Advanced LIGO Assembly & Installation Plan

14 Oct 2004

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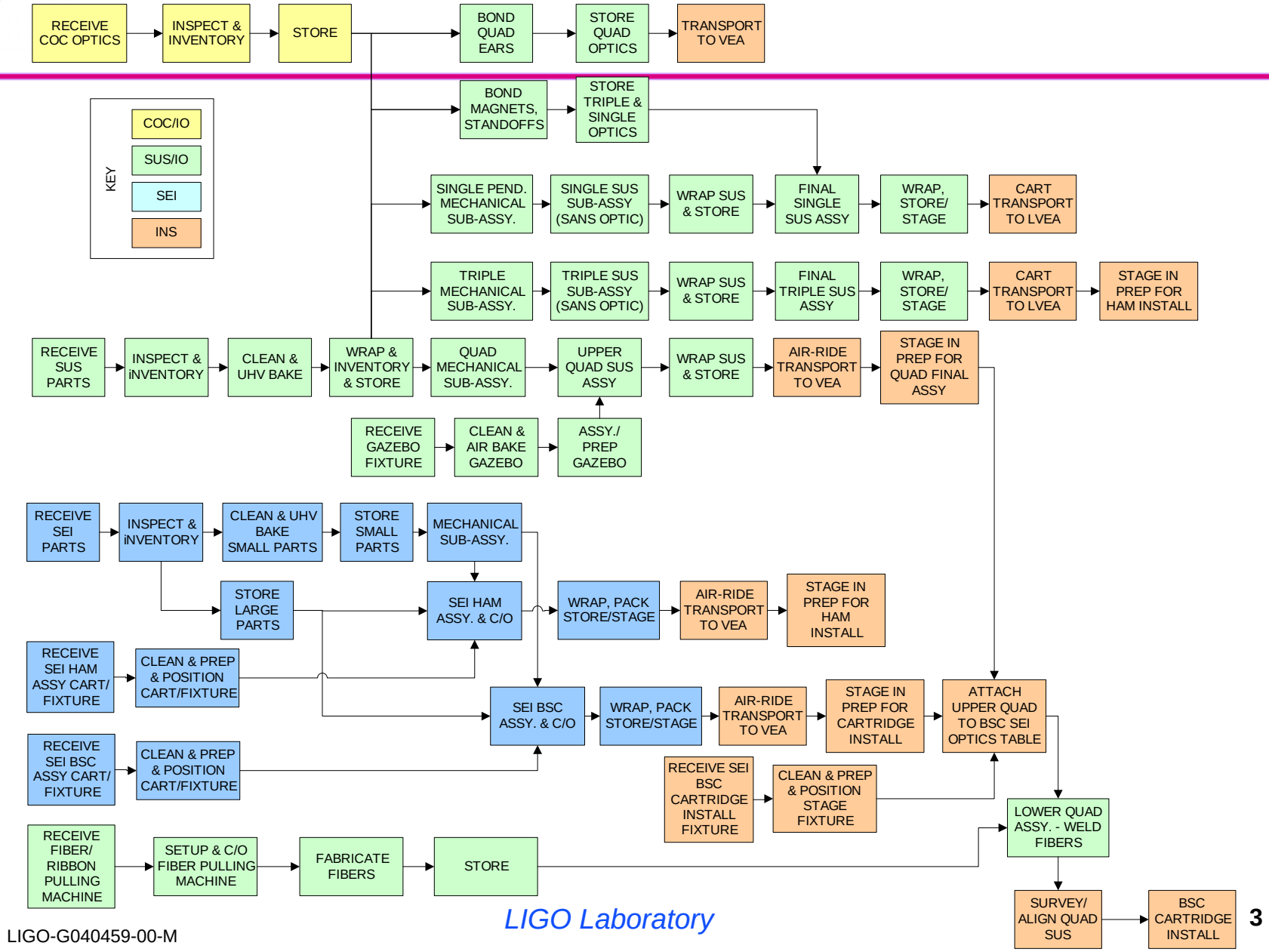
Outline

- **Purpose:**
  - **Outline a top level plan as a starting point for discussion**
  - **Flesh out details with feedback from subsystem leaders and observatory staff**
  - **Determine if there are any significant implications on schedule or costs compared to the current costbook**
  - **Propose a definition for installation readiness**
- **Subsystem Basic Tasks/Activities**
  - **Facility Requirements**
  - **New Equipment &/or Facility/Space Needs**
- **Available Facilities/Spaces**
  - **Assembly**
  - **Storage**
  - **Clean Rooms**
  - **Identify Shared Spaces**
- **Task Sequencing for Assembly**
- **Installation Basic Tasks/Activities and Sequence**

Basic Assembly Tasks (COC/IO, SUS/IO, SEI)



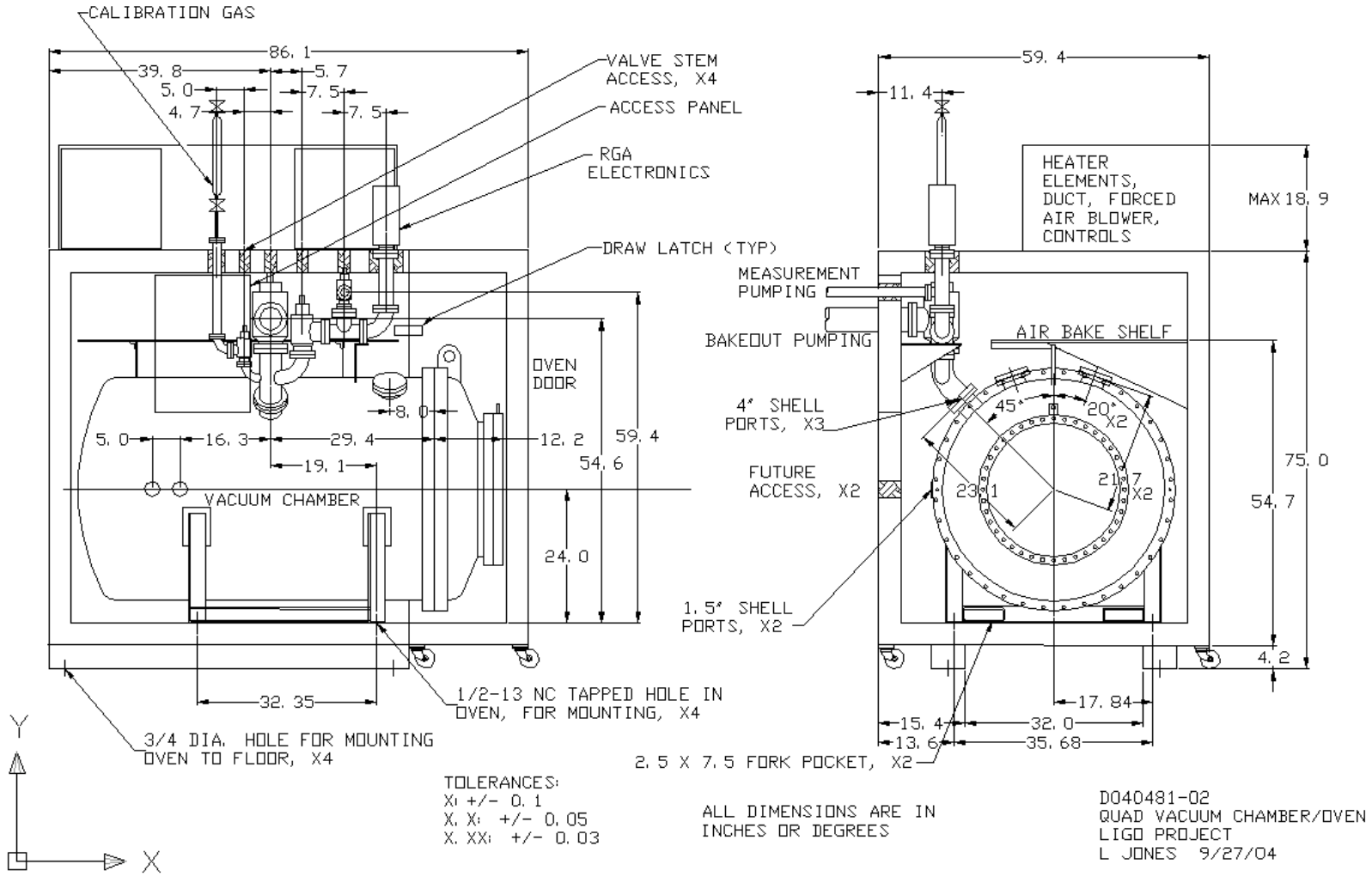
Essential on-site tasks vs. off-site tasks?

- **Limited space and limited availability of observatory staff during science runs for assembly**
- **Perform assembly tasks which do not need to be done at the observatory at CIT, MIT, UFL, … or the other observatory?**
  - » **Risks! e.g. Integration of an ISC Table at MIT and shipping as an assembly was found to be a poor choice in initial LIGO**
  - » **Rather limited space available at CIT, MIT – especially clean room space (but not insignificant)**
  - » **Possible tasks to be performed off-site:**
    - – **HEPI pier assembly**
    - – **Electronics module stuffing, testing**
    - – **Electronics rack, crate assembly**
    - – **Optical lever modules**
    - – **AOS telescope assembly**
    - – **Others?**
  - » **For the chosen tasks/sub-assemblies, Post assembly shipment should not impose difficult design requirements or significant cost or risk**
    - – **i.e. this is a litmus test for tasks best done at the observatory**

Ultra-High Vacuum (UHV) Preparation

- **Proposed requirements (not yet approved by the VRB) are more stringent than for initial LIGO (see T040001)**
  - **~100 x lower partial pressure for high molecular weight hydrocarbons**
  - **Plan to achieve this performance by cleaner bake loads, not added pumping capacity – this approx. at the limit of the sensitivity of the RGAs used on the UHV bake ovens to date**
- **Exploratory large vacuum bake oven being pursued by Larry Jones & Oddvar Spjeld**
  - **Will build unit soon, if funds are approved by the CCB**
  - **Sized to fit the upper quad structure**
  - **Placed within an oven to reduce temperature gradients**
  - **Higher temperature (empty oven) bake**
- **Baseline assumptions:**
  - **one each of these new ovens per observatory, placed into the high bay space (for possible use of electric forklift in loading)**
  - **use of existing ovens (LLO, LHO, CIT)**
  - **Addition of 2 new small ovens at each observatory**
  - **Large SEI parts are ultrasonically cleaned, air baked & FTIR tested**
  - **Class B tools are ultrasonically cleaned, air baked (as before)**

Proposed New Large UHV Bake Oven



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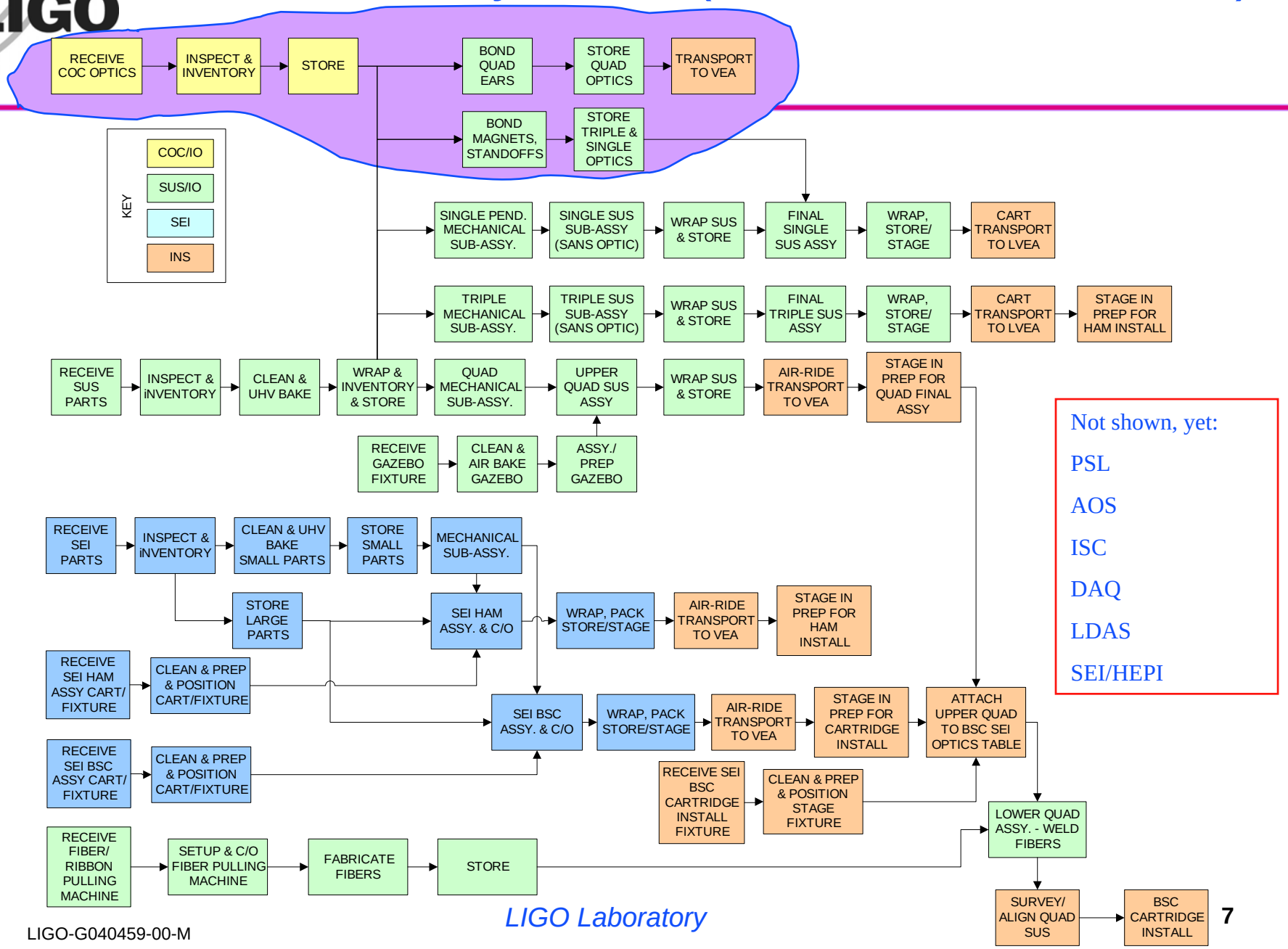


Not shown, yet:

- PSL
- AOS
- ISC
- DAQ
- LDAS
- SEI/HEPI

Limited use of the OSB & LVEA during Science Runs

- **Rules to be verified/reviewed with Observatory staff, …**
- **OSB Labs:**
  - **No use of the vacuum bake oven in the OSB UHV preparation lab**
  - **No use of the HEPI filters (clean rooms) in the OSB optics labs**
  - **Assembly in the electronics shop is OK**
  - **Access to storage areas (shelving) in OSB labs and OSB receiving area is OK for small (hand carried items) – no forklifts**
- **LVEA and VEAs:**
  - **No access for personnel (walking in the vicinity of the chambers can break lock)**
  - **No movement of large loads on the LVEA/VEA slab (can shift alignment)**
  - **No use of overhead cranes**
  - **No use of clean rooms (acoustic and electromagnetic disturbance)**

Optics (COC & IO)

- **Assumption (under review): No metrology at the observatories**
  - » **Polisher/Coater perform all acceptance & characterization measurements**
  - » **Some measurements/checks possible at Caltech**
  - » **Purpose is to minimize exposure**
- **Clean Room Requirements: "better than for initial LIGO at all steps" → Implementation considerations are TBD**
  - » **Assume for now that LIGO Lab spaces plus Class100 clean room erected within is adequate**
- **Optic Cleaning Procedures are TBD**
  - » **Warm liquinox cleaning is no longer acceptable (etches coating)**
  - » **Particulate cleaning: Ionized, particulate free airflow over benches is planned**
- **Basic Paradigm: The optical surfaces are only exposed when absolutely necessary.**
  - » **Special covers to be (essentially) in place at all times**
  - » **More care in keeping particle count down in clean rooms**
  - » **Improved HEPI filtration of lab spaces, work benches**
  - » **Perhaps changed wall & ceiling materials in COC lab space?**
- **Ergonomic Arm for handling large, heavy optics**

ERGO ARM

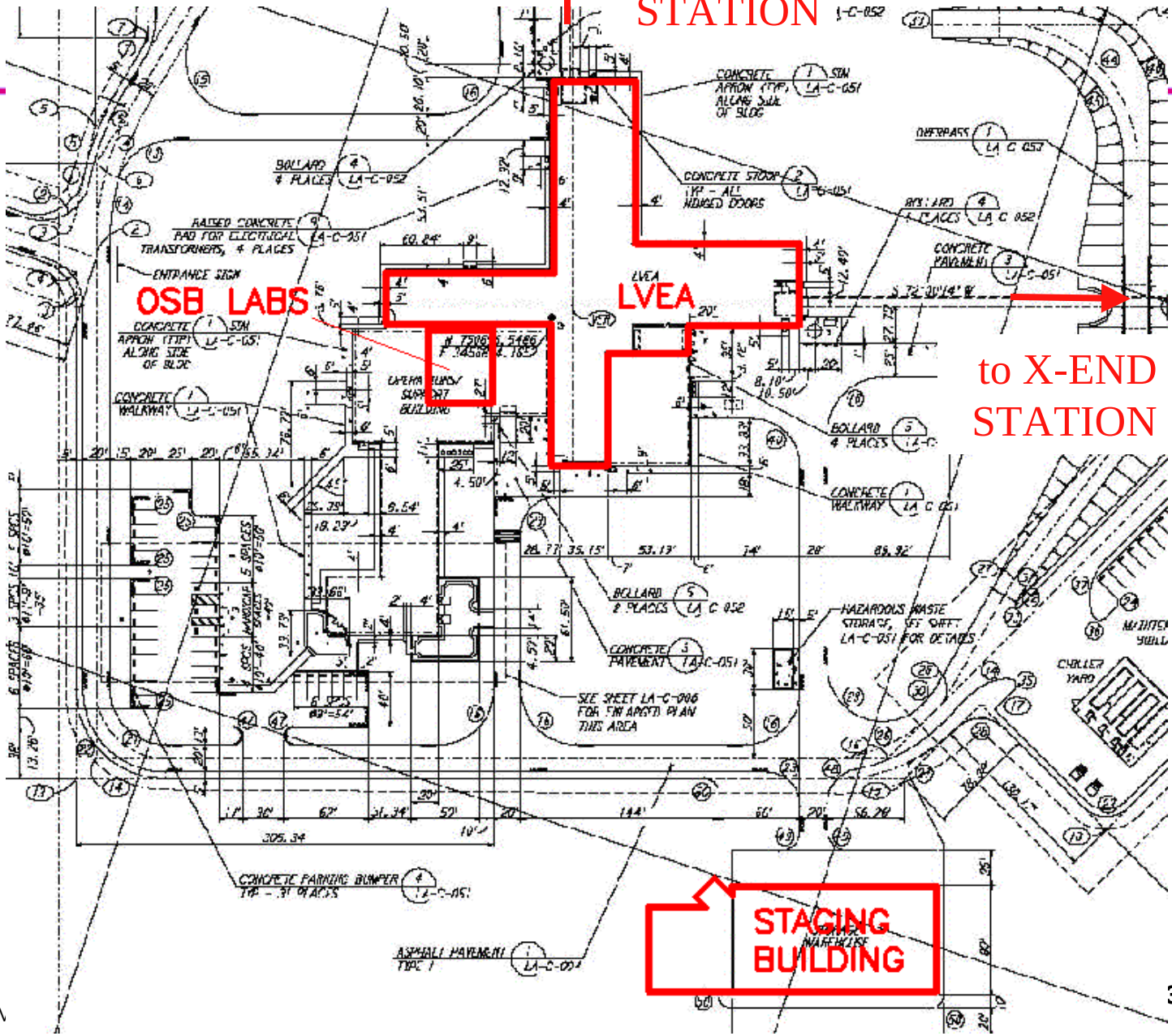
Optics Basic Tasks

- **Receive, Inspect, Inventory**
  - » **Limited inspection to assure no damage in shipment**
  - » **Standard LIGO Lab equipment, plus Ergo Arm (high intensity lamp, microscope, …)**
  - » **Performed in the Staging Building Optics Lab under erected clean room, better than Class 100**
- **Store**
  - » **Special shipping outer crates in "dirty" receiving storage area (OSB)**
  - » **Optics remain in custom shipping containers on shelves in the OSB clean room**
    - – **Approx. 45 large masses max. at any given point in time**
      - COC optics for triples, quads, penultimate masses, reaction mass & reaction penultimate/compensation-plate, large element of IMMT & OMMT
      - ~22" dia. X ~8" high, or ~23 lower shelves in wall cabinets
    - – **Approx. 20 small optics**
      - Singles & triples (IMC, IMMT, OMMT)

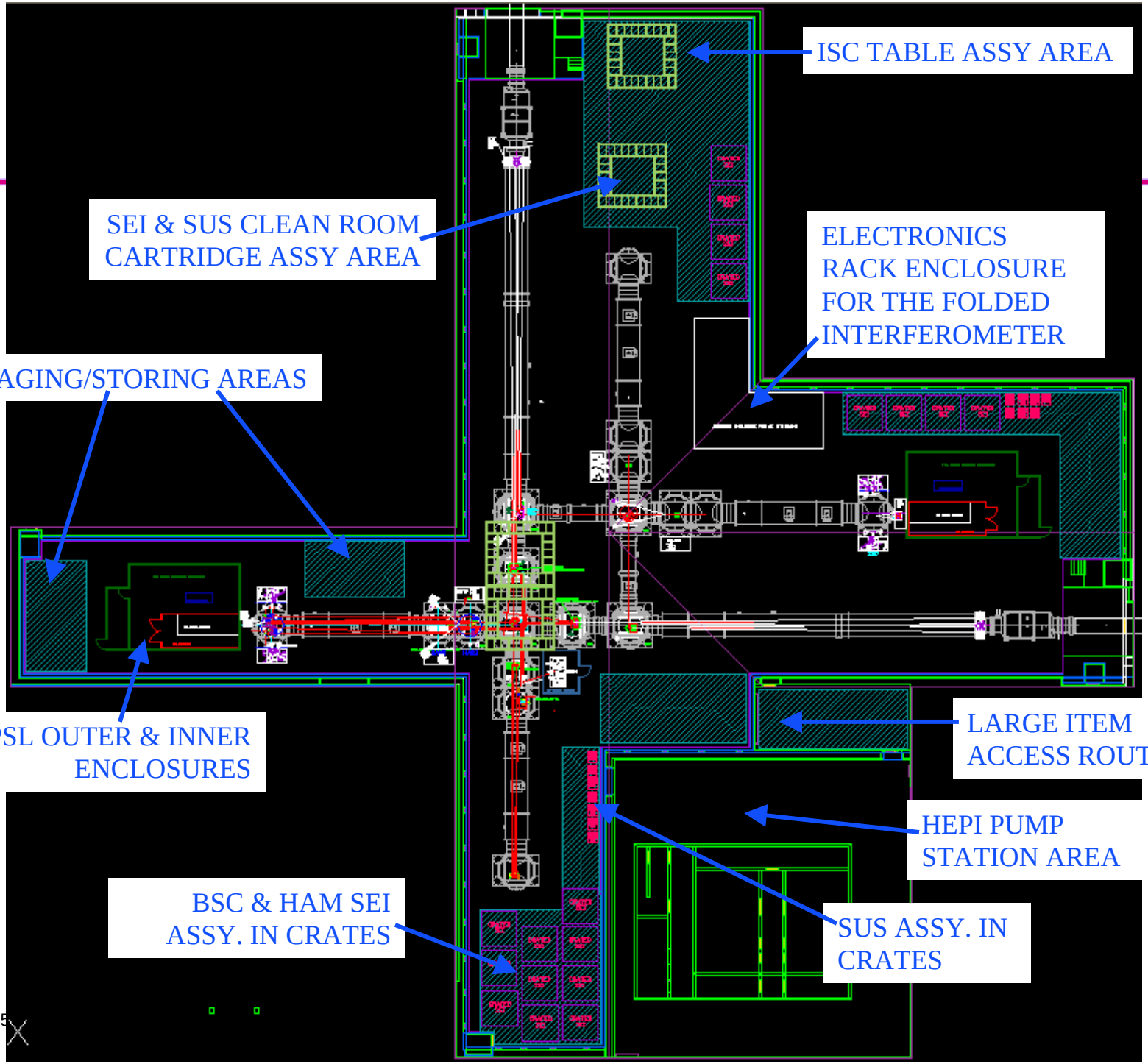
Optics Basic Tasks continued

- **Bond Magnets**
  - » **Single pendulum optics (MMT, SM), penultimate masses**
  - » **Similar procedure as used in initial LIGO, with new fixtures**
- **Bond Ears**
  - » **New process/procedure & tooling (hydroxy catalysis bonding)**
  - » **Clean bench space in OSB optics lab**
  - » **Long room temperature cure (many days); Bond ears, then store again**

LLO Corner Plot Plan

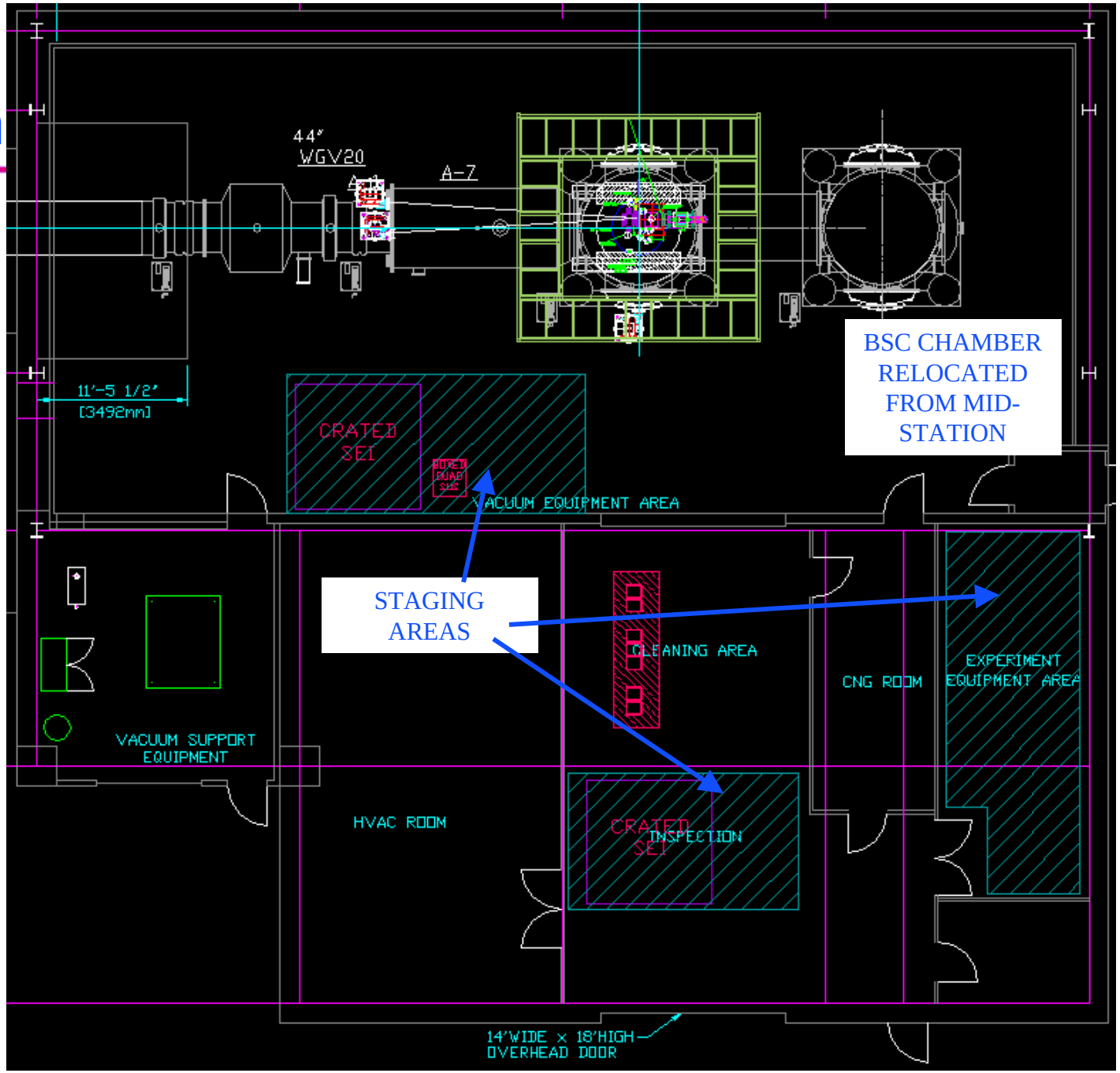


LHO LVEA


ISC TABLE ASSY AREA
SEI & SUS CLEAN ROOM CARTRIDGE ASSY AREA
ELECTRONICS RACK ENCLOSURE FOR THE FOLDED INTERFEROMETER
STAGING/STORING AREAS
PSL OUTER & INNER ENCLOSURES
LARGE ITEM ACCESS ROUTE
HEPI PUMP STATION AREA
BSC & HAM SEI ASSY. IN CRATES
SUS ASSY. IN CRATES

LIGO End Station

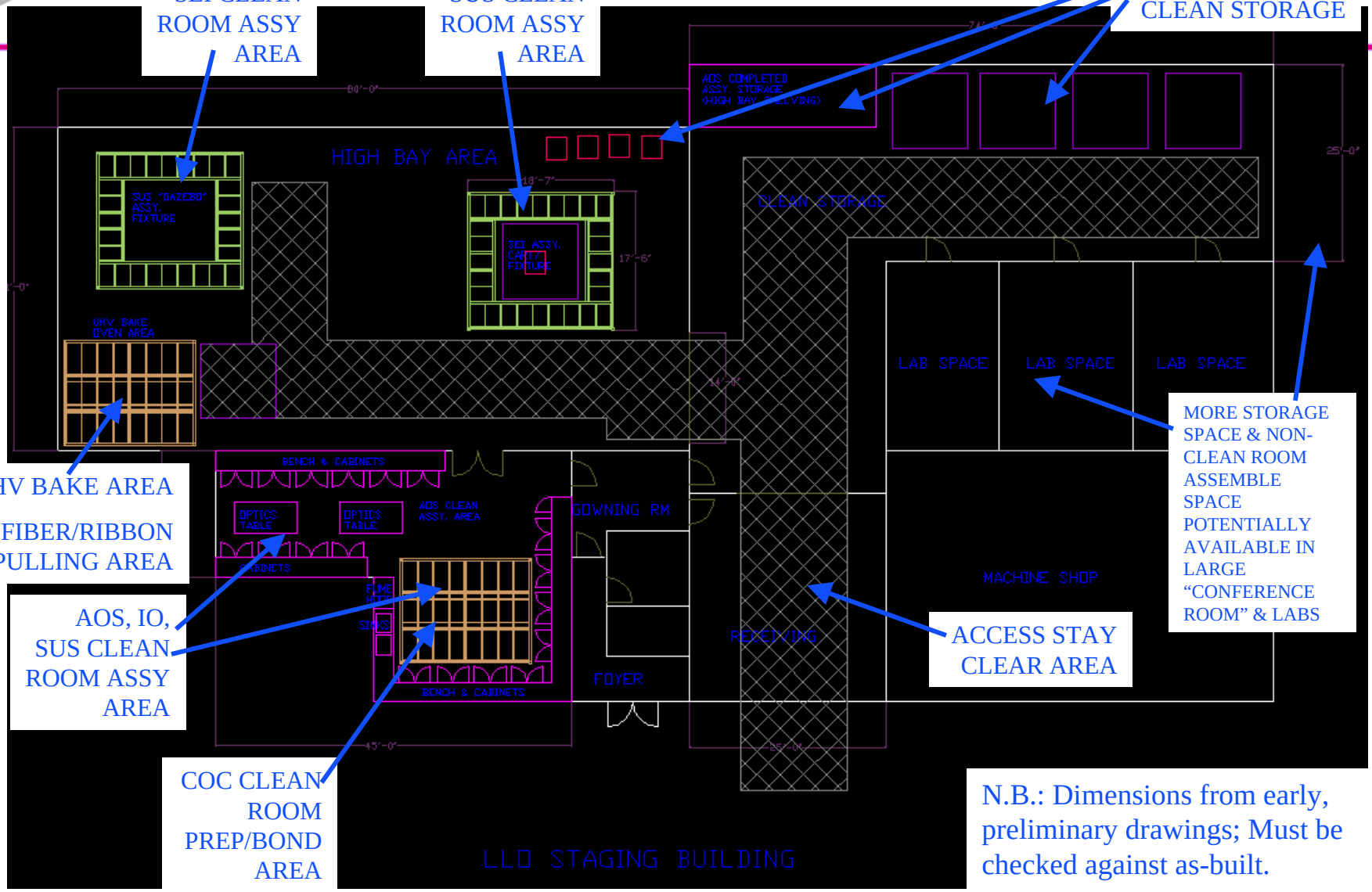
- **Electronics Racks in "cleaning area" (part of the RFI & acoustic mitigation) may block entry for staging SEI into VEA**
- **SEI crate placed in VEA, or large access entry room if Rack cluster blocks entry**



LVEA/VEA STORAGE & STAGING AREAS

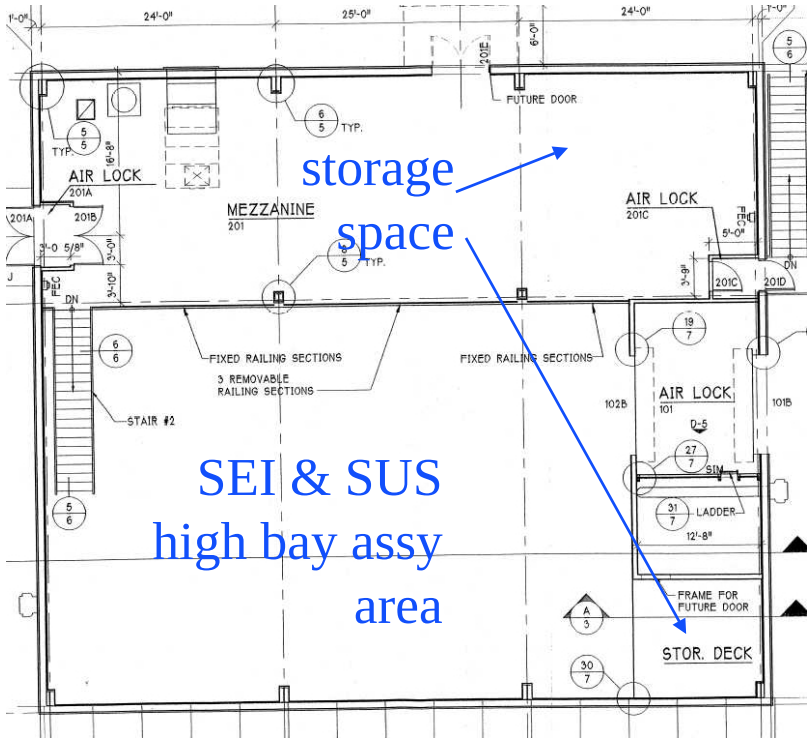
- **Subsystem post-assembly, long-term, storage and staging areas are in the LVEA and VEA**
- **Access is through the large item access route (or the main corner station receiving/cleaning areas)**
- **Floor space in the LVEA and VEA is adequate**
- **Access during Science Runs is strictly prohibited except for brief down times (planned or unplanned)**
  - » **Planned down time for LN2 replenishment, cryo-pump regeneration, OS patch reboots, etc. is approx. 1 day/month (TBR)**
  - » **Sufficient temporary storage is available in the staging building in the interim periods (TBR)**
- **Alternative/additional storage & work space location at LHO:**
  - » **The large storage building across from the OSB**
  - » **Unconditioned space**
  - » **Suitable for HEPI pier assembly, optical lever piers, etc.**
  - » **No equivalent at LLO**

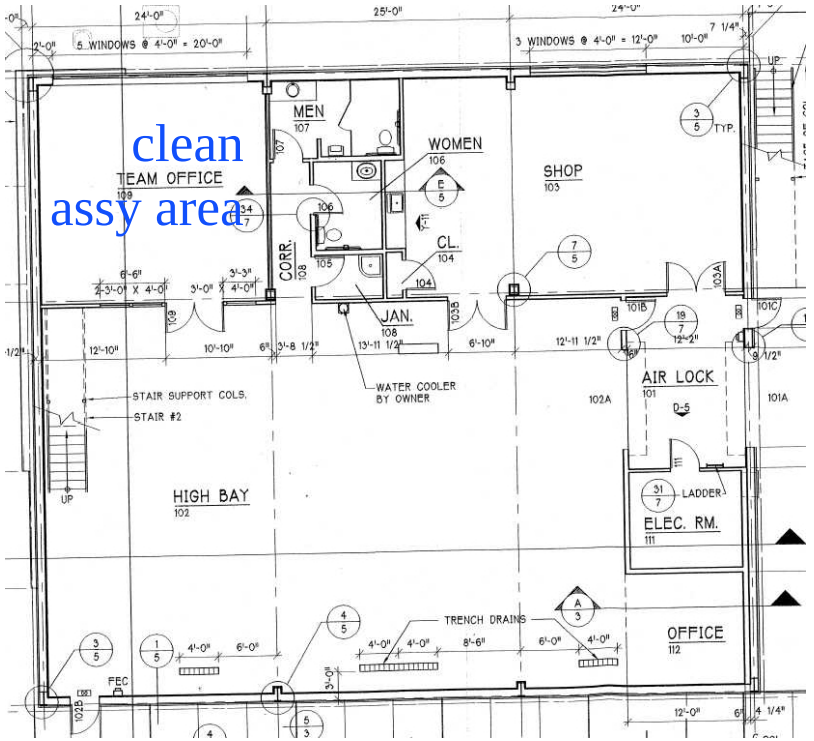
LLO Staging Building



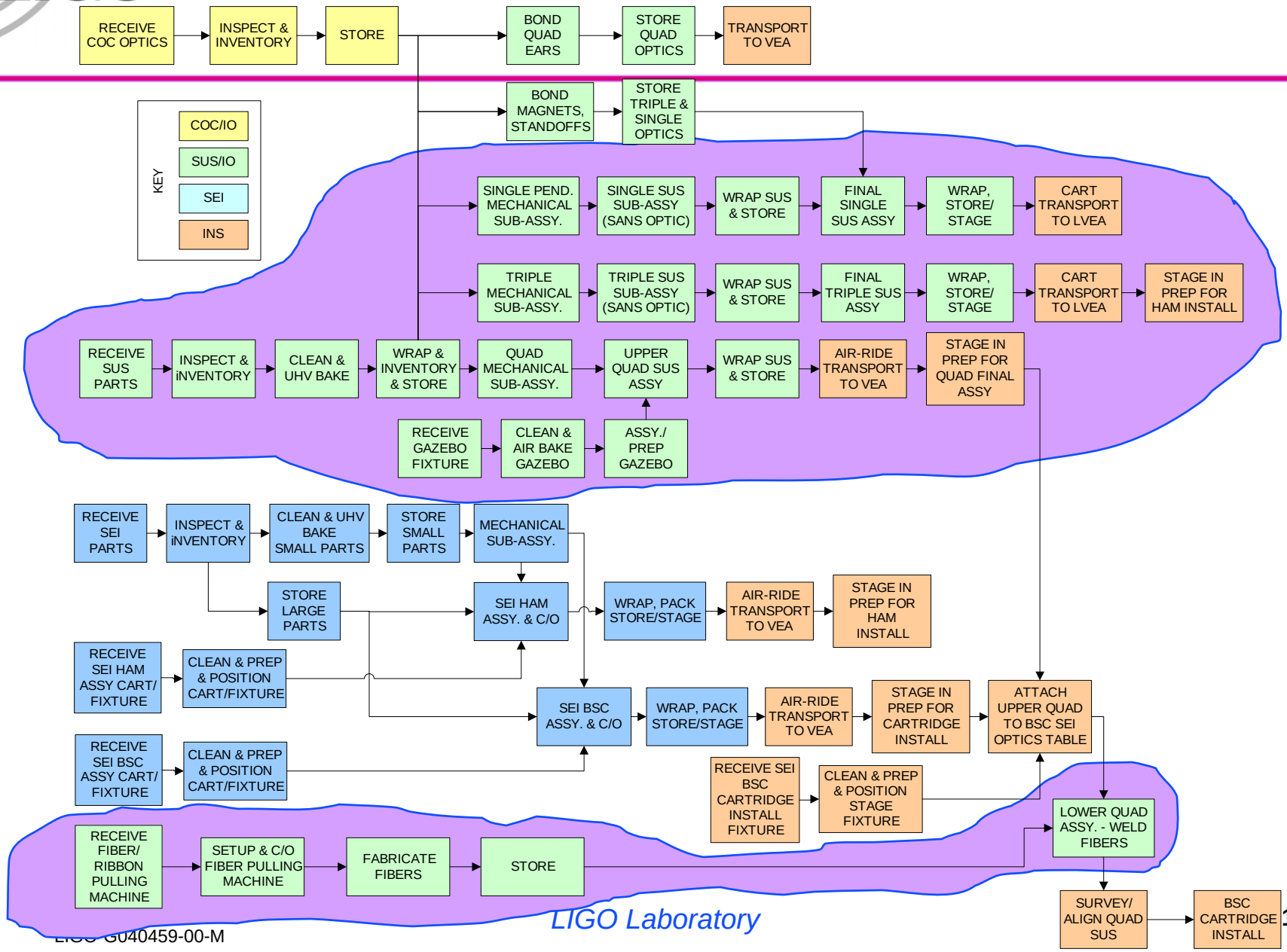
LHO Staging Building

- **LHO Staging building space is less than at LLO**
  - » **LHO high bay space is ~60’ x 40’**
  - » **LLO high bay space is ~80’ x 41’**
  - » **Can simultaneously support 2 BSC clean room stations for either SEI or SUS Assembly**
- **LHO Optics clean room is in separate new office/auditorium bldg**

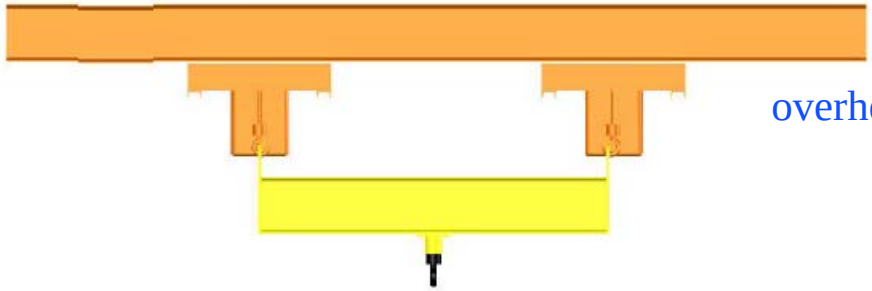




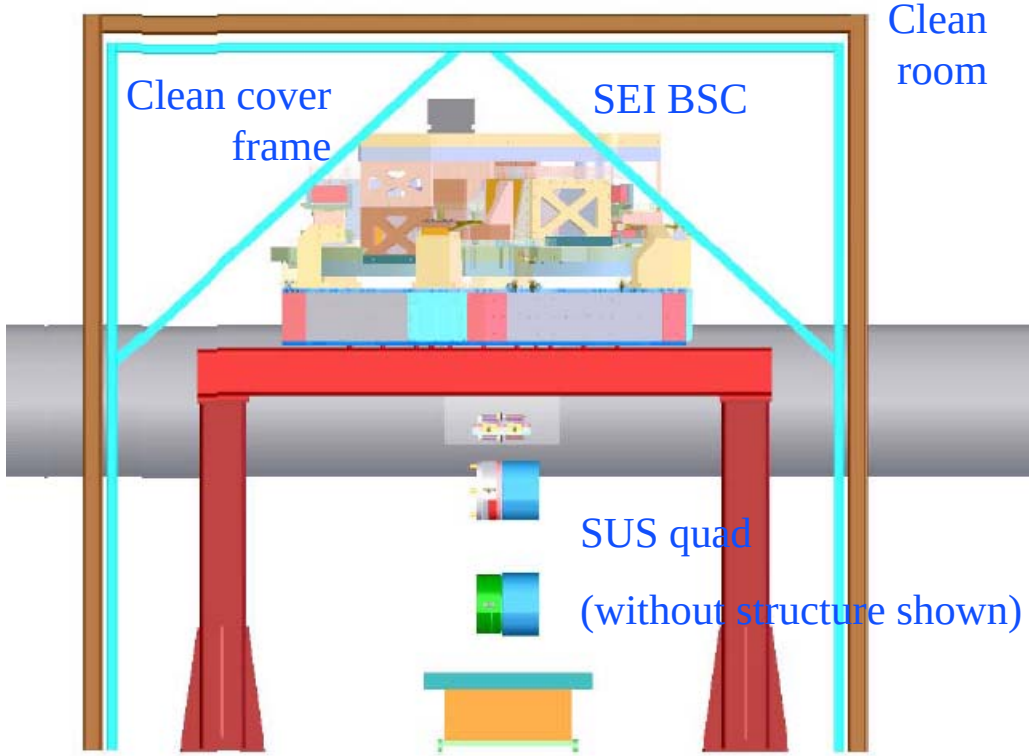
Basic Assembly Tasks (COC/IO, SUS/IO, SEI)



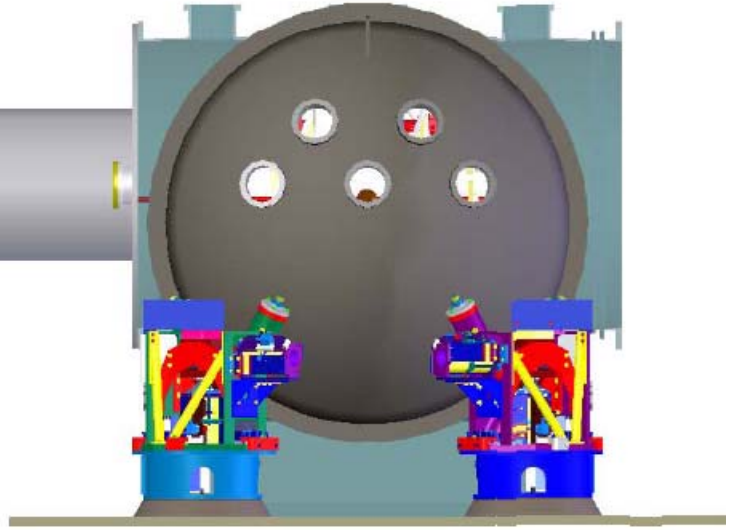
BSC “Cartridge” Assembly



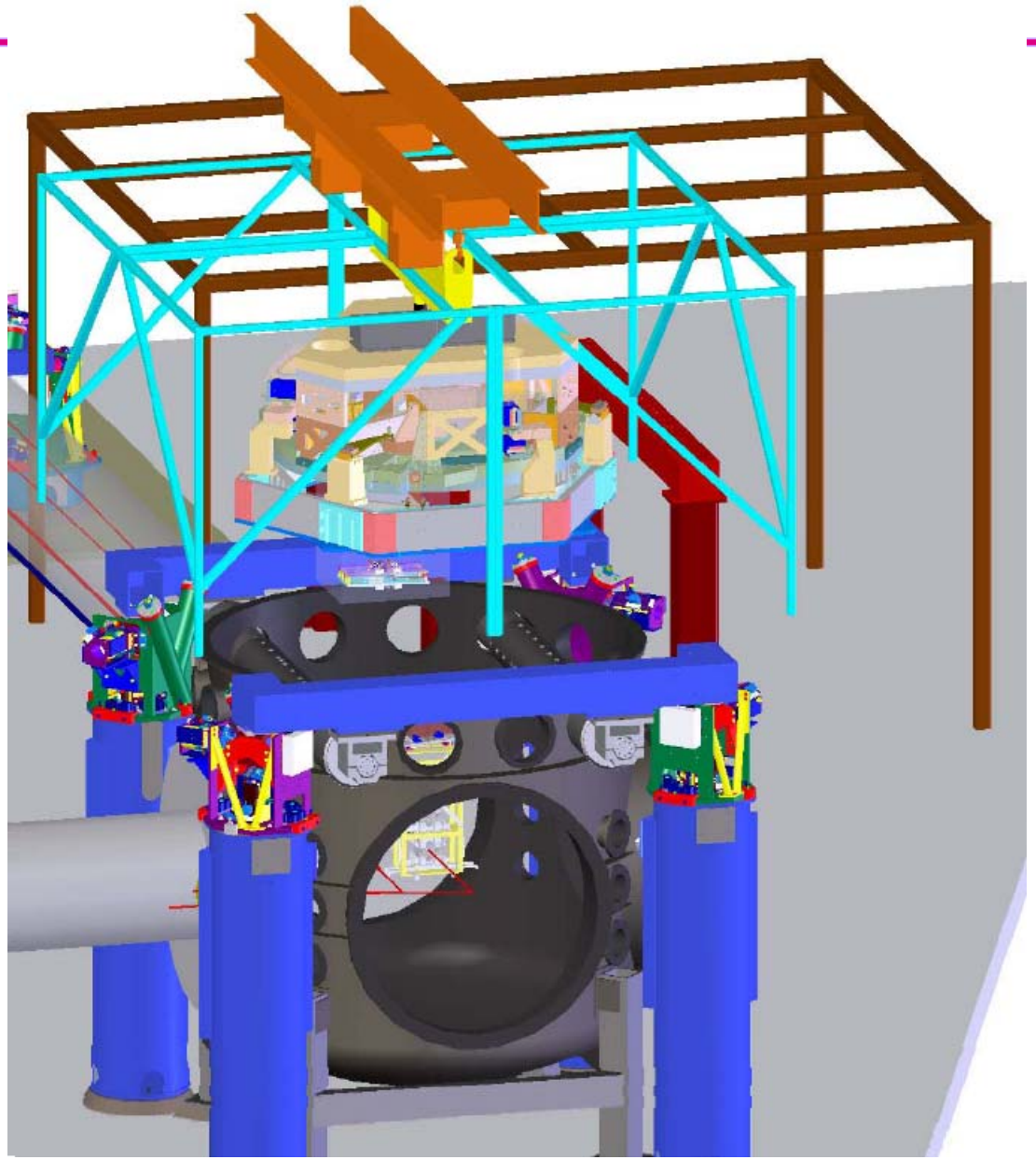
overhead crane



In general the entire BSC optics table payload and all counterbalance mass is installed as part of the “cartridge”



BSC “Cartridge” Insertion



Assembly prior to installation does not include the BSC “cartridge” assembly

- **Assembling BSC “cartridges” and wrapping/storing these assemblies would save some assembly time later during installation**
- **However at the price of:**
  - **A much more unwieldy assembly,**
  - **Requires multiple large support fixtures to permanently support the heavy assembly**
  - **Likely exceeds our lifting capacity for transport to the LVEA/VEA,**
  - **Requires more up front coordination of delivery schedules from all involved subsystems to complete each assembly**

Installation Readiness

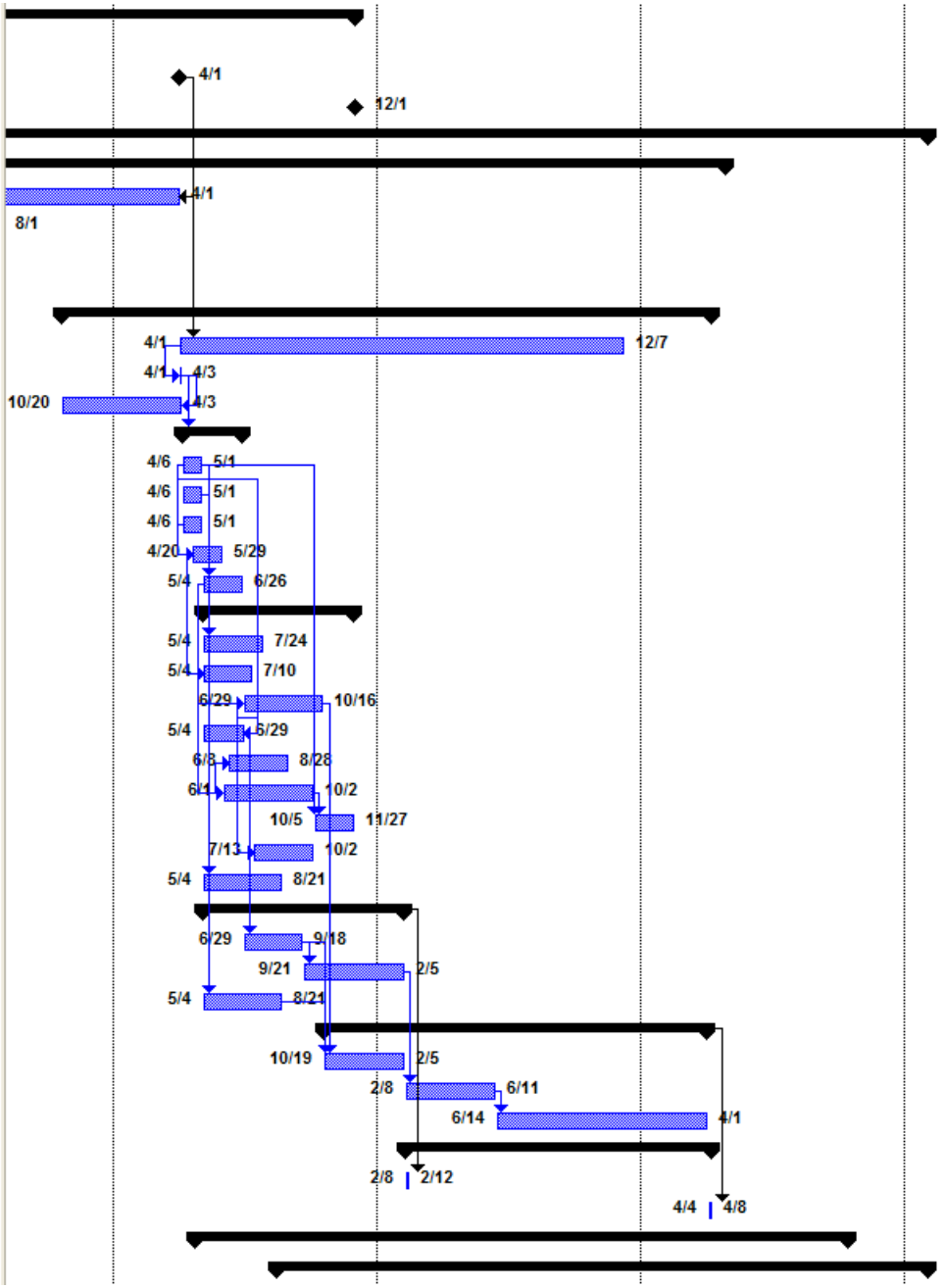
- **An installation readiness review will be held prior to switching off an operating observatory**
- **The proposed litmus test for readiness, applied by the review committee:**
  - **Agreement between the LSC and the LIGO Laboratory that switching off a working LIGO interferometer is not crippling to the overall effectiveness of the world-wide network of gravitational wave observatories.**
  - **All assembly and installation procedures have been written and reviewed. Critical assembly and installation activities and tooling have been tested within the LIGO Laboratory. In particular it is the intent of the laboratory to utilize the LASTI testbed to check out challenging or new procedures to the extent possible and provide some familiarity and training to installation personnel.**
  - **Sufficient assembly, check-out and delivery of subsystem components has been completed and accepted, so that installation is not predicted to be supply chain limited, i.e. INS is self-limited in its schedule and not limited by manufacturing or assembly rates.**
    Sufficient should be deemed to be ~3 month schedule buffer.

Manufacturing & Assembly Rates

- **To be reviewed**
- **Will use to project the “equipment readiness for installation” date**

Aggressive Install/Commiss Schedule

REVISED Interface Milestones (TBR)	**826 days**	**10/2/06**	**12/1/09**
construction funding available	0 days	10/2/06	10/2/06
start LLO install	0 days	4/1/09	4/1/09
start LHO install	0 days	12/1/09	12/1/09
LIGO.4.13 Installation & Commissioning (INS)	**1394 days**	**10/2/06**	**2/2/12**
LIGO.4.13.1 Management	**1192 days**	**10/2/06**	**4/26/11**
LIGO.4.13.2 Planning	12 mons	4/30/08	4/1/09
LIGO.4.13.3 Fixture Design/Fab.	24 mons	10/2/06	8/1/08
LIGO.4.13.4 LHO Vacuum Bake (not used)	0 days	10/2/06	10/2/06
LIGO.4.13.5 LLO Vacuum Bake (not used)	0 days	10/2/06	10/2/06
LIGO.4.13.6 IFO1	**645 days**	**10/20/08**	**4/8/11**
LIGO.4.13.6.1 management	22 mons	4/1/09	12/7/10
LIGO.4.13.6.2 Readiness Review	3 days	4/1/09	4/3/09
LIGO.4.13.6.3 Staging/preparation	6 mons	10/20/08	4/3/09
LIGO.4.13.6.4 De-integration & disposal	**60 days**	**4/6/09**	**6/26/09**
remove racks & cable plant	4 wks	4/6/09	5/1/09
PSL Removal	4 wks	4/6/09	5/1/09
ISCT Removal	4 wks	4/6/09	5/1/09
In-HAM Chamber Removal	6 wks	4/20/09	5/29/09
In-BSC Chamber Removal	8 wks	5/4/09	6/26/09
LIGO.4.13.6.5 Integration	**150 days**	**5/4/09**	**11/27/09**
PSL installation	12 wks	5/4/09	7/24/09
SEI/HAM Installation	10 wks	5/4/09	7/10/09
IO/SUS HAM Installation	16 wks	6/29/09	10/16/09
SUS-HAM electronics installation	8 wks	5/4/09	6/29/09
SUS/BSC Integration ('cartridge')	12 wks	6/8/09	8/28/09
SUS-SEI/BSC 'cartridge' Installation	18 wks	6/1/09	10/2/09
SUS-BSC electronics installation	8 wks	10/5/09	11/27/09
AOS Installation	12 wks	7/13/09	10/2/09
LIGO.4.13.6.6 Cabling	16 wks	5/4/09	8/21/09
LIGO.4.13.6.7 Electronics & Software Inst	**200 days**	**5/4/09**	**2/5/10**
IO controls installation	12 wks	6/29/09	9/18/09
ISC installation	20 wks	9/21/09	2/5/10
DAQ Installation	16 wks	5/4/09	8/21/09
LIGO.4.13.6.8 Commissioning	**380 days**	**10/19/09**	**4/1/11**
PSL/IO Commissioning	16 wks	10/19/09	2/5/10
ISC Commissioning	18 wks	2/8/10	6/11/10
Noise performance improvement	42 wks	6/14/10	4/1/11
LIGO.4.13.6.9 Acceptance Reviews	**305 days**	**2/8/10**	**4/8/11**
installation acceptance	1 wk	2/8/10	2/12/10
commissioning acceptance	1 wk	4/4/11	4/8/11
LIGO.4.13.7 IFO2	**645 days**	**4/24/09**	**10/13/11**
LIGO.4.13.8 IFO3	**645 days**	**8/14/09**	**2/2/12**



Follow up -- Input from Subsystem leads & Observatory Personnel

- **Confirmation of assumptions regarding impact of LIGO science running on assembly and staging**
- **Per Subsystem: Space and special equipment needs and duration for assembly at the observatories**
- **Walkthrough of installation procedures:**
  - » **There are no plans to perform HAM in-chamber installation exercises at the observatory prior to installation**
  - » **A practice BSC cartridge installation could be performed in the staging building at the observatory to walkthrough procedures & tooling**
    - – **for the configuration in a particular chamber or two, not all**
    - – **Perhaps with fiber welding to ersatz optics**
    - – **Up to lifting off the SEI/cartridge support frame (no insertion into a BSC chamber)**
  - » **LASTI is the full scale testbed at which challenging assembly/installation procedures are to be developed/tested**
  - » **Provides an opportunity for training**
  - » **LASTI plan to date is focused on SEI & SUS prototype install & test**
    - – **Do we anticipate the need for additional installation exercises?**
- **Cleanliness issues for core optics**
  - » **Make "better than initial LIGO" more definitive**