LUSI LCLS Ultrafast Science Instruments

PROJECT MANAGEMENT DOCUMENT	Doc. No. PM-391-000-99 R2	LUSI SUB-SYSTEM Management

Preliminary Hazards Analysis Report

Prepared by: Tom Fornek
LUSI Deputy Project Director

Signature Date

Approved by: Jerome Hastings
LUSI Project Director

Signature Date

Approved by: John Galayda
LCLS Project Director

Signature Date

Rev	Description	Date
0	Preliminary Hazards Analysis for Approval of Preliminary Baseline(CD-1)	December 7, 2006
1	Preliminary Hazards Analysis w/January 2007 CD-1 Review Comments	July 12, 2007
2	Initial Release	February 29, 2008

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PRELIMINARY HAZARDS ANALYSIS

for
The Linac Coherent Light Source
Ultrafast Science Instruments (LUSI) Project

Stanford Linear Accelerator Center
for the Department of Energy

Document No PM-391-000-99
Revision 2
February 29, 2008

NAME	DATE
Submitted by:	
Thomas Fornek, LUSI Project Director	
Jereome Hastings, LUSI Deputy Director	
Concurrence:	
John Galayda, LCLS Project Director	

Revision Record

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1. INTRODUCTION

This Preliminary Hazard Analysis Report (PHAR) has been prepared for the Linac Coherent Light Source Ultrafast Science Instruments (LUSI) project as part of the Critical Decision 1 (CD-1) process according with requirements of DOE Order 413.3A, Program and Project Management Practices. The PHAR reflects that the project is being developed following SLAC Integrated Safety Management (ISM) principles and the DOE Accelerator Safety Order, DOE O 420.2A. The LUSI project will design, build, install and test three instruments to be used in conjunction with the Linac Coherent Light Source (LCLS). The instruments will comply with and operate within the bounds of the approved LCLS Accelerator Safety Envelope (ASE).

1.1 ENVIRONMENT, WORKER AND PUBLIC SAFETY

LUSI instruments are being designed so that they will not pose hazards either on or off-site to people or the environment. The most significant potential hazard associated with the LUSI instruments is that associated with prompt ionizing radiation. This radiation is limited to regions where the beam is present and radiation will only result when a beam is present. The LUSI instruments will be designed to the standards defined in 10 CFR 835 that defines radiation protection standards for the protection of individuals from ionizing radiation. The SLAC interpretation of these standards is promulgated in SLAC's Radiological Control Manual.

The Environmental Assessment developed for the LCLS resulted in a DOE Finding of No Significant Impact (FONSI) encompassed the physical space occupied by LUSI and its operations.

Integrated Safety Management System (ISMS) principles have been integrated into the management of the LUSI design and will also be applied in the development of its proposed operating procedures. LUSI is also assuring that safety is integrated in to the design and construction of project instrumentation consistent with the DOE position taken in the Deputy Secretary of Energy's Memorandum *Integrating Safety into Design and Construction*[1] and the requirements of DOE Order 413.3A *Project Management for the Acquisition of Capital Assets.*

Safety parameters of the beam available to the LUSI instrumentation and operating environment have been defined in the Accelerator Safety Envelope developed for the LCLS. Details regarding the ASE can be found in the LCLS Safety Assessment Document.

Environmental protection, worker safety and LUSI relations with stakeholders and the community are based on the direction provided by SLAC's:

- Environmental Management System (EMS),
- Environmental, Safety, Security and Health Policy; and
- Experiment Safety Review Procedures

[1] Integrating Safety into Design and Construction, Clay Sell Memo, Dated December 5, 2005

2. SUMMARY

2.1 OVERVIEW OF HAZARDS

No previously unidentified safety hazards were found in the development of this PHAR beyond the hazards addressed in the LCLS Safety Assessment Document.

The results of this Preliminary Hazards Analysis Report were consistent with those of the LCLS analysis that resulted in a low hazard facility determination following the criteria defined in DOE-O 5481.1B, Safety Analysis and Review System, based on the following findings:

1. LCLS requirements for SLAC Linac operations are well within existing safety and operating envelopes of the facility. While the peak brightness of the LCLS x-ray beam is unprecedented; it should be understood, that this peak brightness is a measure of the instantaneous power density. The average power of the LCLS x-ray beam, the energy and power of the electron beam, and hence radiation hazard they pose are all well within the range of applicability for SLAC and SSRL shielding and safety systems. Radiation shielding analysis revealed that the LCLS presents some complex geometry questions, however the models used to provide minimum shield wall thickness are well understood.
2. The risk (probability & consequences) of all hazards will be similar in nature and magnitude to those already found in the present accelerator storage ring experimental programs. The impact of any hazard will be minor onsite and negligible off-site to people or the environment.
3. Existing and mature programs (citizen safety committees, ES&H division, LUSI ES&H Coordinator) will be engaged to ensure that all aspects of the design, installation, and testing phases of the LUSI project will be properly managed and that they conform to the applicable Work Smart Standards that SLAC has adopted and written into its contract with the DOE.
4. That Integrated Safety Management (ISM) has been fully implemented at SLAC via the DEAR clause and incorporated through the contract between Stanford University and DOE in 1998.
5. The LCLS Environmental Assessment did not identify any previously unrecognized hazards or conditions that would adversely affect worker safety and health or the environment during the assembly and installation of the LUSI instruments.
6. DOE's Office of Science classified SLAC as a **"Radiological Facility";** following criteria defined in the DOE Standard "Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports", DOE-ST-1027-92, December 1992.

2.2 COMPREHENSIVENESS OF THE SAFETY ANALYSIS

This PHAR was developed following the requirements of DOE Order 420.2, Safety of Accelerator Facilities. The Laboratory and project ESH organizational support for the development and assembly of the LUSI components have been addressed. Occupational health and safety hazards, and environmental aspects of the facility have been identified and controls described. A Fire Hazard Analysis developed for the LCLS project includes the area occupied by the LUSI project. No previously unreviewed safety issues were identified in the preparation of the LUSI PHAR.

Radiological occupational exposures will be maintained As Low as Reasonably Achievable, consistent with SLAC objectives. Shielding configuration and maintenance of that configuration will be developed according to SLAC policies and procedures.

2.3 APPROPRIATENESS OF THE ACCELERATOR SAFETY ENVELOPE

The LCLS Accelerator Safety Envelope (ASE) contained in the LCLS Injector Safety Assessment Document ***(SLAC-I-010-30100-015-R001)*** will apply to LUSI. This ASE was been established in accordance with the requirements set forth in DOE Order 420.2B. No revisions to the current ASE are suggested on the basis of the LUSI operation.

3. PROJECT DESCRIPTION

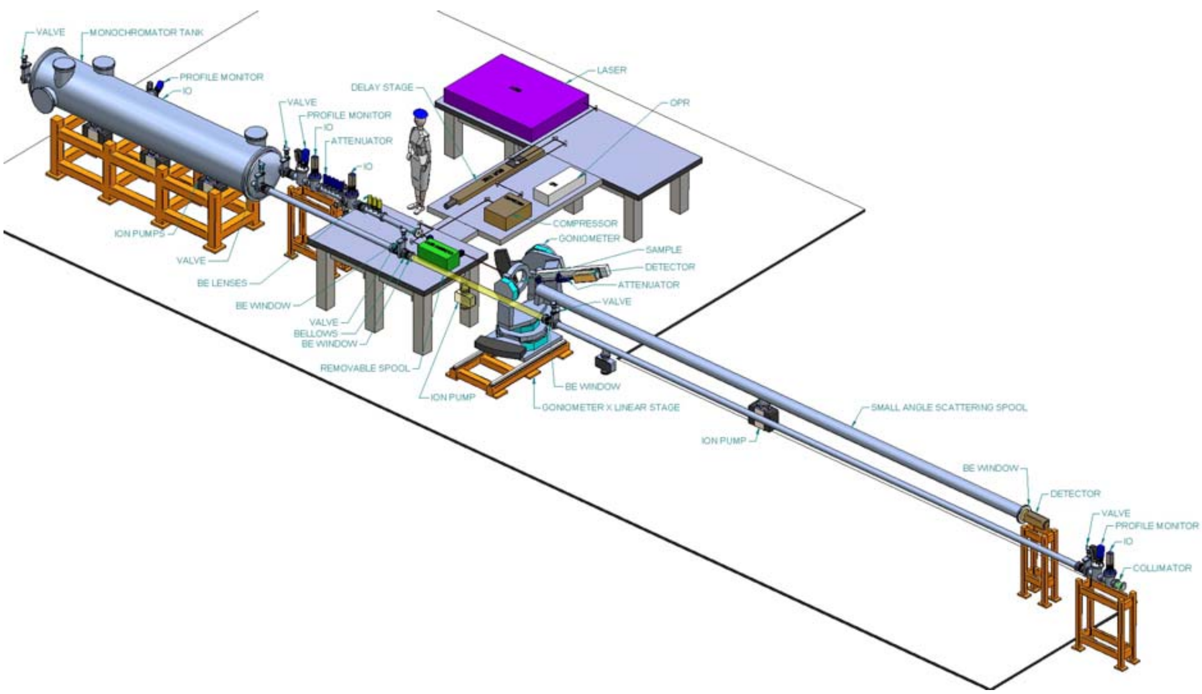
The Stanford Linear Accelerator Center (SLAC) is a national research facility operated by Stanford University for the U.S. Department of Energy (DOE). Research at SLAC centers around experimental and theoretical particle physics using accelerated electron beams, and a broad program of atomic and solid state physics, biology and chemistry using synchrotron radiation from accelerated electron beams.

The Linac Coherent Light Source (LCLS), funded by DOE's Office of Basic Energy Sciences (BES) currently under construction at SLAC, will serve as a research and development center for X-ray Free Electron Laser (XFEL) physics in the hard x-ray regime and as a scientific user facility for the application of XFEL radiation to experimental science. It will bring a completely new dimension to the use of x-rays to study matter through its unique properties that have never before been available. Currently synchrotron light sources produce x-rays to study how atomic structures affect the properties of materials, but synchrotron light sources cannot produce ultra-short pulses, so they cannot resolve the ultra-fast motions of atoms during chemical reactions. The LCLS is a revolutionary advance within the synchrotron radiation world, since it produces the x-rays associated with synchrotron light sources, in ultra-short and ultra-intense pulses. The tremendous brightness of the LCLS x-ray pulse will also be invaluable for imaging the atomic structures of small static objects. Individual single molecules or small clusters of molecules may also be able to be imaged.

The LCLS Ultrafast Science Instruments (LUSI) project will augment the LCLS's initial instrument which is directed towards atomic physics, with three x-ray instruments in order to exploit the unique scientific capability of this new facility. LUSI plans to build these devices over a period of six fiscal years (2007 – 2012). One of two instruments will be optimized for hard x-ray studies of ultrafast dynamics at the atomic level, addressing basic problems in chemistry and materials science. The second instrument will concentrate on hard x-ray coherent imaging of nano-particles and large biomolecules. The third instrument will study equilibrium dynamics on the nanometer scale using hard x-rays.

3.1 X-RAY PUMP/PROBE DIFFRACTION INSTRUMENT

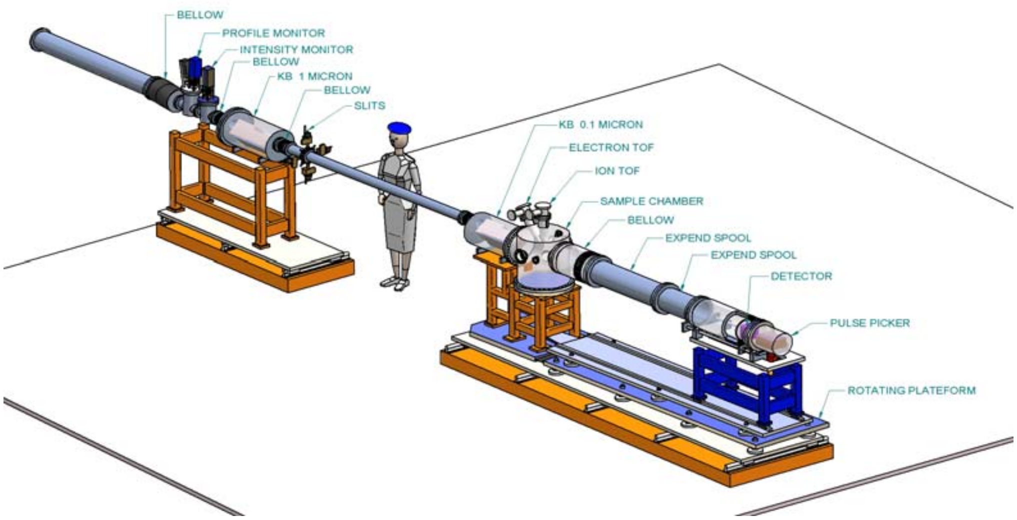
The X-Ray Pump Probe Diffraction (XPP) instrument will predominantly use a fast optical laser to generate transient states of matter, and the hard x-ray pulses from the LCLS to probe the structural dynamics initiated by the laser excitation. The laser pump will have the ability to conduct precise optical manipulations, in order to create the desired excited states. An ultrafast laser pulse excites a brief change in the positions of the atoms in the sample. This change is studied using diffraction of the LCLS x-ray pulse, which follows the laser pulse after a precise time delay.



Pump Probe Diffraction Instrument

3.2 COHERENT X-RAY IMAGING INSTRUMENT

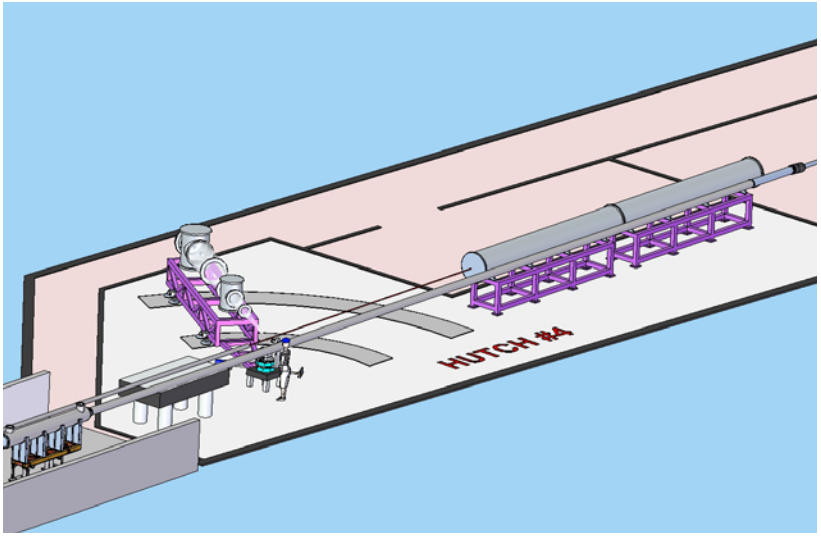
Coherent x-ray imaging can potentially provide a new horizon of imaging nanoscale materials and large single macromolecules at or near atomic resolution in three dimensions. Resolution in these experiments would not depend on sample quality in the same way as in conventional crystallography, but would be a function of radiation intensity, pulse duration, wavelength, and the extent of ionization and sample movement during the exposures. The full peak brightness of the LCLS is fully exploited when imaging biological materials such as viruses and single macromolecules. The penetration depth of hard x-rays in combination with the coherent nature of the radiation will permit detailed 3D study of large, non-periodic structures, and provide capabilities that will go beyond conventional scanning probe microscopy, electron microscopy or x-ray crystallography.



Coherent X-Ray Imaging Instrument

3.3 X-RAY PHOTON CORRELATION SPECTROSCOPY

The unprecedented brilliance and narrow pulse duration of the LCLS provides a unique opportunity to observe dynamical changes of large groups of atoms in condensed matter systems over a wide range of time scales using X-ray Photon Correlation Spectroscopy (XCS). In contrast to the study of stimulated dynamics (pump-probe), the XCS technique studies equilibrium fluctuations excited by the thermal energy of the sample. Images of the speckle scattering pattern are taken with various time delays between images, and the change in the speckle pattern as a function of time delay is used to study the sample dynamics.



X-Ray Photon Correlation Spectroscopy

4. METHODOLOGY

It is SLAC's policy and objective to integrate safety and environmental protection into its management and work practices at all levels, to accomplish its mission while protecting the worker, the public, and the environment. To achieve this objective, SLAC has developed and implemented an Integrated Safety Management System (ISMS), required by DOE P450.4, Safety Management System Policy, which encourages and supports the use of the Work Smart Standards process, development of measurable goals in the form of performance metrics, and uses existing programs and activities that have been deemed successful and which already incorporate the ISMS elements. ISMS is implemented through the incorporation of a contract clause from the DOE Acquisition Regulations (DEAR), specifically DEAR 970.5204.-2, “Integration of Environment Safety and Health Into Planning and Execution”. This clause was incorporated into the contract between DOE and Stanford University for operation of SLAC in February 1998.)

Existing and mature programs at SLAC will be used to ensure that all aspects of the design, installation, and testing phases of the project are properly managed. The LUSI project will be presented to the SLAC Safety Overview Committee, which coordinates and assigns safety reviews for new projects or facility modifications to other citizen committees, which have knowledge or skills in a specific area. The hazards for the LUSI may require reviews from committees including but not limited to: Radiation Safety Committee, Electrical Safety Committee, Earthquake Safety Committee and the Fire Protection Safety Committee.

Safety requirements are identified through the Work Smart Standard process employed at SLAC and are based on known and identified potential hazards. Appendix A identifies these possible hazards and provides a risk determination summary for the LUSI project.

All aspects of the project will conform to the applicable Work Smart Standard that SLAC has adopted and written into its contract with the DOE.

LUSI's ES&H program planning will be standards-oriented. The LUSI project will require its technical managers to address ES&H standards and requirements in their work planning before authorizing work (or purchases) to proceed.

4.1 PROJECT OCCUPATIONAL SAFETY REQUIREMENTS

All LUSI designs shall conform to the requirements of the Occupational Safety and Health Standards 29 CFR 1910. The LUSI equipment shall be designed and constructed in such a manner to protect the safety of workers, the public and the environment. This shall be accomplished following the SLAC Environment Safety and Health program. The safety philosophy and practice to be followed on the LUSI project will include the following elements:

- Safety Management System Policy, DOE Policy, DOE P 450.4 Safety Management System
- Adherence to SLAC Work Smart Standards (WSS)
- Radiation Protection in accordance with 10 CFR 835, "Occupational Radiation Protection"
- Implementation of radiation controls to limit radiation to personnel levels as low as reasonably achievable
- Controlling hazards by eliminating them whenever practical
- Following industry consensus standards, unless a justification to deviate is approved
- Implementing construction safety programs to ensure worker safety during construction and testing
- Performing independent Design Reviews on systems, structures and component designs
- All designs involving the use of lasers shall be compliant with ANSI Z136.1-2000, Safe Use of Lasers, and all laser systems shall be classified by the LSO.

4.2 HAZARDS ASSESSMENT

4.2.1 Design and Installations Phase Hazards

- ***Radiation* –** There is no source of radiation during the design, fabrication and installation phases of the project.

- ***Fire Protection* –**The Fire Protection system that will be installed in the area to be occupied by the LUSI equipment is classified as an "improved risk" system, meeting the objectives of DOE Order 420.1. The LUSI is protected by a conventional fire sprinkler system and a Very Early Smoke Detection Apparatus (VESDA) system. The VESDA air sampling fire detection system continuously samples the air and is tied in to the SLAC site wide fire alarm system. It alarms when it detects by-products of materials as they degrade during the pre-combustion stages of an incipient fire. All facility installations for LUSI designs shall be compliant with the life safety code NFPA 101 and 1910.35 (exit routes, emergency actions plans, and fire prevention plans).

- ***Electrical* –** Electrical hazards will be controlled by adhering to NFPA 70E standards during design and implementation of SLAC and LCLS safe work procedures for operations. To assure the safety of electrical equipment used in the instruments and supporting equipment must be either approved by a Nationally Recognized Testing Laboratory or by an Authority Having Jurisdiction.
- ***Seismic*-** LUSI installations and experiment equipment will be designed and reinforced to withstand projected seismic activity for this area in compliance with UBC and SLAC requirements. This process will include stress analyses for lateral seismic forces for nonstructural anchorage components for LUSI.
- ***Chemical* –** The only chemicals projected to be used at SLAC in the development of the LUSI instrument components or in the installation of the components will be cleaning solvents. These containers will be appropriately labeled and stored following manufacturer MSDS recommendations.
- ***Thermal/Cryogenic* –** No bake-out or use of cryogenics is projected during the development or installation of LUSI instruments.
- ***Mechanical* –** During equipment assembly and installation, movement of components presents the risk of equipment falling and pinch hazards. The control for these exposures will be the use of proper material handling equipment, PPE and effective work planning. Equipment designs will include an ergonomic analysis to mitigate the potential for worker injury.
- ***Environmental Insults*** - The construction of LUSI components and their assembly will not pose a risk to the environment. During operation the potential for air, soil and water activation have been evaluated and are well below SLAC action levels. Equipment activation levels will be low. A determination of a **Finding of No Significant Impact (FONSI)** was reached in the evaluation of the Environmental Assessment developed for the LCLS project which encompassed LUSI fabrication, installation and experimental activities.
    - ***Air Emissions*** - A National Emissions Standards for Hazardous Air Pollutant evaluation determined that dose/risk to the members of the public was minimal.
    - ***Waste Material Disposal*** - Where practical waste materials will be recycled, thus reducing the overall waste stream.
- ***Magnetic* –** No high magnetic fields will be present when assembling or installing LUSI equipment or facilities.
- ***Oxygen Deficiency*** – Oxygen deficiency hazards potential is minimal due the small quantities of gases in liquid state that will be used within the facility. The

requirement for air monitoring will be included in the evaluation of the hutches as the details of the equipment designs mature.

- ***Vacuum / Pressure -*** LUSI equipment will interface with vacuum systems. The presence of pressurized systems will be few. These will be limited to conventional compressed gas systems.

4.2.2 Operations Phase Hazards

- ***Radiation –*** Potential for exposure to radiation during the conduct of experiments is very low when appropriate radiation shielding and Personnel Protective Systems (PPS) are in place. Area radiation monitors interlocked to the injection systems provide redundancy to the system to disable the beam in the event a failure is identified in either the shielding or the PPS. At most General Radiation Training will be required by individuals conducting experiments.
- ***Fire -*** LUSI instrumentation will be contained within enclosed hutches. The hall within which the hutches will be located will have a VESDA system in place and sprinklers. The selection of cable used on the LCLS project and fire breaks in cable trays were chosen with the view of reducing the fire exposure in the Experiment Hall. The design of the hutches includes features to de-energize the hutches in the event of a fire. Packing material and chemicals will be administratively controlled to minimize their presence in the hutches and the Experiment Hall.
- ***Electrical –*** The presence of electrical hazards will be controlled by adhering to NFPA 70E standards and implementing SLAC and LCLS safe work procedures. Electrical equipment used in the instruments and supporting equipment will be approved by either a Nationally Recognized Testing Laboratory or by an Authority Having Jurisdiction. LOTO procedures shall be followed pursuant to the SLAC ES&H Manual Chapter 8 on Electrical Safety and NFPA 70E guidelines.
- ***Seismic-*** LUSI installations and experiment equipment will be designed and reinforced to withstand projected seismic activity for this area in compliance with UBC/SLAC requirements.
- ***Chemicals –*** Chemicals used during the operation of LUSI instruments will be for cleaning components and sample preparation. MSDS will be available for commercially produced chemicals. Chemicals will be labeled and stored in an approved locker. PPE guidelines will be followed as stipulated in the MSDS when handling chemicals and JHAM's for chemical use will be reviewed by SLAC IH. Generally chemicals in the immediate vicinity of the beamlines will be in containers of a gallon or less.
- ***Thermal/Cryogenic –*** Bake-out of instrument components is not viewed as a likely activity during the operation of the LUSI instruments. Some cryogenics may be used to control samples when conducting experiments. Handling of cryogens shall be compliant with SLAC ES&H Manual Chapter 36, Cryogenic

Oxygen Deficiency Hazard Safety, which addresses mitigations for cold burns and ODH.

- ***Mechanical* –** During operations equipment will be regularly assembled and components moved. This creates the potential for equipment falling and pinching hazards. The controls for these exposures are the use of proper material handling equipment, PPE and effective work planning. The layout of equipment will be evaluated from an ergonomic perspective to mitigate the potential for worker injury.
- ***Environmental Compliance* –** The SLAC Environmental Management System will periodically monitor LUSI operations as is done for other SLAC activities to ensure environmental compliance is maintained at a high level. Environmental compliance will be reviewed by SLAC EM, and any spills will be handled in accordance with the SLAC ES&H Manual Chapter 16 for spills, which includes reporting and classifying spills.
- ***Control of Effluents* -** Effluents resulting from sample preparation and resulting from the conduct of experiments when the instruments begin operations will be neutralized and disposed of through SLAC approved processes. Regulated industrial, hazardous, radioactive, mixed and regulated medical wastes will be managed applying SLAC procedures and where possible quantities used will be minimized. Effluents will be managed in accordance with SLAC ES&H Manual Chapter 17 for Hazardous Waste and the SLAC Hazardous Materials Management Handbook. A HWMC will be designated to support the LUSI Project.
- ***Oxygen Deficiency* –** Oxygen deficiency hazards potential is minimal due the limited quantities of gases in liquid state that will be used within the facility.
- ***Vacuum / Pressure* -** LUSI equipment will interface with vacuum systems. The presence of pressurized systems will be few. These will be limited to conventional compressed gas systems. When accelerator and beamline vacuum faults are detected, interlock systems will automatically close sector and beamline valves. Loss of compressed air systems associated with PPS will initiate alarms alerting control room staff to take appropriate action. Oxygen and fuel gases will not be stored together. Compressed gas systems will be equipped with pressure gages, regulators, and provisions will be in place for emergency shutdown. Gas cylinders will be secured and stored in an upright position.

4.2.3 Occupational Safety Considerations for Operations

- **Radiation Exposure Control –** Individuals working in and around the Experiment Stations will require at the most GERT radiation training.
    - Configuration control of radiation shielding will be maintained through the use of Authorization for Work on Accelerator/Beamline Safety System forms.

  - Radiation Monitoring will be conducted through the use of personal and area TLDs.
  - Radiation safety interlocks will be tested on a regular schedule to insure integrity. Management of these systems by Control Room and Accelerator Operations Division personnel.

- **Beam Loss Control –**
  - Controls to prevent or mitigate beam loss and maintain radiological conditions ALARA should include real-time radiation monitors with audio alarms, area and personal TLDs, pre-operations sweep procedures, and access-control (interlock) devices.
  - Control Room beam loss procedures should include lock-out/tag-out procedures, experimental and radiation safety check-off lists, work planning procedures, and radiological training.

- **Waste Minimization –**
  - Chemicals brought to SLAC or used in sample preparation at SLAC will be reviewed when the LUSI Experiment Safety Approval review is conducted. Quantities of chemicals and materials will be kept to a minimum and less hazardous substitutes suggested where possible. Effluents will be managed in accordance with SLAC ES&H Manual Chapter 17 for Hazardous Waste and the SLAC Hazardous Materials Management Handbook. A HWMC will be designated to support the LUSI Project.

4.2.4 Hazard Consequence Rating

The hazards have been rated and tabularized in Appendix A, based on the following criteria

Table 4.1 Hazard Probability Rating Levels

Category	**Category Estimated Range of Occurrence Probability (per year)**	**Description**
High	>10-1	Event is likely to occur several times in a year.
Medium	10-2 to 10-1	Event is likely to occur annually.
Low	10-4 to 10-2	Occurrence is likely to occur, during the life of the facility or operation.
Extremely Low	10-6 to 10-4	Occurrence is unlikely or the event is not expected to occur during the life of the facility or operation.
Incredible	<10-6	Probability of occurrence is so small that a reasonable scenario is inconceivable. These events are not considered in the design or SAD analysis.

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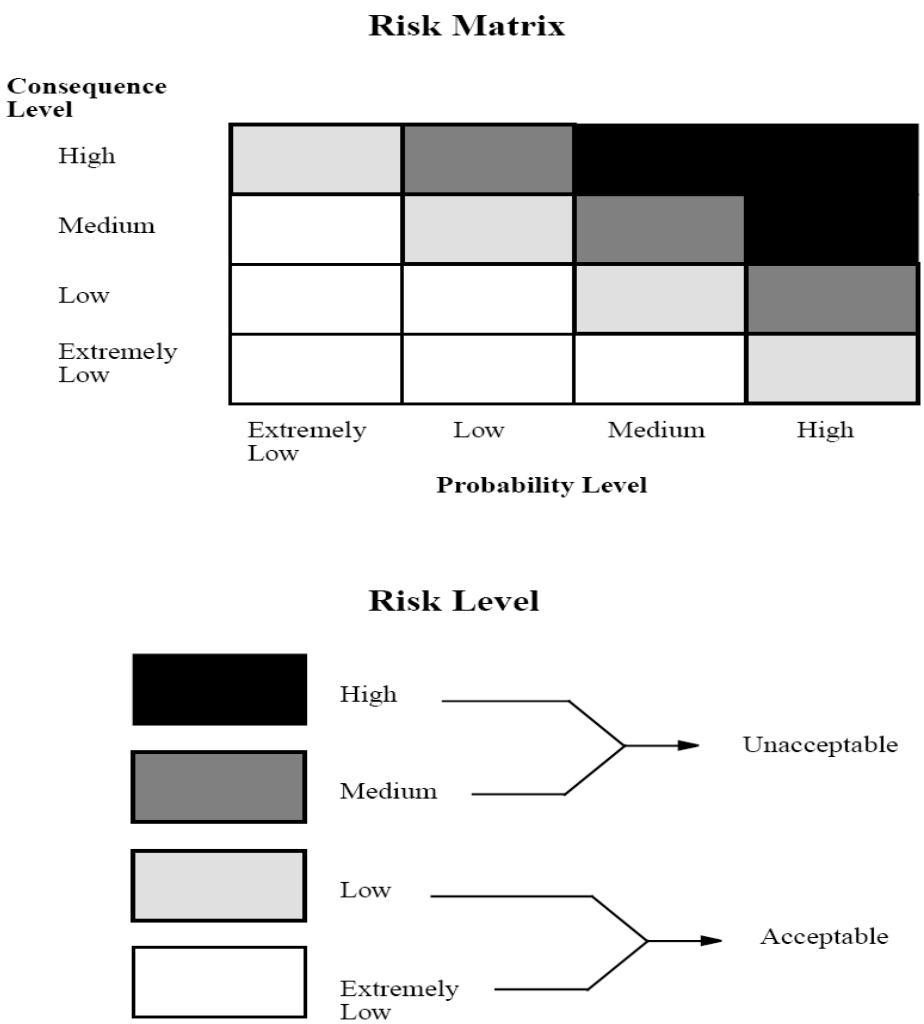
Table 4.2 Hazard Consequence Rating Levels

Consequence Level	**Maximum Consequence**
High	Serious impact on-site or off-site. May cause deaths or loss of the facility/operation. Major impact on the environment.
Medium	Major impact on-site or off-site. May cause deaths, severe injuries, or severe occupational illness to personnel or major damage to a facility/ operation or minor impact on the environment. Capable of returning to operation.
Low	Minor on-site with negligible off-site impact. May cause minor injury or minor occupational illness or minor impact on the environment.
Extremely Low	Will not result in a significant injury or occupation illness or provide a significant impact on the environment.

Figure 4.1 Risk Determination



5. QUALITY ASSURANCE

The LUSI Quality Implementation Plan applies to the work performed at the LUSI. LUSI management is responsible for the quality of fabrication, the operation of the equipment and the work processes in the facility. Responsibility for quality is delegated through the line staff positions and they are responsible for the quality of their own work. LUSI components are evaluated for Environmental, Safety, Health, & Quality (ESH&Q) Risk Level categories A-1 through A-4 as per the Graded Approach for Quality Requirements. The LUSI will conform to the SLAC Quality Assurance Program which in turn implements the requirements of DOE Order 414.1C.

APPENDIX A – HAZARD IDENTIFICATION & RISK DETERMINATION

Item	Hazard	Presence at LUSI	Unmitigated Hazard Level	Prevention/ Mitigation	Potential Impact	Mitigated Hazard
1.	Ionizing radiation exposure inside the accelerator enclosure (greater than 25 rem/h): 1. Prompt	PPS failure or inadequate search	Medium	Personnel Protection System (PPS). PPS operator training. Periodic testing of PPS. Radiation safety training. Ref: *SLAC Guidelines for Operations*, Search Procedures, Entry and Exit Procedures, PPS Interlock Checklists	High radiation exposure	Extremely Low
2.	Ionizing radiation exposure inside the accelerator enclosure (greater than 25 rem/hr): 2. Residual	Work on or near activated components.	Medium	Instrument operations procedures Training - LUSI specific orientation will warn of the hazards of being in the experiment enclosure and the personnel protective systems in place. Shutter open warning lights PPS door lock and PPS interlock for beam cutoff if enclosure door is open when shutter is open. Radiation surveys, Personnel training, and use of Radiological Work Permits Ref: *Radiation Safety Systems*, *Radiation Physics procedures.* *Personal dosimeters. Barriers.*	Exposure to residual radiation.	Extremely Low

Item	Hazard	Presence at LUSI	Unmitigated Hazard Level	Prevention/ Mitigation	Potential Impact	Mitigated Hazard
3.	Ionizing radiation exposure (greater than 25 rem/hr) outside the Linac enclosure	Routine Cable Plant No combustible material in experiment stations, other than small qualities of cleaning supplies. Shielding error and/or beam containment failure.	Medium	Beam Containment System (BCS), Beam Shut-off Ion Chambers (BSOICs), Ref: *Radiological Control Manual* *Beam Authorization Sheet, Pre-run Checks, PPS Safety Inspection Checklists*	Personnel radiation exposure	Extremely Low
4.	Fire	Cable Plant Combustible material in enclosure	Medium	VESDA smoke detection system reporting to the Pyrotronics MXL panel. Fire sprinklers in some areas. Proper selection of cable plant. Fire breaks in cable trays. On-site fire department. Ref: *SLAC ES&H Manual*	Loss of technical equipment Partial loss of cable plant Shut down of operations Personnel Injury	Extremely low

Item	Hazard	Presence at LUSI	Unmitigated Hazard Level	Prevention/ Mitigation	Potential Impact	Mitigated Hazard
5.	Electrical	Installation of standard industrial distribution (< 210 V) systems. Contact with energized cables during installation of instrumentation	Medium	Implementation of building and structural codes (UBC) Design standards and Safety Committee review and inspections. New equipment complies with all applicable electrical codes and standards. All equipment used in LCLS installations must be ELP certified. Certain conventional equipment will be UL listed. Project reviewed by the SLAC electrical safety committee review. LOTO training for all individuals working on exposed electrical systems. Specific LOTO procedure (ELP) for each power supply. Electrical hot work permits, where applicable. Ref: *SLAC ES&H Manual* *Requirements for Work in SLAC Accelerator Housing*	Shock or arc (flash)	Extremely low

Item	Hazard	Presence at LUSI	Unmitigated Hazard Level	Prevention/ Mitigation	Potential Impact	Mitigated Hazard
6.	Seismic	Exposure to chemicals is not likely during system installation. Other than small quantities of lubricants and cleaning supplies. Possible exposure to chemicals during sample development and experiment set up. Falling objects during earthquake	Low	Apply sample development processes that minimize chemical use and where possible substitute chemicals with ones of lesser virulence. SLAC IH monitoring program will periodically assess chemical handling practices. Engineered transport systems will be used to move chemicals to preparation labs. Personnel training MSDS will be available for all chemicals used, and all chemicals will be stored in labeled containers and approved storage lockers. Implementation of building and structural codes Design standards and Safety Committee review and inspections Ref: *Specification for Seismic Design of Building, Structures, Equipment, and Systems*	Personnel struck by or pinched between equipment during an earthquake	Extremely Low

Item	Hazard	Presence at LUSI	Unmitigated Hazard Level	Prevention/ Mitigation	Potential Impact	Mitigated Hazard
7.	Chemical	Cleaning chemical during installation Possible exposure to chemicals during sample development and experiment set up	Low	Personnel Protective Equipment (PPE), Secondary chemical containment CEF and RPFO procedures Ref: *Chemical Process Hazard Analyses*; and *SLAC ES&H Manual* Apply sample development processes that minimize chemical use and where possible substitute chemicals with ones of lesser virulence. SLAC IH monitoring program will periodically assess chemical handling practices. Engineered transport systems will be used to move chemicals to preparation labs.	Contact with personnel, spills,	Extremely low
8.	Thermal / cryogenic	Use of cryogens Vacuum bakeout	Medium	Engineered systems designed to accept daily stress cycles as defined in ASME Pressure Vessel Code. Training Cryogens will not be used during the installation of LUSI instruments. Cryogens are likely to be used during the conduct of experiments.	Personnel cryogenic burn exposures	Low

Item	Hazard	Presence at LUSI	Unmitigated Hazard Level	Prevention/ Mitigation	Potential Impact	Mitigated Hazard
9.	Mechanical	Spills Discharges to sanitary or storm drains Noise Air emissions Vacuum chambers LCW feed & return lines Compressed air and gas lines	Extremely low	Engineered systems designed to conservative standards. Training of personnel in hazard recognition and support Dust management during construction	Personnel injury or exposure	Extremely low
10.	Environmental	Spills Discharges to sanitary or storm drains Noise	Low	Training – Stormwater Awareness Course 298 Hazardous Material Management Core Course 105 Training Secondary containment Minimize of chemicals quantities Management of waste waters from discreet operations (i.e., purging LCW systems, coolant from concrete-saw cutting) IH monitoring Dust management during construction	Personnel exposure Release of liquids to drain system	Extremely low

Item	Hazard	Presence at LUSI	Unmitigated Hazard Level	Prevention/ Mitigation	Potential Impact	Mitigated Hazard
11.	Magnetic	High magnetic fields will not be present in or at points accessible to individuals assembling or installing LUSI equipment. High magnetic fields could be present when conducting experiments that purposely include high magnetic fields.	Extremely low	Limit volumes of gasses in accelerator housings and research areas Equipment/Process review Safe work procedures An ODH analysis will be conducted when the details of the equipment design mature to determine what the potential for an ODH hazard might be. Monitors will be installed if a potential for such an exposure is identified. Training – SLAC magnetic field notification postings Making exposed high magnetic fields inaccessible. Posting for pacemakers. Use of SLAC IH program for monitoring exposed individuals	Personnel injury or damage to medical equipment.	Extremely low

Item	Hazard	Presence at LUSI	Unmitigated Hazard Level	Prevention/ Mitigation	Potential Impact	Mitigated Hazard
12.	Oxygen Deficiency	There will be no oxygen deficient or confined spaces during instrument assembly of installation. There could be an oxygen deficient environment in an experiment station if a dewar of nitrogen spilled.	Low	SLAC safety reviews and training, acceptance testing of pressure devices. Safety reviews will evaluate the need for such devices as barriers for impact debris between workers and equipment if highly pressurized equipment in included in the experimental equipment design. The review will also evaluate the of redundant pressure relief devices, like a self-contained burst disk .Limit volumes of gases in accelerator enclosures. Review by HEEC and application of the requirements in Ch. 36 Safe work procedures. Ref: *SLAC ES&H Manual* Equipment/Process review Safe work procedures	Asphyxiation	Extremely low
13.	Vacuum and Pressure	Pressure devices fail.	Medium	SLAC safety reviews, acceptance testing of pressure devices	Personnel injury	Extremely Low

APPENDIX B – ACRONYMS

BES	Basic Energy Sciences
CD	Critical Decision
CF	Core Function
CXI	Coherent X-ray Imaging
DEAR	DOE Acquisition Regulation
DOE	Department of Energy
ES&H	Environment, Safety, and Health
FEL	Free Electron Laser
GP	Guiding Principles
ISM	Integrated Safety Management
ISMS	Integrated Safety Management System
LCLS	Linac Coherent Light Source
LUSI	Linac Coherent Light Source Ultrafast Science Instruments
XCS	X-ray Correlation Spectroscopy
PHA	Preliminary Hazards Analysis
R&D	Research & Development
SAD	Safety Assessment Document
SLAC	Stanford Linear Accelerator Center
XFEL	X-ray Free Electron Laser
XPP	X-ray Pump Probe