

LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
-LIGO-
CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LIGO-E040507- A- D	12/14/2004
Advanced LIGO SEI Assembly Time Estimates	
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This is an internal working note
of the LIGO Project.

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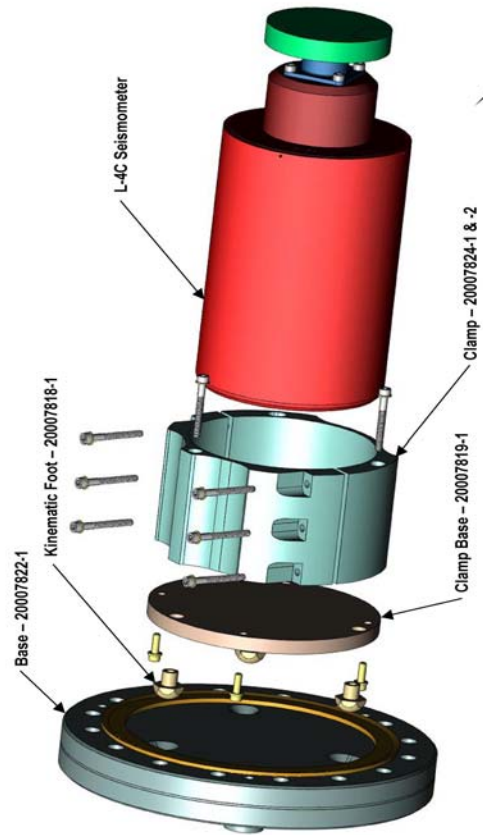
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STEP 1A Pre-assemble (6) L4C POD assemblies

Parts required

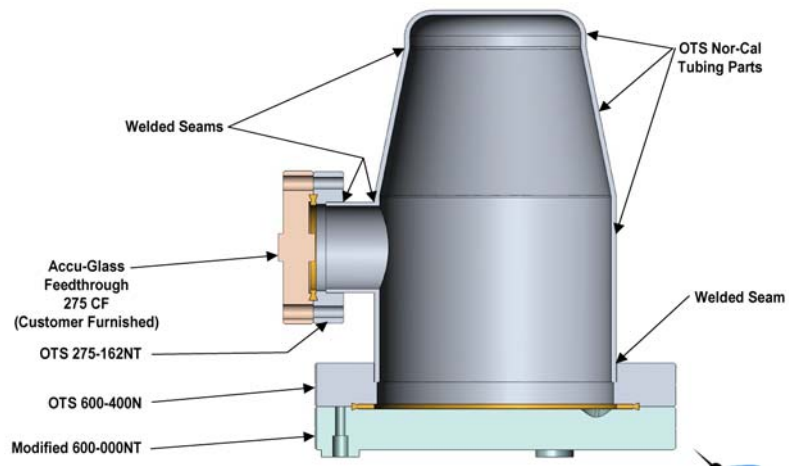
QTY	Part Number	Description
6	20007819-1	seismometer mounting plate
6	20007822-1	L-4C pod baseplate
6	20007823-1	L-4C pod chamber
6	20007824-1	seismometer clamp
6	20007824-2	seismometer clamp - tapped
36		clamp bolts
36		clamp washers
6		inner pod harness
6		conflat seal
96		conflat bolts
96		conflat washers
3		horizontal L-4C
3		vertical L-4C
6		L-4C conflat electrical feedthru
36		L-4C conflat electrical bolts
36		L-4C conflat electrical washers
3		L-4C vertical cable harness 1
3		L-4C horiz cable harness 1
3		L-4C vertical cable harness 2
3		L-4C horiz cable harness 2



Estimated time to assemble (6) units 6hrs

STEP 1B Fill with neon gas, leakcheck, and store

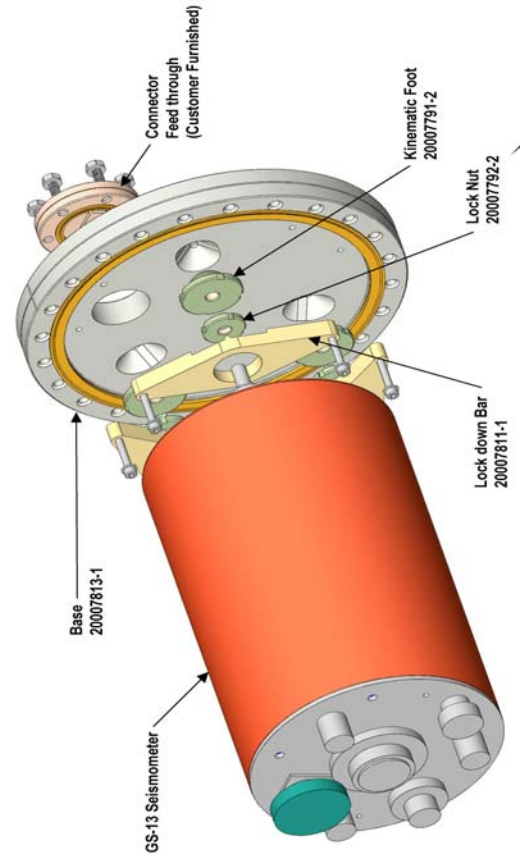
Estimated time to fill (6) units 10 hrs



STEP 2A Pre-assemble (6) GS-13 POD assemblies

Parts required

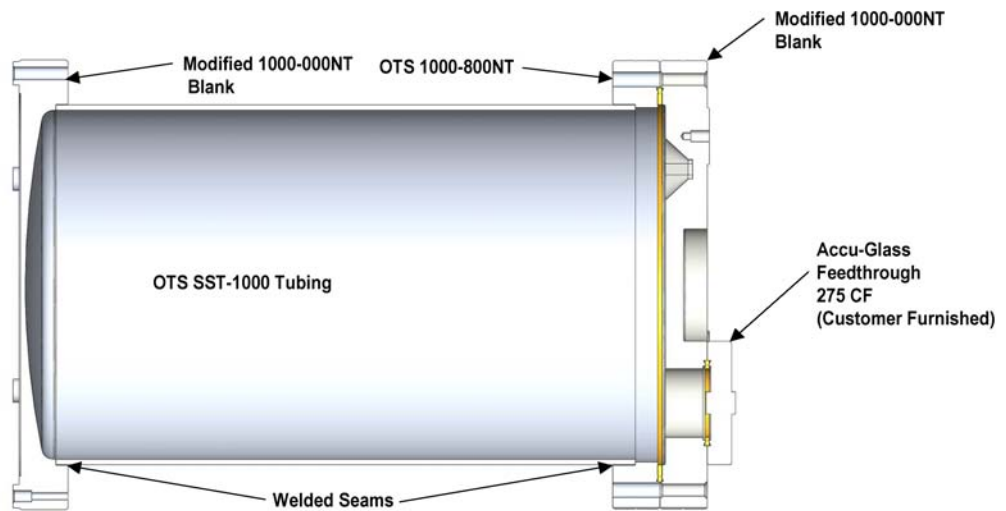
QTY	Part Number	Description
18	20007811	seismometer foot crossbar
6	20007812	GS-13 pod chamber
6	20007813	GS-13 pod baseplate
18	20007791	seismometer foot
18	20007792	seismometer foot jam nut
6		inner cable harness
3		conflat seal
144		conflat bolts
144		conflat washers
36		seismometer foot bolts
36		seismometer foot washers
3		horiz GS-13 seismometer
3		vert GS-13 seismometer
6		electrical conflat feedthru
6		electrical conflat seal
36		electrical conflat bolts
36		electrical conflat washers
		locker assembly



Estimated time to assemble (6) units _____ 12 hrs _____

STEP 2B Fill with neon gas, leak check, and store

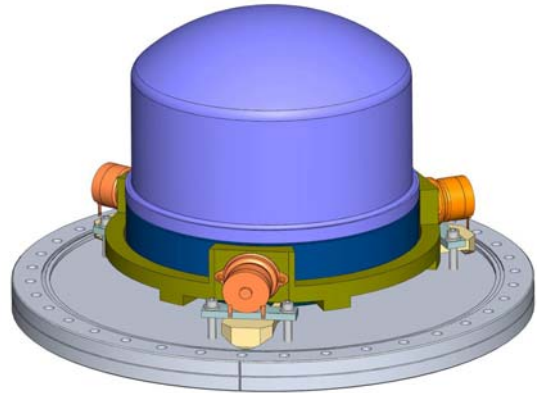
Estimated time to fill (6) units _____ 14 hrs _____



STEP 3A Pre-assemble (3) STS-2 POD assemblies

Parts required

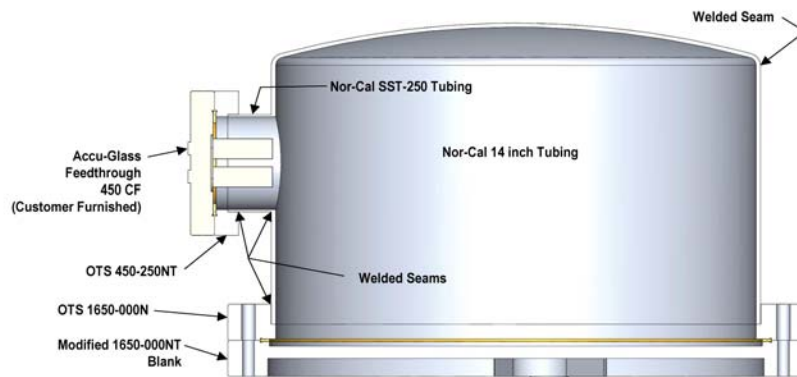
QTY	Part Number	Description
9	20007791	seismometer foot
9	20007792	seismometer foot jam nut
9	20007793	seismometer foot clamp
9	20007794	seismometer foot crossbar
3	20007795	STS-2 pod chamber
3	20007796	STS-2 pod baseplate
3	20007797	cable clamp
3	20007982	STS-2 pod locator, flat
3	20007983	STS-2 pod locator, convex
3	20007985	STS-2 pod locator, front
6	20007984	STS-2 pod locating pin
3		STS-2 pod locating eccentric
3		inner cable harness
3		large conflat seal
108		large conflat bolts
108		large conflat washers
18		seismometer foot bolts
18		seismometer foot washers
3		STS-2 seismometer with locker
3		STS-2 electrical feedthru
3		STS-2 electrical conflat seal
24		STS-2 electrical conflat bolts
24		STS-2 electrical conflat washer
3		STS-2 cable harness,stage 1
3		STS-2 cable harness,stage 2
		locker assembly



Estimated time to assemble (3) units _____ 12 hrs _____

STEP 3B Fill with neon gas and store

Estimated time to fill (3) units _____ 16 hrs _____



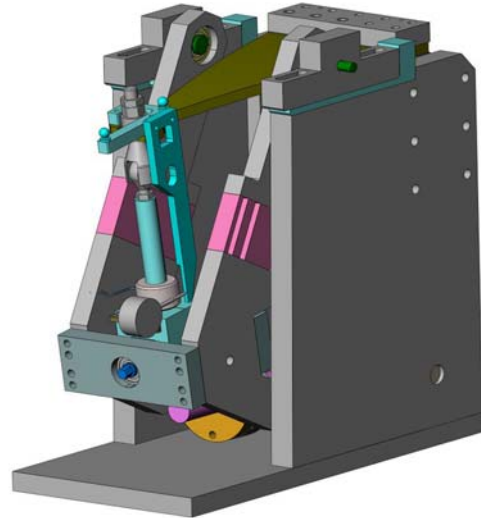
STEP 4A Measure Blade Spring Stiffness

1. Assembly of spring tester required prior to measurements.

Parts required

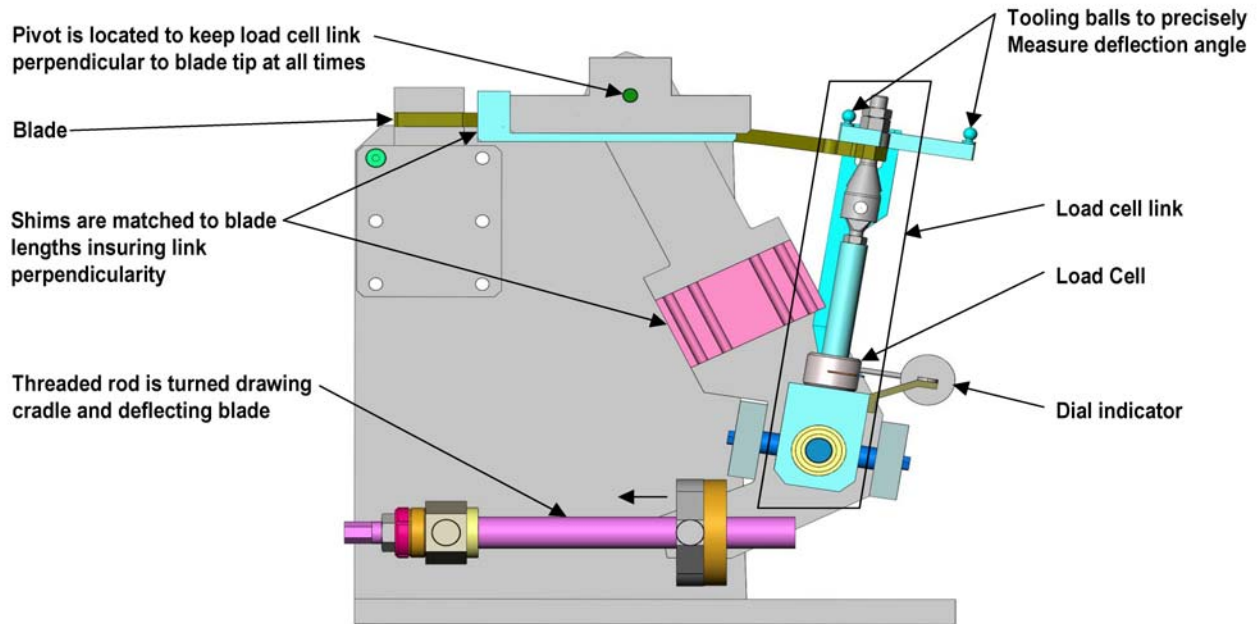
QTY	Part Number	Description
3	20007879	Stage 0-1 blade spring
3	20007891	Stage 1-2 blade spring
1	20008050	Spring test fixture (ASI supplied)

Estimated time to measure (6) springs _____ 4 hrs _____



STEP 4B Grind thickness to match blade stiffnesses to 0.1% per set

1. Record load and deflection at tip
2. Each .0001" thickness change corresponds to .05% change in stiffness
2. Recheck stiffness following final machine

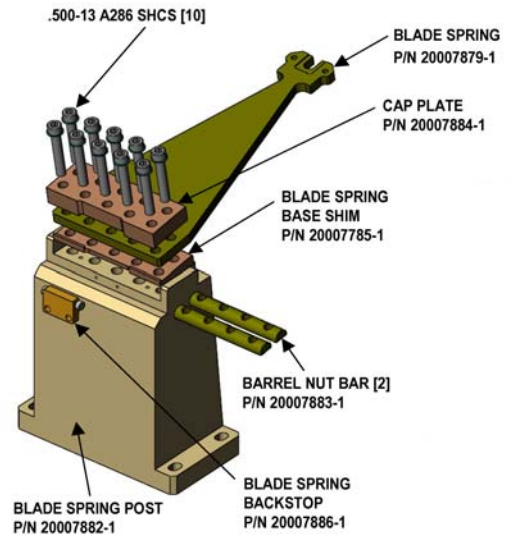


Estimated time to measure and grind (6) springs _____ 20 hrs _____

STEP 5A Pre-assemble (3) Stage 0-1 Spring/Flexure

Parts required

QTY	Part Number	Description
3	20007879	blade spring
3	20007880	flexure rod
3	20007881-1	flex rod shim, spring side
3	20007881-2	flex rod shim, bracket side
3	20007882	blade spring post
6	20007883	barrel nut bar
3	20007884	blade spring cap plate
3	20007885	blade spring base shim
3	20007886-101	blade spring backstop
3	20007886-102	blade spring backstop pin fasteners
10		

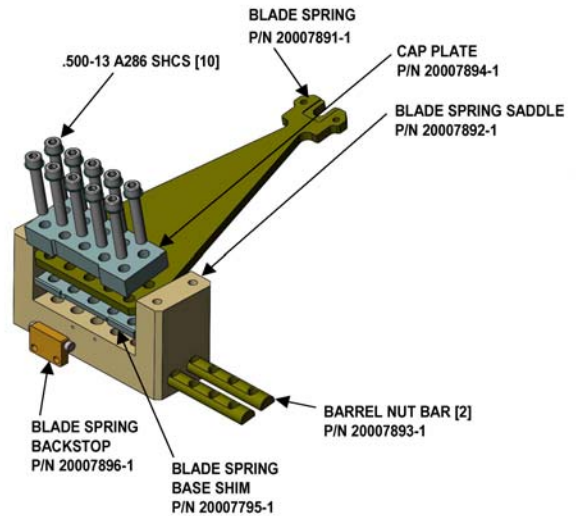


Estimated time to assemble (3) units 2 hrs

STEP 5B Pre-assemble (3) Stage 1-2 Spring/Flexure

Parts required

QTY	Part Number	Description
3	20007880-2	flexure rod
3	20007881-3	flexure rod shim, blade side
3	20007881-4	flexure rod shim, bracket side
3	20007891	blade spring
3	20007892	blade spring saddle
6	20007893	barrel nut bar
3	20007894	blade spring cap plate
3	20007895	blade spring base shim
3	20007896-101	blade spring backstop
3	20007896-102	blade spring backstop pin fasteners
10		

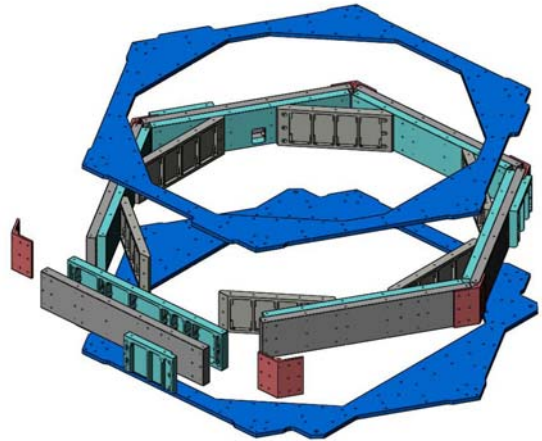


Estimated time to assemble (3) units 2 hrs

STEP 6A Assemble Stage 0 Subassembly on Granite Table

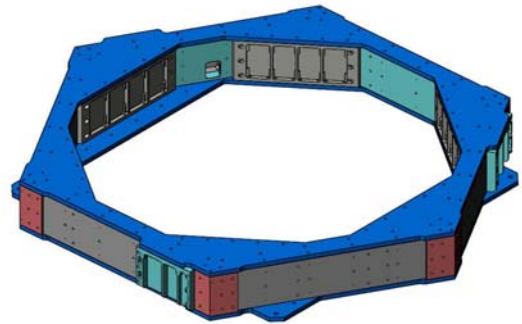
Parts required

QTY	Part Number	Description
1	20007951-1	bottom plate
4	20007952-1	outer hew wall type 1
2	20007952-2	outer hex wall type 2
2	20007953-1	inner hex wall type 1
2	20007953-2	inner hex wall type 2
2	20007953-3	inner hex wall type 3
4	20007954-1	inner hex wall gusset type 1
2	20007954-2	Inner hex wall gusset type 2
2	20007955-1	blade spring post gusset type 1
1	20007955-2	blade spring post gusset type 2
6	20007956-1	hex outer corner clip
1	20007957-1	top plate
1		hardware



Tools required

QTY	Part Number	Description
6		2-4-6 toolong blocks
1		48" 3 pt sling
1		10 - 150 ft lb torque wrench
3		hoist rings
6		1000 # load cells
1		height gage



Estimated time to assemble 24 hrs

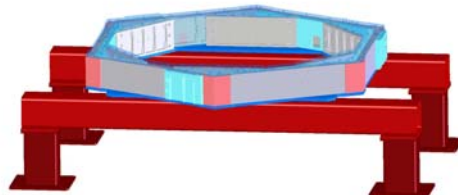
STEP 6B Weigh and record stage 0 weight

1. Assembled weight approximately 1000#s

Estimated time to weigh stage 0 2 hrs

STEP 6C Lift stage 0 and fasten to assembly stand

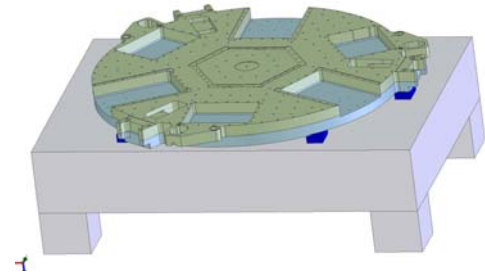
Estimated time to install on assembly stand 2 hrs



STEP 7A Assemble stage 2 optical table on granite plate

Parts required

QTY	Part Number	Description
1	20007846	upper optical table
1	20007847	lower optical table
1		hardware
1250		optical table helicoils



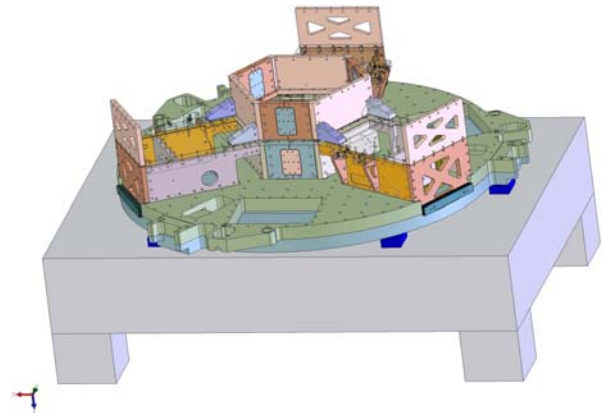
Estimated time to assemble optical table _____ 20 hrs _____

STEP 7B Assemble stage 2 structure assembly on granite table minus keel plate

note: bolts attaching structure to optical table are to be hand tight only.

Parts required

QTY	Part Number	Description
1	20007850-1	base plate
3	20007851-1	side plate
3	20007852-1	side plate gs-13
3	20007853-1	angled hex wall
3	20007854-1	hex half wall, left, optical table
3	20007854-2	hex half wall, right, optical table
3	20007855-1	hex wall splice, thru holes
3	20007855-2	hex wall splice, tapped holes
3	20007856-1	angled hex wall, keel table
3	20007857-1	hex wall half, left keel table
3	20007857-2	hex wall half, right keel table
3	20007858-1	hex wall splice, thru holes
3	20007858-2	hex wall splice, tapped holes
3	20007859-1	gs-13 gusset, solid
3	20007859-2	gs-13 gusset, cutout
3	20007860-1	baseplate stiffeneing gusset, L
3	20007860-2	baseplate stiffeneing gusset, R
3	20007861-1	gs-13 bay closeout plate
3	20007862-1	keel table brace plate
3	20007863-1	gs-13 bay bulkhead plate
3	20007864-1	gs-13 angle bracket, long
3	20007865-1	gs-13 angle bracket, short
3	20007866-1	trim weight plate
1		hardware



Tools required

QTY	Part Number	Description
6		2-4-6 toolong blocks
1		48" 3 pt sling
1		10 - 150 ft lb torque wrench
3		hoist rings
6		1000 # load cells
1		height gage

Estimated time to assemble stage 2 _____ 32hrs _____

STEP 7C Lift structure and record weight

1. Assembled weight approximately 1080#s for structure and 1600#s for optical table

Estimated time to lift and record weight _____ 2 hrs _____

STEP 7D Remove stage 2 structure assembly from optical table and set aside

Estimated time to disassemble stage 2 from optics table _____ 2 hrs _____

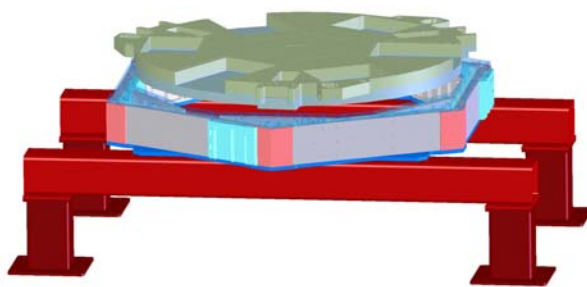
STEP 7E Install optical table to test stand

1. The optical table is attached to the stage 0 structure at three points using tooling posts attached to stage 0
2. The tooling posts nominally position the optical table relative to the stage 0 structure in the x,y, and z directions via precision interfaces machined into the lower half of the optical table
3. Level the optical table using precision level and vertical adjustment on posts.
4. Verify with height gage at 6 locations around the table.

Tools required

QTY	Part Number	Description
3		tooling posts
1		48" 3 pt sling
1		10 - 150 ft lb torque wrench
3		hoist rings
6		1000 # load cells
1		height gage
1		precision machinists level

Estimated time to install optical table to test stand _____ 8 hrs _____

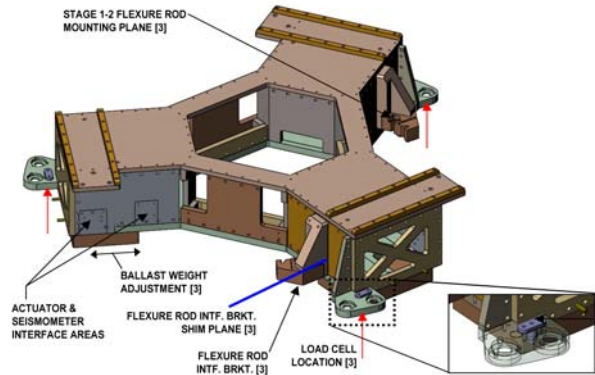


STEP 8A Assemble stage 1 assembly on granite plate

1. Verify flex rod attachment plane interfaces
2. Verify actuator and seismometer locations
3. Shim flex rod brackets to level datum plane
4. Lift assembly and place on 3 load cells
5. Install ballast and trim masses, adjust CG as necessary

Parts required

QTY	Part Number	Description
1	20007826-1	base plate
3	20007827-1	angled hex wall
3	20007828-1	side plate (flex rod interface)
3	20007829-1	side plate (I4-c interface)
3	20007830-1	hex midwall
3	20007831-1	sts-2 bay closeout plate
3	20007832-1	hex inner stiffening bar
3	20007833-1	kinematic lock/locator gusset
6	20007834-1	I4-c overhang tab stiffener
1	20007835-1	stage 1 structure closeout plate
3	20007836-1	ballast weight
3	20007837-1	trim weight plate
3	20007900-1	flex rod bracket shim
3	20007901-1	flex rod bracket
3	20007902-1	flex rod bracket gusset
1		hardware



Tools required

QTY	Part Number	Description
6		2-4-6 toolong blocks
1		48" 3 pt sling
1		10 - 150 ft lb torque wrench
3		hoist rings
6		1000 # load cells
1		height gage

Estimated time to assemble stage 1 24 hrs

STEP 8B Lift structure and record weight

1. Assembled weight approximately 1390#s for structure

Estimated time to lift and record weight 2 hrs

STEP 8C Remove top plate from stage 1 assembly and install sts-2 pod assemblies

Estimated time to install pods 4 hrs

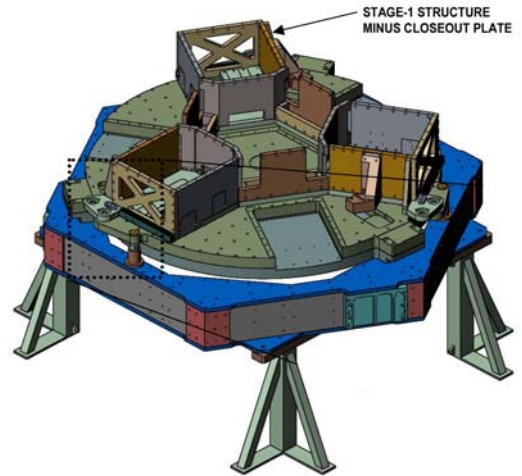
STEP 9A Install stage 1 to test stand

1. Tooling pins are installed that interface with three corresponding radial blind slots on the optical table. This locates the stage 1 structure relative to the optical table in the x,y, and z directions.

Tools required

QTY	Part Number	Description
1		48" 3 pt sling
1		10 - 150 ft lb torque wrench
3		hoist rings
1		height gage
1		precision tooling pin

Estimated time to install stage 1 _____ 8 hrs _____



STEP 9B Install gs-13 pod assemblies to stage 2

Estimated time to install pods _____ 2 hrs _____

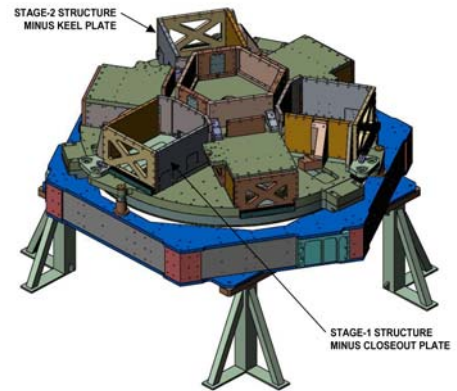
STEP 10A Install stage 2 to optical table with top plate removed

1. The stage 2 structure with keel plate removed is set down and fastened to the optical table.
2. Inspect overall workmanship and torque of fasteners.

Tools required

QTY	Part Number	Description
1		48" 3 pt sling
1		10 - 150 ft lb torque wrench
3		hoist rings

Estimated time to install stage 2 to optical table _____ 8 hrs _____



STEP 11A Install stage 1 top plate to stage 1 structure

Estimated time to install stage 1 top plate _____ 4 hrs _____

STEP 12A Assemble keel plate Subassembly on Granite Table

Parts required

QTY	Part Number	Description
1	20007848-1	upper keel plate
1	20007849-1	lower keel plate
1		hardware

Tools required

QTY	Part Number	Description
1		48" 3 pt sling
1		10 - 150 ft lb torque wrench
3		hoist rings

Estimated time to assemble keel plate _____ 4 hrs _____

STEP 12B Lift keel plate and weigh

1. Weight of keel plate assembly ~ 1400#s

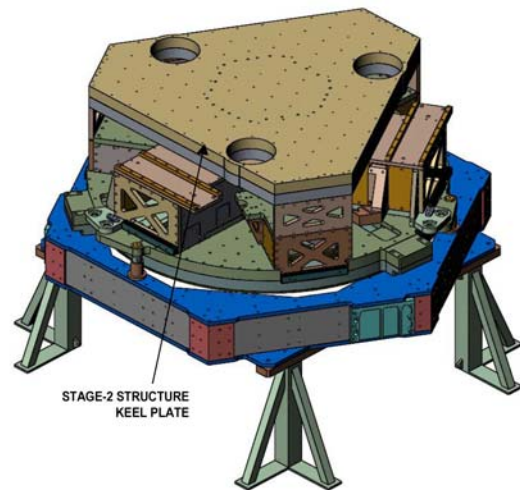
Estimated time to lift and weigh keel plate _____ 2 hrs _____

STEP 12C Attach keel plate to stage 2 structure

Tools required

QTY	Part Number	Description
1		48" 3 pt sling
1		10 - 150 ft lb torque wrench
3		hoist rings

Estimated time to attach keel plate _____ 8 hrs _____

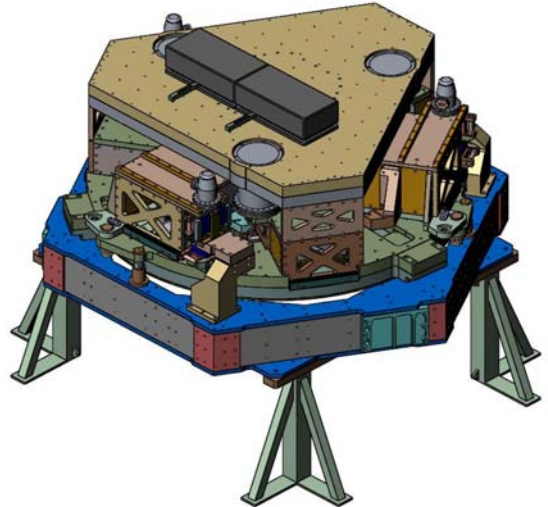


STEP 13A Attach keel mass and mass simulators

1. All masses and mass simulators are installed onto the stage 1 and 2 structure so that each stage is at the correct nominal weight

Parts required

QTY	Part Number	Description
2		keel ballast mass
6		keel ballast tiedowns
6		I4-c pod assembly
6		large actuator bobbin simulator
6		large actuator field simulator
6		small actuator field simulator
6		small actuator bobbin simulator
1		optical payload mass



Tools required

QTY	Part Number	Description
1		48" 3 pt sling
1		10 - 150 ft lb torque wrench
3		hoist rings

Estimated time to attach masses _____ 8 hrs _____

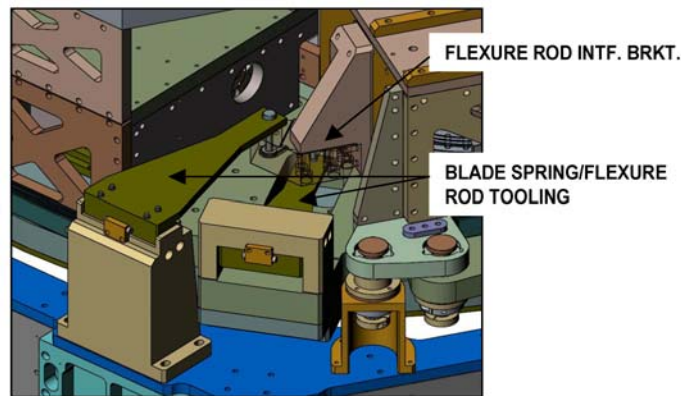
STEP 14A Install stage 0 to 1 and stage 0 to 2 blade spring posts and saddles

1. Stage 0-1 blade spring mounting posts and stage 1-2 blade spring saddles are positioned and installed with tooling which simulates the blade springs and flexure rods when loaded
2. Blade spring posts and saddle mounting bolts are tightened and the tooling removed

Tools required

QTY	Part Number	Description
1		10 - 150 ft lb torque wrench
6		blade spring simulator tools

Estimated time to install spring posts and saddles _____ 4 hrs _____



STEP 14B Install stage 0 to 1 and stage 0 to 2 blade springs to posts and saddles

1. Blade springs are fastened to the respective mounting posts and saddles
2. Blade spring tips are deflected nominally plus 1mm using preload tool to facilitate flex rod installation
3. Flexure rods are installed, seated, and preload tools removed
4. Tooling posts and pins used to secure the stages are removed

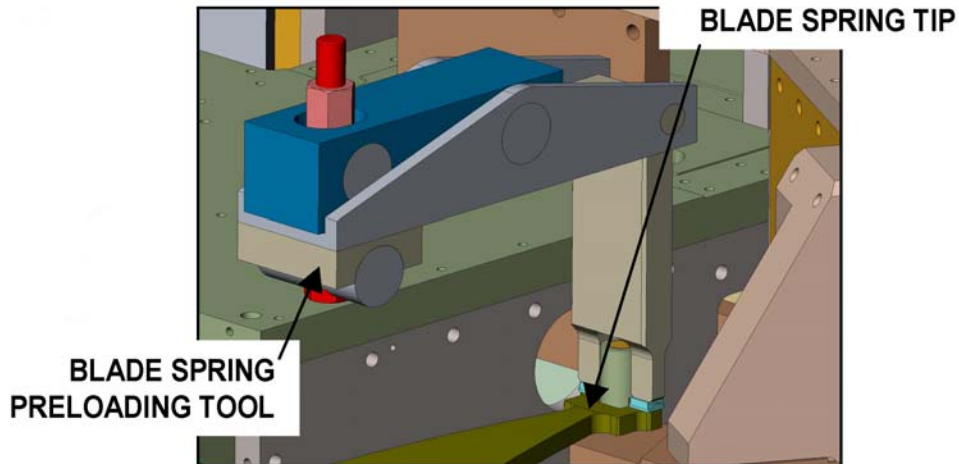
Parts required

QTY	Part Number	Description
3	20007880-1	stage 0-1 flex rod
3	20007881-1	stage 0-1 rod shim, blade side
3	20007881-2	stage 0-1 rod shim, bracket
3	20007880-2	stage 1-2 flex rod
3	20007881-3	stage 1-2 rod shim, blade side
3	20007881-4	stage 1-2 rod shim, bracket
1		hardware

Tools required

QTY	Part Number	Description
1		10 - 150 ft lb torque wrench
6		blade spring preload tool

Estimated time to install springs and flexure rods _____ 12 hrs _____

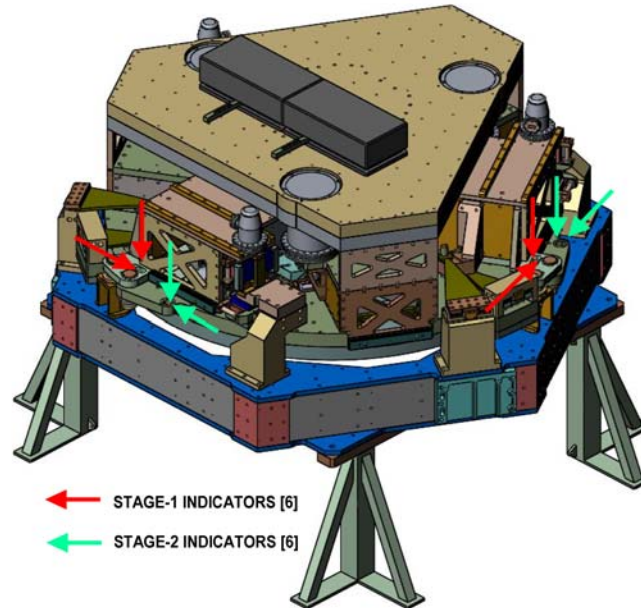


STEP 15A Install stage 0 to 1 actuators, locators, displacement sensors, and locks

Parts required

QTY	Part Number	Description
3	20007903-1	actuator post
3	20007904-1	actuator bridge
3	20007905-1	vertical actuator field adapter
3	20007906-1	vertical actuator coil adapter
3	20007907-1	vertical actuator coil adapt brkt
3	20007908-1	horiz actuator field adapter
3	20007909-1	horiz actuator field adapter brkt
3	20007910-1	horiz actuator coil adapter
3	20007911-1	horiz actuator coil adapter brkt
6	20007977-1	actuator thermal bar, left
6	20007977-2	actuator thermal bar, right
3	20007934-1	kinematic lock locator, male
3	20007935-1	kinematic lock locator, opposer
3	20007913-1	disp sensor target post
6	20007914-1	disp sensor target
6	20007932-1	kinematic lock/locator bracket
3	20007933-1	kinematic lock/locator cup
3	20007937-1	female elongated cone
3	20007938-1	locking collar, large
3	20007939-1	locking collar, small
3	20007940-1	locknut large
3	20007941-1	locknut small
3	20007942-1	z position shim
6		stage 0-1 displacement sensor
1		fasteners

Estimated time to install actuators, locators, displacement sensors, and locks 24 hrs



STEP 16A Install stage 1 to 2 actuators, locators, displacement sensors, and locks

Parts required

QTY	Part Number	Description
3	20007917-1	vertical actuator field adapter
3	20007918-1	vertical actuator coil adapter
3	20007919-1	vertical actuator coil adapt brkt
3	20007920-1	horiz actuator field adapter
3	20007921-1	horiz actuator coil adapter
3	20007922-1	horiz actuator field adapter brkt
3	20007923-1	horiz actuator coil adapter brkt
6	20007925-1	disp sensor target post
6	20007926-1	disp sensor target
3	20007978-1	vert actuator thermal bar, left
3	20007978-2	vert actuator thermal bar, right
3	20007979-1	horiz actuator thermal bar, left
3	20007979-2	horiz actuator thermal bar, right
3	20007934-1	kinematic lock/ locator male
3	20007935-1	kinematic lock/ locator opposer
3	20007936-1	kinematic lock/locator cup
3	20007937-1	female elongated cone
3	20007938-1	locking collar, large
3	20007939-1	locking collar, small
3	20007940-1	locknut, large
3	20007941-1	locknut, small
3	20007942-1	z-position shim
6		stage 1-2 displacement sensor
3		stage 0-1 displacement sensor
6		psi large actuator bobbin
6		psi large actuator field
6		psi small actuator bobbin
6		psi small actuator field

Estimated time to install actuators, locators, displacement sensors, and locks 24 hrs

STEP 17A Install cable clamps, thermal straps, actuator and displacement sensor harnesses

1. Clamps, straps, and harnesses will be located and drilled in place on the prototype unit

Parts required

QTY	Part Number	Description
a/r		cable clamps stage 0
a/r		cable clamps stage 1
a/r		cable clamps stage 2
a/r		thermal straps stage 1
a/r		thermal straps stage 2
a/r		thermal strap clamps
3		sts-2 cable harness stage 1
3		sts-2 cable harness stage 2
3		I4-c vert cable harness stage 1
3		I4-c vert cable harness stage 2
3		I4-c horiz cable harness stage 1
3		I4-c horiz cable harness stage 2
3		stage 0-1 vert disp harness
3		stage 1-2 vert disp harness
3		gs-13 vert harness stage 0
3		gs-13 vert harness stage 2
3		gs-13 horiz harness stage 0
3		gs-13 horiz harness stage 2
3		stage 0-1 horiz disp harness
3		stage 1-2 horiz disp harness
3		psi vert small act harness stg1
3		psi vert small act harness stg0
3		psi horiz small act harness stg1
3		psi horiz small act harness stg0

Estimated time to install clamps, straps, actuator and sensor harnesses 24 hrs

Total estimated hours to assemble BSC prototype 344 hrs

STEP 18 Disassemble entire structure and send for cleaning

Total estimated time to disassemble seismic structure 144 hrs

Total estimated hours to assemble BSC in production 240 hrs