LERF as Cryomodule Testing Facility for LCLS-II Preliminary Hazard Analysis

Revision 0
22 September 2017 - Draft

APPROVALS

Project Engineer	Date
Contractor Project Director	Date

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ATTACHMENTS

1.0 PURPOSE OF THE PRELIMINARY HAZARD ANALYSIS

The scope of the LERF as Cryomodule Testing Facility for LCLS-II
Preliminary Hazard Analysis Hazard Analysis is to:

- Identify hazards associated with the proposed installation of equipment necessary to configure the LERF to test LCLS-II Cryomodules (CM),
- Identify hazards associated with the proposed operation of the LERF for these purposes,
- Identify hazards associated with the restoration of the LERF to its former functionality,
- Verify that ES&H management processes currently exist to mitigate these hazards, and
- Verify that the hazard profile for these activities is within the existing physical and administrative bounding conditions for maintenance and operations at Jefferson Lab.

2.0 PROJECT DESCRIPTION, OBJECTIVE, AND SCOPE

The LCLS II Project at JLab is funded to lessen the testing backlog at the CryoModule Test Facility (CMTF) in the Test Lab. Two LCLS-II style cryomodules (CM) will be tested at a time in the LERF vault. This will be on a ~2 month cycle and will repeat for 4 times, testing a total of 8 CMs. Two CEBAF style CMs will be removed from the vault to be available for the CEBAF machine. The third CM will be relocated from the third position to the first position and be reconnected. This CM will act as a LHe buffer tank and also be used for a series of Q_0 studies over the next year. There is no intension of running any electron beam in the vault for the duration of this project. The project is expected to last ~18 months, then the LERF will be restored to an operational state (as it was before this project).

The scope is to install 16 Solid State Amplifiers (SSAs), & Low Level RF (LLRF) in LERF gallery. These SSAs, which are on loan from SLAC, will be connected to the existing waveguide that routes to tunnel. The klystrons and circulator will be removed and stored to make room the waveguide modifications. Additional waveguide will be purchased to accommodate the SSA connections and the CM connections in the tunnel. The waveguide will be pressurized and interlocked to the PSS, as is the existing system. New cables will be installed for the instrumentation and tuners in the existing penetrations (these are not filled with gravel like CEBAF penetrations). The existing cable trays will be used.

The AC power will be removed from two Cathode Power Supplies (CPSs) and re-routed to two new 480VAC/400Amp service panels to be located in front of the CPSs. These will duplicate the installation of the AC distribution/PSS from Test Lab facility.

A new cryogenic 'end can' and transfer line will be designed, and procured to enable connection for both 2K and 40K shield circuits, supply & return. This transfer line will be designed to use the existing U-Tubes. Since the LCLS-II CMs have the cryogenic connections on the same end of the CM it will connect to the supply of the Zone 2 CM and the return of the Zone 3 CM. The quad girders will be removed from this area to enable ease of access for the U-Tube stabling operation.

The CMs will be transported by flat bed to the LERF parking lot for staging. When starting a new test cycle, the completed CMs in the LERF vault will be disconnected from each other, and from the cryogenic end can, this operation is done with portable clean hoods. The return can on CM#1 will remain in place. The first new (untested) CM will be moved by crane (HR Crane & Rigging, w/lift plan by N. Wilson) off the delivery truck to the parking lot. This will be placed in the #1 position and have the return end can in place. Once the 27 shield blocks have been removed, the tested CM#1 will be either pushed by hand or pulled by 'tug' to the flat section of the LERF truck ramp. This flat section is 40' long, the CM is 37' long. The crane will lift this CM and place directly onto the flat bed. The truck will then return to the test lab to exchange the tested CM#1 for an untested CM, returning to the LERF parking lot. While the exchange was taking place the second tested CM will be moved from the vault, lifted and placed on the parking lot surface. Now the crane will lift the CM off the truck and place it on the flat section of the LERF track ramp. This will then be pushed into the vault position #2 and connection to the cryogenic 'end can' can commence. The crane will then place tested CM#2 on the truck for return to the test lab. Next the crane will deliver the CM#1 to the vault, and it will be placed in/near position #1.

The nomenclature for the CMs are as was for the CEBAF CMs; standing in the middle of the LERF vault, looking at the wall where the waveguides come down, the CM to your right is CM#1, and to your left is CM#2. The cavities count from left to right; so if you walk from the overhead door to the back, west wall you would count CM#1-8,7… CM#1-1, then CM#2-8,7,6… The intention is to purchase two portable clean hoods; one will remain over the cryogenic end can such that it will be 'in-place' when the new CM#2 arrives and is mated to the end can. The second will be wheeled in the center section after CM #2 is placed, before CM #1 arrives. This will prevent the need to bridge the CM once they are in place. There are documented SRF procedures for the bridging and testing of the CMs.

The project will require the installation and commissioning 16 sets of LCLS-II LLRF hardware & software. Most all of this will be EPICS based and provided by SLAC. A new managed Ethernet switch and terminal server will be purchased. This will allow for easier control of remote access from collaborators at SLAC & Berkeley. A dedicated server will also be purchased, SLAC is using EPICS 3.15 version where JLab is using 3.14. The dedicated server will ease any compatibility issues. The CM testing & commissioning tools will be jointly developed. It is envisioned that there will be frequent and extended visits from SLAC personnel to aid in the installation and commissioning of the LCLS-II based cryo, vacuum & interlock systems. The JLab computer center is being consulted on remote access and cyber security aspect of the project.

The baseline is to install and remove the 27 concrete shield blocks for each testing cycle but an assessment of the required shielding has been request.

Restore LERF once CM commissioning is complete at the end of the ~18 month project.

3.0 HAZARD ASSESSMENT

The following is a hazard assessment for the LERF as Cryomodule Testing Facility for LCLS-II Project. The hazard profile contains the following elements:

- Baseline Hazard Profile for the existing LERF facility,
- Proposed Hazard Profile for the LERF as Cryomodule Testing Facility for LCLS-II Project,
- Hazard mitigation measures, and

3.1 Baseline Hazard Profile for the existing LERF facility

The FSAD is designed to address accelerator specific-hazards but is broad enough that it overlaps many of the operational hazards associated with this project. The FSAD identifies five hazard categories:

- Ionizing Radiation,
- Explosion/Fire,
- Oxygen deficiency,
- Equipment damage,
- Non-ionizing radiation.

Until recently, LERF functioned as an accelerator facility. The LERF hazard assessment, including beam operations, is contained in the FSAD Rev. 7a. Operational hazards are repeated below to illustrate the process used in the FSAD and to identify hazards discussed later in this document. The full hazard assessment for accelerator based hazards can be found in the FSAD and is not repeated here. Standard (non-accelerator based) industrial hazards are not evaluated in the FSAD.

For every accelerator-based operational hazard category (1, 2, 3, etc.), the FSAD develops a credible maximum bounding accident scenarios or events (1a, 2b, etc.), determines the consequence, and determines the probability of these events. The consequence and probability for each event is entered into a risk matrix (similar to ES&H Manual Chapter 3210, Appendix T3 Risk Code Assignment in Attachment B). This risk matrix ix used to make a risk level determination for the event and identify necessary mitigations to reduce risk. The risk level determination for specific hazard events from the FSAD after they have been properly mitigated is presented below:

<table>
<tr><th colspan="2">Hazard Event (FSAD Table 4-4, bounding accident scenarios)</th><th>Mitigated Probability Level</th><th>Mitigated Consequence Level</th><th>Mitigated Risk Rating</th></tr>
<tr><td colspan="5">Exposure to Ionizing Radiation</td></tr>
<tr><td colspan="2">Prompt Radiation (1a, 1c,1e, 1h, 1j, 1k, 1o, 1p, 1q, 1r)</td><td>Extremely Low</td><td>Medium</td><td>Acceptable</td></tr>
<tr><td colspan="2">Prompt Radiation (1n, 1s)</td><td>Medium</td><td>Extremely Low</td><td>Acceptable</td></tr>
<tr><td colspan="2">Activated Materials (2a, 2d)</td><td>Low</td><td>Low</td><td>Acceptable</td></tr>
<tr><td colspan="2">Activated Materials (2c)</td><td>Medium</td><td>Extremely Low</td><td>Acceptable</td></tr>
<tr><td colspan="2">Contamination (3a, 3h)</td><td>Extremely Low</td><td>Low</td><td>Acceptable</td></tr>
<tr><td colspan="2">Contamination (3e)</td><td>Medium</td><td>Extremely Low</td><td>Acceptable</td></tr>
<tr><td colspan="2">Explosion/Fire (4a)</td><td>Extremely Low</td><td>Extremely Low</td><td>Acceptable</td></tr>
<tr><td colspan="5">Oxygen Deficiency Hazard</td></tr>
<tr><td rowspan="2">Helium Gas in Accelerator Tunnel and FEL Vault</td><td>(5a, 5c, 5h)</td><td>Medium</td><td>Extremely Low</td><td>Acceptable</td></tr>
<tr><td>(5d, 5j, 5l)</td><td colspan="2">Low</td><td>Low</td></tr>
<tr><td colspan="2">Nitrogen Gas in Accelerator Tunnel and FEL Vault (5k,</td><td>Low</td><td>Low</td><td>Acceptable</td></tr>
</table>

Hazard Event (FSAD Table 4-4, bounding accident scenarios)	Mitigated Probability Level	Mitigated Consequence Level	Mitigated Risk Rating
5l)			
Nitrogen and Helium Gas in Hall Beam line Entrance Tunnel (5i)	Extremely Low	Medium	**Acceptable**
Equipment Damage			
Fire or Incorrect Operation of CEBAF or FEL (6a, 6b, 6c)	Low	Medium	**Tolerable**
Non-Ionizing Radiation			
RF Radiation (7)	Extremely Low	Medium	**Acceptable**

Table 1 - JLab Operational Risk Assessment Based on FSAD Rev. 7a

The LERF as Cryomodule Testing Facility for LCLS-II will not require beam operations or the associated Credited Controls as specified in the Accelerator Safety Envelope Rev. 7. However, FSAD Rev. 7a can substantially serve as a baseline hazard assessment for operational aspects of accelerator-based hazards.

As implied above, the analysis in FSAD Rev. 7a is not necessarily sufficient for installation and removal activities. Further hazard evaluation, that includes standard industrial hazards, is reflected in Attachment A under the "Install / Remove" hazards and discussed further in the following sections 3.2 and 3.3.

Based on the relevancy of accident scenarios for the hazard categories, and the available and proposed mitigating hazard control measures, an acceptable level of risk for each identified *operational* hazard associated with the project is achieved. The means of addressing *operational* risks specific to the project are further discussed in Section 4.2 below.

3.2 Project Hazard Profile for the LERF as Cryomodule Testing Facility for LCLS-II Project

Attachment A is a Hazard Profile Assessment Worksheet. It provides a means of comparing the baseline hazards know for LERF and the hazard profiles expected for the project. The worksheet is based on the existing Jefferson Lab Hazard Issue List contained in the ES&H Manual Chapter 2410, Appendix T1 Hazard Issues List. The hazards associated with the existing facility are labeled (B) for baseline. The hazards associated with the project are labeled (P). The label (X) is used for hazards that are not applicable.

The assessment of facility hazards will continue throughout the design process and ultimately through the operation. At this point in the hazard assessment, there are no additional hazards that are not already considered in the baseline hazards for LERF. Operations will be governed by current Integrated Safety Management Policies and Procedures as specified in the Jefferson Lab ES&H Manual.

3.3 Hazard Mitigation Measures

A discussion of specific mitigation measures associated with each of the hazard categories in the Hazard Profile Assessment Matrix is provided below. In some cases the mitigation discussion is more detailed due to the nature of the hazard or the exposed population. The technical staff and safety professionals will continue to work together during the design, construction, and pre-ops phases of the project to recommend appropriate methods for mitigating occupational hazards.

3.3.1 Chemicals and Hazardous Materials

ES&H Manual Chapter 3210, Work Planning, **Control, and Authorization Process**, addresses employee exposure to hazards in general during work planning and execution. Employee exposure to and use of chemicals and hazardous materials is addressed specifically by SAF000 Hazard Communication Training and Chapter **6610 Chemical Hygiene** Program**.** The purpose of the training is to provide employees with knowledge based on the appropriate combination of experience and Jefferson Lab-specific training to:

- Understand the types of chemicals used in their immediate work area and how to recognize their release,
- The hazardous properties of these chemicals,
- Precautionary measures and protective equipment for their use and handling,
- Special work practices, including the use of ventilation systems and other controls,
- What to do in an emergency: spills, skin or eye contact, ingestion, etc., and
- The location of the local area Material Safety Data Sheet (MSDS) set, and how to read and understand MSDSs, and where to go to get more information.

The MSDS, product label information, and work-area postings should be the focal point for supervisor-provided training. Employees should understand how to get information from these sources. Any employee is entitled to a copy of a MSDS on request. The EH&S Manual Chapter provides 8 Technical Appendices that address everything from use of Safety Data Sheets, receiving/storing/using chemicals, PPE, etc.

3.3.2 Electrical

All electrical installations and practices conform to the National Electrical Code (NEC), National Electrical Manufacturing Association (NEMA) standards and Virginia Uniform Statewide Building Code (2003 Edition). Jefferson Lab ES&H Manual Chapters 6200 Jefferson Lab's Electrical Safety Program, 6220 AC Electrical Equipment Safe Work Program, 6230 Electronic Equipment Safe Work Program, and 6240 Electronic Equipment - Construction and Modification Safety define the electrical safety program. This program sets out the requirements for rendering safe any equipment utilizing electrical power (lock/tag/try) and details local safety requirements for constructing electrical equipment, making electrical equipment safe, and in special cases for working on energized electrical equipment. Normally, all such equipment is operated inside locked and interlocked enclosures complete with appropriate safeguards for de-energizing and grounding the system.

Jefferson Lab currently complies with National Fire Prevention Association (NFPA) 70E for arc flash and arc blast hazards associated with unintentional shorting high voltage, high current electrical conductors. The program involves the identification of specific hazards by equipment so that Personal Protective Equipment (PPE) can be tailored to planned work. Electrical services are being designed to accommodate the electrical power requirements of the project. Once the actual electrical equipment to be installed is identified, then short circuit analysis, breaker coordination, and arc flash calculations will be performed as needed to mitigate the potential electrical hazards.

3.3.3 Environmental

Jefferson Lab ES&H Manual Chapter 8010, Environmental Protection Program, establishes requirements for the environmental monitoring program, described in Chapter 8011, and sets guidelines for examining all actual and hazardous effluents from the facility.

An integral part of the Jefferson Lab Environmental Monitoring Program is routine sampling of environmental media (air, surface water, and groundwater). These media are monitored (depending on the applicable permit or lab program) to ensure that Jefferson Lab effluents are not having a negative impact on the surrounding environment, and that effluent parameters stay within the acceptable range. The ES&H Manual, Chapter 8011 address the environmental monitoring program at Jefferson Lab.

Jefferson Lab in its operations and activities will demonstrate leadership and environmental stewardship through an ISM-based Environmental Management System (EMS) program that:

- Ensures Jefferson Lab's compliance with all applicable environmental laws, regulations, standards, and contractual commitments,
- Identifies and implements techniques and environmentally sound practices that emphasize pollution prevention through source reduction, reuse, recycling, treatment, and environmentally sound disposal,
- Promotes continual improvement in the Lab's ISM System Plan, and therefore EMS practices to lead to improved environmental performance,
- Openly communicates to all employees and the public the Lab's ES&H Policy, our identified environmental aspects, objectives, and targets, and the programs to achieve them, and the results of these efforts,
- Provides human, financial, and technical resources appropriate to the active management and maintenance of the ISM System and the acknowledged EMS, and
- Encourages all employees, to the best of their abilities, to be accountable for implementing, maintaining, and upholding the Lab's policy and contractual requirements.

There are several related ES&H Manual Chapters that are integral to the environmental monitoring program: 8012 Environmental Review for Projects/Activities/Experiments, 8020 Outdoor Air Quality Management Program, 8030 Water Quality and Conservation Program, 8050 Environmentally Harmful Materials, 8060 Waste and Recyclable Materials Management, 8061 Hazardous Waste Management, and 8070 Waste Minimization and Pollution Prevention (WMin/P2) Program.

3.3.4 Fire

Jefferson Lab has an established Fire Protection Program (FPP). Jefferson Lab’s FPP, as described in ES&H Manual Chapter 6900 Fire Protection Summary is a strategy for incorporating fire safety into facility planning, operations, and maintenance. It has features for assessing its effectiveness and identifying areas for improvement. Its overarching goal is to support the research mission of the laboratory by preserving life and protecting property and the environment through minimizing the detrimental effects of fire. This program implements applicable codes, standards, regulations and contractual commitments.

The primary objectives of the FPP are to:

- Reduce the probability and severity of fires by downsizing ignition sources and by minimizing fire loads—the combustible contents of a building—to be as low as practicable and within accepted limits,
  - Protect human life, minimize the impact of a fire on the mission of the laboratory by the use of well accepted fire-protection engineering methods, standards, and systems,
  - Design, maintain, and use mission-essential facilities in accordance with high protected risk (HPR) criteria as generally defined by the fire and property insurance industry,
  - Ensure that fire does not cause release of hazardous or radiological material that threatens health or the environment, prevent fire damage to essential material and safety systems, and
- Promote continued effectiveness of fire-protection systems through a program of regular inspection, testing, and maintenance.

These objectives are reached by incorporating everyday fire-safety practices, and related training requirements for employees, users, and subcontractors in the other chapters of the Jefferson Laboratory ES&H Manual: 3410 Subcontractor Construction Safety, 3510 Emergency Response Activities, 6122 Hot Work (i.e. Welding, Cutting, Brazing, and Grinding) Safety Program, 6150 Gas Cylinder Safety - Storage, Movement, and Labeling, 6610 Chemical Hygiene, and 6160 Confined Space Entry.

3.3.5 Magnetic Fields

The ES&H Manual Chapter 6420, Non-Ionizing Radiant Energy (i.e.: Radio Frequency (RF), Microwave, and Static Magnetic Fields), describes the potential hazards of static magnetic fields and the controls and practices used at Jefferson Lab to reduce these hazards to all employees, users and site visitors.

The static magnetic fields associated with most magnets used at Jefferson Lab are confined to their interiors and hence do not present an exposure hazard. A notable exception is fields from specialized magnets that are operated in experimental areas. The static magnetic fields associated with these devices may be as high as several Tesla and, though the intensity decreases rapidly with distance, may require many feet/meters to fall to negligible levels. Whenever practical, magnets creating such fields are de-energized during periods whenever personnel exposures would occur, such as during lengthy downtimes associated with accelerator operations.

Protection from static magnetic fields is accomplished by:

- Conducting Exposure Assessments for magnetic field strength,
- Hazard Communication using approved lights and signs,
- Work control documents with specific robust requirements,
- Adhere to exposure limits for static magnetic fields,
- Electrical safety requirements, and
- Quench Protection - emergency shutdown system designed to allow for the safe dissipation of stored energy and disconnection from the source.

3.3.6 Material Handling

The movement of heavy loads by hand and the handling of sharp tools are of particular concern in any industrial setting. These two activities constitute the majority of personnel injuries associated with construction and maintenance activities at Jefferson Lab. The principal mechanism for identifying concerns related to manual materials handling – really any task hazard – is found in the processes described in ES&H Manual Chapter 3210, Work Planning Control and Authorization, 3210 T1 Appendix T1 Work Planning, Control, and Authorization Procedure, and the Technical Appendices 3210-T2, and Appendix T3 Risk Code. Key to addressing hazards associated with moving heavy loads by hand is Chapter 6106 Ergonomics Program. EH&S Manual Chapter 6120 Portable Hand Tool Safety addresses handling sharp tools.

In addition, two concerns are foremost in materials handling safety when using powered assist: 1) operability of powered industrial lifting devices and associated operator training, and 2) task hazard analysis including the development of a lift plan when necessary.

Jefferson Lab ES&H Manual Chapters 6140 and 6141 address Material Handling Equipment Program and Rigging, Cranes, and Hoists. crane and hoist safety and forklift safety. In addition, the Jefferson Lab Material Manager (MHM) is available to review complex, unusual, or potentially high consequence lifts and the associated lift plans. The MHM provides training and assistance with special lifts, approved lift plans and provides for the coordination of the design, procurement, construction, acceptance testing, warranty management of new cranes/hoists and subcontracted crane/hoist operations (whether with Jefferson Lab-owned or subcontractor-owned equipment) cranes.

As identified above, the chief tool for avoiding materials handling injuries, whether powered or unpowered, is the task hazard analysis. A task hazard assessment uncovers and identifies hazards that exist in the workplace, generally focusing on a particular activity, project, or a given person's activities. If the risks are not sufficiently low, then additional controls or alternate methods can be identified and applied. Jefferson Lab ES&H Manual Chapter 3210 provides the tools and methodology for carrying out a hazard analysis in more subtle and complex situations encountered during work at Jefferson Lab and can provide guidance on where the "acceptable" level of risk lies.

3.3.7 Radiation

3.3.7.1 Ionizing

Ionizing radiation is produced when high energy electrons interact with beam line components and beam termination devices. No source of electrons is provided for the LCLS-II CM testing; this testing does not require a source of electrons. Some electrons are produced from field emission. These electrons may be coupled to RF and transported through a CM or from one CM to another depending on a number of parameters.

For activities that use a source of electrons and intentionally transport be for nuclear physics research, Jefferson Lab uses a reasoned combination of passive (radiation shielding and other physical barriers and administrative procedures) and active devices (radiation monitors, beam loss detection, and beam termination instruments) to provide personnel protection from the associated prompt ionizing radiation. These personnel protection devices are currently installed in the LERF and will be maintained operational during LCLS-II CM testing. They will be used to provide radiation protection for all LCLS-II CM related testing activities.

This approach will be used to maintain compliance with 10 CFR 835 and is designed to provide protection for occupied work areas and the site boundary to the general public. In practice, there are three protection devices with at least two different technologies used at Jefferson Lab for the purposes of personnel protection from prompt ionizing radiation from electron beams. This is an effective approach. Collective dose to Jefferson Lab employees and experimenters is consistently less than 2-person rem. The collected dose to all individuals exposed to ionizing radiation at the Lab is less than the 5-rem administrative control limit imposed by the Department of Energy for any single individual at the Lab. The highest individual dose post CEBAF commissioning was less than 200 mrem for a year; less than the 250 mrem CEBAF design goal (see Table 2 below).

	Occupational Dose	General Public Dose
Annual Limit	5000 mrem	100 mrem
Action Level	1000 mrem	50 mrem
Jefferson Lab Design Goal	250 mrem	10 mrem

Table 2 - Summary of JLab Rad-Con Manual Radiological Dose Limits

The radiation protection program at Jefferson Lab, outlined in ES&H Manual Chapter 6310, Ionizing Radiation Protection and the Radiation Control Manual, was developed to address the potential radiological hazards. No radiological conditions are predicted that exceed the capacity of the existing radiation control program. See Attachment A, Sheet 4 for the hazard profile assessment matrix for ionizing radiation.

3.3.7.2 Non-Ionizing

ES&H Manual Chapter 6420, Non-Ionizing Radiant Energy (i.e.: Radio Frequency (RF), Microwave, and Static Magnetic Fields), addresses hazards associated with RF energy used to generate the accelerating fields in the superconducting cavities. The energy is normally contained within the cavities and wave-guide system or in coaxial cable. There are two types of wave-guide systems used, pressurized and non-pressurized. Pressurized systems are preferred when direct observation of their operational performance cannot be achieved. The wave-guides are pressurized with dry nitrogen to detect leaks and are monitored by pressure sensors that are interlocked to the RF power supply. Non-pressurized RF wave-guides are typically shorter runs that can be fully observed during operations. These are most often the subject of a configuration control process that includes a procedure for controlled installation of wave-guide fasteners and are checked for RF leaks using a calibrated device. See Attachment A, Sheet 3 for the hazard profile assessment matrix for non-ionizing radiation. Pressurized waveguides interlocked to the RF power supply will be used in LCLS-II CM testing applications.

3.3.8 Oxygen Deficiency Hazards

Loss of cryogen in confined regions could present a problem from lowered oxygen levels. The risk of asphyxiation to personnel is mitigated in a number of ways:

- Persons engaged in work in confined areas containing liquid helium are trained in the correct response to any emergency releases of liquid helium,

- Equipment such as portable personal oxygen deficiency monitors (ODM) and emergency breathing sets are available,
- Main (LERF) control room operators to have written procedures for limiting helium releases,
- Oxygen deficiency monitors installed at key locations around the LERF, and
- Lintels and dams are used constrain helium gas to desirable pathways – such as ducts and vents - for passive release.

3.3.9 Mechanical Hazards

Explosion hazards can occur not only with pressure vessels but also with vacuum vessels, which under failure conditions, could become pressurized. Certain types of equipment at Jefferson Lab create hazards associated with high pressure including fragments or objects resulting from mechanical failure such as the rupture of highly stressed components, failure of fasteners, or from machine shop metal working operations where inadequate protection is used. Powerful magnetic fields can also turn steel objects, such as hand tools, into missiles. In addition, the rupture of cryogenic components such as cryostats and superconducting magnets and the implosion of vacuum components contribute to the hazards. The use of compressed air and bottled gases is regarded as a normal industrial problem and is not discussed in any detail.

Liquefied gases are used for the superconducting RF. Approximate quantities of these cryogens likely to be held in the liquid state on site are: helium, 120,000 liters; nitrogen, 75,000 liters; and argon 500 liters.

Liquid hydrogen, approximately 15 liters, is used for experimental physics targets in the end stations. Since the quantity is very small, this is regarded as a risk of negligible consequence in the large end-stations. Other combustible gases such as methane or propane are used in some detector equipment as well as some normal industrial applications.

Containers for storage and transport of the liquids incorporate the required safeguards for venting, filling and emptying. Special codes of practice have been established for the safe transfer and use of all liquid gases required at Jefferson Lab.

The ES&H Manual Chapter 6500 Cryogenic Safety Program and its Technical Appendices address cold burns and freezing hazards, Chapter 6540 Oxygen Deficiency Hazard (ODH) Control Program addresses asphyxiation (oxygen deficiency) hazards and Chapter explosion hazards associated with pressure build-up and chemicals. EH&S Manual Chapter 6151 Pressure and Vacuum Systems Safety

Program, based on the American Society of Mechanical Engineers (ASME) Code, addresses leakage, rupture, explosion or implosion from systems.

3.3.10 Personnel Hazards

The management process for defining mechanisms for mitigating personnel hazards is provided in ES&H Manual Chapter 3210, Work Planning Control and Authorization and the Technical Appendices 3210-T2, Task Hazard Analysis Worksheet and 3210-T3, Risk Code Assignment. Controls are based on a heirarchy: engineering controls, administrative controls, and personal protective equipment. EH&S Manual Chapters 6620 Personal Protective Equipment (PPE) Program, 6630 Respiratory Protection Program, and 6640 Hearing Conservation Program address the use of PPE based on hazard.

Jefferson Lab's Occupational Medicine Department provides occupational medicine services to employees and to contractors in an emergency. The Occupational Medicine Department services are reinforced by local 911 emergency services.

Hazards associated with animal and insect bites and stings are addressed in EH&S Manual Chapter 6800 Occupational Medicine Appendix T2 Injuries and Illnesses Requiring First Aid.

3.3.11 Emergency Preparedness

The Jefferson Lab Emergency Management Plan, establishes the policies of the Emergency Management Program, designates staff authority and responsibility for the program, and establishes specific emergency plans, procedures, and reporting requirements. It is a comprehensive program that addresses the needs of Jefferson Lab in the area of emergency management. EH&S Manual 3510 Emergency Response Activities and it’s Technical Appendicees discuss drills and response procedures for different emergencies.

3.3.12 Other

Additional hazards are identified in the “Other” Section of the Hazard Profile Assessment Matrix Worksheet (Attachment A). These include Traffic and Vehicle Safety and Engineered Nanoparticles. Traffic and Vehicle safety is addresses in two places: JLab Admin Manual 301.03 Use of Laboratory Vehicles and specifically in 6145 Material Handling Equipment - Forklifts and Attachments and 6146 Material Handling Equipment - Non-Emission (Battery Operated or Manually Propelled) Equipment (Tunnel Vehicles). Engineered nanoparticles are addressed in EH&S

Manual Chapter 6650 Unbound Engineered Nanoparticle Program, however, this is not part of the hazard profile for this work.

3.4 Assessment of risk based on hazard profile and hazard mitigation measures

Attachment B shows the risk assessment process used in the Environment Health and Safety Manual. The risk for a given hazard event is identified as a function of the probability of that hazard event and the consequences of the hazard event.

Analysis of risk based on the hazards and hazard mitigation measures is provided in Attachment C –Assessment of risk based on hazard profile and hazard mitigation measures. Jefferson Lab Project Hazard Risk Matrix for Key Activities, provides a collected set of activities, un-mitigated risk, and mitigation strategies that will be used for the project in general Attachment C provides a risk assessment based on categories of hazard events and indicates that hazards associated with the project are within acceptable low levels using the mitigation measures discussed in the previous section.

4.0 Hazard Management

4.1 Installation / Removal Activities

The anticipated hazard profile for installation / removal activities is provided in Attachment A. This hazard profile addresses hazards associated with the installation of equipment in LERF and removal/restoration of LERF to its prior operating configuration. Based on this profile, Jefferson Lab employees will define personnel hazards associated with installation and mechanisms for mitigating those hazards based on ES&H Manual Chapter 3210, Work Planning Control and Authorization and the Technical Appendices 3210-T2, Task Hazard Analysis Worksheet and 3210-T3, Risk Code Assignment. Jefferson Lab employees will maintain safe conditions or terminate work based on ES&H Manual Chapter 3330, Stop Work and Re-Start for Safety Program.

4.2 Operational Activities

The anticipated hazard profile for operational activities is provided in Attachment A – Hazard Profile for Operations Related Activities. Based on this profile, Jefferson Lab employees will define personnel hazards associated with operations and mechanisms for mitigating those hazards based on ES&H Manual Chapter 3210, Work Planning Control and Authorization and the Technical Appendices 3210-T2, Task Hazard Analysis Worksheet and

3210-T3, Risk Code Assignment and on ES&H Manual Chapter 3310, Operational Safety Procedure Program, 3310 Appendix T1 Operational Safety Procedure (OSP) and Temporary OSP Procedure, and ES&H Manual Chapter 3320 , Temporary Work Permits. Jefferson Lab employees will maintain safe conditions or terminate work based on ES&H Manual Chapter 3330, Stop Work and Re-Start for Safety Program**.**

5.0 SUMMARY

Hazards are routinely reevaluated as part of Jefferson Lab's approach to conduct of operations and routine work planning and control processes. The Lab's worker protection program encompasses the concept of prudent avoidance of worker exposures to any occupational hazards. Prudent avoidance involves minimizing the number of individuals at risk of exposure, minimizing individual worker's potential for exposure, and controlling all exposures to chemical, physical, biological, safety, and radiological hazards. The occupational and environmental hazards associated with activities related to this project are effectively addressed by these programs. This hazard assessment identifies no additional hazards that are not already considered in the baseline hazards for the LERF or in the operational hazards associated with CM testing in the LERF. Certain hazards will be re-evaluated to ensure the project scope does not invalidate the analysis.

6.0 REFERENCES

- Final Safety Assessment Document Revision 7a, Approved: August 27, 2012; Revised 12/16/2014
- DOE Order 420.2B, "Safety of Accelerator Facilities"
- 10 CFR 851, "Worker Safety and Health Program"
- Jefferson Lab, Environment, Health, and Safety Manual
- TJNAF 10CFR851/Worker Safety and Health Protection Program

ATTACHMENTS

Attachment A- Project Hazard Profile Assessment Matrix Worksheet, Sheet 1

X – Not applicable
B – FSAD Hazard Baseline supported by system/experiment specific safety assessments

P – associated with LCLS-II CM Testing Project

		HAZARD CATEGORIES																							
		Chemicals									Electrical			Environmental											
AREA	**HAZARD PROFILE**	Acids and bases	Solvents	toxic agents	Reactions	Exposures exceeding Personal Exposure Limits	Carcinogens				>50 V AC	(042) Electricity-stored energy>10 joules, capacitive, inductive, or battery	> 60 V DC	Solid Waste Generation	Liquid Waste Generation	Land Disturbance	Nonhazardous Solid Waste and Regulated Materials (e.g., waste oil, batteries, fluorescent	Hazardous Waste	Groundwater Protection	Ambient Air Quality (including Greenhouse Gas	Discharges to the Sanitary Sewer	Discharges to Surface Water and Storm Sewers;			
LERF	Existing	B	B	B	B	B	B				B	B	B	B	B	B	B	B	B	B	B	B			
	Install / Remove	X	X	X	X	X	P				P	P	P	P	X	X	P	P	X	X	X	X			
	Operate	X	X	X	X	X	P				P	P	P	P	X	X	P	P	X	X	X	X			

Attachment A- UIM Project Hazard Profile Assessment Matrix Worksheet, Sheet 2

X – Not applicable
B – FSAD Hazard Baseline supported by system/experiment specific safety assessments
P – associated with LCLS-II CM Testing Project

		HAZARD CATEGORIES																		
		Hazardous Materials															Magnetic Fields			
AREA	HAZARD PROFILE	Chemicals including: acids and bases, solvents, toxic agents, reactions, exposure exceeding personal	Heavy Metals including lead and beryllium	Dust: hazardous, nuisamce	Fumes including but not limited to: hot work, chemical	Air Contaminants	Silica: (Crystalline aka Quartz)	Hazardous Material: spills and releases, storage, handling, disposal, transport (on and off site)	Asbestos	Noise (High Noise)							Static Magnetic Fields including: Fringe	Static Magnetic Fields including: High	Static Magnetic Fields including: Quench Effect	
LERF	Existing	B	B	B	B	B	B	B	B	B							B	B	B	
	Install/Remove	X	P	P	P	P	X	X	X	P							P	P	P	
	Operate	X	X	X	X	X	X	X	X	X							P	P	P	
	Operate											X	P	P	P	P	P	P	P	

Attachment A- UIM Project Hazard Profile Assessment Matrix Worksheet, Sheet 3

X – Not applicable
B – FSAD Hazard Baseline supported by system/experiment specific safety assessments
P – associated with LCLS-II CM Testing Project

		HAZARD CATEGORIES																											
		Material Handling								Non-ionizing Radiation			ODH			Occupational Hazards								Occupational Medicine					
AREA	HAZARD PROFILE	Cranes and Hoists	Lifting moving objects	Powered Industrial Trucks including: forklifts	Aerial Work Platforms					Non-ionizing Radiation-lasers (to incl. manufacture of lasers)	Non-ionizing Radiation-radio frequency radiation	Non-ionizing Radiation-ultraviolet, infrared, and visible light	Oxygen Deficiency Hazards-cryogenic gas leaks	Oxygen Deficiency Hazards-cryogenic liquid leaks	Cryodgenic Material – gas and liquids	Machine Tools: Grinding, Cutting, Drilling, Rotating Parts	Stored Energy Sources including Mechanical, Hydraulic,	Portable Hand Tools	Sharp Edges and Pinch Points	Confined Space	Area Temperature: heat and cold stress			Bloodborne Pathogens	Ergonomics:Lifting and Carrying, Heavy Objects, Repetitive	Slips, Trips & Falls	Animal/Insect Bites		
LERF	Baseline	B	B	B	B					B	B	B	B	B	B	B	B	B	B	B	B			B	B	B	B		
	Install/Remove	P	P	P	P					X	X	X	P	P	P	P	P	P	P	X	X			P	P	P	X		
	Operate	X	X	X	X					P	X	X	P	P	P	X	X	X	X	X	X			X	X	X	X		

Attachment A- UIM Project Hazard Profile Assessment Matrix Worksheet, Sheet 4

X – Not applicable
B – FSAD Hazard Baseline supported by system/experiment specific safety assessments
P – associated with LCLS-II CM Testing Project

		HAZARD CATEGORIES																										
									Radiation			Thermal				Emergency Preparedness				Other								
AREA	HAZARD PROFILE								Occupational Radiation Exposure	Storage and Handling of Radioactive Materials	Sources of Radiation: Prompt, Induced	Thermal-cold work environments	Thermal-high temperature equipment	Thermal-hot work environments	Thermal-ultraviolet radiation/sun exposure	(152) Emergency preparedness-severe weather	(153) Emergency preparedness-workplace violence			Traffic and Vehicle Safety	NANOTECHNOLOGY – Engineered Nanoparticles							
LERF	Baseline								B	B	B	B	B	B	B	B	B			B	B							
	Install/Remove								P	P	P	X	X	X	X	P	P			P	X							
	Operate								P	P	P	X	X	X	X	P	P			P	X							

Attachment A- UIM Project Hazard Profile Assessment Matrix Worksheet, Sheet 5

X – Not applicable
B – FSAD Hazard Baseline supported by system/experiment specific safety assessments
P – associated with LCLS-II CM Testing Project

		HAZARD CATEGORIES																								
		Fire							Pressure Systems			Working at Elevations				Hot Work										
AREA	HAZARD PROFILE	Excess Combustible Material Accumulation (aka Combustible							Pressure Vessels, Boilers and Vacuum Vessels	Pressurized, Vacuum Lines, and Piping Systems		Ladders	Scaffolding	Fall Protection	Aerial Work Platforms	Fire Protection	Welding, Cutting, Brazing, and Grinding									
LERF	Baseline	B							B	B		B	B	B	B	B	B									
	Install/Remove	P							P	P		P	X	X	X	P	P									
	Operate	P							X	X		X	X	X	X	P	P									

Attachment B – Hazard Risk Assessment Methodology

1. Assigning Consequence Levels to Identified Accident Scenarios

Consequence Level	Severity	Property Loss
High (H)	Serious impact on-site. May cause death or loss of facility operation. Major impact on the environment.	> $100,000
Medium (M)	Significant impact on-site. May cause severe injury, severe occupational illness to personnel, major damage to the facility operation, or impact on the environment.	> $50,000
Low (L)	Minor impact on-site. May cause minor injury, minor occupational illness, or minor impact on the environment.	> $500
Extremely Low (EL)	Insignificant injury, occupational illness, or impact on the environment.	< $500

2. Assigning a Probability Rating to Identified Accident Scenarios

Probability Level	Description*	Estimated Probability of Incident Occurrence per Year
High (H)	An incident is likely to occur several times during task.	$> 10^{-1}$
Medium (M)	An incident may occur during the task.	10^{-2} to 10^{-1}
Low (L)	Probability of an incident occurring is unlikely to happen during the task.	10^{-4} to 10^{-2}
Extremely Low (EL)	Probability of an incident occurring is extremely unlikely to happen during the task.	10^{-6} to 10^{-4}

Risk Level Matrix

Consequence Level					
	H	1	3	4	4
	M	1	2	3	4
	L	N*	1	2	3
	EL	N*	N*	1	1
		EL	L	M	H
		Probability Level (Estimated likelihood per full-time active person)			

*Negligible Risk

Attachment C –Assessment of risk based on hazard profile and hazard mitigation measures

Hazard Event	Un-Mitigated Risk Level	Mitigation Measures	Mitigated Risk Level
Radiation from Operations			
Direct Radiation Exposure	High	Engineering Control – Shielding, labyrinths, access controls, site boundary fence Administrative Control – ES&H Manual, Chapters 3000, 4000, 6300 Personal Protective Equipment – Task specific	Low
Activation – gases & material	Low	Engineering Control – Shielding, ventilation, system specific controls Administrative Control – ES&H Manual, Chapters 3000, 4000, 6300, 6700	Negligible
Activation – surface discharge	Negligible	Engineering Control – Shielding, collection sumps, holding tanks, site boundary fence, system specific controls Administrative Control – ES&H Manual, Chapters 3000, 4000, 6300, 6700	Negligible
Cryogenics			
Cold Burns	High	Engineering Control – System specific Administrative Control – ES&H Manual, Chapters 3000, 4000, 6500, 6600, 6800 Personal Protective Equipment – Task specific	Low
ODH	High	Engineering Control – System specific Administrative Control – ES&H Manual, Chapters 3000, 4000, 6500, 6600, 6800 Personal Protective Equipment – Task specific	Low
Explosion – pressure	High	Engineering Control – System specific Administrative Control – ES&H Manual, Chapters 3000, 4000, 6500, 6600, 6600 Personal Protective Equipment – Task specific	Low
Explosion – chemical	Negligible	Administrative Control – ES&H Manual, Chapters 3000, 4000, 6100, 6400, 6600 Personal Protective Equipment – Task specific	Negligible

Electrical			
AC/DC electrocution	High	Engineering Control – System specific Administrative Control – ES&H Manual, Chapters 3000, 4000, 6100, 6200, 6600 Personal Protective Equipment – Task specific	Low
RF Exposure	High	Engineering Control – System interlocks Administrative Control – ES&H Manual, Chapters 3000, 4000, 6100, 6400, 6600, 6800 Personal Protective Equipment – Task specific	Low
Static Magnetic Fields			
Projectile	Low	Administrative Control – ES&H Manual, Chapters 3000, 4000, 6100, 6400 Personal Protective Equipment – Task specific	Negligible
Chemical			
Exposure to chemicals	Low	Engineering Control – grounded flammable storage cabinets Administrative Control – ES&H Manual, Chapters 3000, 4000, 6600 Personal Protective Equipment – Task specific	Negligible
Nature/Environment			
Hurricane	Low	Administrative Control – ES&H Manual, Chapters 2240, 3000, 6900	Low
Flood	Low	Administrative Control – ES&H Manual, Chapters 2240, 3000, 6900	Low
Tornado	Low	Administrative Control – ES&H Manual, Chapters 2240, 3000, 6900	Low
Lightning	Negligible	Administrative Control – ES&H Manual, Chapters 2240, 3000, 6900	Negligible
Earthquake	Negligible	Administrative Control – ES&H Manual, Chapters 2240, 3000, 6900	Negligible
General Industrial			
Material Handling	High	Administrative Control – ES&H Manual, Chapters 3000, 4000, 6100, 6600 Personal Protective Equipment – Task specific	Low

Noise	Meduim	Engineering Control – Physical barriers Administrative Control – ES&H Manual, Chapters 3000, 4000, 6600, 6820 Personal protective Equipment	Low
Fire	High	Engineering Control – Fire protection systems, grounded flammable storage cabinets Administrative Control – ES&H Manual, Chapters 3000, 4000, 6900	Low