OVERVIEW OF FERMILAB FACILIITES

SECTION I CHAPTERS 01-10 OF THE FERMILAB SAD

Revision 4 March 1, 2024

This Section I of the Fermilab Safety Assessment Document (SAD) contains an overview of the Fermilab Facilities, and contains general information that can be applied to all areas covered in subsequent Sections of the Fermilab SAD.

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SAD Chapter Review

This Section I, Chapters 01-10 of the Fermi National Accelerator Laboratory (Fermilab) Safety Assessment Document (SAD), *Overview of Fermilab Facilities*, was prepared and reviewed by the staff of the Environment, Safety & Health Division (ESH) Accelerator Safety Department.

Signatures below indicate review of this Chapter, and recommendation that it be approved and incorporated into the Fermilab SAD.

☐ ____
Chief Safety Officer

☐ ____
Accelerator Safety Department Head

☐ ____
SAD Review Subcommittee Chair

☐ ____
Senior Radiation Safety Officer

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Revision History

Printed versions of this Chapter of the Fermilab Safety Assessment Document (SAD) may not be the currently approved revision. The current revision of this Chapter can be found on ESH DocDB #1066 along with all other current revisions of all Chapters of the Fermilab SAD.

Author	Rev. No.	Date	Description of Change
John E. Anderson Jr.	0	October 26, 2010	Initial release of the Fermilab SAD Section I, Chapter 1 – 10, Overview of Fermilab Facilities
John E. Anderson Jr. TJ Sarlina	1	January 4, 2017	• Updated personnel titles, references, and hyperlinks. • Cryogenics, ODH, and Flammable Gases were moved from Accelerator-Specific Hazards to Conventional Hazards. • O2 Monitoring Systems, Flammable Gas Detection Systems, Cryo Vessel Pressure Relief Valves, and Cryo System Approvals were removed from the Credited Controls section. • Updated ORC Process • Referenced specific FESHM, FRCM, and QAM chapter numbers where applicable.
John E. Anderson Jr.	2	November 11, 2019	• Added information regarding the protocols used for the FAST Control Room Operations. • Updated organizational changes with the ESH&Q Section splitting into the ES&H Section and Quality Section.
Maddie Schoell	3	December 21, 2023	• Update layout to be consistent with Lab-wide SAD and ASE Update • Updated organizational changes • Updated Section I-4 to discuss the updated Risk Assessment methodology following DOE-HDBK-1163-2020. Expanded and reorganized the hazards discussed to align with updated groupings and identifications of Non-Accelerator Specific Hazards (NASHs) and Accelerator-Specific Hazards (ASHs). Risk Matrix tables for common NASHs discussed in Section I-4 have been added as Appendix C to the SAD. • Included ODH as Accelerator Specific Hazard. • Removed specific references to FESHM. • Updated Section I-4 to describe new Maximum Credible Incident (MCI) assessment methodology.

Sergey Koshelev Maddie Schoell	4	March 1, 2024	• Update I-1 to clarify which hazards follow which assessment methodology • Updated I-4.2.2 and I-4.3.2.2 with additional information for cryogenics systems and oxygen deficiency hazard • In response to "Approval of the Fermi National Accelerator Laboratory Safety Assessment Document Appendix A.1 Accelerator Safety Envelope – Fermilab Main Accelerator, Revision 13, and Appendix B.2 Fermilab Unreviewed Safety Issue Process, Revision 0" dated January 11, 2024, updated Table 2 within I-4.2.1.1 to exactly reflect the defined boundary conditions for the General Site and Public Areas • Updated I-3.2.1 to include additional description of the Fermilab Site in relation to locations where members of the public are authorized on site and description of surrounding areas • Updated I-3.2 to include a sub-section for Site Access information • Updated I-4.2.1.1 to clarify how "General Site Basis" locations are demarcated • In response to request from Fermilab Site Office on 2/2/2024, Updated I-4.3.3 to include new sub-section Obvious and Operating Barriers as a Passive Credited Control • Update Section I-4.1.8 with additional information related to controls in place for fringe fields.

Table of Contents

I-1. Executive Summary

The Fermi National Accelerator Laboratory (Fermilab) facilities are all considered to be accelerator facilities, as the work performed is all in support of accelerator operations, and are subject to the requirements of the Department of Energy (DOE) Accelerator Safety Order (ASO), DOE O 420.2D, *Safety of Accelerators*[1]. These requirements are promulgated through the Fermilab Policies[2], the Fermilab Environment, Safety, and Health Manual (FESHM)[3], the Fermilab Radiological Control Manual (FRCM)[4], and the Fermilab Quality Assurance Manual[5] (QAM)[5].

A detailed analysis of the hazards found at Fermilab has been conducted and is documented in this Safety Assessment Document (SAD). Prompt ionizing radiation hazards have been analyzed using a quantitative Maximum Credible Incident (MCI) analysis methodology. All other hazards have been analyzed using a qualitative risk assessment methodology in accordance with DOE-HDBK-1163-2020, *Integration of Hazard Analyses*[6]. The results presented in this SAD, along with the supporting documentation, describe that the standards presented in the FESHM, FRCM, and QAM result in the risk of hazards being reduced to an acceptable level, either per approved dose levels (see Table 2 in Section I-4.2.1.1) or per the criteria provided in DOE HDBK 1163-2020. From these analyses, the Accelerator Safety Envelopes (ASE), within Appendix A, have been developed to define the physical and administrative controls that define the bounding conditions for safe operations of the accelerators. Accelerator operations within the applicable ASE provide adequate assurance that the risk of accelerator-specific hazards to employees, the public, and the environment from facility operations are acceptable both onsite and offsite.

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I-2. Introduction

Fermilab is operated by the Fermi Research Alliance (FRA), LLC for the United States Department of Energy. This SAD has been prepared to meet the requirements and definitions of the DOE Accelerator Safety Order, DOE O 420.2D.

I-2.1. Scope, Objective, and SAD Document Layout

The scope of this document covers the Fermilab facilities, experimental areas and experimental detectors, accelerator research and development areas, and radiological facilities serving accelerator operations.

The objective of this safety assessment is to document both the non-accelerator and uniquely accelerator-specific hazards presented by the operation of the Fermilab facilities. The assessment identifies the preventive and mitigative measures specified in the Fermilab Policies, Fermilab Environment, Safety, and Health Manual (FESHM), the Fermilab Radiological Control Manual (FRCM), and the Fermilab Quality Assurance Manual (QAM) that address these hazards. These documents contain Fermilab's implementation of all applicable ES&H laws, regulations, and contractual requirements, and provide the framework for Fermilab's ES&H training program. This SAD provides the necessary information to demonstrate that operation of Fermilab's accelerators, associated experimental areas, and accelerator research and development areas ("facilities") can be conducted in a manner that will result in acceptable risks to the health and safety of the workers (including the facility worker and the co-located worker), members of the public, and the environment.

The hazards are analyzed for each facility for three categories of personnel – the facility worker, the co-located worker, and members of the public – and for the environment. For purpose of these analyses, the following definitions are used:

- Facility Workers: Individuals, whether Fermilab employees, sub-contractors, affiliates, users, business visitors, or urgent short-term workers, doing the work.
- Co-Located Workers: Individuals, whether Fermilab employees, sub-contractors, affiliates, users, business visitors, or urgent short-term workers, on-site in areas not accessible to the public, not involved in the work activity, but potentially subject to the hazard being assessed.
- Maximally-exposed Off-site Individual (MOI): Per the methodology used in DOE HDBK 1163-2020, this would be the maximally exposed member of the public who is off-site. Due to Fermilab's publicly accessible campus, this category cannot be limited to off-site members of the public. Therefore, the term MOI will be used to refer to the maximally exposed member of the public whether off-site or in an area of the Fermilab Batavia campus accessible to the public.

The SAD is based on the premise that the three categories of personnel described above is a complete set of potential receptors. Fermilab, consistent with all DOE facilities, periodically provides tours of areas that are not generally accessible to the public. These tours may include dignitaries and other personnel that might be deemed members of the public. However, these tours are well-structured with facility operations controlled to eliminate or reduce hazards and include close supervision and monitoring of the personnel on the tour. Consequently, Fermilab considers establishing acceptable risks for co-located workers and members of the public in publicly accessible areas is adequate to protect personnel on tours and a separate analysis of the risk to personnel on tours is not required.

The SAD is divided into six major sections and three appendices. Section I contains an overview of the Fermilab facilities and a discussion of the non-accelerator specific hazards and accelerator-specific hazards at the lab. Section II covers the radiological support facilities that serve accelerator operations. Section III contains a description of each accelerator segment that makes up the Fermilab Main Accelerator. An accelerator segment is a distinct, stand-alone section of the Fermilab Main Accelerator. Section IV describes the experimental areas and experimental detectors used at Fermilab. Section V covers the advanced accelerator research and development accelerator. Section VI covers test stand accelerators. Section VII contains the appendices. Appendix A contains the ASEs, one for each accelerator. Appendix B contains Fermilab accelerator safety Policies and Programs. Appendix C contains hazard risk matrix tables for some of the non-accelerator specific hazards (NASHs). Common tables have been prepared for those NASHs which are handled in essentially the same way across the lab. The document layout creates the framework necessary to develop a SAD that is coherent; readily adaptable to the ever-changing program of accelerators, experiments, and their operations; internally consistent in both content and nomenclature; and non-redundant in content.

I-2.2. Assessment Methodology

The process begins with a comprehensive list of possible hazards at the Fermilab site. Each hazard on the list is either a non-accelerator specific hazard (NASH) or an accelerator-specific hazard (ASH). Per DOE O 420.2D, differentiation between these two categories is described as follows: “All hazards at an accelerator fall within two categories: 1) hazards that are safely managed by other DOE approved applicable safety and health programs and/or processes; or 2) accelerator specific hazards that are analyzed and safely managed by the SAD and provisions of the ASE.” In this SAD, hazards in the first category are considered NASHs, hazards in the second category are considered accelerator-specific hazards. Each laboratory facility has a chapter in the SAD, and in that chapter the facility evaluates the applicability of each of the hazards on the comprehensive list to their facility. Each hazard is evaluated as follows:

1. The hazard is not applicable to that facility. In this case, the hazard is listed, but a statement is made explaining that this hazard does not apply to this facility.
2. The hazard does apply to this facility and is a non-accelerator specific hazard (NASH).
    a. A lab-wide common hazard risk matrix exists for this NASH – An assessment is made as to whether the hazard in this facility has any unique aspects or if the lab-wide analysis of this hazard fully describes the hazard and the preventive and mitigative measures in place at the facility. If the lab-wide analysis applies, that analysis is referenced without further discussion. If not, the elements that are unique are discussed.
    b. A lab-wide common hazard risk matrix does not exist for this NASH – A facility specific hazard risk matrix table is generated that assesses the unmitigated risk, the preventive and mitigative measures, and the residual risk associated with that hazard.

3. The hazard does apply to this facility and is either an accelerator-specific hazard, or a contributor/initiator to an accelerator accident. In this case, a facility specific hazard risk matrix table is generated that assesses the unmitigated risk, the preventive and mitigative measures, and the residual risk associated with that hazard.

Section I Chapter 04 takes a systematic approach to analyzing NASHs. If the hazard exists in a similar way at most facilities and preventive and mitigative measures are applied similarly across the lab, a lab-wide hazard risk table is prepared using the process of DOE-HDBK-1163-2020. For each of these hazards, the unmitigated risk is determined, specific preventive and mitigative measures from Fermilab Policies are identified, and using the rules and criteria in DOE-HDBK-1163-2020 the residual risk is determined.

Section I Chapter 04 also provides an overview discussion of the hazards that are accelerator-specific along with the preventive and mitigative measures used to reduce the risk to acceptably low levels. The hazards in this category form the basis for the Credited Controls that are necessary for safe accelerator operations and the set of the Credited Controls for the accelerator form the applicable ASE, detailed in Appendix A. Additional details and analysis of these uniquely accelerator-specific hazards for a specific facility are contained in the individual Chapters of Sections II through VI.

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I-3. Site, Facility Design Criteria, and Operations

I-3.1. Fermilab Purpose

The primary purpose of Fermilab is to produce particle beams in the accelerators and make them available to qualified experimenters conducting high energy physics and particle beam physics research. Fermilab is uniquely positioned at the energy and intensity frontiers providing proton and electron beams for this kind of basic research.

The mission of Fermilab is to advance the understanding of the fundamental nature of matter and energy by providing leadership and resources for qualified researchers conducting basic research at the frontiers of high energy physics and related disciplines. This mission is accomplished by Integrated Safety Management of operational and safety concerns at all levels of the laboratory organization. The laboratory is committed to excellence based on its use of best business management practices and continuous improvement in all aspects of its work. This includes ensuring the safety and health of staff (including employees, sub-contractors, affiliates, users, business visitors, or urgent short-term workers) and visitors, a safe work environment, and minimal impact to the environment.

I-3.2. Site Overview

I-3.2.1 Site Location

The Atomic Energy Commission acquired the 6,800-acre Fermilab site in the late 1960s from the State of Illinois; see Section I-3.2.2 below for an aerial site map. The dividing line between Kane County and DuPage County passes through the site from north to south, with the majority of the site located in DuPage County.

The development of permanent facilities has generally followed the initial site planning, which was accomplished in the late 1960s and early 1970s, and has been modified periodically by programmatic needs to the current date.

The Fermilab Main Accelerator is made up of multiple segments. The Tevatron enclosure is located in the south-central portion of the site with the adjacent Linac, Booster, and Main Injector including the Recycler, located to the west along with the Muon Campus. Three major fixed-target beam line areas, Meson, Neutrino, and Proton, extend from the Switchyard area which in turn extends from the northwest side of the Tevatron enclosure and points in a northeasterly direction. The two neutrino beamlines, Booster Neutrino Beam (BNB) and Neutrinos at the Main Injector (NuMI), extend from the northeast side of the Main Injector in a northwesterly direction. New facilities are assessed as they are developed, for environment, safety, and health considerations, early in the design process, according to the requirements of the FESHM.

The FAST accelerator is located in the north-central portion of the site, in the New Muon Lab (NML) building, north of the Fermilab Main Accelerator fixed-target beamlines.

The CMTS1 and PIP2IT accelerators are located in the north-central portion of the site, in the Cryomodule Test Facility (CMTF) building, north of the Fermilab Main Accelerator fixed-target.

The VTS accelerator is located in the central portion of the site, in the Industrial Building complex.

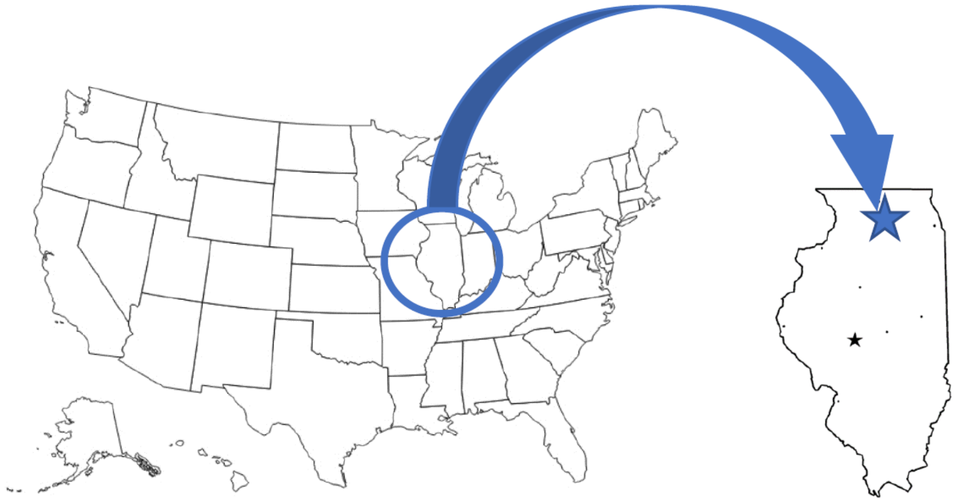

Figure 1. Regional view showing the location of the Fermilab site in Batavia, IL.

I-3.2.2 Site Map

Aerial view of Fermilab site with Fermilab Main Accelerator sections overlaid.

Figure 2. Aerial View of Fermilab Showing Fermilab Main Accelerator.

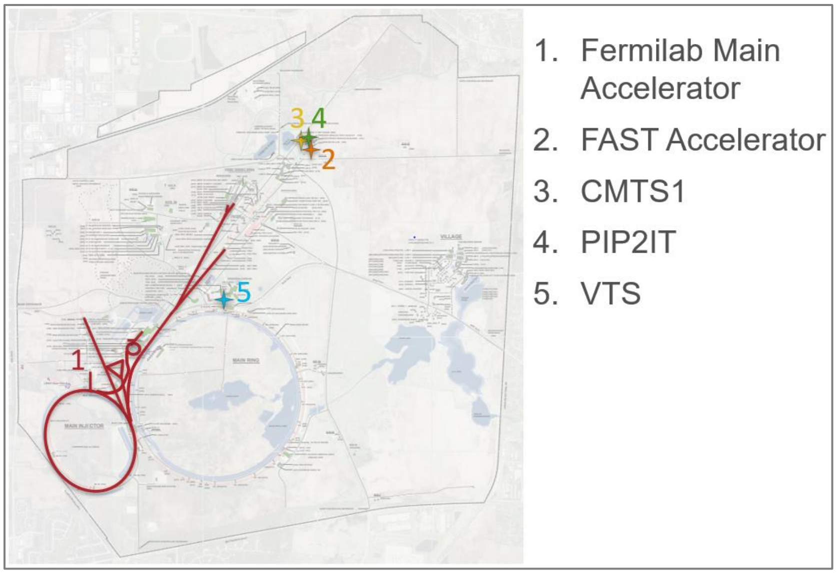

Figure 3. Arial View of Fermilab Showing the Location of all Accelerators.

I-3.2.3 Site Access

The Fermilab Batavia, IL site boundary is not physically demarcated by use of a fence or other physical barrier. The areas immediately beyond the site boundary include hiking trails, roads, residential neighborhoods, and local business. The closest of which is the Prairie Path trail to the Southeast of the Lab, parallel to a portion of the Main Injector/Recycler segment of the Fermilab Main Accelerator.

The Fermilab site also authorizes the public on site in select locations. Locations where public is not authorized use a variety of notification and control methods, depending on the hazards present and security needs. Notification and control methods include but are not limited to: signs, lights, manned and un-manned card readers, and gates. In locations where card readers are used, they verify that the individuals are authorized to pass beyond the access point. Depending on the location, authorization may mean having a valid Fermilab ID badge (which means the individual has received New Employee/User/Contractor Orientation training and General Employee Radiation Training (GERT)), or it may include facility-specific training. Non-badged personnel may be authorized to allow access, including but not limited to escorted Business Visitors and escorted deliveries.

Obvious and Operating Barriers are in use to allow only authorized personnel, individuals having GERT training or are escorted by individuals who have GERT training, into the south part of the Fermilab Batavia, IL site. The Obvious and Operating Barriers are monitored by Security, visually and via remote camera, to ensure functionality per the Performance Assurance Program (PAP) Plan, and have Security Post Orders in place for if various functions of the Obvious and Operating Barriers (e.g., gate and un-manned card readers) fail, to ensure appropriate measures are in place to continue controlling access to only authorized personnel. These Obvious and Operating Barriers ensure only authorized personnel access to areas surrounding several operational segments and experimental areas of the Fermilab Main Accelerator where the "General Site Basis" applies:

- 400 MeV Test Area (MTA)
- Booster
- 8 GeV Line
- Booster Neutrino Beam (BNB)
- MiniBooNE Detector
- Short Baseline Neutrino Experimental Areas (SBND, MicroBooNE, & ICARUS Experiments)
- Main Injector / Recycler
- Neutrinos from the Main Injector (NuMI)
- NOvA Detector
- Main Injector Neutrino Oscillation Search (MINOS) Hall Detectors
- Muon Campus

Figure 4. Location of Obvious and Operating Barriers.

Fermilab Security routinely patrols the Fermilab Batavia, IL site and challenges potential unauthorized access.

I-3.2.4 Design Criteria

The Fermilab facilities must conform fully to the requirements imposed by all applicable Federal, State and local laws, Executive and DOE Orders, and regulations concerning Environment, Safety and Health as expressed in the Fermilab Policies. The operations also shall conform fully to the requirements imposed by the FESHM, the FRCM, the QAM and the Fermilab Comprehensive Emergency Management Plan[7].

The civil construction phases follow all applicable building codes and standards at the time of construction. Where no specific codes or Fermilab standards exist, the designers use best engineering practices, peer review, and/or outside consultants during the design stage. In instances where applicable ES&H requirements are in conflict, the requirements leading to the higher level of safety are applied.

I-3.2.4.1 Worker Safety Program

Fermilab Policy states that employees, sub-contractors, affiliates, users, business visitors, and urgent short-term workers will only perform work in a safe and environmentally sound manner. The Fermilab Worker Safety and Health Program (WSHP)[8] is the top-level document which describes management's commitment to, and the responsibility for, establishing a worker protection program that will reduce or prevent the potential for injuries, illnesses, and accidental losses by providing workers with a safe and healthful workplace. The WSHP implements DOE regulations found in Title 10, *Code of Federal Regulations (CFR),* Part 851[9].

Fermilab management and staff are committed to safe operations. The laboratory has established the following safety priorities: 1) the Chief Safety Officer is a member of the Laboratory's Senior Leadership Team; 2) weekly senior staff meetings include safety discussions; 3) cutting edge communications and data management tools advance safety performance; 4) program documentation such as the Fermilab Policies, the FESHM, the ES&H training program, and relevant databases and guidance are readily available on the ES&H website; and 5) employee input assures a more complete program tailored to the hazards and the work to be performed. Employee involvement also promotes employee acceptance of requirements and commitment to comply.

I-3.2.4.2 Radiation Safety Program

The operation of the Fermilab facilities conforms to the FRCM, and thus achieves conformance with applicable requirements of Title 10, *CFR*, Part 835[10] and DOE Order 458.1[11]; keeps radiation exposures to personnel As Low As Reasonably Achievable (ALARA); maintains control of radioactive contamination and radioactive materials; complies with environmental radiation limits; and satisfies environmental monitoring requirements. Design, installation, use and maintenance of the following are also in conformance with the FRCM and are consistent with the Fermilab SAD: signs and posting of areas in which radiation may be present, radiation safety interlock systems (including search and secure), interlocked radiation detectors, controlled access procedures, personnel training, procedures for maintenance and testing of radiation safety interlock systems, and documentation of radiation safety interlock systems.

I-3.2.4.3 Environmental Protection Program

All operations and maintenance activities shall conform to environmental protection requirements stated in the 8000 series chapters of the FESHM as well as applicable state and federal regulations (e.g., Title 40 of the *Code of Federal Regulations* and Title 35 of the *Illinois Administrative Code*). FESHM Chapter 8010 describes Fermilab's overall Environmental Management System that was developed to conform to ISO standard 14001. Specific environmental topics covered in the 8000 series include, but are not limited to, erosion control, chemical and radioactive waste management, wastewater discharges to sanitary sewers, oil pollution prevention, air emissions control, and National Environmental Policy Act (NEPA) review.

I-3.2.4.4 Fire Protection Program

The operation and maintenance of the Fermilab facilities follows the fire safety requirements found in the FESHM. A computerized Fermilab Incident Reporting and Utility System (FIRUS) monitors the accelerator facility fire alarm systems. Fire protection-related equipment or status that FIRUS monitors includes: smoke and heat detectors, sprinkler flows, pull stations, High Sensitivity Air Sampling Detection (HSSD) systems, emergency power back-up generators, and redundant sump pumps. FIRUS also monitors other equipment not related to fire protection (e.g., site utility and security systems). The Communications Center continually monitors the FIRUS system and dispatches the on-site Fermilab Fire Department and other emergency services in response to an alarm.

The Fermilab Fire Department provides site fire suppression and emergency medical services (EMS). The Fire Department is certified by the State of Illinois and follows the National Fire Protection Association (NFPA) 1500, Standard on Fire Department Occupational Safety, Health and Wellness Program, and NFPA 1710, Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments, requirements for Fire Departments.

Buildings are designed to the International Building Code and applicable NFPA Codes and Standards and maintained under the code of record. Underground facilities are designed using NFPA 520, Standard on Subterranean Spaces. The Site-Wide Emergency Warning System (SEWS) provides mass emergency notification to all occupied buildings and remote personnel through integration with life safety voice systems and pagers.

I-3.2.4.5 Other Design Criteria

The operation of the Fermilab facilities conforms to the Occupational Safety and Health requirements stated in the appropriate chapters of the FESHM. Topic areas addressed include: powered lifting equipment; pressurized gas safety - including pressure vessels; general electrical safety; chemical safety, industrial hygiene requirements, biological hazards, engineering controls, protective clothing and equipment, warning signs and devices; and lock out and tag out procedures. Construction modifications or additions involving subcontracted labor to the Fermilab facilities also conform to the requirements stated in the FESHM.

I-3.2.5 Organization

The Fermilab organization is based on a line management structure. The head of the Laboratory organization is the Director. The laboratory is further divided into Directorates and Divisions based on organizational and project needs.

The laboratory ES&H Division primarily advises the Director and the other Directorates/Divisions on all ES&H matters, whereas the Director and heads of the Directorates/Divisions implement ES&H policies through the line management organization. The ES&H responsibilities of the ES&H Division and the other Directorates/Divisions are provided in detail in the FESHM.

The Laboratory Director has established the Fermilab Environment, Safety, and Health Committee (FESHCom). It is chaired by the Director and consists of a representative from each Directorate/Division. The FESHCom has established several standing subcommittees. These subcommittees are composed of technical and ES&H professionals with the subcommittee Chairs also being FESHCom members. The subcommittees provide a means for independent safety reviews of designs by people who are both technically knowledgeable and independent of the line managers who have direct line responsibility for the work that is under review.

The Chair of FESHCom has established a review subcommittee, the Safety Assessment Document review subcommittee. The subcommittee has the responsibility to review the results of each Safety Assessment Document chapter for methodology, completeness, and compliance with the FESHM and FRCM.

I-3.2.6 Experimental Programs

Scientists have identified three frontiers of scientific opportunity for the field of particle physics: the Energy Frontier, the Intensity Frontier, and the Cosmic Frontier. Answers to the most challenging questions about the fundamental physics of the universe will come from combining the most powerful insights and discoveries at each of the three frontiers. Fermilab's scientific program pushes forward with world-leading research at all three interrelated frontiers.

I-3.2.6.1 Energy Frontier Physics

Particle accelerators at the Energy Frontier produce high-energy collisions that signal new phenomena from the origin of mass to the nature of dark matter and extra dimensions of space. Fermilab is the U.S. host laboratory for the CMS experiment at the Large Hadron Collider (LHC) at CERN, in Geneva, Switzerland. Some 1,700 U.S. scientists from 87 universities and seven national laboratories carry out research at the LHC, the world's new energy-frontier accelerator.

I-3.2.6.2 Intensity Frontier Physics

At the Intensity Frontier, scientists use intense beams from particle accelerators for intensity-frontier experiments that explore neutrino interactions and ultra-rare processes in nature. Neutrino discoveries are central to understanding key questions of 21st century physics: How did the universe come to be? What happened to the anti-matter? Do all the forces unify? Precise observations of nature's rarest processes open a doorway to realms of ultra-high energies beyond those that any particle accelerator could ever directly achieve, to the region where physicists believe all of nature's forces become one.

I-3.2.6.3 Cosmic Frontier Physics

At the Cosmic Frontier, astrophysicists use the cosmos as a laboratory to investigate the fundamental laws of physics from a perspective that complements experiments at particle accelerators. Thus far, astrophysical observations, including the bending of light known as gravitational lensing and the properties of super-novae, reveal a universe consisting mostly of dark matter and dark energy. A combination of underground experiments and telescopes, both ground- and space-based, will explore these mysterious dark phenomena that constitute 95 percent of the universe.

I-3.2.7 Operations

The Fermilab facilities include a complex of particle accelerators and beam transport enclosures used to provide the particle beams used in the Laboratory's experimental research program. The Fermilab Main Accelerator produces beams of accelerated particles which are directed upon a number of stationary targets in various locations and are then distributed among some number of fixed-target beam lines. Each of the fixed-target beam lines can also operate in a variety of different modes depending on the needs of the experimenters using them.

There are also experimental research and test stand accelerators that accelerate electron beams that are directed upon stationary fixed targets or test accelerator components. Like the Fermilab Main Accelerator, these experimental research and test stand accelerators can operate in a variety of operating modes.

The Accelerator Directorate's Operations Department is responsible for the operation of the Fermilab Main Accelerator. The experimental research facilities associated with the Fermilab Main Accelerator are operated by approved members of the experimental collaboration. The Fermilab Accelerator Science & Technology (FAST) accelerator is operated by a written Accelerator Division Administrative Procedure (ADAP), as described in Section V Chapter 01 FAST for the specific reference. The Test Stand Accelerators are operated by approved and qualified operators for the specific facility, as described in the specific chapters within Section VI.

I-3.2.7.1 Commissioning Activities

Initial commissioning of new accelerators, accelerator segments, or experiments is conducted in phases. For accelerator segments, the beamline components are generally divided into three separate commissioning phases: a) system checkout, b) commissioning with primary beam to satisfy key performance indicator requirements, and c) commissioning with primary beam to satisfy physics requirements. The commissioning phases are described in detail in the accelerator module commissioning plans that are part of the Accelerator Readiness Review (ARR).

System checkout is performed after all necessary safety approvals are granted. An ESH/QA review committee oversees the review process for each project. When the project reviews are complete for systems that pose unique hazards, prior to the checkout phase, the review committee requests approval for initial system operation from the relevant Directorate/Division Head.

For accelerators within the Accelerator Directorate (AD), after all system checkouts are complete, the accelerator segment is physically ready for beam. The AD Head grants approval for start of commissioning after all necessary safety reviews have been completed, the Accelerator Safety Envelope has been approved, and the Operation Authorization Document, typically a Beam Permit and Running Condition, has been approved. The Operation Authorization Document states the maximum beam intensity that is authorized for the area, the applicable Credited Controls, and any administrative controls (including Defense-in-Depth controls) that are required to be in place before the Operations Department is authorized to transport beam within that accelerator and/or segment.

For accelerators in other Directorates/Divisions, approval for operation is granted by the owning Directorate/Division Head, rather than the AD Head, via an Operation Authorization Document.

Experiments approved for operation provide a Preliminary Hazard Assessment as part of their Technical Scope of Work (TSW) with the Laboratory. The Directorate/Division hosting the experiment is responsible for conducting ES&H reviews of the systems identified in the Preliminary Hazard Assessment. Documentation of these reviews is the first part of the Operational Readiness Clearance (ORC) described in FESHM 2005. The ORC is a permit approved by the relevant Directorate/Division Head for the commissioning and unattended operation of an experiment system or detector. The ORC process requires documentation of potential hazards and their mitigation, a review of the documentation, and a walk-through inspection of the experiment installation. Sub-systems within a detector can be reviewed individually and granted a partial ORC. As detector installation progresses, partial ORCs are accumulated for all sub-systems. The relevant Directorate/Division management and/or the Division Safety Officer (DSO) assigns a review committee to conduct the sub-system reviews and inspections of installations in the experimental areas.

The relevant Directorate/Division Head grants a final ORC approval to the experiment, which has the following components:

- Sign-offs from the ES&H review committee(s). This is a collection of partial ORCs.
- Directorate/Division management determination that the experiment is covered by this SAD. This statement specifies that the experiment complies with the requirements of a specific version of the Safety Assessment Document.
- Directorate/Division management determination of the need for an experiment Conduct of Operations document. This statement documents the determination that sufficient engineered controls are in place to obviate the need for formal Conduct of Operations.
- Verification from spokesperson that any required procedures are approved and in effect. Where safety procedures are required, as determined by the partial ORC reviews, the experiment must demonstrate to the relevant Directorate/Division Head that these procedures are in place and that appropriate training has been given.

I-3.2.7.2 Normal Operations

The operational safety of accelerators and/or experimental areas is maintained through both administrative and hardware mechanisms. The hardware serves as the primary protection and the administrative procedures normally serve as a backup to support or reinforce the limits set through hardware. The exceptions are those administrative mechanisms through which the safety envelope is determined and enforced.

Governing accesses into Exclusion Areas (“enclosures”) is an important part of the responsibilities of the AD Beams Division Operations Department. There are two basic types of access to these enclosures: Supervised and Controlled. A Supervised Access is used when there is a need for extensive and/or prolonged work inside an enclosure. In this case, a full radiological survey is performed to document the radiological hazards, and the hardware safety system is used to disable beam so that a Search and Secure of the enclosure needs to be performed before beam can be re-enabled. Each accelerator is required to have a Search and Secure, performed before a beam permit can be issued by the safety system. The Search and Secure is designed to ensure that all personnel have been cleared from an enclosure. Responsibility for performing the Search and Secure lies with the qualified operators of that accelerator and/or members of the AD Beams Division Operations Department, except when specifically delegated to others via an agreement document.

A Controlled Access is used whenever limited and/or short duration work is being performed and it is desirable to maintain the security of the enclosure. This method of access limits the extent of the access and removes the need for a subsequent Search and Secure. All personnel entering an enclosure under Controlled Access conditions are required by the FRCM to complete Fermilab Controlled Access Training, or to be escorted by trained personnel. During a Controlled Access, each person entering the enclosure must have an enclosure Enter key in their possession at all times. The enclosure Enter key is interlocked to the radiation safety interlock system thereby disabling accelerator operations until the access is complete and the enclosure Enter key is returned. Current written procedures for Controlled Access are maintained by the ES&H Division within FESHM.

The AD Operations Department verify the training requirements for people making an access before issuing an enclosure Enter key. The access training may include such courses as Radiological Worker, Controlled Access, Oxygen Deficiency Hazard (ODH), Confined Spaces, and Lockout/Tagout (LOTO) Level 2.

Before maintenance is performed on devices connected to hazardous energy sources, Lockout/Tagout is performed in compliance with OSHA 29 CFR 1910.147 and FESHM 2100. In addition to LOTO, as a supplemental safety feature, power supplies with exposed connections and potentially hazardous devices are interlocked off via the safety system.

Accelerator operations occur when all Credited Controls are in place, including the Operation Authorization Document.

The ES&H Division Radiation Physics personnel keeps a log of the total beam intensities accelerated, transported, and/or delivered to targets, beam absorbers, and experiments. Summaries of these logs are included as part of the Environmental Monitoring Program described in Section I Chapter 6. This program defines administrative limits on the total amount of beam that can be delivered to these areas annually.

I-3.2.7.3 Emergency Management

Emergencies affect normal operations. For on-site emergencies, the laboratory has an emergency management structure led by the Chief Operating Officer, members of the Emergency Operations Center (EOC) staff, and in conjunction with the Incident Commander in the field. The EOC interfaces with outside agencies, DOE Headquarters, the media, and coordinates emergency response assets and resources. Emergency response procedures are in the Fermilab Comprehensive Emergency Management Plan. The Comprehensive Emergency Management Plan[12], updated triennially, contains details of the types of emergencies Fermilab can experience.

Emergencies requiring AD Operations Department response include such things as fire alarms, ODH alarms, radiation alarms, spills and leaks, flammable gas alarms, and other potentially dangerous situations affecting the facility. The AD Operations Department has emergency response procedures that are kept up to date and are consistent with the Fermilab Comprehensive Emergency Management Plan. These procedures consist of specific instructions and/or flowcharts for use by both the MCR staff and the operators responding to the emergency in support of the emergency response organization of the Laboratory.

Other events which are beyond the scope and control of the emergency management system include severe weather and offsite events having the potential to impact laboratory operations. The laboratory utilizes the SEWS to pass on information to personnel.

I-3.2.7.4 Decommissioning Activities

Decommissioning is a general term for a formal process to remove an activity, operation, or facility from active status. As the Fermilab accelerators are developed over time, support facilities, accelerator and beamline equipment, and experiments will proceed through a life cycle. At the completion of the operational stage of the life cycle of a given facility, decommissioning will be conducted. FESHM chapter 7050 is the relevant statement of Fermilab's policies on decontamination and decommissioning activities. Per DOE O 420.2D, DOE Field Element Manager approval shall be obtained prior to the start of any decommissioning activities.

I-3.2.7.4.1 The Forms of Decommissioning

Decommissioning activities can take several forms:

1. Placement of a given module in a state of preservation awaiting possible resumption of use in a configuration similar in kind to that previously operational state (so-called "mothballing");
2. Continued maintenance of the civil structure with removal of the equipment utilized during the operational state;
3. Removal of the previously operational equipment with the civil structure reconfigured to await some future purpose, defined or undefined at the time of decommissioning;
4. Removal of the equipment and civil structure and replacement with a new module;
5. Removal of the equipment and civil structure with restoration of the site to a condition similar to the pre-operational state; and
6. Removal of the equipment and civil structure with restoration of the site to a condition similar to that found before the creation of Fermilab.

I-3.2.7.4.2 Data Collection in Support of Decommissioning

The implementation of FESHM 8070 throughout the life cycle of a given accelerator, inclusive of all Fermilab support facilities, will ensure the collection of the information needed to effectively implement decommissioning, once that time in the life cycle is reached. In particular, this information should include for each module to be decommissioned:

1. Volumes, locations, and levels of radioactivity in radioactivated items of equipment, parts of the civil structure, and adjacent shielding components such as soil, concrete, and earth as well as levels of removable radioactivity from components;
2. Locations and quantities of hazardous and regulated chemicals;
3. Identification of possible areas of potential interference with utilities (electrical, domestic water lines, industrial cooling water systems, low conductivity water systems, cryogenic transfer lines, radiofrequency systems, fire protection systems, controls and communications systems, HVAC systems); and

4. Identification of any environmental monitoring points or locations crucial to environmental permit compliance.

I-3.2.7.4.3 The Process of Decommissioning

Decommissioning will proceed through a sequence of stages tailored to the particular end objective of the process as defined by overall Fermilab plans. These stages are anticipated to meet the needs of a particular defined future use for a given facility being decommissioned but, in alignment with any relevant DOE-specified project planning activities, would be expected to follow a process such as:

1. Identification of need and scope of decommissioning;
2. Compliance with NEPA requirements as needed during the planning process;
3. Detailed planning including preparation for removal of regulated and hazardous materials, removable radioactivity, activated components and structures, and activated shielding materials as defined within the scope of decommissioning;
4. Planning for appropriate disposal of materials and components removed from the module;
5. Supervision of subcontractor services used to perform the decommissioning including documentation of all stages of the process, with special attention given to any structures and components that remain in place;
6. Documentation of the final state subsequent to completion of decommissioning; and
7. Certification of completion of decommissioning by Fermilab management including the Chief Safety Officer.

I-4. Safety Assessment

This safety assessment is intended to document the non-accelerator specific and accelerator-specific hazards found at the Fermilab facilities. For each facility, each hazard is either declared as non-applicable or a hazard risk matrix table exists either by reference or prepared specifically for that facility.

The non-accelerator specific hazards section contains hazards that are generally found in most industrial environments. For those NASHs that are generally handled the same way across the lab, a common hazard risk matrix table is generated using the methodology and criteria of DOE-HDBK-1163-2020. These tables are in Appendix C and specify the unmitigated risk, the preventive and mitigative measures in place, and the resultant residual risk. In the SAD Chapter for each facility, the facility identifies for each NASH if that hazard exists in that facility. If it does, the facility evaluates if any aspect of the hazard or the preventive and mitigative measures applicable to the facility differs from the information in the lab-wide hazard risk matrix for that NASH. If there are no differences, the SAD Chapter refers to the lab-wide hazard risk matrix. If there are differences, the differences are described. If a lab-wide hazard risk matrix table does not exist, the facility has prepared a facility-specific hazard risk matrix table.

The accelerator-specific hazards section outlines the accelerator-specific hazards and typical preventive and mitigative measures employed to control these hazards. The SAD Chapter for each facility identifies the accelerator-specific hazards that apply to that facility and identify the preventive and mitigative measures for each hazard and the resultant residual risk. The preventive and mitigative measures listed in the individual SAD Chapters for accelerator-specific hazards form the basis for the ASE.

For prompt ionizing radiation, a quantitative Maximum Credible Incident (MCI) analysis methodology is used to identify Credited Controls to ensure residual dose levels are below acceptable values of 5 rem in one hour in any area accessible by facility workers or co-located workers, 500 mrem in one hour in all Laboratory areas to which the public is assumed to be excluded, or 100 mrem in one hour at Fermilab's site boundary and/or in any area onsite in which the public is authorized (as further described in in Table 2 in Section I-4.2.1.1 below). The MCI analysis is summarized in the facility-specific chapter and is not included in the risk matrix table.

The Fermilab Environment, Safety and Health Manual (FESHM) describes the various programs in place to protect against the non-radiological hazards. The FESHM is the implementation of the DOE approved Worker Safety and Health Plan. The Fermilab Radiological Control Manual (FRCM) describes the radiological programs in place to protect against the radiological hazards. The FRCM is the implementation of the DOE approved Radiation Protection Program.

The table below includes the complete list of hazards evaluated in the SAD. Hazards in bolded purple font (Prompt Ionizing Radiation and Cryogenics ODH) are considered accelerator-specific hazards. The remaining hazards are treated as NASHs. Lab-wide hazard risk matrix tables have been generated for all the NASHs except for those in the Radiological category. Because the specifics of the radiological hazard vary from facility to facility, a common hazard risk matrix table was not deemed useful. Each facility will address these hazards specifically for their facility in their SAD Chapter.

Table 1. Hazard Identification (HID) Table

	Radiological		Toxic Materials
☐	Prompt Ionizing Radiation	☐	Lead
☐	Residual Activation	☐	Beryllium
☐	Groundwater Activation	☐	Fluorinert & Its Byproducts
☐	Surface Water Activation	☐	Liquid Scintillator Oil
☐	Radioactive Water (RAW) Systems	☐	Ammonia
☐	Air Activation	☐	Nanoparticle Exposures
☐	Closed Loop Air Cooling		**Flammables and Combustibles**
☐	Soil Interactions	☐	Combustible Materials (e.g., cables, wood cribbing, etc.)
☐	Radioactive Waste	☐	Flammable Materials (e.g., flammable gas, cleaning materials, etc.)
☐	Contamination		**Electrical Energy**
☐	Beryllium-7	☐	Stored Energy Exposure
☐	Radioactive Sources	☐	High Voltage Exposure
☐	Nuclear Material	☐	Low Voltage, High Current Exposure
☐	Radiation Generating Devices (RGDs)		**Kinetic Energy**
☐	Non-Ionizing Radiation Hazards	☐	Power Tools
	Thermal Energy	☐	Pumps and Motors
☐	Bakeouts	☐	Motion Tables
☐	Hot Work	☐	Mobile Shielding
☐	Cryogenics (ODH and burns)		**Magnetic Fields**
	Potential Energy	☐	Fringe Fields
☐	Crane Operations		**Other Hazards**
☐	Compressed Gasses	☐	Confined Spaces
☐	Vacuum/Pressure Vessels/Piping	☐	Noise
☐	Vacuum Pumps	☐	Silica
☐	Material Handling	☐	Ergonomics
	Access & Egress	☐	Asbestos
☐	Life Safety Egress	☐	Working at Heights

I-4.1. Non-Accelerator Specific Hazards

This section describes the non-accelerator specific hazards (NASHs) from the table above. Although some of these hazards occur as a result of accelerator operations, the hazards are not unique to accelerators and these hazards are safely managed by other DOE approved safety and health programs and/or processes. For those NASHs evaluated on a lab-wide basis, the corresponding hazard risk matrix table, which describes the unmitigated risk, the preventive and mitigative measures applied at the lab, and the resultant residual risk, is in Appendix C.

I-4.1.1 Radiological Hazards

The Fermilab Radiological Control Manual (FRCM) establishes practices for the conduct of radiological control activities at the Fermi National Accelerator Laboratory. It states Fermilab's positions and views on the best courses of action currently available in the area of radiological controls. The FRCM has been endorsed by the Fermilab Director, the contractor senior site executive. It is considered to be part of the FESHM and thus conforms to all other documented safety plans required under the DOE-FRA contract. The FRCM is kept current and is a controlled document maintained by the Environment, Safety, Health

(ES&H) Division. Even when an accelerator and/or segments of the accelerator are not in operation, many enclosures remain radiological areas because of residual activation, and therefore access is tightly controlled. These controls include verification of training, centralized authorization, and key entry. The level of control depends on the level of residual radiation. The controls required for different radiation levels are detailed in the FRCM. A feature of the access control procedures for these areas is that the access keys ("enclosure Enter keys") are issued only to individuals who have received the required training or have received explicit approval for a waiver of the required training(s) by the DSO or Radiation Safety Officer (RSO) and have a qualified escort.

Work in High Radiation Areas (>100 mrem/hr) is further restricted through Radiological Work Permits (RWPs) and specific RSO approval.

The bulk of radioactivity produced is at locations selected by beamline design that include beam collimators, primary target stations, and beam absorbers. Other locations that routinely exhibit high levels of radioactivity are those areas where the particle beam is altered from its normal circulating, accelerating, or transport path.

Large radiation doses to personnel are usually avoided by simply delaying any required work in these areas and allowing for a period of time for radiation levels to decay for the typical accelerator-produced radioisotopes.

In order to locate areas that contain residual radioactivity, radiation rates are measured during Controlled Accesses, and radiation surveys are performed and documented prior to allowing Supervised Accesses. The procedures for performing, documenting, and filing the surveys are approved by the ES&H Division Radiation Physics Operations Department. During the survey, all areas with dose rates at or exceeding limits specified in the procedures are posted with dose rate information. Pre-printed survey maps are used to log this information in the respective enclosure. In addition to checking for dose rates, the survey crew also checks for loose surface radioactive contamination and, where appropriate, decontamination procedures are subsequently employed.

After the survey is complete and acceptable radiological conditions are verified, qualified personnel may enter the enclosures on Supervised Access. The two primary means of understanding the radiological hazards present in the enclosures are by referring to the survey maps and by taking note of the local postings where work is to be performed. Survey maps and Radiological Work Permits (RWPs), when necessary, are made available to personnel in the Main Control Room (MCR) or at the point of entry for review prior to entering the enclosures.

I-4.1.1.1 Residual Activation

The hazard resulting from material that has become radioactive as a result of exposure to the beam. This hazard is evaluated by each facility and, if applicable, a facility specific hazard risk matrix table is in the facility's chapter.

I-4.1.1.2 Groundwater Activation

The hazard resulting from water radioactively activated by the beam that gets into the groundwater. This hazard is evaluated by each facility and, if applicable, a facility specific hazard risk matrix table is in the facility's chapter.

I-4.1.1.3 Surface Water Activation

The hazard resulting from water radioactively activated by the beam that gets into the surface water. This hazard is evaluated by each facility and, if applicable, a facility specific hazard risk matrix table is in the facility's chapter.

I-4.1.1.4 Radioactive Water (RAW) Systems

The hazard resulting from systems within the facility that contains radioactive or potentially radioactive water. This hazard is evaluated by each facility and, if applicable, a facility specific hazard risk matrix table is in the facility's chapter.

I-4.1.1.5 Air Activation

The hazard resulting from air being radioactively activated by the beam. This hazard is evaluated by each facility and, if applicable, a facility specific hazard risk matrix table is in the facility's chapter.

I-4.1.1.6 Closed Loop Air Cooling

The hazard resulting from cooling targets with closed loop air systems which may pick up and concentrate contaminants. This hazard is evaluated by each facility and, if applicable, a facility specific hazard risk matrix table is in the facility's chapter.

I-4.1.1.7 Soil Interactions

The hazard resulting from soil being radioactively activated by the beam. This hazard is evaluated by each facility and, if applicable, a facility specific hazard risk matrix table is in the facility's chapter.

I-4.1.1.8 Radioactive Waste

The hazard resulting from handling radioactive waste material from lab operations. This hazard is evaluated by each facility and, if applicable, a facility specific hazard risk matrix table is in the facility's chapter.

I-4.1.1.9 Contamination

The hazard resulting from loose and fixed radioactive contamination on equipment or in facilities. This hazard is evaluated by each facility and, if applicable, a facility specific hazard risk matrix table is in the facility's chapter.

I-4.1.1.10 Beryllium-7

The hazard resulting from the radioactive isotope Beryllium-7 which occurs as a result of activation from the beam in certain circumstances. This hazard is evaluated by each facility and, if applicable, a facility specific hazard risk matrix table is in the facility's chapter.

I-4.1.1.11 Radioactive Sources

The hazard resulting from the radioactive sources used as calibration or check sources for equipment/instrumentation, research purposes, and radiography. This hazard is evaluated by each facility and, if applicable, a facility specific hazard risk matrix table is in the facility's chapter.

I-4.1.1.12 Nuclear Material

The hazard resulting from nuclear material, including depleted uranium, normal uranium, californium, americium, deuterium, tritium, thorium, or other nuclear material. This hazard is evaluated by each facility and, if applicable, a facility specific hazard risk matrix table is in the facility's chapter.

I-4.1.1.13 Radiation Generating Devices (RGDs)

The hazard resulting from the radiation emitted from RGDs. This hazard is evaluated by each facility and, if applicable, a facility specific hazard risk matrix table is in the facility's chapter.

I-4.1.1.14 Non-Ionizing Radiation Hazards

The two common types of non-ionizing radiation hazards found in use at the laboratory are radiofrequency (RF) radiation and coherent light sources (e.g., lasers). RF systems are utilized to accelerate particle beams. The primary mechanism to protect personnel from exposure is to contain the RF waves inside of coax cabling or waveguide. Periodic surveys are performed by the ES&H Division Industrial Hygiene Group for stray RF fields.

Lasers are used in some beamlines and experiments to provide light sources for beam diagnostics, detector calibration or provide photo-cathode light excitation to an electron gun. The use of lasers is governed by the requirements found in the FESHM. Most lasers are Class 1, Class 2, or Class 3R, where it is unlikely that the laser would cause an inadvertent injury. In the locations where Class 3B or Class 4 lasers are used, additional measures, including approval by the laboratory Laser Safety Officer prior to operation, are in place to control this hazard.

A lab-wide hazard risk matrix table has been prepared for this hazard, Table C.1 in Appendix C. Acceptable risk levels of III or IV are obtained for all elements of this hazard.

I-4.1.2 Toxic Material Hazards

Controlling industrial hygiene (IH) hazards is addressed through the application of the relevant OSHA standards and other applicable standards (such as ANSI and ACGIH). The Laboratory employs a professional ES&H staff that monitors industrial hygiene hazards for compliance with the national standards and the FESHM requirements. When necessary, the ES&H staff develops additional procedures to mitigate the hazards.

I-4.1.2.1 Lead

Lead is used in a number of applications throughout the lab. In most cases, the lead is encapsulated, but potential exposure to lead can occur during manual handling of un-encased lead bricks, lead shot, lead sheets, lead paint, and soldering operations. The primary preventive and mitigative controls consist of training for lead handling, Personnel Protective Equipment (PPE), and IH monitoring. This hazard is covered in a lab-wide hazard risk matrix table, Table C.2 in Appendix C. An acceptable risk levels of IV was obtained for this hazard.

I-4.1.2.2 Beryllium

Beryllium has limited applications around the lab, but there are some applications, such as windows into vacuum chambers. The hazard is potential exposure to beryllium dust during manual handling of un-encased beryllium material, including clean-up in instances where a beryllium window has ruptured. The primary preventive and mitigative controls consist of training for beryllium handling, PPE, and IH monitoring.

This hazard is covered in a lab-wide hazard risk matrix table, Table C.2 in Appendix C. An acceptable risk level of IV was obtained for this hazard.

I-4.1.2.3 Fluorinert

Fluorinert is a non-hazardous high dielectric liquid that is used for heat transfer and immersion cooling. Although Fluorinert itself is non-hazardous, when exposed to heat, hazardous decomposition products can be produced. The primary preventive and mitigative controls consist of use of closed systems and filtration.

Potential exposure to fluorinert is covered in a lab-wide hazard risk matrix table, Table C.2 in Appendix C. An acceptable risk level of IV was obtained for this hazard.

Potential exposure to fluorinert decomposition products is covered in a lab-wide hazard risk matrix table, Table C.2 in Appendix C. An acceptable risk level of III was obtained for this hazard.

I-4.1.2.4 Liquid Scintillator Oil

Some liquid scintillator oil contains 5.35% pseudocumene or other hazardous additives. The pseudocumene is an eyes, skin and respiratory irritant, central nervous system depressant, and is toxic to marine life. A job-specific hazard analysis and procedure govern filling the detector and prescribe PPE to prevent worker contact with the liquid scintillator. The PVC modules, once filled, completely contain the pseudocumene, resulting in no further exposure. Emergency spill equipment, an eye wash and PPE are stationed near the detector in the event of a release. The entire detector is inside of a secondary containment membrane that has the capacity to contain 100% of the liquid scintillator oil and prevent a release to the environment This hazard is covered in a lab-wide hazard risk matrix table, Table C.2 in Appendix C. An acceptable risk level of IV was obtained for this hazard.

I-4.1.2.5 Ammonia

Ammonia may be used as a necessary component for an experiment within the accelerator facility. The primary hazard is airborne exposure to ammonia vapor and skin irritation/burn due liquid or solid contact with skin. This hazard is prevented based on operating procedures and mitigated by PPE and area ventilation.

This hazard is covered in a lab-wide hazard risk matrix table, Table C.2 in Appendix C. An acceptable risk level of IV was obtained for this hazard.

I-4.1.2.6 Nanoparticle Exposures

Nanoscale particles, often referred to as nanomaterials, have unique properties that may pose serious health hazards that are greater than the same material of the same chemical composition in a non-nanoscale form. When nanomaterials become airborne, they are particularly hazardous since they can enter the deepest tissues of the lung. Although the exact health effects this may have in humans is not known, animal studies have shown adverse lung effects, including pulmonary inflammation and rapidly developing, persistent fibrosis. Several animal studies have shown a possible cancer link. The results from animal research therefore indicate that human exposure needs to be minimized until further information is available on human health effects. FESHM addresses the handling of intentionally produced unbound engineered nanoscale particles. The primary preventive measure are engineering controls, such as proper ventilation or use of a glove box, and proper PPE.

This hazard is covered in a lab-wide hazard risk matrix table, Table C.2 in Appendix C. An acceptable risk level of IV was obtained for this hazard.

I-4.1.3 Flammables and Combustibles

The accelerator areas are classified as a non-accelerator specific hazard (NASH) in terms of fire prevention. Fire prevention and protection is enhanced by independent fire department inspections, Highly Protected Risk (HPR) Assessments, and prompt on-site fire department response. Continuous monitoring of systems also contributes to quick detection of problems. Equipment is designed with the application of the criterion that minimizes or eliminates combustible material.

Service buildings and beamline enclosures are constructed primarily of non-combustible material. The primary fire hazard is from the numerous power and signal cables that are distributed throughout the buildings and enclosures. Extensive tests of fire propagation in horizontal cable trays were conducted. The results indicate that cable tray fires propagate extremely slowly, generate only low temperatures, and self-extinguish. The major concern is smoke propagation. Where possible, penetrations between services buildings or equipment galleries and enclosures are sealed.

Fire detection and suppression systems for service buildings and enclosures were installed at initial construction. These systems were based on the fire loading, codes, and/or design criteria in place at the time of construction. Additional systems have been installed and upgrades to pre-existing systems have been made in conjunction with facility modifications and the application of more stringent criteria. For instance:

- Alarm systems consisting of manual pull stations are located in all service buildings and enclosures with a few minor exceptions.
- Ionization smoke detection systems are present in most service buildings.
- Other service buildings and some beamline enclosures have HSSD systems.
- Linear heat detector systems are in some beamline enclosures.
- Wet-pipe sprinkler systems are in several service buildings and in alcove areas of the Main Injector beamline enclosure.
- Selected helium compressor buildings have special total-flooding type suppression systems, which utilize water mist or a dry chemical extinguishing agent.
- Halon protection has been maintained in the Main Control Room and two central computer rooms.
- Activation of the detection or suppression systems initiates local alarms and a central alarm is also transmitted via the FIRUS system to the Fermilab Emergency Dispatcher.

General housekeeping is the responsibility of line management. The Building/Area Manager Program and scheduled walk-through inspections of all areas contributes to the monitoring and minimization of excessive accumulations of flammable and combustible materials. Minimization of excess material and proper housekeeping for the enclosures is specifically addressed by radiological worker training and waste minimization practices. Flammable materials are stored in approved flammable storage cabinets. Hazardous operations, such as welding, cutting, and brazing, are regulated by appropriate permits issued by the Fermilab Fire Department.

I-4.1.3.1 Combustible Materials

This hazard is covered in a lab-wide hazard risk matrix table, Table C.3 in Appendix C. An acceptable risk level of IV was obtained for this hazard.

I-4.1.3.2 Flammable Materials

This hazard is covered in a lab-wide hazard risk matrix table, Table C.3 in Appendix C. An acceptable risk level of IV was obtained for this hazard.

I-4.1.3.2.1 Flammable Gases

The use of flammable gases in physics experiments presents a unique type of installation, requiring special considerations. In many cases, mixing of gases is involved. Large volumes of gases may be present; thus, even small leaks or ruptures of thin windows may cause incursions into the flammable concentration region with a large inventory to support fire. Some flammable gases may be stored in the liquid state, increasing the inventory. Electrical equipment is an integral part of such installations and can thus provide an ignition source if such a system is improperly designed, fabricated, or operated.

FESHM outlines the requirements for storage and use of flammable gases. FESHM requires that a risk analysis be developed, and a review of the system be performed by the designated Fire Safety Subcommittee, followed by operational authorization from the Directorate/Division Head responsible for the area. The operational authorization documentation is maintained by the respective

Directorate/Division. The risk analysis, independent review, and operational authorization effectively mitigates the hazards from the use of flammable gasses so that potential impacts to personnel are minor on site and there is no potential impact off site.

This hazard is covered in a lab-wide hazard risk matrix table, Table C.3 in Appendix C. An acceptable risk level of IV was obtained for this hazard.

I-4.1.4 Electrical Energy

Construction or modification of electrical equipment at Fermilab conforms to the safety and design standards of the FESHM, the Fermilab Engineering Manual[13], the National Electrical Code (NEC NFPA 70), the National Electrical Safety Code (ANSI C2-1984) and OSHA 29 CFR 1910.331-335 "Safety Related Work Practices" where applicable. FESHM describes Fermilab's Electrical Safety Program.

Electrical bus work is either protected by physical barriers or is de-energized by the electrical interlock system prior to personnel access to the area. Power supplies that feed power to exposed conductors within interlocked enclosures are required by FESHM to be connected into the electrical interlock systems. The electrical interlock system provides an additional level of safety but does not replace the need for LOTO when working on hazardous energy sources.

I-4.1.4.1 Stored Energy Exposure

The primary concern for stored electrical energy is personnel electrical shock and arc flash burns. Preventive and mitigative measures consist of mechanical isolation during operations and interlocks, administrative controls (LOTO), and electrician training to ensure de-energization prior to contact during maintenance.

This hazard is covered in a lab-wide hazard risk matrix table, Table C.4 in Appendix C. An acceptable risk level of IV was obtained for this hazard.

I-4.1.4.2 High Voltage Exposure

The primary concern for stored electrical energy is personnel electrical shock and arc flash burns. Preventive and mitigative measures consist of mechanical isolation during operations and interlocks, administrative controls (LOTO), and electrician training to ensure de-energization prior to contact during maintenance.

This hazard is covered in a lab-wide hazard risk matrix table, Table C.4 in Appendix C. An acceptable risk level of IV was obtained for this hazard.

I-4.1.4.3 Low Voltage, High Current Exposure

The primary concern with low voltage, but high current is the potential for personnel electrical shock and fire hazard from high current causing smoke inhalation and burns. The preventive and mitigation measures are essentially the same as applicable for high voltage exposure.

This hazard is covered in a lab-wide hazard risk matrix table, Table C.4 in Appendix C. An acceptable risk level of IV was obtained for this hazard.

I-4.1.5 Thermal Energy

This hazard addresses instances where high or very low temperatures can result in personnel burns and where high temperatures can potentially be an ignition source.

I-4.1.5.1 Bakeouts

Bakeouts can heat equipment to over 100°C for multiple days. Preventive measures are a combination of personnel access control, hot work permits, and work planning and control process. Mitigative measures include the fire detection and suppression systems discussed elsewhere.

This hazard is covered in a lab-wide hazard risk matrix table, Table C.5 in Appendix C. An acceptable risk level of IV was obtained for this hazard.

I-4.1.5.2 Hot Work

Hot work includes welding, brazing, grinding, and other operations which create high temperatures which can ignite a fire. Fermilab has a hot work permit system that ensures the hot work site is properly protected to prevent the spread of high temperature particles to areas where combustible material exists. The worker performing the hot work must be trained and qualified. Mitigative measures include the fire detection and suppression systems discussed elsewhere in this Section I-4.

This hazard is covered in a lab-wide hazard risk matrix table, Table C.5 in Appendix C. An acceptable risk level of IV was obtained for this hazard.

I-4.1.5.3 Cryogenics (personnel burns)

Superconducting and other cryogenically-cooled components are used in the Fermilab facilities. They are cooled by liquid helium, liquid nitrogen, and/or liquid argon distribution systems. The design and operation of the components, their power supplies, and the associated low-temperature cryogen distribution systems considers the following potential hazards arising from the use of the cold, pressurized, liquid helium, nitrogen, and/or argon:

1. High speed gas flow from venting;
2. Freezing from contact with the extremely cold fluids and gases or material in contact with them; and
3. Suffocation from the displacement of oxygen by these inert gases. (The Oxygen Deficiency Hazard (ODH) is being covered in Section I-4.2.2, with the accelerator-specific hazards, and will not be further discussed here.)

The high-speed gas flow from venting hazard exists at the roof of operational compressor buildings. Sudden venting activity has the potential of significantly startling personnel who might be present on the roof to the extent that they might fall off the roof. This hazard is mitigated by procedurally restricting access to the roofs of operational compressor buildings.

The freezing hazard posed by extremely cold fluids and gases is addressed in training for affected personnel and by requirements for wearing of personal protective equipment (PPE) in performing work with, or in the vicinity of, cryogens. PPE requirements are addressed in cryogenic operating and maintenance procedures.

The safety analysis and review program for cryogenic systems has been developed at Fermilab with the help of ad hoc External Cryogenic Review. Details of this program are described in the FESHM.

Cryogenic systems may only be operated after review by the designated Cryogenics Safety Subcommittee Review Panel followed by operational authorization from the Directorate/Division Head responsible for the area. The cryogenic system operational authorization documentation is maintained by the respective Directorate or Division.

This hazard is covered in a lab-wide hazard risk matrix table, Table C.5 in Appendix C. An acceptable risk level of IV was obtained for this hazard.

I-4.1.6 Kinetic Energy

This hazard concerns the potential for injury due to moving material or equipment. Several types of kinetic energy hazards and the preventive and mitigative measures for these hazards are common throughout Fermilab; e.g., power tools and pumps and motors. For these common hazards, lab-wide hazard risk matrix tables were prepared. Movement of material by use of cranes and forklifts is covered under Potential Energy hazards.

I-4.1.6.1 Power Tools

This hazard deals with the potential injuries that can occur with the use of power tools. The primary preventive and mitigative measures are training, use of tool guards, maintenance of tools in proper condition, and use of PPE.

This hazard is covered in a lab-wide hazard risk matrix table, Table C.6 in Appendix C. An acceptable risk level of IV was obtained for this hazard.

I-4.1.6.2 Pumps and Motors

This hazard addresses entrapment and containment that may occur with rotating equipment and exposure to the pressure on the outlet and suction on the inlet of operating pumps. The preventive measures applicable to this hazard are the equipment guards that exist on rotating equipment, the work planning and control rules that require a hazard analysis to address hazards specific to the work planned, and Lock Out/Tag Out process to ensure equipment is isolated and depressurized prior to work.

This hazard is covered in a lab-wide hazard risk matrix table, Table C.6 in Appendix C. An acceptable risk level of III was obtained for this hazard.

I-4.1.6.3 Motion Tables

Motion tables are used in various locations around the lab to position equipment for experiments or to meet other operational needs. These tables pose a personnel hazard due to pinch points or striking personnel. The preventive measures include safety stops, warning labels, and Lock Out/Tag Out procedure to prevent motion during work on or in the area.

This hazard is covered in a lab-wide hazard risk matrix table, Table C.6 in Appendix C. An acceptable risk level of III was obtained for this hazard.

I-4.1.6.4 Mobile Shielding

In certain applications, shielding may be placed on rollers or structures to allow for large and/or heavy shielding to be movable by hand. The risk here is injury due to contact of personnel with shielding as it is being moved or it moves uncontrollably from its installed position. The preventive and mitigative measures include engineered design of the shielding, work control processes for moving shielding, use of spotters during movement, and proper handling by trained personnel.

This hazard is covered in a lab-wide hazard risk matrix table, Table C.6 in Appendix C. An acceptable risk level of III was obtained for this hazard.

I-4.1.7 Potential Energy

I-4.1.7.1 Crane Operations

The primary hazard is personnel injury due to uncontrolled movement of the load, dropping of the load, or failure of the crane. The primary preventive controls are to ensure the cranes are in satisfactory condition by proper maintenance and crane certifications and that crane operators and riggers are properly trained and qualified. These requirements are specified in the FESHM.

This hazard is covered in a lab-wide hazard risk matrix table, Table C.7 in Appendix C. An acceptable risk level of IV was obtained for this hazard.

I-4.1.7.2 Compressed Gasses

The primary hazard is personnel injury due to unexpected release, or unsecure tanks. The primary prevention measures are control of compressed cylinders when not in use (capped and secured) and training of personnel in using the gas cylinders. The FESHM contains requirements for storage and testing of gas cylinders.

This hazard is covered in a lab-wide hazard risk matrix table, Table C.7 in Appendix C. An acceptable risk level of IV was obtained for this hazard.

I-4.1.7.3 Vacuum/Pressure Vessels/Piping

High pressure gas systems and pressure vessels are potential mechanical hazards. There are many such systems throughout the Laboratory. The Laboratory has established policy for reviewing pressure vessel safety which is outlined in the FESHM. Laboratory policy requires that pressure vessels purchased by or built at Fermilab be fabricated in accordance with the American Society for Mechanical Engineers (ASME) code, Section VIII. Pressure vessels built at Fermilab must be designed according to requirements of the ASME code and reviewed by an independent, qualified reviewer other than the designer and preferably from another group not reporting to the designer or their supervisor.

Engineering Notes are required of all pressure vessels in use at Fermilab and include details of design calculations, materials specifications, test data, operating procedures and welding information.

Engineering Notes are retained by the Directorate/Division responsible for the equipment. The Laboratory Director is authorized to grant an exception from the Laboratory policy as stated in FESHM 1010 if that exception is explained and analyzed in the Engineering Notes. Documentation associated with these exceptions remains with the Engineering Note.

This hazard is covered in a lab-wide hazard risk matrix table, Table C.7 in Appendix C. An acceptable risk level of III/IV was obtained for this hazard.

I-4.1.7.4 Vacuum Pumps

The primary hazard is personnel injury due to interaction with existing vacuum. The primary preventive measure is personnel training.

This hazard is covered in a lab-wide hazard risk matrix table, Table C.7 in Appendix C. An acceptable risk level of III/IV was obtained for this hazard.

I-4.1.7.5 Material Handling

The primary hazard is personnel injury due to moving/handing material (rollovers, crush, etc.). This category includes movement by material by forklifts. Primary preventive and mitigative measures include training, equipment maintenance, and PPE.

This hazard is covered in a lab-wide hazard risk matrix table, Table C.7 in Appendix C. An acceptable risk level of IV was obtained for this hazard.

I-4.1.8 Magnetic Fields

In general, administrative rules, enforced by use of the electrical interlock system, prohibit personnel from being in enclosures when electromagnets, other than small powered correction elements, are energized. The fields associated with permanent magnets used in certain accelerator and beamline applications and the small powered correction elements that might be energized during normal access are normally confined to the interior of the magnets. Leakage fields from such magnets do not present a significant exposure hazard. Under most conditions, there can be no possibility of personnel exposure to high strength magnetic fields. In some cases, however, specialty magnets in the enclosures need to remain on. In those cases, access to the magnetic fields is restricted and areas above the limits stated in FESHM are posted.

The controls described above are adequate to decrease the hazard risk level of magnets to a level IV when not considering the impact magnetic fields may have on implanted medical devices, such as pacemakers. Additional controls measures including work planning and control and an additional layer of notifications using either enclosure Hazard Specification Sheets or facility-specific training decrease the hazard risk level to a level III

This hazard is covered in a lab-wide hazard risk matrix table, Table C.7 in Appendix C.

I-4.1.9 Other Hazards

General hazards not covered above are captured in this section of the SAD. Work involving confined space, ergonomics, silica, asbestos, noise and working at heights are detailed below and in the lab-wide risk matrix tables in Appendix C.

I-4.1.9.1 Confined Spaces

Working in confined spaces present unique hazards because environmental conditions can change rapidly, and it may be difficult to quickly exit the space. Some of the most common problems associated with confined spaces include hazardous atmospheres (e.g., reduced oxygen, flammable, toxic), slippery surfaces, electric shock, poor illumination, and flooding. FESHM provides the requirements to reduce the hazards associated with confined space entry/work. Required permits, training, specific work procedures, atmosphere monitoring, and other additional measures are executed at Fermilab to reduce risk.

This hazard is covered in a lab-wide hazard risk matrix table, Table C.9 in Appendix C. An acceptable risk level of III was obtained for this hazard.

I-4.1.9.2 Noise

Fermilab has a variety of high noise sources, categorized as continuous and/or impact, such as compressors, pumps, and machine tools. Standard industrial measures are in place to mitigate the risk of high noise. Hearing conservation program requirements are discussed in FESHM and include training, PPE, posting high noise areas, equipment isolation, and noise surveys.

This hazard is covered in a lab-wide hazard risk matrix table, Table C.9 in Appendix C. An acceptable risk level of IV was obtained for this hazard.

I-4.1.9.3 Silica

Silica poses a serious health hazard when it becomes airborne as respirable crystalline particulates. Activities that occur at Fermilab including, but not limited to: sandblasting, grinding, cutting, mixing, and drilling of concrete, brick, grout, and rock; miscellaneous sand and gravel operations; and repair or removal of furnace insulation, are all capable of exposing personnel to the silica hazard. Measures in place to reduce the risk of silica exposure are training, work planning, PPE, and engineering controls.

This hazard is covered in a lab-wide hazard risk matrix table, Table C.9 in Appendix C. An acceptable risk level of IV was obtained for this hazard.

I-4.1.9.4 Ergonomics

Personnel injury due to strains, sprains, repetitive motion, and other related events is a standard occupational hazard across all industries. Fermilab's Occupational Ergonomics Program consists of four activities: workplace analysis, hazard prevention and control, medical management, and training.

This hazard is covered in a lab-wide hazard risk matrix table, Table C.9 in Appendix C. An acceptable risk level of IV was obtained for this hazard.

I-4.1.9.5 Asbestos

Exposure to asbestos increases the risk of developing lung disease. A combination of control measures are in place to mitigate the risk of asbestos exposure at Fermilab. The Asbestos Control Program, work planning and control requirements, abatement efforts, and pre-work sampling reduce the likelihood of personnel exposure. FESHM further describes the control of asbestos exposure.

This hazard is covered in a lab-wide hazard risk matrix table, Table C.9 in Appendix C. An acceptable risk level of IV was obtained for this hazard.

I-4.1.9.6 Working at Heights

Working at heights poses two primary hazards: personnel falls and injury from dropped items. Several control measures are prescribed in Fermilab documents to mitigate the hazards associated with working at heights. The fall protection program controls working at heights. FESHM provides the requirements for fall protection as well as for ladder and scaffolding safety.

This hazard is covered in a lab-wide hazard risk matrix table, Table C.9 in Appendix C. An acceptable risk level of III was obtained for this hazard.

I-4.1.10 Access & Egress

The unique construction of many facilities at Fermilab complicates the ability to evacuate a building in the event of an emergency. The ability to ensure emergency egress is not hindered is provided through routine inspections by fire protection personnel and the building code official. Additionally, exit paths are marked and emergency lighting is provided. The life safety systems are tested at prescribed intervals. These control measures coupled with fire protection system operations reduces the hazard of preventing facility egress.

I-4.1.10.1 Life Safety Egress

Evacuation of facilities during events (e.g., fire, earthquake, ODH, etc.) is critical to life safety. FESHM covers the requirements for egress.

This hazard is covered in a lab-wide hazard risk matrix table, Table C.10 in Appendix C. An acceptable risk level of IV was obtained for this hazard.

I-4.1.11 Environmental

Environmental hazards are addressed through compliance with legal and regulatory requirements imposed by DOE Orders, Federal/State/local regulations, and FESHM. Numerous activities at Fermilab have the potential to produce environmental impacts. These include air emission sources such as fuel combustion, component cleaning, paint spray booths, soil erosion from construction activities, oil spills from transformers and generators utilized within the electrical distribution system, and glycol spills from various cooling systems. The laboratory has an IEPA-approved air emissions permit and a Spill Prevention, Control and Countermeasures Plan (SPCC) that has been certified by a registered Professional Engineer. New activities are reviewed for potential environmental and regulatory issues as part of the NEPA process.

The environmental radiation hazards considered include off-site radiation doses from muons produced by proton interactions with targets, activation of the air in enclosures which is subsequently released to the environment, and irradiation of unprotected soil surrounding the enclosures leading to radioactivity in the groundwater or surface water.

These hazards are concentrated at the target stations and beam absorbers. By limiting the total amount of beam that may be sent to these areas, the amount of radiation that is released into the environment is kept within the limits specified in FRCM. The total beam limitations due to activation of air, groundwater, surface water, soil, and external exposure have been determined for each of the accelerator enclosures, target stations, and beam absorbers. The most limiting is included in determining the ASE. Target and absorber locations routinely incorporate “Closed Loop” water systems to contain the activated water for proper disposal in accordance with FRCM.

Locations where there is a potential for the release of airborne radionuclides in measurable concentrations are identified and appropriately monitored to insure compliance with applicable standards. Groundwater and surface water are monitored on an as needed basis by the assigned RSO or the ES&H Division to insure compliance with the FRCM and applicable standards.

The methodology of DOE-HDBK-1163-2020 was used to evaluate the environmental hazards to air, water, and soil from both radiological and chemical releases. The hazard risk matrix table documenting the results of this review on a lab-wide basis is in Appendix C. Facility-specific aspects of environmental protection are covered in the individual facility chapters.

I-4.2. Accelerator-Specific Hazards

This section describes the accelerator-specific hazards and outlines the preventive and mitigative measures employed to control these hazards. This section forms the basis for the ASE and outlines the typical Credited Controls instituted to mitigate these hazards to acceptable levels.

Each Chapter in Sections II – VI has a hazard table at the beginning of the chapter outlining the hazards found within that section of the facility. The hazard table outlines both the non-accelerator specific hazard (NASH) and accelerator-specific hazards found within a specific portion of the facility. Not all areas will contain all of the accelerator-specific hazards outlined below. In the case where an accelerator-specific hazard exists within an area, additional safety analysis is warranted and will be described further in the relevant section of the Chapter.

I-4.2.1 Radiological Hazards

The predominant radiation hazard in the Fermilab accelerator areas is caused by the interaction of beam particles in the materials surrounding the beam pipes and beam line elements. Additional radiation hazards involve the handling and use of radioactive sources and X-ray producing devices. The FRCM describes the policies and procedures that must be followed in order to provide appropriate protection of personnel against radiation hazards.

The ES&H Division Radiation Physics personnel administer and monitor access control procedures, radiation interlocks, and personnel training that have been developed to protect personnel from possible exposure to radiation inside the beam enclosures. This program follows the ALARA principles specified in the FRCM.

There are three categories of beam-induced radiation hazards:

1. Prompt radiation levels inside and surrounding the enclosures, which are present during beam transport, may propagate offsite;
2. Residual radiation due to activation of beamline components, which can give rise to radiation exposures to personnel during accesses to the beam enclosures for repair, maintenance and inspection activities; and
3. Environmental radioactivity due to the operation of the accelerators and beam transport systems, particularly at the beam absorbers and targets such as the activation of air, soil, and groundwater.

Fermilab has radiological controls and postings that implement the requirements of 10 CFR 835 and are implemented through the FRCM. For example, for a radiologically controlled area, individuals who enter only controlled areas without entering a radiological area are not expected to receive a total effective dose of more than 100 mrem in one year (2000 hours). At Fermilab, members of the public cannot access radiologically controlled areas, unless formally approved and under strict escort.

The combination of our radiation shielding, monitors, and engineering controls is designed and operated to maintain these 10 CFR 835 required levels during any beam operations. For the SAD and ASE for the Linac and MTA, we credit radiation shielding, monitors, and engineering controls that we use to meet 10 CFR 835 requirements. In the case of credited radiation monitors for the Linac and MTA, although a credited control trip setting in the ASE may be shown as 100 mrem/hr, the actual trip setting is often substantially lower that the credited control limit to meet 10 CFR 835 requirements.

In the extremely unlikely event that a maximum credible incident scenario is realized, the instrument noted in the example above would trip to maintain levels in a radiologically controlled area to less than 100 mrem. Therefore, in the case of the Linac and MTA, the actual integrated dose that would result from a maximum credible incident scenario for an individual that is within the radiologically controlled area would likely be a fraction of the 100 mrem/year limit set by the 10 CFR 835 limit for members of the public but could be up to 100 mrem total. Radiation levels outside of radiologically controlled areas, which in some cases could be accessible by the public, would always be less than 100 mrem/year and will decrease at least linearly with distance from the source of the radiation.

I-4.2.1.1 Prompt Ionizing Radiation

In order to protect workers and the general public, the enclosures and beam pipes are generally surrounded by sufficient amounts of shielding (earth, concrete, lead or iron). The shielding creates Exclusion Areas that are interlocked by the Radiation Safety Interlock System (RSIS). In areas where there is insufficient shielding, networks of interlocked radiation monitors keep any prompt radiation within acceptable levels. Detailed analyses of the Maximum Credible Incident (MCI) have been performed and are updated as necessary to determine that the shielding is adequate during beam operations, or determine need for additional preventative or mitigative measures.

The Maximum Credible Incident (MCI) is the worst-case accelerator accident due to prompt-ionizing radiation. For each segment, it is determined the maximum intensity possible due to machine limitations and the maximum duration of a beam loss. Beam loss of that maximum-possible intensity for that maximum duration is then analyzed to determine potential dose on the outside of the enclosure or surrounding shielding. Potential dose is then compared to acceptable levels, which ensures doses are below occupational and public regulatory limits, as described in Table 2.

Table 2. Acceptable Dose Levels Used in MCI Analysis.

Dose Level	Location	Potentially Exposed Individual
Worker Basis: Mitigated consequence of any credible postulated accident scenario at maximum operating intensity that could potentially result in **5 rem** in one hour in any area accessible by facility workers or co-located workers	Inside service buildings, where public cannot access	Facility Worker and/or Co-Located Worker
General Site Basis: Mitigated consequence of any credible postulated accident scenario at maximum operating intensity that could potentially result in **500 mrem** in one hour in areas to which the public is assumed to be excluded	Outside of enclosure/facility and surrounding shielding, in non-publicly accessible areas (beyond Obvious and Operating Barriers to Ensure Only Authorized Access)	Members of the public if they access areas where they are not authorized
Public Area Basis: Mitigated consequence of any credible postulated accident scenario at maximum operating intensity that could potentially result in **100 mrem** in one hour at Fermilab's site boundary AND/OR in any areas onsite in which the public is authorized. • Batavia Road, Prairie Path (MBO), parking lots open to the public. • All General Access Areas, including but not limited to the following: ○ Wilson Hall ○ Ramsey Auditorium ○ Lederman Science Center ○ Building 327	Outside of enclosure, in location where the public is authorized	Maximally-exposed Off-Site Individual (a.k.a., a member of the public)

Locations beyond Obvious and Operating Barriers to Ensure Only Authorized Access fall into the "General Site Basis" for determining acceptable dose limits.

If the MCI analysis determines that the dose is below acceptable levels, then the identified surrounding shielding used in the MCI analysis are defined as the Credited Control, and no additional passive or active engineered Credited Controls are necessary.

If the MCI analysis determines that the dose is above acceptable levels, then additional passive Credited Controls (e.g., shielding or fencing) and/or active engineered Credited Controls (e.g., radiation monitors) must be established. Alternatively, other types of active engineered Credited Controls can be established to lower the intensity and/or beam loss duration, in which case the MCI analysis is re-done to ensure identified surrounding shielding is sufficient.

Any shielding in place in addition to the identified surrounding shielding used in the MCI analysis is considered to be Defense-in-Depth control.

Further preventative mitigative measures may be in place due to 10 CFR 835 and/or FESHM requirements to maintain doses ALARA. These controls are determined through the Shielding Assessment for the segment, which is performed at the normal operating intensity, rather than the maximum intensity. Controls identified in the Shielding Assessment that are in addition to controls that are identified in the MCI analysis are considered to be Defense-in-Depth control.

Radiation exposure to personnel is possible for those in enclosures during beam operation. This hazard is averted by excluding access to the enclosures when beam is potentially present. In addition to the training of all personnel, the principal means of protection of personnel against this hazard is a fail-safe, redundant system of interlocked access gates, doors, and critical devices. Critical devices, which are interfaced to this system, are driven to such a state so as to prohibit beam from entering an enclosure for which the Radiation Safety Interlock System (RSIS) has been broken. Critical devices include such equipment as bending magnet power supplies, beam stops, and collimators. The design, review, approval, and operating criteria for the Radiation Safety Interlock System are described in the FRCM. The Radiation Safety Interlock System test procedures and results are kept as part of Fermilab's permanent records. Operations utilize components of the RSIS to perform a Search and Secure to reestablish the interlocks and allow beam operations. The sole purpose of the Search and Secure is to ensure there are no personnel in the enclosure prior to allowing beam operations. The Search and Secure is incorporated within the RSIS Credited Control to prevent potential exposure to personnel within the enclosure.

Each facility for which prompt ionizing radiation is a hazard will have in its Chapter a hazard Risk Matrix table identifying the preventive and mitigative measures in place and the resultant residual risk level for this hazard.

I-4.2.2 Cryogenics (Oxygen Deficiency Hazard)

Cryogenic vessels and piping systems at use in the Laboratory follow Prevention through Design methodology to minimize oxygen deficiency hazard. A comprehensive study has been made of conceivable types of incidents involving cryogens for all Fermilab facilities. A safety analysis for each cryogenic subsystem is reviewed by the Cryogenic Safety Subcommittee Review Panel. The

Directorate/Division Head approves operations based on the recommendations of the Panel. The following items of documentation are provided by the system designers for review by the subcommittee: a system description including engineering design criteria, system schematics, preliminary operating procedures, results of system operating tests, and hazards analyses such as "failure mode and effects" analyses and "what-if" analyses.

The Laboratory has developed a policy detailed in FESHM and procedures for addressing potential oxygen deficiency hazards. The policy requires that, in potential ODH areas, the probability of a fatality shall be clearly below the value for workers in U.S. industry as a whole. The ODH policy also requires a calculation for each such work area and specifies the appropriate environmental, personnel, and administrative controls.

Personnel are note exposed to oxygen deficiency hazard (<19.5% O_2) under normal operating conditions. Under failure conditions in the cryogenic systems the potential exists for an oxygen deficiency. Each operation or event with the potential for causing oxygen deficiency in a given enclosure or service building is evaluated for its probability of occurrence and the associated ODH consequences. In addition, enclosures or service buildings adjacent to potential event areas, which have a leakage path, are evaluated, and an appropriate ODH Class is assigned. FESHM describes the procedures used to determine the ODH Class. The Accelerator Directorate ODH Assessment documents the ODH analysis and classifications within the Fermilab AD facilities.

Fermilab is able to mitigate oxygen deficiency hazards, so that potential impacts to personnel on site are minor and are nonexistent off site. The Directorate/Division Cryogenics Department or Group maintains both the documented analyses for determining the ODH classifications and the pertinent review panel correspondence. The safety measures implemented within our ODH program align with the defense-in-depth strategy. Deployment of engineering controls such as personal and fixed oxygen monitors, self-contained breathing apparatuses, and forced ventilation, provides defense against potential oxygen deficiency hazard. Augmenting these measures, our entry control and posting measures provide additional layers of protection, reinforcing the safety framework. Safety analyses, reviews, and classification determination regarding oxygen deficiency hazard in cryogenic system operations, coupled with established policies and procedures, collectively ensure mitigation of risks within oxygen-deficient areas.

Oxygen deficiency hazards from the use of Sulfur Hexafluoride (SF_6) as a dielectric insulating gas is also assessed in accordance with FESHM. The resultant risk assessment is reviewed by an independent engineer and approved by the Directorate/Division Head. The oxygen deficiency hazards posed by the use of SF_6 are mitigated by engineered controls, risk assessment and reviews, resulting determination of ODH Classification, and adherence to established policies and procedures related to ODH area entry. This, in conjunction with review and necessary authorization by the Directorate/Division Head to transfer SF_6 gas, effectively mitigates oxygen deficiency hazards so that potential impacts to personnel are minor on site and no impact off site.

Each facility for which oxygen deficiency is a hazard due to cryogenics will have in its chapter, a hazard risk matrix table identifying the preventive and mitigative measures in place and the resultant residual risk level for this hazard.

I-4.3. Credited Controls

Credited Controls are the primary controls that assure that the level of risk to all workers, the public, and the environment is maintained at an acceptable level. The Credited Controls listed in the ASE must be in place and functional for all operational areas.

The Credited Controls are divided up into three main categories: passive controls, active engineered controls, and administrative controls. Passive Credited Controls are elements that are part of the physical design of the facility that require no action to function properly. These are fixed elements that take human intervention to remove. Active Engineered Credited Controls are systems designed to reduce the risks from accelerator operations to an acceptable level. These are automatic systems that limit operations, shutdown operations, or provide warning alarms when operating parameters are exceeded. Administrative Credited Controls encompass the human interactions that define safe operations. These are the accelerator operating policies and procedures that are followed to ensure safe accelerator operations.

This Section lists types of Credited Controls that are in use at the various accelerators at Fermilab. Each accelerator, or accelerator segment, uses only those Credited Controls identified in their respective MCI or ODH analyses, where applicable.

I-4.3.1 Passive Credited Controls

Passive Credited Controls reflect features that are part of the physical design of the accelerator facilities or other features that are incorporated into the fundamental design of the accelerators that require no action to function properly. These are the fixed elements of the accelerator. The passive controls considered necessary to ensure safe accelerator operations are discussed below.

I-4.3.1.1 Shielding

I-4.3.1.1.1 Permanent Shielding Including Labyrinths

The passive shielding is the radiation shielding that is located between the Exclusion Areas and occupied areas to keep personal exposure to ionizing radiation within the limits specified in the FRCM. This shielding includes the concrete structure (e.g., walls, floors, and labyrinths) and the required soil surrounding the structure.

I-4.3.1.1.2 Movable Shielding

The movable shielding is the radiation shielding that is placed between Exclusion Areas and occupied areas during accelerator operations to keep personnel exposure to ionizing radiation within the limits defined in the FRCM. This shielding is a Credited Control that may be moved during maintenance periods for equipment access.

I-4.3.1.1.3 Penetration Shielding

The penetration shielding is the radiation shielding that is placed in penetrations, such as utility and RF waveguide routing, between the Exclusion Areas and occupied areas during accelerator operations to keep personnel exposure to ionizing radiation within the limits defined in the FRCM. This shielding is a Credited Control that may be moved during maintenance periods for installation of additional utilities or equipment access.

I-4.3.1.2 Obvious and Operating Barriers to Ensure Only Authorized Access

To permit entry to only authorized individuals into the area where the "General Site Basis" applies (see Figure 4). Obvious and Operating Barriers shall be established as Credited Controls at the following locations to permit only authorized access:

- Wilson Hall West
- Wilson Hall East
- Site 55

These Obvious and Operating Barriers may use any of the following methods to satisfy the Credited Control function of ensuring entry is permitted to only authorized individuals:

- Gates & card reader
- Bollard
- Security Guard

During maintenance periods of the existing barrier which would remove or diminish functionality of the existing barrier, another approved method, listed above, shall be used.

I-4.3.2 Active Engineered Credited Controls

Active Engineered Credited Controls are systems designed to reduce the risks from the Maximum Credible Incident (MCI) to an acceptable level. The Active Engineered controls considered necessary to ensure safe accelerator operations are discussed below.

I-4.3.2.1 Radiation Safety Interlock System

Radiation Safety Interlock Systems (RSIS) are used to prevent injury, death, or serious over-exposure from beam-on radiation. The principle method employed by the RSIS is to establish and maintain Exclusion Areas surrounding accelerator operating areas. Prior to accelerator operations, a Search and Secure is performed to establish the interlock system for the Exclusion Area(s). This Search and Secure ensures no personnel are remaining within the Exclusion Area(s) during accelerator operations. The interlock barriers are established such that sufficient distance is maintained between beamline operating components and the closest point of approach. If there is a potential for personnel to be within the defined Exclusion Area, the RSIS is designed to inhibit accelerator operations in that area.

The RSIS also includes interlocked radiation monitors required by the MCI analysis to supplement passive shielding Credited Controls. If dose rates exceed specified levels analyzed in the MCI, the RSIS is designed to inhibit accelerator operations in that area.

The RSIS utilize a modular redundant design where no single component failure will result in a loss of protection. To accomplish this, two separate fail-safe circuits are used to detect specific conditions. (For example, each door that is monitored uses two separate switches to detect the status of the door. Each of these switches is connected to separate control circuits. If a failure occurred in one switch, the other would still operate providing the necessary protection.) All circuits within the RSIS are designed in such a way that if a circuit fails, or specified input is lost, the failure would initiate a system shutdown resulting in a safe condition. Since the interlock system cannot detect all component failures, periodic functional testing in accordance with the FRCM, and specified in the ASE, is necessary to ensure reliable operations.

I-4.3.2.1.1 Required Calibration, Testing, Maintenance, and Inspection Schedules for RSIS Credited Controls

The schedules below are defined to meet radiological controls manual requirements defined in FRCM Chapter 10, Part 1004 and FRCM Chapter 5, Part 5.5.2.

Operation of all access control interlock components shall be functionally tested at an interval no greater than 15 months.

Area radiation monitors shall be maintained and calibrated on an interval no greater than 15 months.

I-4.3.2.2 ODH Safety System

ODH Safety Systems are used to prevent injury or death from exposure to oxygen deficient environments. ODH Classifications are determined based on a quantitative risk assessment, further described in FESHM. ODH Classifications are then used to determine required personnel training and qualification and other ODH control measures. ODH Safety Systems utilize various components (e.g., area oxygen monitors, vents, fan, etc.) to maintain the posted ODH Classification.

ODH Safety System component failures are taken into account in the initial ODH analysis, and surveillance requirements are determined based on the analysis. In the event of a known failure of an ODH Safety System component that is necessary to evacuate personnel in the event of inert gas release, the area is evacuated and ODH Classification is updated as needed based on existing out-of-service policy or updated ODH analysis.

ODH Safety System components that are required to evacuate personnel in the event of inert gas release within an interlocked and/or posted Exclusion Areas will be identified as Credited Controls and summarized in this ASE.

I-4.3.2.2.1 Required Calibration, Testing, Maintenance, and Inspection Schedules for ODH Safety System Credited Controls

The schedules below are defined to meet ODH equipment testing requirements defined in FESHM Chapter 4240, Section 6.3.

Operation of all ODH monitoring components shall be functionally tested at an interval no greater than 12 months.

I-4.3.3 Administrative Credited Controls

Administrative Credited Controls encompass the human interactions that define safe operations. These are the accelerator operating policies and procedures that are followed to ensure safe accelerator operations. The Administrative Credited Controls in use for the Fermilab Main Accelerator are discussed below.

I-4.3.3.1 Operation Authorization Document

An Operation Authorization Document, which may be in the form of Beam Permits/Running Conditions, RWP, or other approval document, is used to summarize the bounding conditions for safe operation of the accelerator or specific segment of the accelerator, and to provide explicit approval for the operations of the accelerator of specific segment of the accelerator. The following information must be included in the applicable Operation Authorization Document: segment/accelerator name, issue date, mode(s) of operation, operating parameters, critical device controller, critical devices, Exclusion Area(s), and Credited Controls. Additional information beneficial to those operating the accelerator/segment may also be included in the Operation Authorization Document.

I-4.3.3.2 Staffing

To ensure operations within the bounding condition(s) specified in the Operation Authorization Document, and to disable operations to the segment/accelerator and initiate an immediate response in the event of a determined ASE violation, sufficient staffing of qualified operators shall be in place during applicable accelerator operations. Staffing requirements for each accelerator is described in its applicable ASE.

I-4.3.3.3 Accelerator Operating Parameters

The accelerator operating parameters are the bounding condition(s) for safe operation of the accelerator. For accelerators utilizing particle beams, this is determined to be the maximum intensity permitted (either due to the physical characteristics of the machine or other engineered controls limiting intensity) for the segment. For test stand accelerators, this is determined uniquely based on each accelerator’s unique capabilities, scope and purpose. The basis for determining the accelerator operating parameters is detailed in the applicable SAD Chapter and ASE.

I-5. Accelerator Safety Envelope Basis

The ASE is a set of physical and administrative conditions based on ES&H considerations as defined in the DOE Accelerator Safety Order, DOE O 420.2D. The ASE establishes and defines the boundaries within which an accelerator may be operated. Operations performed within the boundaries of the ASE provide for protection of the laboratory staff (including employees, sub-contractors, affiliates, users, business visitors, or urgent short-term workers), the general public, and the environment. The bounding conditions are designed to prevent the effects of unscheduled, but anticipated events from causing violations of the ASE. For example, an accelerator facility can experience an unplanned event, such as a power outage, that may interrupt operations but does not compromise the safety of the facility.

The ASE is composed of passive, active engineered, and administrative Credited Controls applicable to the Fermilab accelerator facilities and provides for safe operation of the laboratory's accelerators. The Credited Controls are included in the ASE to mitigate the accelerator-specific hazards identified for the facility in their specific SAD Chapter, analyzed following the process described in SAD Section I Chapter 4. Some of the controls, such as shielding, apply to all of the accelerator facilities, whereas others are specific to each accelerator and/or segment of the accelerator. Significant changes to these controls, operating conditions, or the facility that go through the Unreviewed Safety Issue (USI) Process will require a revision or supplement to this SAD.

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I-6. Environmental Monitoring

The strategy for environmental monitoring and surveillance at Fermilab is established in the Fermilab Environmental Monitoring Program[14]. This program ensures compliance with legal and regulatory requirements imposed by DOE Orders, Federal, State, and local agencies, confirms adherence to permit conditions, provides data for permit revision/renewal, detects unplanned releases to the environment, and provides data to support environmental management decisions. The comprehensive site-wide monitoring program assesses the effect of past, current, and future activities by measuring and monitoring effluents and emissions from Fermilab operations and by calculating the effects of those operations on the environment and public health. An important consideration in the development and implementation of the monitoring program has been to ensure that the monitoring activities at specific sites are appropriate for individual facility operations.

The scope of the environmental surveillance conducted on-site encompasses potential and identified effluents to air, surface waters, drinking water, storm and sanitary sewers, soil, and groundwater and includes analyses for both chemicals and accelerator-produced radionuclides. Penetrating radiation outside of the shielded areas is also monitored. Samples are collected and analyzed according to a predefined schedule. Measured concentrations of radioactive materials and chemicals are compared to applicable standards, concentration guides, natural levels, and previous results.

A detailed description of the environmental monitoring and surveillance program can be found in "The Report to the Director on the Fermilab Environment"[15]. This report, which is prepared for each calendar year, contains an annual summary of monitoring results, subsequent exposure pathway analysis, and dose assessment, where applicable. Approved environmental sampling procedures have been established. Protection of groundwater resources is addressed in the Fermilab Groundwater Management Plan[16]. The environmental monitoring programs are utilized to track, trend, and evaluate process environmental discharges of air and water, along with accelerator operating intensities of the individual areas, for compliance with all applicable standards and in support of the laboratory environmental monitoring program.

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I-7. Quality Assurance

Quality assurance applies to all work conducted at Fermilab. It enables the laboratory to maintain programs in a high state of readiness, reliability, and sustainability to support the Nation's efforts of using high-energy physics to advance our understanding of the fundamental nature of matter and energy. Fermilab uses a graded approach to define and integrate the appropriate level of quality controls based upon risk of the subject initiative or operation. Using a graded approach is paramount to an effective and efficient quality program to ensure that the effort expended provides value to the organization based on the analysis of identified risks.

Fermilab's Integrated Quality Assurance program is composed of the Integrated Quality Assurance (IQA) program document, Quality Assurance Manual, and Directorate/Division implementing procedures. The IQA Program is a key component of the Quality Management System supporting the Fermilab Contractor Assurance System (CAS) required by the prime contract between the Department of Energy and the Fermilab Research Alliance, LLC.

The IQA establishes the requirements necessary to implement and comply with DOE Order 414.1D[17]. This IQA applies to Fermi Research Alliance, LLC and all staff (including employees, sub-contractors, affiliates, users, business visitors, or urgent short-term workers) when performing work that affects the laboratory. It identifies quality requirements necessary to consistently meet the DOE contract obligations throughout the laboratory's organizations and ensures that quality, safety, health, security, cyber-security, environmental, facilities/infrastructure maintenance and performance of research are integrated into all work conducted under the contract. The IQA program provides a system to monitor, control, and continually improve the laboratory's activities, processes, and systems.

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I-8. Post-Operations Planning

It is Fermilab's policy as outlined in FESHM to maintain information necessary for future decontamination and decommissioning (D&D) of any or all of the laboratory facilities. This documentation is maintained by the ES&H Division to provide adequate safeguards against injury or illness for employees, sub-contractors and the public or damage to the environment at such time that facilities are demolished.

Each Directorate/Division Head is responsible for informing the Chief Safety Officer (CSO), who is responsible for the Laboratory's master D&D files, concerning any activities affecting possible future D&D activities. This includes updating the Radiological Facility Use records on at least an annual basis to identify any hazardous materials, other chemicals, and radioactivity in their facilities that are not removable. "As built" drawings are maintained to show the location and inventory of contamination. The CSO is notified of any changes of facility usage, for inclusion in the D&D files.

All actions taken to decontaminate a facility or to fix contamination prior to actual D&D work are documented by the laboratory organization that supervises the D&D work and transmitted to the ES&H Division prior to commencing actual D&D activities. Items to be documented include the means for accomplishing the D&D and may include, as necessary, regular environmental reviews, Radiological Facility Use reports, and activity-specific communications.

The Laboratory has comprehensive programs for the handling, storage, and disposal of both radioactive wastes and hazardous chemical wastes. The various waste programs are described in the FRCM.

Per DOE O 420.2D, DOE Field Element Manager approval shall be obtained prior to the start of any decommissioning activities for applicable accelerator facilities.

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I-9. Acronyms

ACGIH	American Conference of Governmental Industrial Hygienists
ACNET	Accelerator Control Network System
AD	Accelerator Directorate
ADAP	Accelerator Division Administrative Procedure
AHJ	Authority Having Jurisdiction
ALARA	As Low As Reasonably Achievable
ANSI	American National Standards Institute
APS-TD	Applied Physics and Superconducting Technology Directorate
ARA	Airborne Radioactivity Area
ASE	Accelerator Safety Envelope
ASH	Accelerator Specific Hazard
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASO	Accelerator Safety Order, referring to DOE O 420.2D *Safety of Accelerators*
^{7}Be	Beryllium-7
BLM	Beam Loss Monitor
BNB	Booster Neutrino Beam
BPM	Beam Position Monitor
BY	Boneyard
CA	Controlled Area
CA	Contamination Area
CAS	Contractor Assurance System
CC	Credited Control
CCL	Coupled Cavity Linac
CDC	Critical Device Controller
CERN	European Organization for Nuclear Research
CFM	Cubic Feet per Minute
CFR	Code of Federal Regulations (United States)
Ci	Curie
CLW	Co-Located Worker (the worker in the vicinity of the work but not actively participating)
cm	centimeter
CPB	Cryogenics Plant Building
CSO	Chief Safety Officer
CUB	Central Utility Building
CW	Continuous Wave
CX	Categorically Excluded

D&D	Decontamination and Decommissioning
DA	Diagnostic Absorber
DAE	Department of Atomic Energy India
DCS	Derived Concentration Standard
DocDB	Document Database
DOE	Department of Energy
DOT	Department of Transportation
DR	Delivery Ring
DSO	Division Safety Officer
DSS	Division Safety Specialist
DTL	Drift Tube Linac
DUNE	Deep Underground Neutrino Experiment
EA	Environmental Assessment
EA	Exclusion Area
EAV	Exhaust Air Vent
EENF	Environmental Evaluation Notification Form
EMS	Environmental Management System
EOC	Emergency Operations Center
EPA	Environmental Protection Agency
ES&H	Environment, Safety and Health
Fermilab	Fermi National Accelerator Laboratory, see also FNAL
FESHCom	Fermilab ES&H Committee
FESHM	Fermilab Environment, Safety and Health Manual
FHS	Fire Hazard Subcommittee
FIRUS	Fire Incident Reporting Utility System
FNAL	Fermi National Accelerator Laboratory, see also Fermilab
FODO	Focus-Defocus
FONSI	Finding of No Significant Impact
FQAM	Fermilab Quality Assurance Manual
FRA	Fermi Research Alliance
FRCM	Fermilab Radiological Control Manual
FSO	Fermilab Site Office
FW	Facility Worker (the worker actively performing the work)
GERT	General Employee Radiation Training
GeV	Giga-electron Volt
^{3}H	Tritium
HA	Hazard Analysis
HAR	Hazard Analysis Report
HCA	High Contamination Area

HCTT	Hazard Control Technology Team
HEP	High Energy Physics
HFD	Hold for Decay
HLCF	High Level Calibration Facility
HPR	Highly Protected Risk
Hr	Hour
HRA	High Radiation Area
HSSD	High Sensitivity Air Sampling Detection
HVAC	Heating, Ventilation, and Air Conditioning
HWSF	Hazardous Waste Storage Facility
Hz	Hertz
IB	Industrial Building
IBC	International Building Code
ICW	Industrial Cooling Water
IEPA	Illinois Environmental Protection Agency
IEEE	Institute of Electrical and Electronics Engineers
INFN	Istituto Nazionale di Fisica Nucleare
IMPACT	Integrated Management Planning and Control Tool
IPCB	Illinois Pollution Control Board
IQA	Integrated Quality Assurance
ISD	Infrastructure Services Division
ISM	Integrated Safety Management
ITNA	Individual Training Needs Assessment
KeV	kilo-electron volt
kg	kilo-grams
kW	kilo-watt
LBNF	Long Baseline Neutrino Facility
LCW	Low Conductivity Water
LHC	Large Hadron Collider
LLCF	Low Level Calibration Facility
LLWCP	Low Level Waste Certification Program
LLWHF	Low Level Waste Handling Facility
LOTO	Lockout/Tagout
LPM	Laser Profile Monitor
LSND	Liquid Scintillator Neutrino Detector
LSO	Laser Safety Officer
m	meter
mA	milli-amp
MABAS	Mutual Aid Box Alarm System

MARS	Monte Carlo Shielding Computer Code
MC	Meson Center
MC&A	Materials Control and Accountability
MCR	Main Control Room
MEBT	Medium Energy Beam Transport
MEI	Maximally Exposed Individual
MeV	Mega-electron volt
MI	Main Injector
MINOS	Main Injector Neutrino Oscillation Search
MMR	Material Move Request
MOI	Maximally-Exposed Offsite Individual *(Note: due to the Fermilab Batavia Site being open to the public, the location of the MOI is taken to be the location closest to the accelerator that is accessible to members of the public.)*
MP	Meson Polarized
mrad	milli-radian
mrem	milli-rem
mrem/hr	milli-rem per hour
MT	Meson Test
MTA	400 MeV Test Area
MTF	Magnet Test Facility
^{22}Na	Sodium-22
NASH	Non-Accelerator Specific Hazard
NC	Neutrino Center
NE	Neutrino East
NEC	National Electrical Code
NEPA	National Environmental Policy Act
NESHAPS	National Emissions Standards for Hazardous Air Pollutants
NFPA	National Fire Protection Association
NM	Neutrino Muon
NMR	Nuclear Material Representative
NOvA	Neutrino Off-axis Electron Neutrino (ve) Appearance
NPH	Natural Phenomena Hazard
NRTL	Nationally Recognized Testing Laboratory
NIF	Neutron Irradiation Facility
NTSB	Neutrino Target Service Building, see also TSB
NuMI	Neutrinos at the Main Injector
NW	Neutrino West
ODH	Oxygen Deficiency Hazard
ORC	Operational Readiness Clearance

OSHA	Occupational Safety and Health Administration
pCi	pico-Curie
pCi/mL	pico-Curie per milliliter
PE	Professional Engineer
PIN	Personal Identification Number
PIP	Proton Improvement Plan
PIP-II	Proton Improvement Plan - II
PHAR	Preliminary Hazards Analysis Report
PPD	Particle Physics Directorate
PPE	Personnel Protective Equipment
QA	Quality Assurance
QAM	Quality Assurance Manual
RA	Radiation Area
RAF	Radionuclide Analysis Facility
RAW	Radioactive Water
RCT	Radiological Control Technician
RF	Radio-Frequency
RFQ	Radio-Frequency Quadrupole
RIL	RFQ Injector Line
RMA	Radioactive Material Area
RMS	Root Mean Square
RPCF	Radiation Physics Calibration Facility
RPE	Radiation Physics Engineering Department
RPO	Radiation Physics Operations Department
RRM	Repetition Rate Monitor
RSI	Reviewed Safety Issue
RSIS	Radiation Safety Interlock System
RSO	Radiation Safety Officer
RWP	Radiological Work Permit
SA	Shielding Assessment
SAA	Satellite Accumulation Areas
SAD	Safety Assessment Document
SCF	Standard Cubic Feet
SCFH	Standard Cubic Feet per Hour
SEWS	Site-Wide Emergency Warning System
SNS	Spallation Neutron Source
SR	Survey Riser
SRF	Superconducting Radio-Frequency
SRSO	Senior Radiation Safety Officer

SSB	Switchyard Service Building
SSP	Site Security Plan
SWIC	Segmented Wire Ionization Chambers
TLM	Total Loss Monitor
TLVs	Threshold Limit Values
TPC	Time Projection Chamber
TPES	Target Pile Evaporator Stack
TPL	Tagged Photon Lab
TSB	Target Service Building, see also NTSB
TSCA	Toxic Substances Control Act
TSW	Technical Scope of Work
T&I	Test and Instrumentation
UPB	Utility Plant Building
UPS	Uninterruptible Power Supply
USI	Unreviewed Safety Issue
VCTF	Vertical Cavity Test Facility
VHRA	Very High Radiation Area
VMS	Village Machine Shop
VMTF	Vertical Magnet Test Facility
VTS	Vertical Test Stand
WSHP	Worker Safety and Health Program
µs	micro-second

I-10. References

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