ENGINEERING SPECIFICATION DOCUMENT (ESD)	Doc. No. SP-391-000-62 R0	LUSI SUB-SYSTEM XPP DIFFRACTOMETER

LUSI XPP Detector-Mover Engineering Specification
DRAFT

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R0		Initial release	

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1. Scope

This document describes and defines the engineering requirements for a hardware system to move the LUSI XPP wide-angle detector. This device will subsequently be known as the “detector mover”. Description, definition and specification of the detector mover requirements is referred to as “detector motion”.

2. Detector Mover Summary

The Detector Mover is used to position a custom, large area detector (1024 x 1024 pixels, approx. 200mm square) centered on a pre-defined interaction point, coincident with a sample goniometer coordinate system. The center of motion may be located within either of two widely separated regions. The detector will be moved over spherical surfaces with radii ranging from 10 – 100cm. The surface normal vector of the detector face center must point toward the pre-defined interaction point at all times. The rotation of the detector face about the motion radial vector must be accurately known at all times. Hardware systems and / or software programs must be developed and implemented to avoid defined “stay clear” areas.

3. Glossary / Definitions

Accuracy: Defines the ability to establish location or angle to a predetermined value, with respect to a fixed coordinate system.
Detector: Transduction Hardware
Detector Mover: Hardware designed to position a detector
Detector Motion: Parameters and tolerances defining the detector mover requirements
Diffractometer system: Hardware employed to position and translate both sample and detector
FEH: Far Experimental Hall
IP: Interaction point, the intersection of x-ray, pump laser, sample
Kappa Goniometer: Hardware employed to position and rotate a sample
LCLS: Linac Coherent Light Source
LUSI: LCLS Ultrafast Science instruments
NEH: Near Experimental Hall
Range: The total available limit of motion with respect to a fixed coordinate system origin or axis
Repeatability: Defines the ability to successively reestablish a desired location or angle, with respect to a fixed coordinate system.
Resolution: Defines the uncertainty of a measurement of location or angle with respect to a fixed coordinate system. Also defines the minimum measurable difference between two dissimilar values.
Roll: Rotation about the Z-Axis. Rotation about the radial axis.
SLAC: Stanford Linear Accelerator Center
Stability: Defines accuracy for a specified time
Tilt Platform: Hardware employed to position and rotate a sample
XPP: X-ray Pump Probe

4. Applicable Documents, Specifications and Codes

4.1. SLAC Documents and Specifications

AP-391-000-59: "Engineering Review Guidelines"
DS-391-000-36, "Design Standards Supplement"
GP-391-300-00, "Hutch 3 - XPP Arrangement"
ID-391-300-10, "XPP- Sample Goniometer Installation"
GP-391-750-14, "Hutch 3 - XPP Sub-system Stay Clear Definitive Lay-out"
SLAC-I-720-0A24E-002: Specification for Seismic Design……..at the Stanford Linear Accelerator"

4.2. Industry Specifications and Codes

OSHA technical manual, section IV, chapter 4; "Industrial Robot and Robot System Safety"
ANSI / RIA R15.-06; "American national Standard for Industrial Robots and Robot Systems"
NEC, NFPA 70; "National Electric Code,
NEC, NFPA 70E; "Electrical safety in the Workplace"
UBC 1997: "Uniform Building Code, 1997"

5. General Area / Adjacent Equipment Description

5.1. LCLS / LUSI overview

The Linacr Coherent Light Source (LCLS) is a machine for the production of coherent hard x-rays (IE: x-ray laser light). The LCLS complex consists of a electron linear accelerator (1km of the 3km long Stanford Linear Accelerator), an electron beam transport system, a 100 meter long undulator for production of the X-ray beam, and an X-ray transport optics-diagnostics system. The overall length of the LCLS machine is approximately 1.8 km.

The LCLS Ultra-fast Science Instruments (LUSI) program consists of a suite of x-ray instruments for exploiting the scientific capability of the LCLS machine. These instruments will be housed in experimental hutches located in a Near Experimental Hall (NEH) and a Far Experimental Hall (FEH).

The linear architecture of the LCLS complex, as compared to previous storage ring light sources, and the stringent requirements necessary to maintain the coherent x-ray beam properties, coupled with the need to maximize user scientific productivity, determine unique requirements for the LUSI instruments.

5.2. XPP Instrument Overview

The X-ray Pump Probe (XPP) instrument is one of the experimental configurations for the LUSI program. XPP combines an optical "pump" laser, to excite the atomic structure of a sample, and the X-ray beam to “probe” the properties of that structure. The major XPP subsystems and locations are shown in GP-391-300-00.

XPP is located in Hutch 3 of the NEH.

Due to the linear architecture of LCLS, the XPP instrument hardware must have the capability of reconfiguring to enable beam sharing with other experiments.

XPP configured for data taking at “Position 1” blocks X-ray beam from propagating to the FEH.

XPP configured for data taking at “Position 2” permits X-ray beam to propogate through to the FEH.

To maximize scientific output, all XPP systems will be designed, constructed and installed to support hardware reconfiguration, realignment and recalibration in 8 hours or less. This includes hardware repositioning from position 1 to position 2, or visa-versa.

All Hardware for XPP will be specified, designed, fabricated and installed in such a way as to provide for function at both x-ray beam sample positions (position 1 and position 2).

5.3. Hutch 3 / XPP Hardware Layout

The XPP hutch 3 floor plan consists of a main experimenter area and a down-beam alcove.

Overall **hutch 3 dimensions are shown in figure 1**.

A master coordinate system, to define locations of hardware in hutch 3, is also defined in this figure. The master coordinate system is right handed Cartesian with its origin nominally 1.4 meters above the floor and the Z+ axis in the nominal direction of X-ray beam propagation, parallel to the floor. The X+ axis is in the horizontal plane and Y+ axis is vertically up.

An interaction point is defined as the location where the x-ray beam and optical pump laser intersect the sample. XPP will have two nominal interaction point locations (IP1 and IP2), also shown in **figure 1**. IP1 is actively defined when XPP is in “straight ahead” mode, blocking x-ray propagation to the FEH. IP2 is actively defined when XPP is using monochromatic offset x-ray beam. The nominal separation between IP1 and IP2 is 0.60 meter.

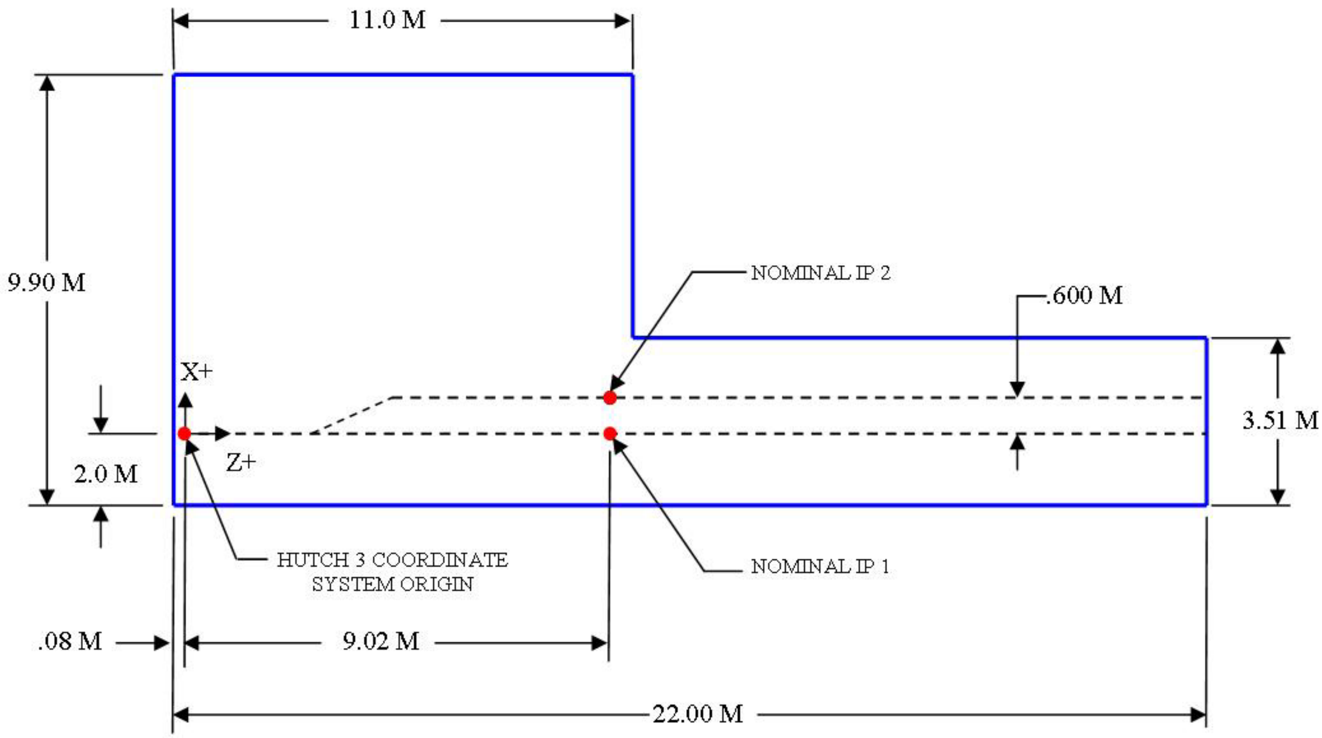

Figure 1
Hutch 3 – XPP Floor Plan

The major XPP subsystem locations are shown in GP-391-300-00.

5.4. Coherent X-ray Beam

Up-beam optical transport elements can have a significant effect on the position of the x-ray beam entering hutch 3.

The active interaction point and subsequently **the true, aligned, location of the diffractometer system rotation center will vary by up to 4 mm (+/- 2 mm tol) from nominal**.

Some classes of XPP experiments will require the x-ray beam to have a down angle at the sample surface interface (IE: active interaction point) . Elements in the optics-diagnostic section will be employed to steer the x-ray beam to the desired down angle. This down angle translates to a vertical offset of the active interaction point.

The maximum vertical offset of the active interaction point, and subsequently **the true, aligned, vertical location of the diffractometer system rotation center will vary by up to 30 mm**.

The horizontal and vertical extents of possible diffractometer rotation center locations, with respect to the two nominal locations, is shown in **figure 2**. The view is shown with the X-ray beam into the page. **Detector mover hardware will be constructed to allow the rotation center to be aligned within these two zones**.

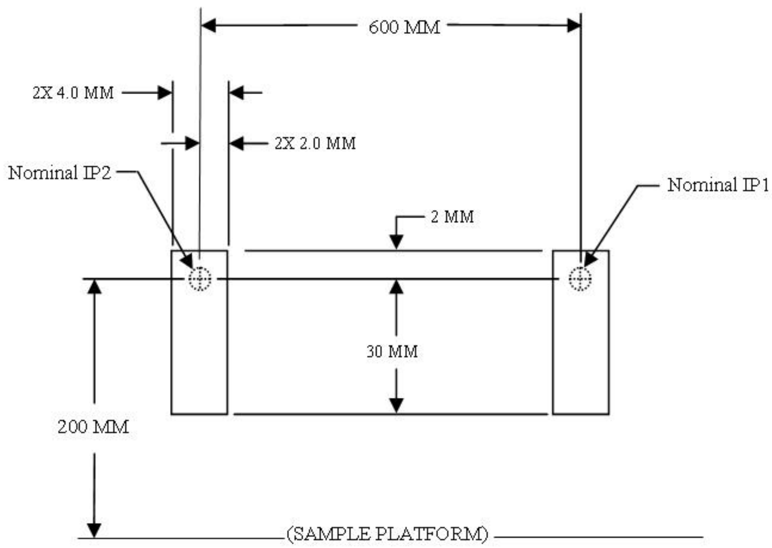

Figure 2
Active Interaction Point Zones

5.5. Diffractometer Sample Goniometer

The diffractometer system is a critical component for XPP experiments. **The diffractometer system consists of two main components: the detector mover (topic of this specification) and the sample goniometer.**

The sample goniometer system serves to precisely control the sample spatial position and angular orientation.

The sample goniometer will be designed to translate its rotation center over the active interaction point zones shown in figure 2. Indeed **the intersection of sample, goniometer rotation center and x-ray beam defines the exact location of the interaction point** (IE: active interaction point location) for a given experimental configuration.

The sample goniometer will be designed to provide maximum flexibility for rotation axis configurations (tilt platform, kappa platform), sample environments (vacuum chamber, cryostat system, pressure cell, liquid jet, etc) and sample mounting hardware configuration.

The complete sample goniometer hardware configurations and space requirements are impossible to describe completely. In **all cases the detector motion system must function in such a way as to minimize, or eliminate, the possibility of hardware interference / crashes.**

Definitive sample goniometer hardware configuration(s) can be found in SLAC document number ID-391-320-01.

Independent of the hardware configuration, a diffractometer coordinate system is defined by, and has it origin at, the sample goniometer center of axis rotation. The diffractometer coordinate axis are oriented in the same nominal directions as the hutch master coordinate system. The Z+ axis is oriented in the nominal direction of the x-ray beam. The X+ axis is in the horizontal plane and the Y+ axis is vertically up.

6. Detector-Motion Coordinate System and Alignment

The detector mover system shall translate and position the x-ray detector along precise commanded paths on a spherical surface centered on the active interaction point. The detector motion shall have a coordinate system defined to establish relative position and velocity with respect to the sample, sample goniometer and x-ray beam (i.e.: active interaction point).

The detector motion coordinate system shall, by definition, be a modified spherical system with its origin located at the center of spherical motion. Since the detector is an array device, the rotation of the detector face, about the coordinate system radial, will need to be known to precisely define the position of each detector pixel (ref; figure 6).

Four variables are required to completely define the detector-pixel in space within the detector motion coordinate system (IE: with respect to the active interaction point).

The detector array-face center location and rotation is defined by: **(R, ν, δ, ψ).**

R:	Distance from detector coordinate system origin to detector face array center
Nu (ν):	Azimuth angle with respect to diffractometer system coordinate Z+ (IE: angle in the diffractometer X-Z plane)
Delta (δ):	Elevation angle with respect to diffractometer system X-Z plane (IE: angle above the diffractometer system X-Z plane)
Psi (ψ):	Rotation of detector face normal about detector coordinate system radial.

The detector local coordinate system is defined by (X_d, Y_d). Its origin is located at the array central pixel,

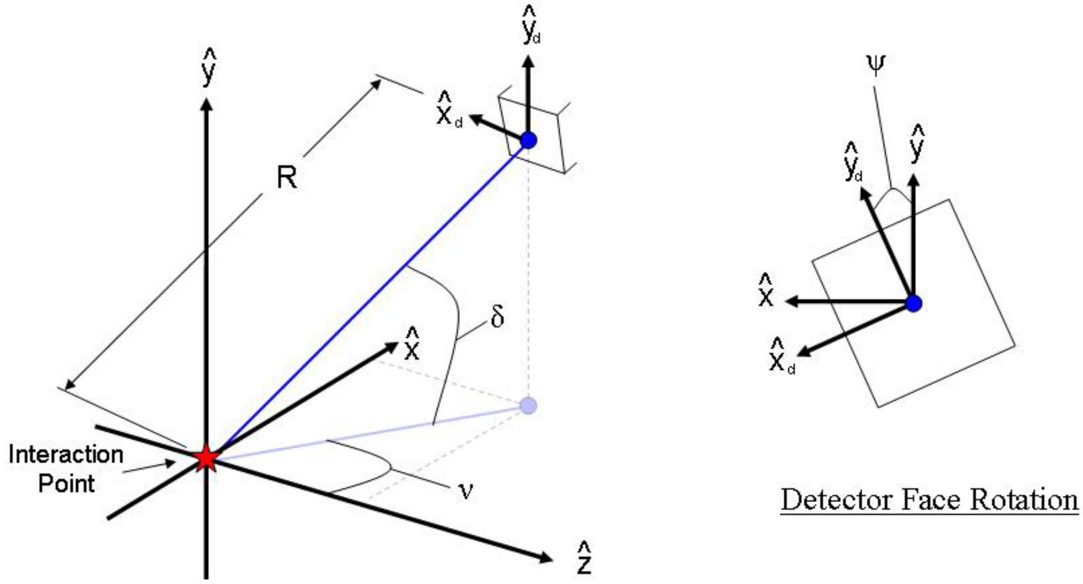

Figure 3
Detector Motion Coordinate System

The detector motion coordinate system shall be aligned such that its origin will be collocated with the Diffractometer coordinate system origin to within the specified value (tol) as defined in table 1. Additionally the (R,0,0,ψ) {Z^} axis and the (R,90,0,ψ) {X^} axis will be aligned to the diffractometer Z+ axis and diffractometer X+ axis, respectively, to within the specified solid angle values (tols) as defined in table 1.

variable	unit	value (+/-tol)	Notes
Origin position	micron	300 (+/-150)	(1)
Z^ orientation	degree	.012 (+/-.006)	(2), (3)
X^ orientation	degree	.012 (+/-.006)	(2), (4)
Psi (ψ)	degree	.080 (+/-.040)	(5)

Table 1
Motion Alignment Requirements

Notes;
1: Detector coordinate origin coincident with sample goniometer system center
2: Approximately 2 pixel at R = 100 cm
3: Solid angle, detector system (R, 0, 0, ψ) axis to sample goniometer system Z+
4: Solid angle, detector system (R, 90, 0, ψ) axis to sample goniometer system X+
5: Approximately 1 pixel at 71 mm.

7. Detector Motion Range Extents

Detector motion range will be defined for "forward scattering" and "backward scattering". Stated range requirements shall apply individually for detector motion centered in either active IP zone shown in figure 2.

Forward scattering range:

Variable	minimum value	maximum value
Nu:	-15 degrees	+105 degrees
Delta:	-15 degrees	+90 degrees
R:	10 cm	100 cm

Backward scattering range:

Variable	minimum value	maximum value
Nu:	+105 degrees	+180 degrees
Delta:	-15 degrees	+90 degrees
R:	10 cm	50 cm

The detector face will have the ability to move over the entire angular range regardless of the specific commanded radius of motion.

XPP hardware stay clear requirements (ref: section 8) are distinct from, and considered independently of, the motion range extents.

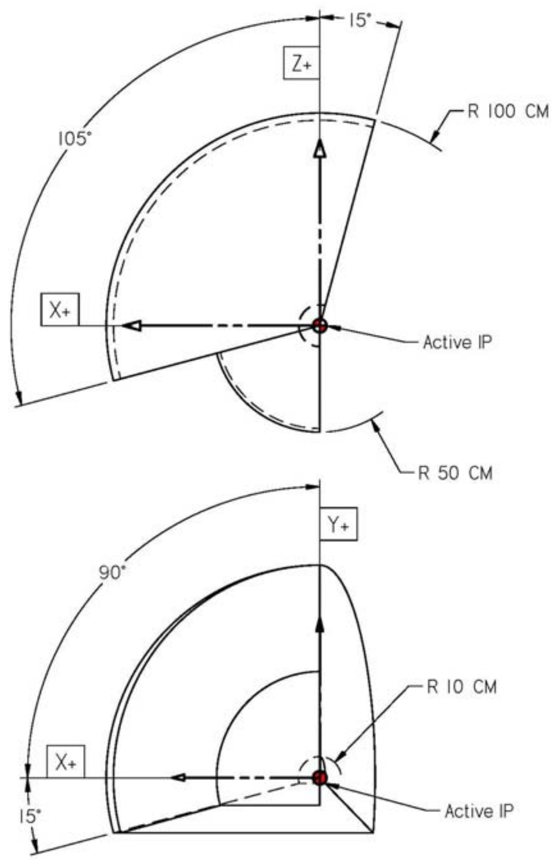

Figure 4
Detector Motion Range Volume(s)

The requirements for crash avoidance and hardware protection will be addressed in the context of the stated motion full range requirements and a specific experimental hardware configuration.

8. Detector-Mover Stay-Clear Requirements

The Hutch 3 XPP subsystem stay-clear volumes are shown in SLAC Document number GP-391-750-14. **All mechanical equipment designed and installed for the detector mover system must respect the boundaries of the stay clear volumes for adjacent equipment shown**.

Any approved personnel protection system (PPS) hardware for the detector mover system shall account for requirements of accessibility to the stay-clear volumes depicted in GP-391-750-14.

A nominal sample equipment-environment stay clear zone is defined as a 1.0 meter diameter vertical axis cylinder. The axis is centered on the sample goniometer coordinate system origin. The cylinder extends 0.2 meter below and 0.3 meter above the coordinate system X-Z plane.

Minimum requirements for detector mover reach capability defines that the mover will achieve the full range extents as specified in section 7, at maximum radius, for both backscatter and forward scatter conditions, without violating the nominal sample equipment-environment stay clear zone. Encroachment will be minimized within the portion of stay clear volume that exceeds the maximum detector motion radius.

As previously stated sample goniometer and sample environment flexibility is to be maximized. This makes it impossible to completely define detector mover stay clear volumes for all conditions. The operational control of these stay clear requirements will be addressed by passive or active crash protection (see “crash protection” section 10).

9. Detector-Motion Performance Requirements

The position of the Detector must be manipulated in a accurate, stable, and reproducible fashion.

Accurate motion of the detector within the motion coordinate system via the detector mover system is critical to the determination of the complete diffraction pattern.

Accurate location, with respect to the x-ray beam and sample, of each pixel of the detector array is of critical importance to the successful XPP experiment (IE: accurate, repeatable data defining the roll of the detector face around the radial coordinate is required).

Repeatability of detector – pixel position is critical to verify and reproduce results.

Long term (hours) fixed position stability of the detector – pixel position during data taking is critical for accurate data integration.

Accuracy, stability, & repeatability are far more important than rapid positioning speeds. Further more, rapid accelerations are unnecessary and undesirable.

Commanded detector motions may require relatively low velocities (0.25 to 0.50 mm/sec).

The angle of the detector face normal with respect to the detector motion coordinate system radial is important in maintaining accurate pixel position / array spacing parameters.

Motion performance values (tolerances) are defined in Table 2. All Values are taken with respect to the Hutch 3 master coordinate system. IE: values include all detector mover hardware from base mounting at / on the hutch to the detector.

Parameter	Unit	Value (+/-tol)	Notes:
Accuracy	micron	140 (+/- 70)	(1)
Repeatability	micron	140 (+/- 70)	(1)
Resolution	micron	100 (+/- 50)	
Stability	micron / hour	25 (+/- 25)	
Velocity, max	meter / second	0.2	(2)
Face angle	degree	2.0 (+/-1.0)	(3)
Accel, max	g	1.0	(4)

Table 2
Detector Motion Performance Requirements

Notes;
1: Approximately 1.4 (+/-.7) pixel
2: Maximum planned commanded detector assembly velocity
3: Defines the maximum acceptable solid angle between detector face normal and coordinate system radial
4: Maximum acceptable acceleration of detector assembly

Continuous full range motions, without interruption / variation of detector radial, rotation, or velocity parameters is highly desired. Reduced instruction set command programs are encouraged. “Canned’ programs to execute full range azimuth-fixed value elevation or fixed value azimuth-full range elevation scans are suggested.

Maximum mover system payload requirements are 25 kilogram (~55 Lb weight). This includes detector assembly (ref: section 11), system alignment hardware (ref: section 12.2) and crash protection hardware (ref: section 10).

10.Crash Protection

Prevention of detector mover system, array detector or adjacent hardware from damage due to mechanical interference (crash) is of the utmost importance. XPP subsystem hardware stay clear volumes are defined in GP-391-750-14. Nominal sample equipment - environment stay clear requirements are established in section 8.

The hardware configuration flexibility inherent in the XPP design requires that the detector mover shall have layered system crash protection. Crash protection may take the form of any, or all, of the following methods.

Software – user interface controls: Methodologies to preview and verify motion controlling programs to minimize crash hazard prior to data taking.

Proximity sensor – light curtains – etc: Hardware systems (possibly of flexible configuration) to halt commanded motion prior to interference.

Force sensor: Hardware-software system(s) integral to mover device to halt motion and limit damage in the event of unintended contact.

Crash shrouds: Hardware protective cover(s) to insure survivability of high value components (array detector) in the event of uncontrolled interference event (crash).

11. X-ray Detector

The XPP X-ray detector to be mounted on the detector mover is a silicon based 1024 x 1024 square pixel array detector. The total detector package will include integral detector elements, ASIC and ADC components, electrical connection elements and possible cooling fluid connections.

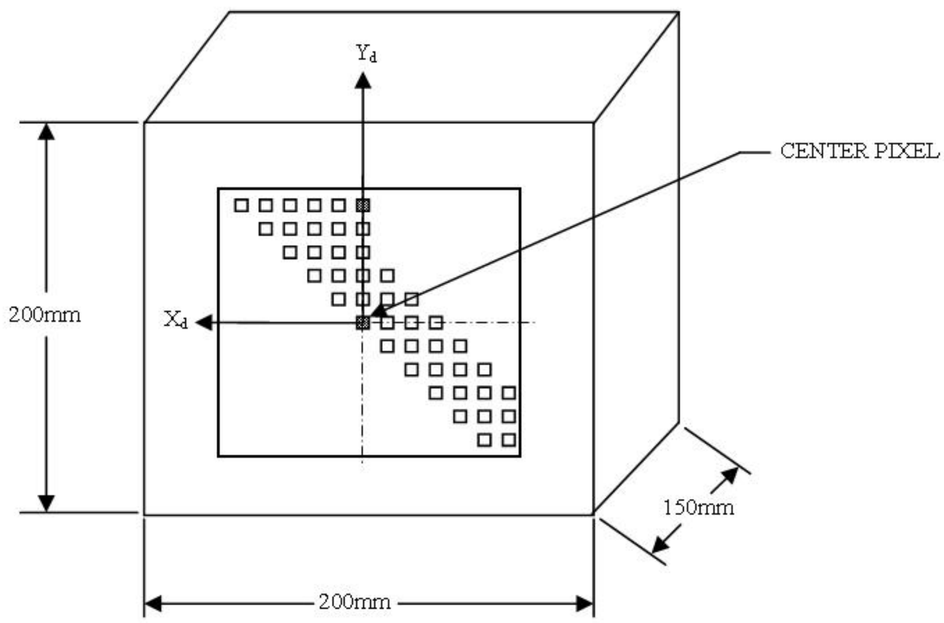

Figure 6
Detector dimension, coordinate system

11.1. Detector Mechanical Properties

Pixel size is 90 micron on an approximately 100 micron spacing. Overall width and height of the array is approximately 100 mm square.

The mounted detector assembly package will be 200 mm square by 150 mm deep and will weight 20 Kg maximum.

11.2. Detector Power and Data Connection Requirements

Cable / Wire / Fiber Inventory: TBD

Minimum bend radii: TBD

Connector Specification(s): TBD

Rf / signal interference shielding – protection: TBD

11.3. Detector Mounting Requirements and Geometry

The array detector interface is shown in **figure 6** **(TBD)**. This interface establishes and maintains the array rotation reference datum. Detector mover hardware shall be compatible with this interface and provide features to maintain detector rotation values / information.

Array detector mounting hardware may be integrated with detector motion coordinate system alignment hardware and / or crash protection equipment.

12. Mechanical Interface

12.1. Base Mounting Requirements

Detector mover system hardware may be mounted in any location that does not violate adjacent equipment stay-clear volumes as defined in SLAC document number GP-391-750-14.

Hutch floor, wall and / or ceiling are acceptable locations for mover system mounting. **Base mounting performance (deflection, etc) shall be considered in the overall detector motion performance as defined in section 9.**

SLAC is situated in an active seismic zone. All hardware exceeding a weight of 300 Lbs. and / or mounted greater than 4 feet above the floor will be reviewed by a SLAC “citizen safety committee” for seismic loading resistance. Applicable loads and structural behavior will be evaluated for compliance to the 1997 version of the uniform building code and SLAC publication SLAC-I-720-0A24E-002: “Specification for Seismic Design of Buildings, Structures, Equipment, and Systems at the Stanford Linear Accelerator”.

12.2. Coordinate System Alignment Fixture Interface:

Methodology and tooling for aligning the detector-motion coordinate system, as described in section 6, can be mechanical, electro-mechanical or opto-mechanical.

Hardware and tooling attached to the detector-mover may be permanently affixed providing fundamental functionality is not compromised.

Hardware or tooling attached to or proximate to the sample goniometer may be temporarily affixed providing fundamental system functionality is not compromised. Detector mover alignment hardware may be integrated with sample goniometer to active interaction point alignment tooling.

Sample goniometer system interface details are defined in SLAC document number ID-391-300-10.

13. Power – Data – Fluid Requirement / Interface:

TBD:

Adjacent cable trays and control racks may be available for use with the detector mover system.

14. Controls Requirement / Interface:

TBD:

15. User Interface:

The detector mover user interface should be intuitive and seamlessly integrated into the greater XPP user interface. Use of, or ability to interface with, EPICS control system architecture is strongly desired.

The detector mover system shall be easily and completely accessible at remote locations (IE: accessible beyond the confines of the XPP hutch 3).

Clearly defined teach-learn, training and maintenance modes shall be integrated into the user control interface. These special modes shall be easily accessible and clearly distinguished from normal data taking motion control modes.

Interface displays information shall clearly show command values, actual values, programmed path mapping, etc.

16. Materials Standards / Requirements

All parts and materials for the device shall be new and compatible with the performance requirements of this specification.

No system, sub-system or part shall be reconditioned or remanufactured.

All applicable material safety data sheets (MSDS) shall be provided and stored in an accessible location.

17. Environmental Safety and Health Requirements

17.1. Reviews

All systems hardware will be subject to SLAC review and approval. Reviews will be conducted in accordance with SLAC document number AP-391-000-59: "Engineering Review Guidelines". SLAC reserves to right to employ an internal (SLAC direct), external independent, or mixed source review panel.

Particular review attention will be devoted to:

- Personnel access restriction methodology
- Emergency stop methodology / mechanisms
- Power failure provision – fault modes
- Electrical subsystem Lock-Out / Tag-Out:
- Training mode functionality
- Maintenance mode functionality

As previously stated, all hardware exceeding a weight of 300 Lbs. and / or mounted greater than 4 feet above the floor will be reviewed by a SLAC "citizen safety committee" for seismic loading resistance.

All electrical hardware and connections will be reviewed for compliance to local electrical code(s).

17.2. Applicable Standards

All hardware designs and installation will be reviewed for compliance one or more of the following codes – specifications for personal safety criteria:

OSHA technical manual, section IV, chapter 4; "Industrial Robot and Robot System Safety"

ANSI / RIA R15.-06; "American national Standard for Industrial Robots and Robot Systems"

18. Supplemental System Requirements:

Requirements, including the following topics, will be addressed in detail in subsequent procurement specifications and contracts.

i. Inspection, testing and acceptance
ii. Installation support services
iii. Training support services
iv. Maintenance procedures, schedules and assistance
v. Repair and overhaul services