no First Contact ™ film or in the interior but only on the First Contact™ film and (c) contact very gently.

- Record the depth gauge measurement as well as the Retro-Reflector (corner cube) offset constant:

Retro-Reflector-to-HR face distance	mm
Retro-Reflector (corner cube) offset constant	30 mm

- ⚠ Do not remove or adjust the Retro-Reflector or the mount until after the last Electronic Distance Measurement (EDM) has been completed with the Total Station.
- Use Total Station EDM to measure the axial (X) position of the ITMx HR face (remember to account for the offset distance from the retro-reflector to the optic HR face). Record the distance (desired distance is L = 6578.0 mm):

	Trial 1	Trial 2	Trial 3
Retro-reflector to HR face distance	mm	mm	mm
EDM distance	mm	mm	mm
Sum = L (ITM HR longitudinal distance to Total Station)	6576.0 mm	mm	mm

7.1.4 Measure Lateral Position Error of ITMx

Datum: X-Arm Axis derived from IAM 76

Equipment: Total Station

Accuracy: ±1 mm

Procedure:

- With the Total Station, sight the left edge of the optic. Record yaw the angle (left optic edge angle = 90° – angle sighted)
- Sight the right edge of the optic. Record the yaw angle (right optic edge = angle sighted – 90°)
- Calculate the lateral position error (formula in table below)

	Trial 1	Trial 2	Trial 3
Left optic edge (A)	24.687 mrad	mrad	mrad
Right optic edge (B)	24.919 mrad	mrad	mrad
Center error angle E = (B-A)/2	116 microrad	microrad	microrad
Center error distance L * E	+0.77 mm	mm	mm

7.1.5 Measure Vertical Position Error of ITMx

Datum: X-Arm Axis derived from IAM 76

Equipment: Total Station

Accuracy: ±1 mm

Procedure:

- With the Total Station, sight the bottom edge of the optic. Record the pitch angle difference (bottom optic edge = angle sighted - 89° 58' 56")
- Sight the top edge of the optic and record the pitch angle difference (top optic edge = 89° 58' 56" – angle sighted)
- Calculate the vertical position error (formula in table below)

	Trial 1	Trial 2	Trial 3
Bottom optic edge (A)	25.666 mrad	mrad	mrad
Top optic edge (B)	25.487 mrad	mrad	mrad
Center error angle E = (B-A)/2	-89.5 microrad	microrad	microrad
Center error distance L * E	-0.59 mm	mm	mm

7.1.6 Measure Pitch & Yaw Errors

Datum: Optical axis as established by the total station.

Equipment: Newport Electronic, Visible Laser Autocollimator (LAC)

Accuracy: ±50 microradians yaw goal, ±50 microradians pitch goal

Procedure:

- Insure that the optics and masses, of the main suspension chain, are free (not 'clamped' or on the mechanical stops or earthquake stops)
- Use the Laser Autocollimator to measure the TM optic yaw angle. All personnel should exit the chamber, purge air flow should be off or minimized, and electronic damping should be active for the suspension. If necessary, use a low pass filtering amplifier and display the pitch and yaw on an oscilloscope with trace persistence and cursors to get the average angles
- Record the pitch and yaw errors:

	Trial 1	Trial 2	Trial 3
Yaw error	15 microrad CCW	microrad	microrad
Pitch error	microrad	microrad	microrad

7.1.7 Translate Cartridge with HEPI to Correct Axial, Lateral, Vertical and Yaw Errors

Datum: Optical axis as established by the total station.

Equipment: HEPI static adjusters, Total Station, Retro-Reflector Assembly, Newport Electronic Visible Laser Autocollimator

Accuracy: ±50 microradians yaw goal with HEPI, ±1 mm transverse, ±1 mm vertical, ±3 mm axial

Procedure:

- Use the HEPI static adjustment procedure (per procedure E040011, "HEPI Assembly and Installation Procedures") to correct the axial, lateral, vertical and yaw errors until the residual errors are within the allowed tolerance.
- After, or during, HEPI adjustments measure the axial, lateral, vertical and yaw errors to guide the HEPI adjustment.

7.1.8 Correct Pitch Error

Datum: Optical axis as established by the total station.

Equipment: ITM Suspension pitch adjuster, Newport Electronic Visible Laser Autocollimator

Accuracy: ±50 microradians pitch goal

Procedure:

- Use the Laser Autocollimator to measure the TM optic pitch angle. All personnel should exit the chamber, purge air flow should be off or minimized, and electronic damping should be active for the suspension. If necessary, use a low pass filtering amplifier and display the pitch and yaw on an oscilloscope with trace persistence and cursors to get the average angles
- Use the TM Suspension static pitch adjustment procedure (E1000006-v20, section 5, "Quad Suspension Metal-Build Assembly Procedure") to reduce the residual pitch errors to within the allowed tolerance
- Record the residual pitch error:

	Trial 1	Trial 2	Trial 3
Pitch error	71 microrad up	microrad	microrad

7.1.9 Fine Pitch & Yaw Error Correction

Datum: Optical axis as established by the total station.

Equipment: ITM Suspension actuation (BOSEMs), Newport Electronic Visible Laser Autocollimator

Accuracy: ±10 microradians goal

Procedure:

- Use the Laser Autocollimator to measure the TM optic pitch and yaw angles. All personnel should exit the chamber. Purge air flow should be off or minimized. Electronic damping should be active for the suspension. If necessary, display the pitch and yaw on an oscilloscope with cursors to get the average angles
- Use the TM Suspension controls interface to set pitch and yaw bias values to correct the residual errors
- Record the pitch and yaw bias values:

Pitch bias	counts
Yaw bias	counts

8 Align Arm Cavity Baffle (ACB) Assembly

Datums: Optical axis as established by the total station

Equipment: Total station, pusher assembly (D060052).

Accuracy: ±2 mm

Procedure:

- ☐ Install and suspend the ACB from stage-0 of the ISI using procedure E1100810, "Arm Cavity Baffle Installation Procedure"
- ☐ Re-level table using HEPI (see section 7.1.1)
- ☐ Set up the total station as done in section 7.1.2
- ☐ Install the ACB Alignment Mount (D1201560) into the ACB opening and secure with the provided clamps. Ensure the ACB Alignment Target D1300977 is installed with the "Down ETM" at the bottom of the target
- ☐ If both vertical and horizontal positional errors are < 2mm, then the baffle is aligned. Otherwise, reposition using the pusher assemblies (D060052) per procedure T080230 until the positional errors are within tolerance