Physics Requirements for the
XTOD Mechanical-Vacuum Systems

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Brief Summary: This document provides general physics requirements and design philosophy for mechanical systems and vacuum systems for the portion of the LCLS described by WBS section 1.05, the X-Ray Transport and Diagnostics. These systems comprise all the non-controls hardware in the XTOD area, namely all the optics, instruments and diagnostics and vacuum transport hardware.

Change History Log

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Check the LCLS Project website to verify that this is the correct version prior to use.
1. **Introduction**

Considered individually, the vacuum requirements for sub-systems in the LCLS XTOD area span a wide range. Both the degree of vacuum required and its cleanliness span from quite modest in the case of low-scatter transport of the x-ray beams to demanding UHV conditions for mirror systems, and possibly for other diagnostic systems. Although tailoring the vacuum system for each instrument to its inherent requirements might seem a cost-effective approach, the consequences of contamination can compromise other systems, and even the performance of the facility as a whole. For this reason, the entire XTOD vacuum system must be designed and constructed with a major emphasis on eliminating contamination sources, i.e. built essentially as an all-metal, UHV-capable, clean-vacuum system.

ESD 1.1-302, “LCLS Mechanical Vacuum Specification”, applies to the entire LCLS complex, including XTOD. It cites SLAC-I-007-12004-001, “SLAC Guidelines for Vacuum Systems” as the primary, guiding document. This second document mandates vacuum systems constructed ONLY of metallic and ceramic materials, using techniques and processes designed to minimize hydrocarbon contamination and contamination from other volatile materials.

2. **Vacuum Systems: General**


2.1.1. “Only metallic or ceramic materials may be used in the construction of any component or system which interfaces with the vacuum system.” (Section 3.1).

2.1.2. “Elastomers or organic materials are not permitted, unless they are specifically authorized by” the Systems Manager of LCLS Photon Beam Systems, or designee. (Section 3.1).

2.1.3. Design, fabrication, cleaning, assembly, testing and processing shall follow requirements stated in these documents.

2.1.4. For some systems or components, bake-out under vacuum may not be required. (Section 12).

2.2. The design pressure of a particular sub-system must consider the pressure requirements of all adjacent sub-systems.

2.3. According to PRD 1.5-001, “Physics Requirements for the LCLS X-Ray Transport and Diagnostics”:

2.3.1. Average pressure less than $10^{-5}$ Torr.

2.3.2. Pressure at ion pumps low enough to ensure pump life $> 10$ years.

2.3.3. Components highly susceptible to radiation damage discouraged.
3. **Vacuum-Mechanical Systems**

3.1. Where possible, consider placing precision mechanics outside vacuum and use metal bellows to transfer motions to simple shapes in-vacuum. This can help minimize outgassing in the system, and can often improve reliability.

4. **Mechanical Stiffness**

4.1. For precision mechanical systems, minimize amplification of floor vibrations by using designs with sufficient stiffness. In most locations, the amplitudes of floor vibrations generally fall rapidly with increasing frequency. At the Stanford Synchrotron Radiation Laboratory, mechanical designs whose fundamental modes of vibration lie above about 120 Hz have proven successful.

4.2. In precision mechanical systems, consider using viscoelastic damping polymers and foils in mounts and support structures to attenuate transmission of vibrations from the floor to the system.

5. **Standard Alignment Provisions**

5.1. Provide standard tooling-ball sockets and alignment degrees-of-freedom to enable fiducialization, alignment and installation by the SLAC Alignment Engineering Group. (Example photographs and drawings of the standard tooling ball and sockets are available on their web site.)

5.2. Provide “traveler” document to detail fiducialization, alignment and installation sequence and tolerances.

6. **Beam Clearance Specifications**

6.1. According to PRD 1.5-001, “The vacuum flight path must be sized to exclude the possibility of being struck by the x-ray beam.” The motivation for this statement is interpreted as follows: Components which may be damaged if struck by the beam must not be struck. Also, irrespective of a damage issue, components which, if struck, would result in the generation of significant radiation background in occupied areas, must not be struck. Therefore, the FEL beam, the spontaneous beam or both may have to be considered, depending on the specific situation.

6.2. Require FEL beam clearance of 3 mm minimum to components which may be damaged by beam strike. 5 mm desired. 2 mm only with special considerations and means to assure clearance.

6.3. Calculate full mis-steer envelope for any component which may be damaged by beam strike. These calculations must be based on the specifications for beam source location and direction and their worst-case variation, provided by the LCLS Accelerator Group, or fixed aperture locations and their alignment tolerances.
7. Thermal Loading Considerations

7.1. Evaluate all designs intercepting beam power for steady-state equilibrium temperature rise. This will assure that an adequate thermal path exists for removal of the admittedly-small incident power levels, and that thermal expansion issues related to precise positioning or size are addressed.

8. Controls Specifications

8.1. According to PRD 1.5-001, “all control systems must be EPICS compatible. EPICS-based systems are preferred.”

8.2. Wherever feasible, motor-driven motions should incorporate limit switches at each travel extreme, and hard-stops at each extreme and a direct, absolute (not incremental) encoder for the entire motion range. An exception is “two-state” motions (e.g. a viewing screen which is either “in” or “out”), for which no encoder is required.

8.3. Limit switch and hard-stop adjustments shall be designed to facilitate rapid, precise settings. This is an area where a little “good engineering” and forethought can result in substantial savings in technician time and effort. The setting precision required depends upon the individual system specifications, but the adjustment of a single switch or hard-stop should only require a few minutes, whenever feasible.

9. Documentation

9.1. Drawings of all LCLS collaboration hardware shall be generated, exchanged and delivered as agreed to in ESD 1.1-320, “LCLS Collaboration Drawing Control”.

9.2. Copies of vendor-provided instruction and operation manuals shall be supplied for all purchased components.

9.3. System operation documentation shall be developed and provided.