



Advanced LIGO
SUS Installation into BSC Chambers:
Mechanical Fixtures

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(with input from many)

G050245-00

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Scope

- Scope limited to installation of Adv. LIGO SUS into BSC chambers (although use of fixtures for installation of other equipment is noted)
- Identify the major steps in the mechanical installation sequence and the tooling or procedure development needed to support the installation
- Specifically address review of two special purpose installation fixtures:
 - Payload Polar Positioning Fixture (P3F)^[1]: A fixture which supports payloads for the BSC optics table from underneath and precisely positions the payload (in a polar coordinate system).
 - Articulated Installation Arm: A multi-linkage fixture which mounts to the BSC main access port flange, reaches outside to pick up BSC optics table payloads and reaches inside to transfer the payload to the P3F (or possibly to directly transfer the payload to the optics table, if a vertical lift/positioning capability is added to its interface).
- Subsystem assembly is not addressed. Electronics installation and optical alignment are also not within the scope of this document or associated review.

^[1] OK, I admit that this is a lame name, but I don't care for the alias "lazy Susan". Any better names?



Applicable Documents

- 1) O. Spjeld, Advanced LIGO Quad Suspension Installation Fixtures Design Review, 26 Apr 2005, LIGO-T050071-00
- 2) K. Mailand, Advanced LIGO Lower Quad Suspension Installation Fixture Arm, 2 May 2005, LIGO-T050073-00
- 3) D. Coyne, Stress Analysis of the Lower BSC Chamber with an Installation Fixture Cantilevered from the Main Port Flange, 17 Dec 2004, LIGO-T040234-00
- 4) D. Coyne, Advanced LIGO Assembly & Installation Plan, 14 Oct 2004, LIGO-G040459-00
- 5) J. Romie, C. Torrie, M. Perreur-Lloyd, Advanced LIGO Quadruple Pendulum Suspension Failure Modes and Subsequent Repair Approaches, 19 Jul 2004, LIGO-E040329-03
- 6) B. Bland, C. Gray, K. Ryan, R. Savage, Observatory Contamination Control Plan, 8 Mar 2001, LIGO-M990034-C
- 7) K. Mason, Initial Alignment Storyboard (LASTI), 18 Mar 2005, LIGO-pending.
- 8) C. Torrie, et. al., Controls Prototype ETM Suspension, presentation at the LSC Meeting, 22 Mar 2005, LIGO-G050175-01
- 9) C. Cantley, et. al., ETM Controls Prototype: "3 & 1" Assembly Technique, LIGO-T050034-00
- 10) D. Coyne, Seismic Isolation System (SEI) Payload Mass Properties (Advanced LIGO), 18 Mar 2004, E040136-00
- 11) ...

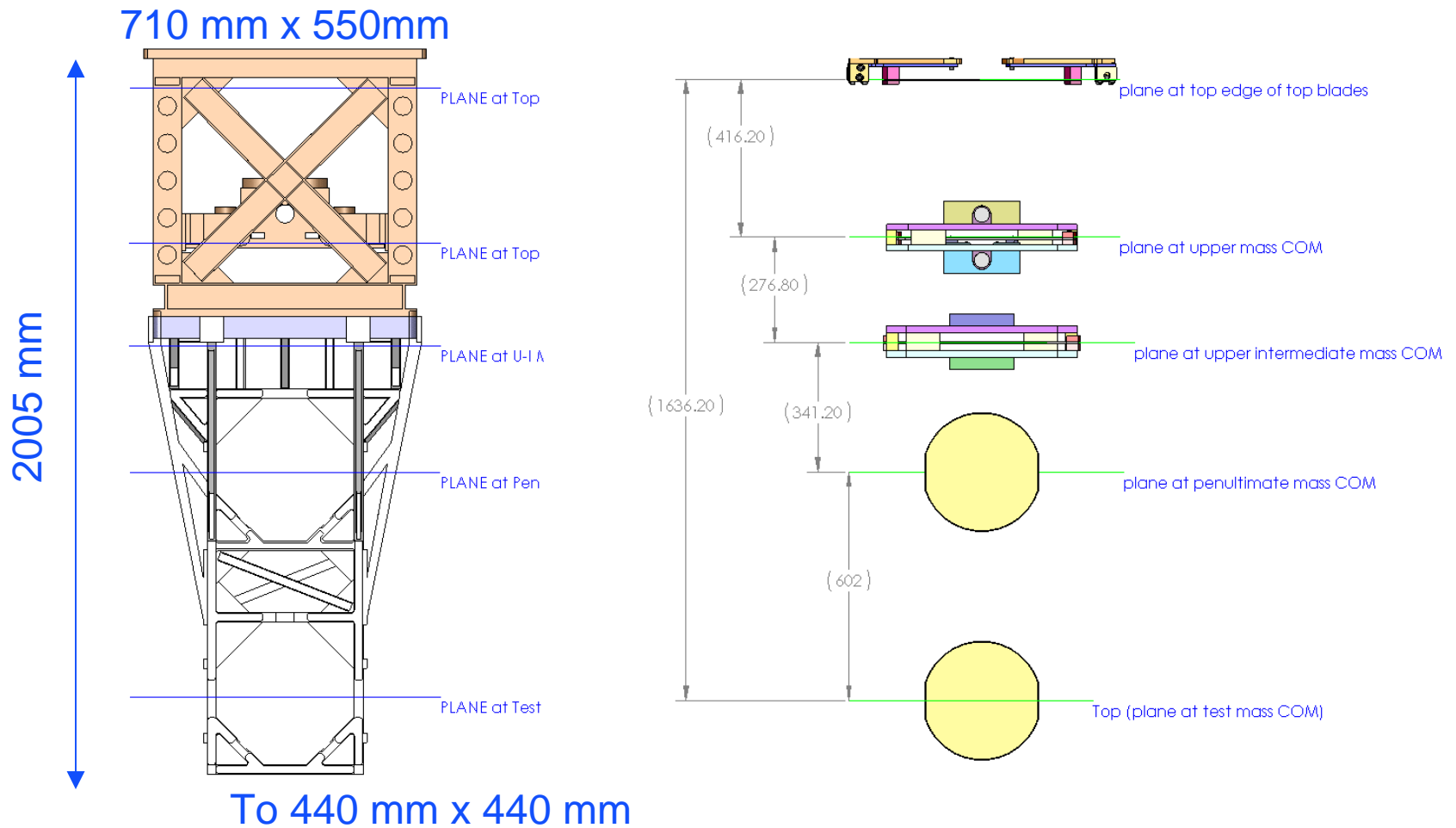


Payload to be Installed in BSC Chambers

- SUS:
 - » ITM (quadruple pendulum)
 - » ITM/FM combined assembly
 - » BS (triple pendulum)
 - » ETM (quadruple pendulum)
 - So far this is the only SUS/BSC assembly with any significant design detail
 - ITM is very similar
 - BS is lighter but similar in dimensions
- Non-SUS:
 - » AOS ETM Transmission Telescope
 - » AOS Beam Dumps (possibly baffles separate from SUS)
 - » AOS Pick Off Mirror Assemblies
 - » SEI Payload Mass Make-Up & Balance Mass
 - » Instrumentation, misc.



Layout of the ETM SUS Controls prototype, reference LIGO-T010103





ETM Controls Prototype Mass Budget

Cf. 418 kg from LIGO-T030137

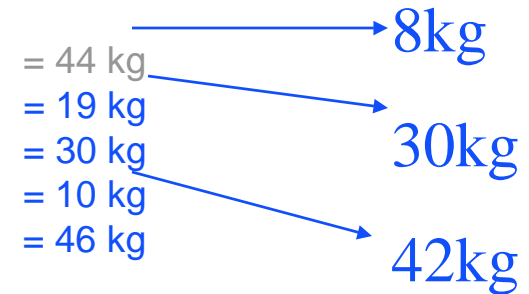
Upper Section = 149 kg, or 328 lbs.
 Lower Section = 272 kg, or 600 lbs
 Total = 422 kg, or 930 lbs.

18th March



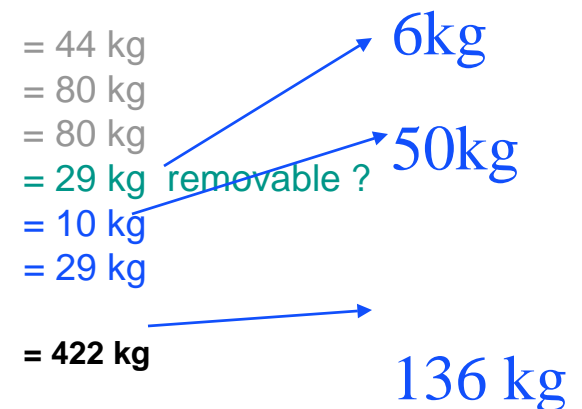
● UPPER

- » TOP MASS, 22 kg x 2 (S)
- » Tablecloth etc ... (NS) 15 kg + 25 % C
- » Top Stage (NS) 24 kg + 25 % C
- » Ring (NS) 5 kg + 100 % C
- » UPPER STRUCTURE 37 kg + 25 % C



● LOWER

- » UI MASS, 22 kg x 2 (S)
- » PEN MASSES, 40 kg x 2 (S)
- » TEST MASSES, 40 kg * 2 (S)
- » CLAMPING etc, 23 + 25 % C (NS)
- » Ring (NS) 5 kg + 100% C
- » Lower Structure (NS) 23 kg + 25% C



TOTAL

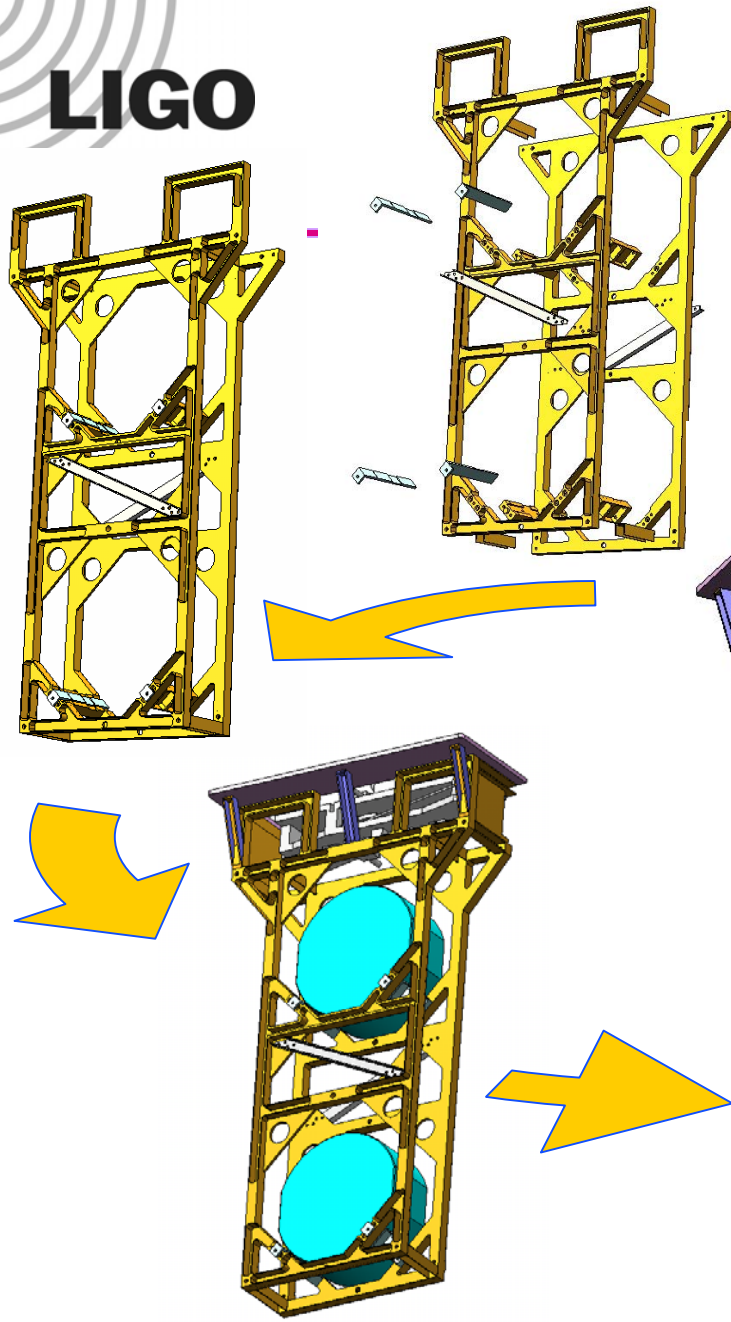
OVERALL NON-SUSPENDED inc. STRUCTURE

~ 140 kg *

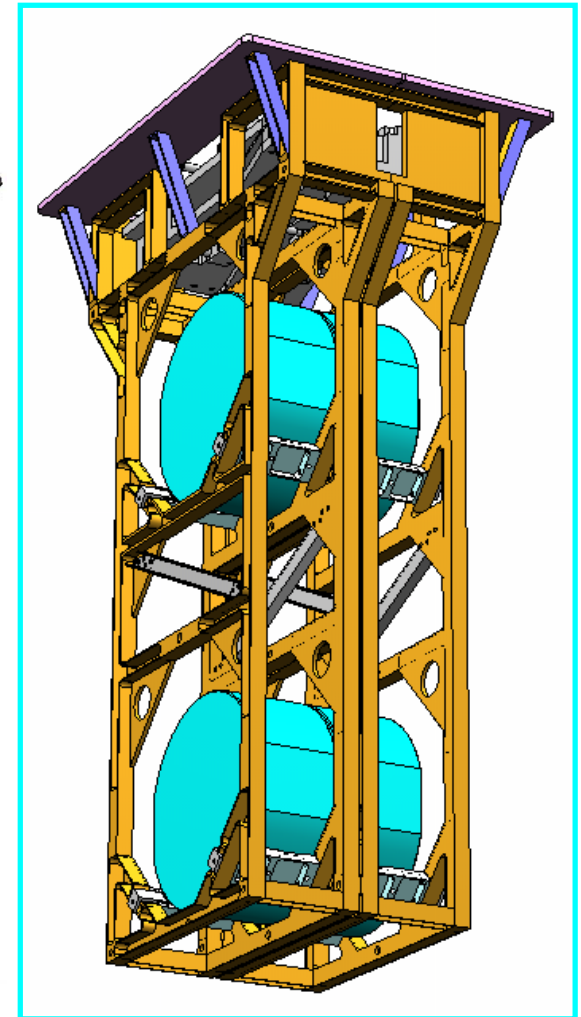
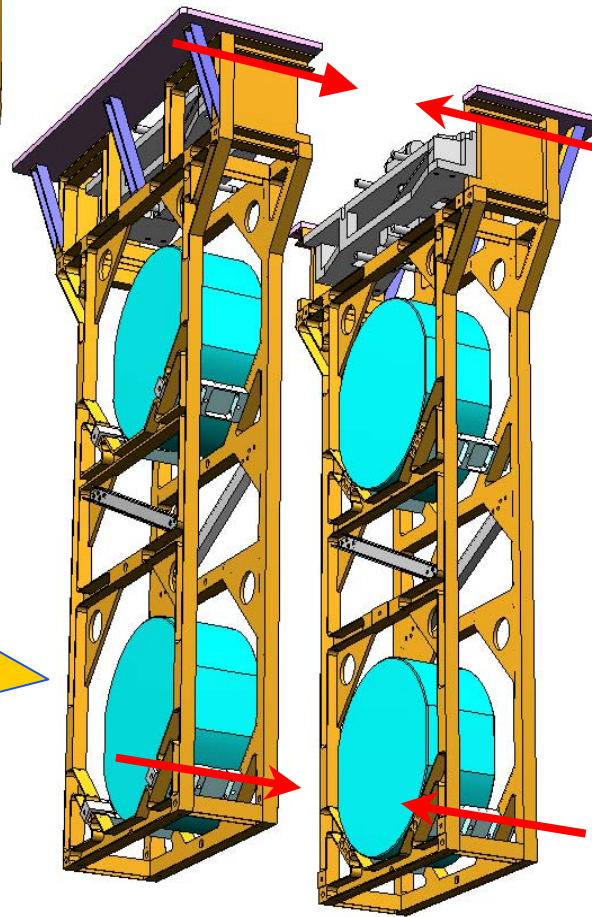


BSC SUS are Two-Part Assys

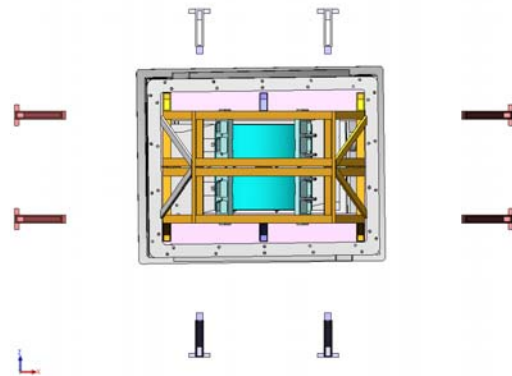
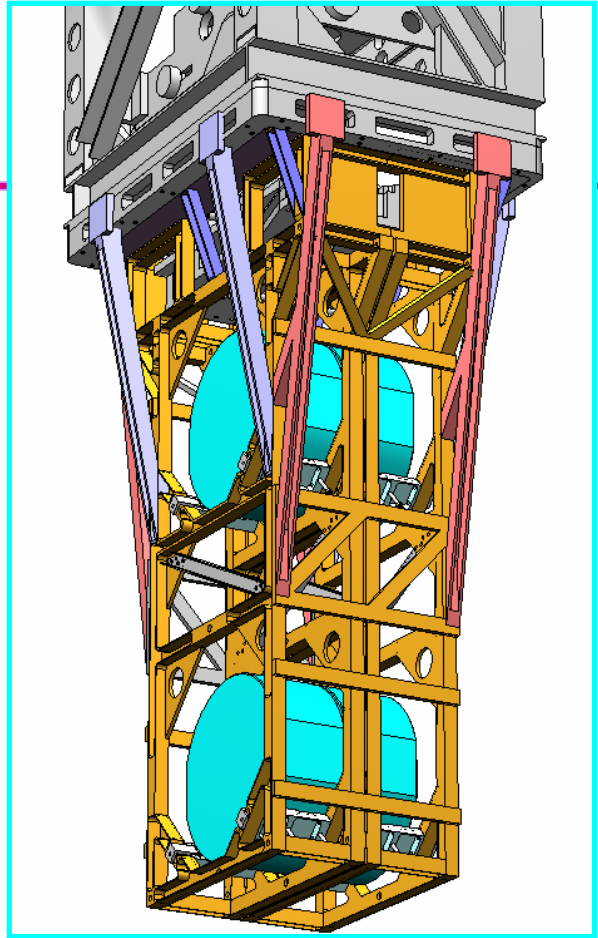
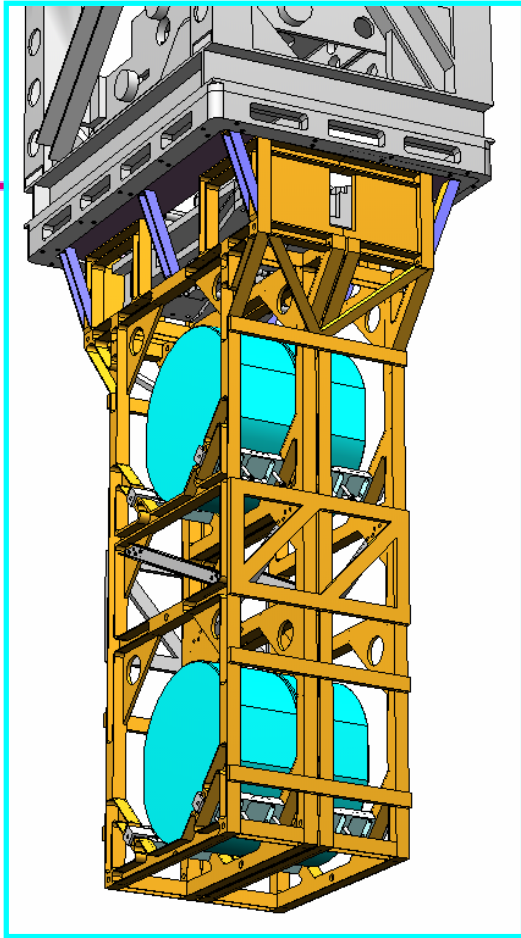
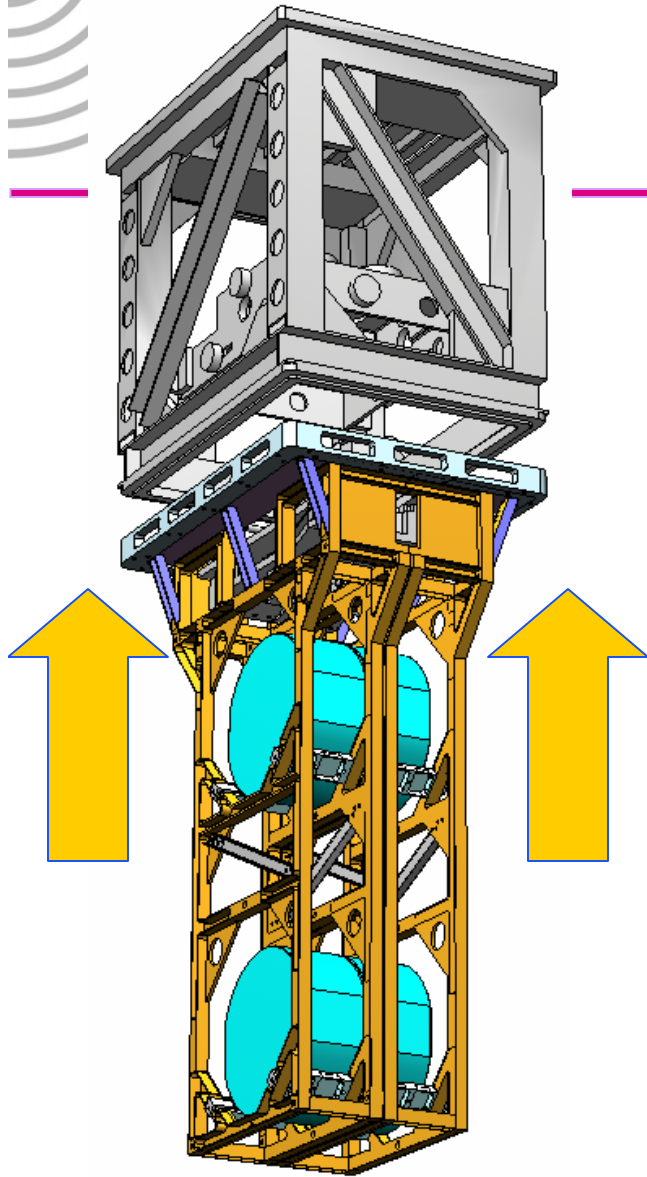
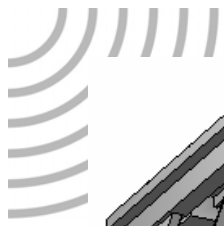
- The BSC SUS assemblies have an upper and lower section which are joined just before installation
 - » Two-section design facilitates welded silica fiber welding and upper stage wire suspension assembly & disassembly (in the event of fiber failure)
 - » Total height of BSC SUS assemblies exceeds BSC door height, but individual sections can fit through the door
- Enables two fundamental approaches to installation:
 - » Assembly entire SUS onto SEI optics table outside the chamber & then install as a “cartridge” from above (after removing BSC chamber dome)
 - This is the preferred approach for initial installation
 - » Bring lower section through one of the BSC access ports and join to the upper section
 - This is essential for repairs and replacement (e.g. broken silica fiber or magnet bond)



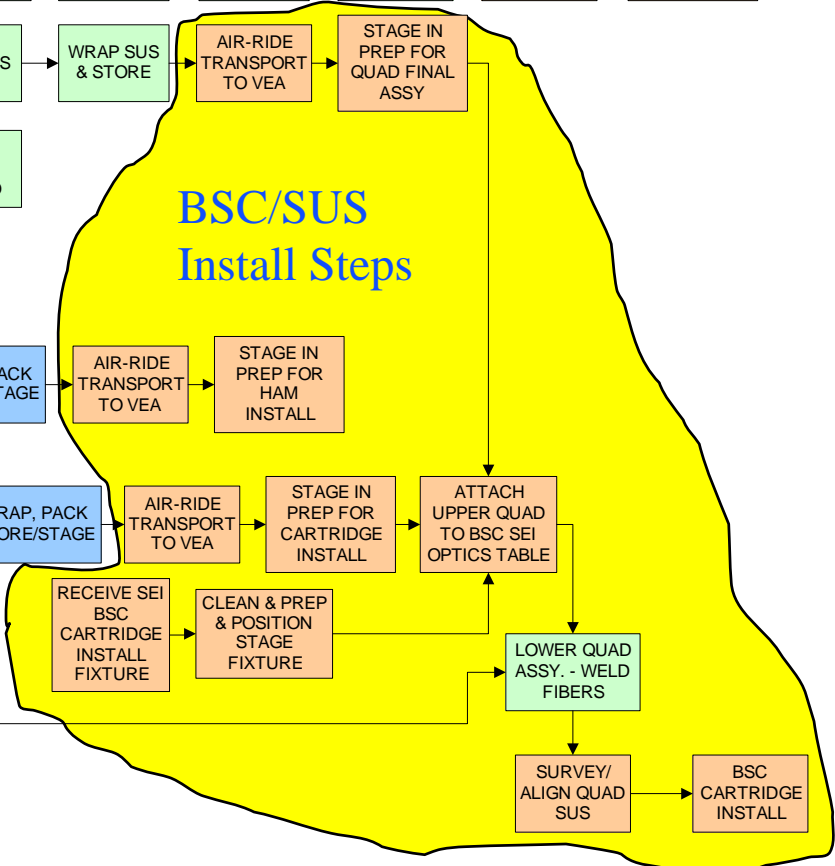
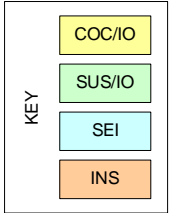
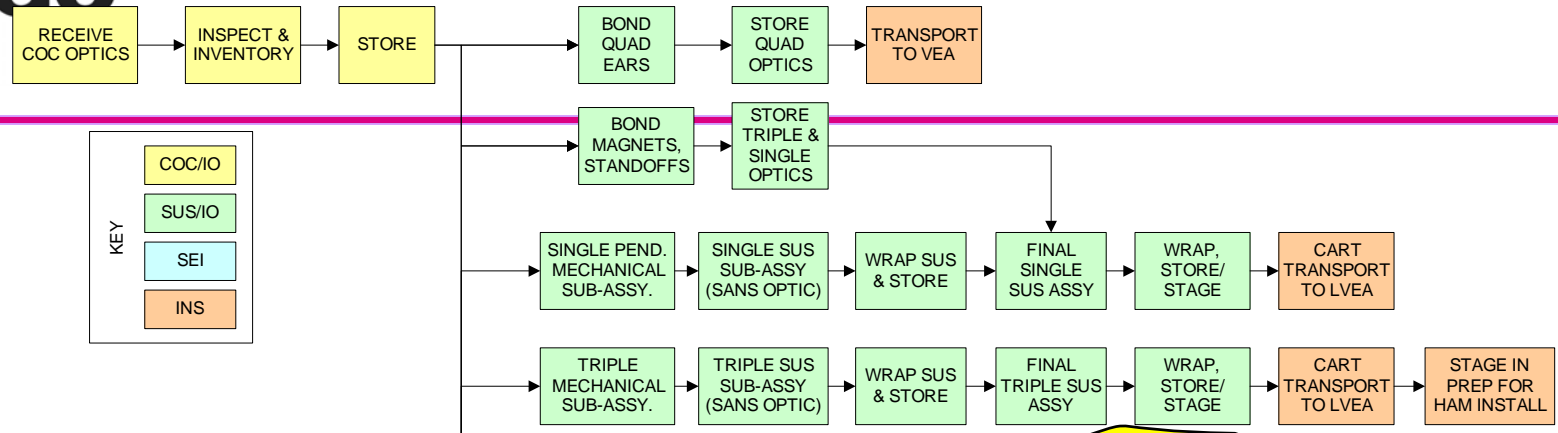
“3 & 1” assembly Technique,
reference LIGO-T050034



LIGO-G050xxx-00-D



LIGO-G050xxx-00-D

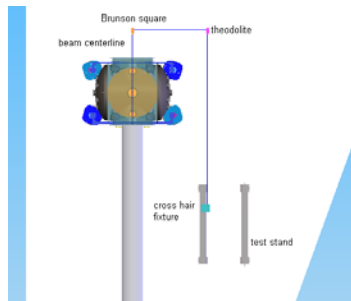




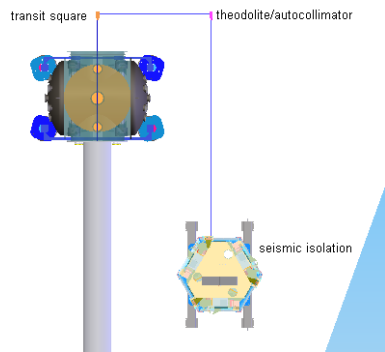
Basic BSC Cartridge Installation

(0) Prerequisites completed (Initial LIGO detector components removed, HEPI installed, etc.)

(1) Stage cleaned, assembled, tested subsystem units in (L)VEA, Place Cleanrooms, Remove Upper Dome from the BSC chamber, prepare ...

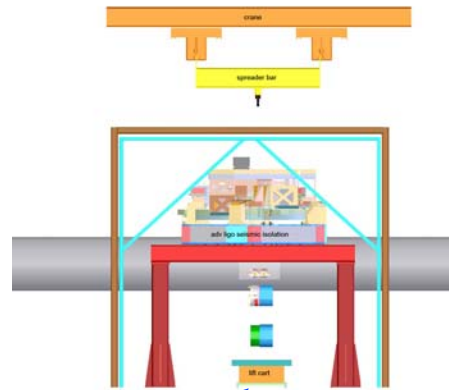


(2) Set up Cartridge Assembly Stand under BSC cleanroom adjacent to BSC chamber



(3) Place Internal Seismic Isolation (ISI) part of SEI onto Cartridge Assembly Stand. Set up alignment references.

LIGO-G050xxx-00-D



(4) Assemble payload assemblies onto the BSC optics table. Use standard handling equipment for transport to Cartridge assembly stand area under BSC cleanroom.

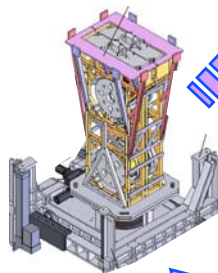
P3F Lift Table (without support beam, placed on stand to set proper height).

Lower Section of Quad placed on P3F support plate using Genie Lift or similar handling equipment

Upper section of Quad placed atop lower section also using Genie lift (or similar) where precision positioning is provided by the P3F.

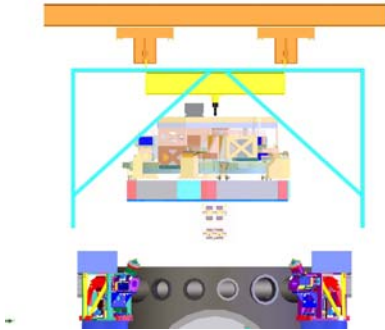
Once the upper & lower sections of the SUS are joined, the P3F is used to position and lift/attach the SUS to the optics table, guided by LOS/IAS optical survey.

“cartridge” assembly continues with payload elements positioned/aligned attached to the optics table on the assembly stand. Co-alignment/positioning of element (relative to one-another is important) and absolute alignment is less important at this point.



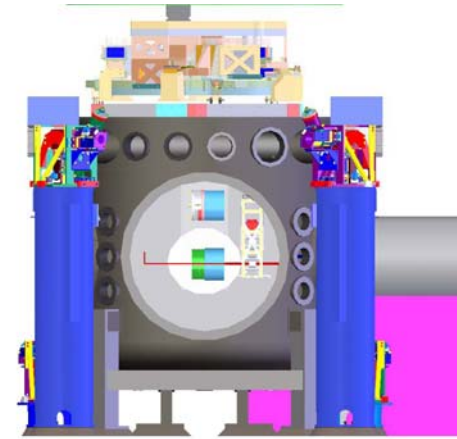


Basic BSC Cartridge Installation continued

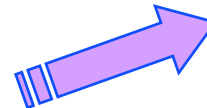
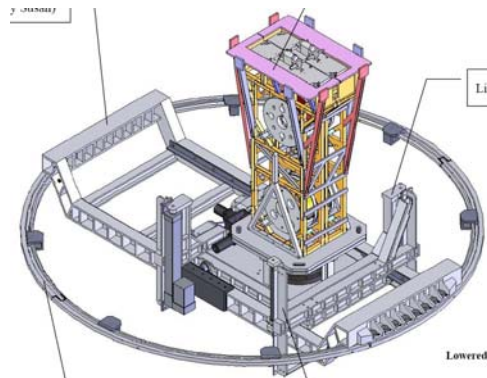


(5) Overhead crane lift of the “cartridge” assembly with a protective shroud (Tyvek or similar wrapping around a frame) & insert into the BSC chamber from above. Attach the ISI/SEI to the support tubes.

(6) Using the +/- 5mm range of the HEPI system (actuators disconnected, offload spring adjustments), fine align the position and orientation of the cartridge, guided by optical survey equipment



(7) The P3F is only needed for the cartridge installation if an error has been made in the relative positioning of payload elements, or the error in positioning exceeds the HEPI static re-positioning range.



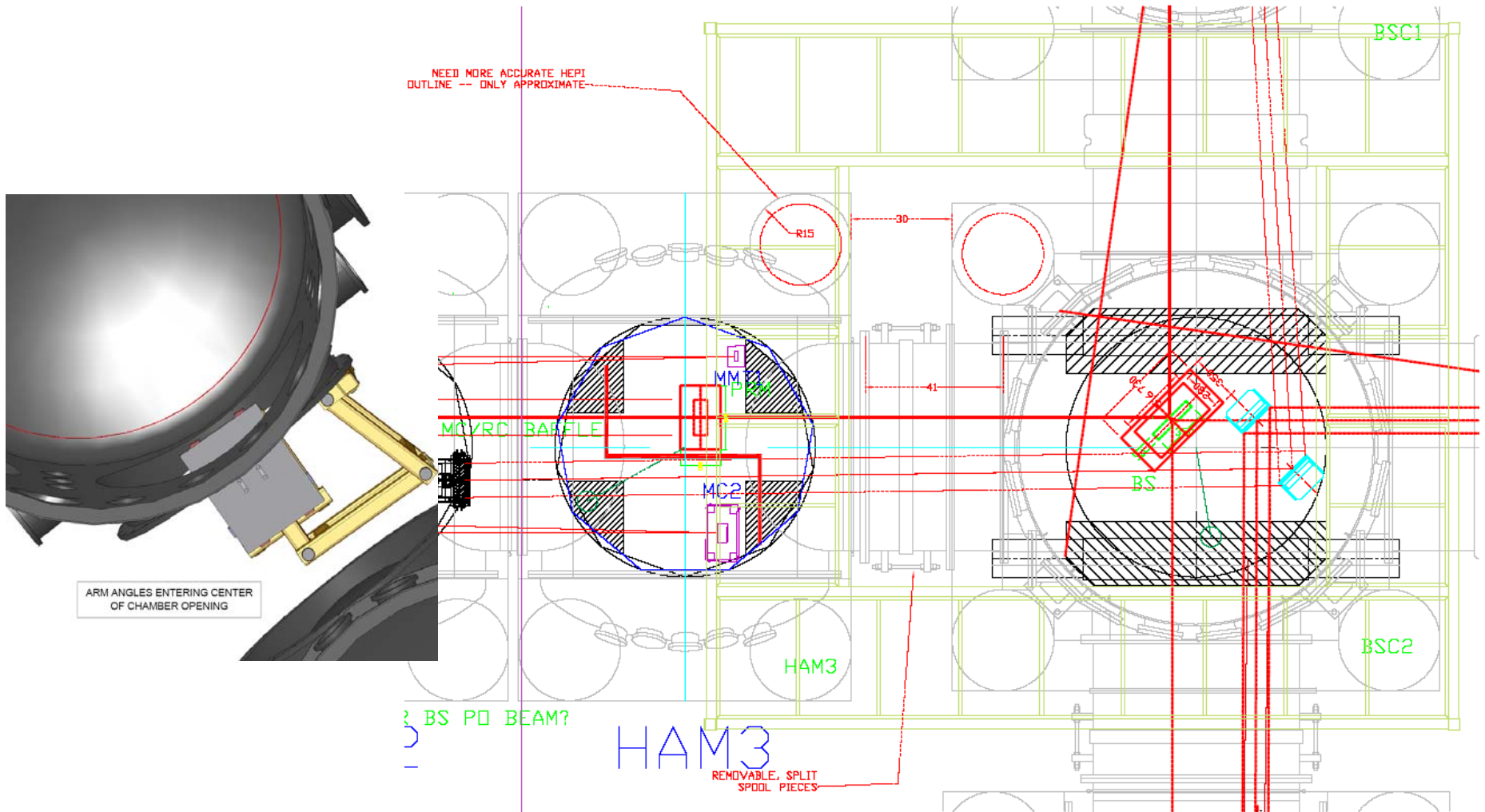


BSC SUS R&R

- Repair & Replacement: some failure modes require (or may require) removal of the SUS assembly, or the lower section of the SUS
 - » Fiber failure(s)
 - » Magnet bond failure
 - » COC “ear” bond failure, etc.
 - » Damaged or contaminated optic
- SUS R&R should not (generally) necessitate BSC upper dome removal; repair should be made through the main BSC chamber access ports
 - » Can be accomplished by installing the P3F under the SUS
 - » Transfer the lower SUS section (or even the entire SUS assembly) to the F3P and move to the BSC door
 - » Transfer from the F3P out of the BSC with a suitable interface structure mounted to the forklift
 - » Exceptions:
 - The BSC chamber with the BS SUS – can’t reach with the forklift -- use the Articulated Installation Arm for transfer out of the chamber
 - Tight access areas like around BSC1 – use the Articulated Installation Arm mounted to the Forklift boom or the BSC chamber



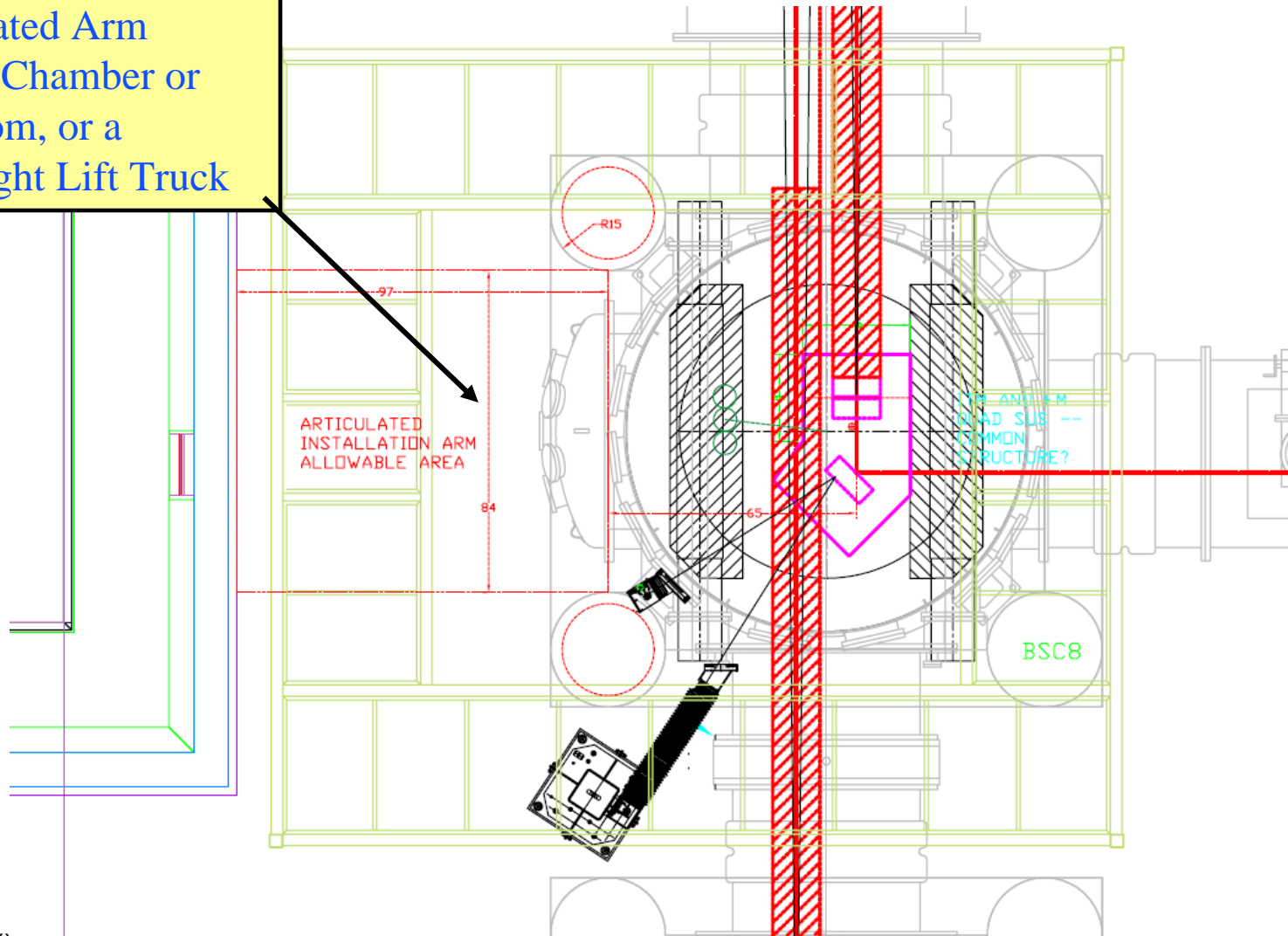
Articulated Installation Arm @BSC2





Restricted access for transfer into P3F

Use Articulated Arm Mounted to Chamber or Forklift Boom, or a Counterweight Lift Truck





Other uses for the Articulated Installation Arm

- Removal & replacement of the lower SUS section without the use of the F3P?
 - » The compliment of the F3P fixture for initial LIGO was cumbersome & time consuming to install
 - » The new design should eliminate the binding problems but it is still a formidable assembly to install around our delicate optics
 - » With a suitable vertical lift and tip/tilt capability added to the end of the arm, it might serve as a more efficient means for R&R of the lower SUS section (especially the BS which is considerably lighter)
- Installation of other payload elements added to the end of the arm:
 - » Counterbalance masses
 - » ETM Transmission telescope
 - » Pick-off Mirror assemblies
 - » Etc.

