FERMI NATIONAL ACCELERATOR LABORATORY

ACCELERATOR SAFETY ENVELOPE

Fermilab Accelerator Science & Technology (FAST) Accelerator

Revision 0 August 10, 2023

Appendix A of the Safety Assessment Document

Accelerator Safety Envelope

Fermilab Accelerator Science & Technology (FAST) Accelerator

Approval Page

Line Organization Review and Recommendation

This Appendix A Chapter 02 of the Fermi National Accelerator Laboratory (Fermilab) Safety Assessment Document (SAD), *Accelerator Safety Envelope – Fermilab Accelerator Science & Technology (FAST) Accelerator*, was prepared and reviewed by the staff of the Environment, Safety & Health Division (ESH) Accelerator Safety Department in conjunction with the Accelerator Directorate (AD) Line Management for the FAST Accelerator.

Signatures below indicate review of this Accelerator Safety Envelope (ASE), and recommendations that it be incorporated into the Appendices of the Fermilab SAD.

☐ ______________________________________
AD Associate Lab Director

☐ ______________________________________
Accelerator Safety Department Head

☐ ______________________________________
SAD Review Subcommittee Chair

Directorate & Fermi Site Office Final Approval

Final approval of this Accelerator Safety Envelope for the Fermilab Accelerator Science & Technology (FAST) Accelerator is granted by the Fermilab Director and the DOE Field Element Manager.

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Director, Fermi National Accelerator Laboratory

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DOE Field Element Manager, Fermi Site Office

Revision History

Author	Rev. No.	Date	Description of Change
Maddie Schoell Dan Broemmesliek	0	August 10, 2023	Initial issue of this standalone Accelerator Safety Envelope (ASE) for FAST, separating it from the Fermilab Main Accelerator ASE.

Table of Contents

Section 1. Introduction and Scope

This document constitutes the Accelerator Safety Envelope (ASE) for full power operation of the Fermilab Accelerator Science & Technology (FAST) Main Accelerator. It defines the Credited Controls that are established for the FAST Accelerator to assure that the level of risk to all workers, the public, and the environment is maintained at acceptable levels. This ASE is established in accordance with the DOE Order 420.2D, *Safety of Accelerators*, (DOE O 420.2D), and as flowed down through the Fermilab Environment, Safety and Health Manual (FESHM) including the Fermilab Radiological Control Manual (FRCM).

Section 2. Select Definitions and Acronyms

The following terms and/or acronyms are commonly used when discussing operation of the FAST Accelerator. Definitions that come directly from DOE O 420.2D, *Safety of Accelerators*, are noted with an asterisk (*), with further information on the interpretation and application of the definition for use at the FAST Accelerator in italics.

***Accelerator** A device and its components employing electrostatic or electromagnetic fields to impart kinetic energy to molecular, atomic, or sub-atomic particles and capable of creating a radiological area as defined by 10 CFR Part 835, Occupational Radiation Protection. Accelerator components include injectors, targets, beam dumps, detectors, experimental enclosures, accelerator enclosures, experimental areas, and experimental apparatus utilizing the accelerator. The accelerator also includes associated support and test facilities, equipment, systems, and utilities necessary to operate the accelerator or utilize the accelerated beam.

***Accelerator Facility** The accelerator, plant, buildings, structures, and equipment supporting the accelerator and its operations that are under direct control of the contractor

All facilities at Fermilab in some way contain components or conduct activities supporting an accelerator and its operations. As such, all facilities are described in the Safety Assessment Document (SAD).

***Accelerator Operations** Activities within the accelerator facility that, over the lifecycle of the facility, support 1) production or utilization of accelerator beams; 2) research and experimental activities utilizing accelerator beams; 3) handling, storage and analysis of accelerator induced radioactive components and materials within the accelerator facility boundary; 4) receipt, preparation, assembly, inspection, and installation of samples into the accelerator beam; or 5) removal, disassembly, handling, analysis, and storage for radioactive dose minimization to meet the definition of ALARA in 10 CFR Part 835, Occupational Radiation Protection, or transportation requirements, and packaging of samples after use in the accelerator beam. Accelerator Operations excludes radioisotope processing activities that are not required to operate or maintain the accelerator.

***Accelerator Readiness Review (ARR)** A structured method for verifying that hardware, personnel, and procedures associated with commissioning or routine operations are ready to permit the activity to be undertaken safely.

***Accelerator Safety Envelope (ASE)** A documented set of verifiable physical and administrative requirements, bounding conditions, and credited controls that ensure safe operation and address accelerator specific hazards and risks.

Accelerator Safety Envelope Intensity Calculated intensity that, assuming a one (1) hour point source loss would produce a 500 mrem accident condition

Accelerator Specific Hazard Hazards are classified as Accelerator Specific when their nature is uniquely defined by the configuration of the accelerator and they are not fully mitigated by Fermilab standard safety management programs. The passive, active engineered, and administrative mitigations which reduce accelerator specific hazards within Applicable Accelerator Facilities from unacceptable to acceptable risk are the Credited Controls

Applicable Accelerator Facility An Accelerator Facility further posted as an Exclusion Area.

***Commissioning** A phase of an accelerator facility operation that is typically used to conduct initial beam testing and/or verify design specifications. Commissioning periods may be tailored to the needs of each facility and there may be great variations in their duration, breadth, and formality, but in all cases, the activities will be bounded by an ASE and preceded by an ARR and DOE approval.

Compensatory Measure An approved alternative measure that may be used on a case-by-case basis in lieu of a Credited Control, with appropriate and documented approvals.

***Credited Control** Controls determined through the Safety Analysis to be essential for safe operation directly related to the protection of workers, the public, and the environment.

Credited Controls are implemented to mitigate Accelerator Specific Hazards within Applicable Accelerator Facilities to acceptable levels. For other facilities, controls to mitigate similar hazards are managed through programs and requirements specified in FESHM.

***DOE Element** First-tier organizations at DOE/NNSA HQ and in the field as listed in the Correspondence Style Guide, Office of the Executive Secretariat.

***DOE Field Element Manager** The manager having overall responsibility for a DOE field element including execution of oversight policy implementation. The Field Element Manager directs activities of DOE/NNSA field or site offices and has line accountability for all site program, project execution, and contract management.

The Fermilab Site Office (FSO) Manager is the DOE Field Element Manager.

***DOE Program Secretarial Officer (PSO)** An Assistant Secretary, Office Director, Head of Program Element, or NNSA Deputy Administrator to whom designated field offices directly report and who has overall landlord responsibilities for the assigned direct reporting elements.

Nominal Operating Intensity Intensity identified by the machine and/or Project, analyzed in the Shielding Assessment.

Maximum Operating Intensity The maximum intensity a given segment is allowed to operate at without requiring additional actions/approvals/responses. This value is the Nominal Operating Intensity plus 5%, in order to accommodate potential fluctuation in beam intensity due to changes in efficiency.

***Radiation** Ionizing radiation, including the accelerated particle beam and the radiation produced when the beam interacts with matter or changes direction. Radiation includes alpha particles, beta particles, gamma rays, X-rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of producing ions.

***Radioisotope Processing** Chemical, thermal, or physical actions taken to separate, isolate, refine, or enrich specific isotopes of a chemical element.

***Residual Radioactivity** Radioactivity in structures, materials, soils, groundwater, and other media at a site resulting from the accelerator or accelerator operations.

***Reviewed Safety Issue** The outcome of the evaluation and determination phase of the USI Process.

***Risk** A quantitative or qualitative expression of possible harm, which considers both the probability that a hazard will cause harm and the amount of harm; or, alternatively, an estimate of the probability of occurrence of a hazard-related incident and the severity of the consequence associated with the incident.

Fermilab utilizes a qualitative risk assessment, following the methodology found in DOE-HDBK-1163-2020, Integration of Hazard Analyses.

***Safety Analysis** A documented process to systematically identify the hazards of a given operation; including a description and analyses of the adequacy of measures taken to eliminate, control, or mitigate the hazards and risks of normal operation; and identification and analyses of potential accidents and their associated risks.

***Safety Assessment Document (SAD)** A document containing the results of a Safety Analysis for an accelerator or accelerator facility pertinent to understanding the risks to workers, the public, and the environment of operating the accelerator.

***Unreviewed Safety Issue (USI)** An activity or discovered condition with accelerator specific hazards that have yet to be evaluated to determine if the activity or discovered condition introduces accelerator specific hazards that are not adequately addressed by the current SAD and approved ASE.

***USI Process** The process or methodology used to evaluate/review USIs to determine if the activity or discovered condition is adequately addressed by the current SAD and approved ASE.

Section 3. Description of Credited Controls

The Credited Controls identified in the ASE are a set of passive, active engineered, and administrative controls in use at the FAST Accelerator that define the bounding conditions and limitations for safe and environmentally sound operations. In accordance with FRCM Article 236, Fermilab utilized Credited Passive and Active Engineered Controls whenever the maximum calculated accident condition can exceed 500 mrem in an hour. The Credited Controls listed in the ASE must be in place and functional for all operational areas. During periods of down time or maintenance, Credited Controls may be removed and managed under the Safety Configuration Management program to ensure they are replaced prior to resumption of operations.

For each Credited Control, the following is specified:

- **Applicability** – the condition in which the Credited Control is valid.
- **Basis** – description of the need for the Credited Control.
- **Requirement** – specific elements that must be in place during beam operation. Beam operation to the affected area without required elements in place is an ASE violation.
- **Compensatory Measure(s)** – An approved temporary alternative that may be taken to allow for safe operation when a requirement is not in place.
- **Required Surveillance** – management and monitoring practices that must be performed to assure continued effectiveness of the Credited Control. Surveillances are to be carried out at the minimum specified interval. Beam operation to the affected area without the required surveillance being performed within the minimum specified interval is an ASE violation.
- **Response** – actions to be taken if there is a suspected deficiency, missing control, or other potential ASE violation for that particular Credited Control.

The Credited Controls are divided into three main categories: passive controls, active engineered controls, and administrative controls.

Passive

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. The types of Passive Credited Controls in use for the FAST Accelerator include:

- Shielding (i.e., Permanent/Structural, Labyrinths, Movable, Penetration Shielding)
- Fencing (i.e., Radiation Area fencing, Controlled Area fencing)

Acceptable methods for configuration of movable and/or penetration shielding include, but is not limited to: locked chains, Unistrut to block or inhibit movement, cover plates over penetration holes, etc.

Fermilab uses a more current methodology, utilizing engineering drawings and Monte Carlo simulations, to perform shielding assessments which do not have easily produced tables of required shielding. For these areas, the shielding assessment and its references should be used to easily convey required shielding. For shielding assessments that utilize an incremental shielding assessment methodology, there are tables specifying shielding. For these areas, the tables of shielding will be summarized in the SAD and ASE.

Active Engineered

Active Engineered Credited Controls are systems designed to reduce the risks from accelerator operations to an acceptable level. The types of Active Engineered Credited Controls in use for the FAST Accelerator include:

- Radiation Safety Interlock System (RSIS)
- Oxygen Deficiency Hazard (ODH) Safety System

Radiation Safety Interlock System (RSIS)

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. If there is a potential for personnel to inadvertently access the defined Exclusion Area, the RSIS is designed to inhibit accelerator operations in that area.

The RSIS may also include interlocked radiation monitors to supplement passive shielding Credited Controls. If dose rates exceed specified levels analyzed in the Shielding Assessment, 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. 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.

Oxygen Deficiency Hazard (ODH) Safety Systems

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 4240. 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 maintain the original ODH Classification, 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 maintain the posted ODH Classification within an interlocked and/or posted Exclusion Areas will be identified as Credited Controls and summarized in this ASE.

Administrative

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 types of Administrative Credited Controls in use for the FAST Accelerator include:

- Operation Authorization Document
    - Must include the following information:
        - Issue Date
        - Mode(s) of Operation
        - Operating Parameters (i.e., ASE Intensity Limit)
        - Critical Device Controller (CDC)
        - Critical Devices
        - Exclusion Area(s)
        - Credited Controls
            1. Shielding Requirements
            2. Fencing Requirements
            3. RSIS Required Components and Inputs, including interlocked detectors
            4. ODH System Requirements
            5. Staffing Requirements
            6. Accelerator Operating Parameters (i.e., ASE Intensity Limit)

  - May also include additional information beneficial to those operating the FAST Accelerator (e.g., Nominal Operating Intensity, Maximum Operating Intensity, assigned Radiation Safety Officer, cool off period, etc.)
- Staffing
- Accelerator Operating Parameters

ASE Intensity Determination

The Accelerator Beam Intensity Limit is determined as follows –

Fermilab rigorously maintains normal operations as defined in the various radiological shielding assessments through passive shielding, movable shielding, penetration shielding, radiological fences, radiation safety interlocks, and the approved Beam Permit and Running Condition for each operating area. The beam intensity limits for Normal operations are to ensure compliance with the requirements established in the Fermilab Radiological Control Manual (FRCM) and applicable federal regulations such as 10 CFR 835 and 40 CFR 141. The use of beam intensity limits for Normal operations are excessively conservative in our application of the basis for the Accelerator Safety Envelope with respect to abnormal operations.

The FRCM provides guidance that impacts associated with abnormal operations should be adequately addressed to assure that the level of risk to a person offsite or outside the facility is maintained at an adequate level. We currently limit operations on the basis of the normal and accident condition postings, at the Nominal Operating Intensity, that are associated with a given area, and recognize that should a beam loss accident occur, it would likely last for significantly less than one hour. Since we maintain a relatively open site, the risk to a person offsite or outside the facility is one in the same.

The FRCM requires credited passive or active engineered controls to be established to protect from abnormal beam loss events when the calculated dose from beam lost in a point source, at the same place, continuously for one hour can produce a 500 mrem accident condition outside of the accelerator shielding. This accident condition is not considered credible since such a high beam power lost in a point source would likely degrade the accelerator vacuum such that continued operations would not be possible. However, it does provide an upper limit on the allowable beam intensity to identify when credited passive or active engineered controls are necessary.

Each shielding assessment for operating areas was reviewed to determine the beam intensity needed to create a 500 mrem accident condition, the ASE Intensity. When reviewing the shielding assessments, the following scaling criteria were used.

1. Areas protected by interlocked detectors were ignored since the detector will limit the duration of any accident condition. An exception was made for the Linac, Booster, and FAST areas since their shielding assessments are based on the use of interlocked detectors. In those three cases, the detector trip setting was scaled to a 500 mrem accident condition. The calculated scaling factor was then used to calculate the beam intensity needed to cause the 500 mrem accident condition based on the current operating limits.

2. When shielding spreadsheets were available, the category 1, 2, & 3 areas were changed to category 4 and the beamline intensity was increased until a failure appeared on the spreadsheet.
3. When shielding spreadsheets were available, the beam intensity for category 4 areas was increased until a failure appeared. The beam intensity needed for a category 4 area failure was then scaled up by a factor of 100. Category 4 areas are required to be fenced and locked radiological areas. The assumption made is the dose on the outside of the fenced in area would be 5 mrem or less for a 500 mrem accident condition inside the fenced area, or a factor of 100 less.
4. When actual accident condition doses were known through MARS, similar Monte Carlo modeling, or measurements, the dose was simply scaled to a 500 mrem accident condition dose to derive the beam intensity scaling factors needed to create a 500 mrem accident condition. The beam intensity was then scaled by the calculated scaling factor.
5. When fences were used for normal operating losses, up to 100 mrem inside of the fenced area, the intensity was scaled up by a factor of 100. The assumption made was the dose on the outside of the fenced in area would be 5 mrem or less for 100 mrem normal operating condition inside the fenced area, or a factor of 100 less than the 500 mrem accident condition.

For each area reviewed, the most conservative intensity limit was identified and used to define the Accelerator Safety Envelope (ASE) Intensity for the area. The intensity limits, their basis, and scaling calculations are summarized in Section 7. The ASE Intensity limits are specified in protons or electrons/hour since the concern is prompt radiation exposures from beam operations.

Risk assessment methodology from DOE-HDBK-1163-2020 was used to determine the potential risk of an accident scenario at ASE Intensities. A 500 mrem accident scenario at ASE Intensities would have a negligible consequence to members of the public. The likelihood of a 500 mrem accident scenario at ASE Intensities is Beyond Extremely Unlikely based on the intrinsic design of the accelerator. This would result in a Baseline Risk level of IV, which per DOE-HDBK-1163-2020 is an acceptable level of risk requiring no additional controls. As a result, controls are established and put in place based on the Operating Intensity assessed in the applicable Shielding Assessments rather than the calculated ASE Intensity.

Radiological Hazard Consequences, derived from Figure C-1, "Example Qualitative Consequence Matrix", DOE-HDBK-1163-2020.

Likelihood (L, of event)/year	Consequence (C, of event)/year	Risk (R, Qualitative Ranking)
A = Anticipated (L > 1.0E-02) **U** = Unlikely (1.0E-02> L >1.0E-04) **EU** = Extremely Unlikely (1.0E-04 > L >1.0E-06) **BEU** = Beyond Extremely Unlikely (1.0E-06> L)	**H** = High **M** = Moderate **L** = Low **N** = Negligible	**I** = situation (event) of major concern **II** = situation (event) of concern **III** = situation (event) of minor concern **IV** = situation (event) of minimal concern

Control(s) Type
P = Preventive (reduce event occurrence likelihood)
M = Mitigative (reduces event consequences)
Acronyms
MOI = Maximally-exposed Offsite Individual
rem = Roentgen equivalent man

C	Offsite (MOI)	Onsite-2 (co-located worker)	Onsite-1 (facility worker)
H	**C** ≥ 25.0 rem	**C** ≥ 100 rem	**C** ≥ 100 rem
M	25.0 rem > **C** ≥ 5 rem	100 rem > **C** ≥ 25 rem	100 rem > **C** ≥ 25 rem
L	5 rem > **C**	25 rem > **C**	25 rem > **C**
N	0.5 rem > **C**	5 rem > **C**	5 rem > **C**

Risk Matrix

Consequences	Likelihood: A	U	EU	BEU
H	I	I	II	III
M	II	II	III	IV
L	III	III	IV	IV
N	IV	IV	IV	IV

Figure 1. Summary Table Explaining the Risk Assessment for Radiological Hazards Derived from DOE-HDBK-1163.

Section 4. ASE Violation Determination and Actions

Determination

Any beam operation of the FAST Accelerator with a known loss of Credited Control (except ODH Safety System Credited Controls) and/or the safety function of the Credited Control is a violation of the ASE.

> For Credited Controls that have additional overburden or Defense-in-Depth controls, it may not be immediately obvious if a deficiency is in the overburden or in the Credited Controls. In this case, it is not yet known if there even is a deficiency in Credited Controls constituting an ASE Violation. In these circumstances, the appropriate Line Organization and ESH Division Subject Matter Experts (SMEs) will investigate to determine if Credited Controls were impacted. This determination shall be documented following the USI Process, as described in Section 6 of this ASE. If it is determined that Credited Controls were impacted, beam operations shall be terminated immediately and not resume until the Reviewed Safety Issue (RSI) is finalized. If beam operations were to resume without the Reviewed Safety Issue (RSI) being finalized, that would constitute an ASE Violation.

For ODH Safety System Credited Controls, in the event of a known failure of an ODH Safety System component that is necessary to maintain the original ODH Classification, and the Cryo Coordinator/Facility Manager determine that there is a need to reclassify the area (as opposed to replacing components), the area is evacuated and ODH Classification is updated as needed based on existing out-of-service policy or updated ODH analysis. Reentry into the area, before the ODH Classification is updated, is limited to personnel approved by the Cryo Coordinator/Facility Manager to perform work necessary for the ODH reclassification, any other access is a violation of the ASE.

Beam operation of the FAST Accelerator beyond the specified ASE Intensity Limit is a violation of the ASE.

Beam operation of the FAST Accelerator with required surveillance of a Credited Control not conducted within specified frequency, as defined in Section 7 of this ASE, is an ASE violation.

Questions regarding determination of an ASE violation shall be addressed to the Environment, Safety & Health (ESH) Division Accelerator Safety Department Head and the Accelerator Division (AD) Associate Lab Director.

Actions

In the event that the ASE is violated, beam operations of the FAST Accelerator shall be terminated and put in a safe and stable configuration, and not resume until the circumstances of the event are reviewed and approval to resume operations is received. The USI Process, as described in Section 6 of this ASE, will be used to analyze and document the circumstances of the ASE violation. Once the RSI has been finalized for the event causing the ASE violation, approval to resume operations of the FAST Accelerator will be issued by the AD Associate Lab Director and the DOE Field Element Manager.

Events determined to be ASE violations follow FESHM Chapter 3010 *Significant and Reportable Occurrences*, to provide the appropriate DOE notification and reporting.

Section 5. Configuration Management for Credited Controls

To ensure the integrity of the Credited Controls during accelerator operation, several methods of Configuration Management are in place.

- Excavation within the “Excavation Waiver Prohibited Zone” around the accelerator are required to go through the JULIE process. Part of the JULIE process includes ES&H Division Radiation Safety personnel review to determine if required shielding may be impacted.
- Required movable and penetration shielding is posted and locked and/or bolted in place where applicable.
- Components that are part of the Radiation Safety Interlock System (RSIS) are labeled.
- Surveillance is performed, as specified in Section 7.

If shielding or fencing is planned to be removed, the assigned Radiation Safety Officer (RSO) is responsible for ensuring the FAST Accelerator is locked off in a safe state, using RSO Configuration Control locks.

If any Credited Control is not in place, either planned or discovered, the assigned RSO is responsible for ensuring the FAST Accelerator is locked off in a safe state, using RSO Configuration Control locks.

Removal of Credited Controls (i.e., rescinding Operation Authorization Documents, removing shielding or fencing, etc.) during maintenance periods is common, and the assigned RSO is responsible for ensuring the FAST Accelerator is locked off in a safe state, using RSO Configuration Control locks.

The ES&H Division Radiation Physics Operations and Accelerator Safety Departments utilize a Configuration Control Log to track instances of placing the FAST Accelerator in a Configuration Controlled off state. This Log keeps track of reasons why the FAST Accelerator was locked off, what must be done prior to resuming operations, and confirmation that conditions are back in place and confirmed and operations was permitted to resume.

Section 6. Unreviewed Safety Issue (USI) Process

The Unreviewed Safety Issue (USI) Process is used to evaluate proposed activities/modifications and/or discovered conditions to ensure all hazards are adequately addressed in by the current SAD and approved ASE. The USI Process begins with completion of the USI Determination form, which includes multiple questions that will evaluate the proposed activity/modification and/or discovered condition to determine if it is already fully evaluated and included in the SAD and ASE or if and updated evaluation is necessary. At the conclusion of the USI Process, the review of the proposed activity/modification and/or discovered condition is classified as a Reviewed Safety Issue (RSI).

Proposed activities/modifications and/or discovered conditions at the FAST Accelerator are subject to the USI Process.

Compensatory Measures shall be reviewed and approved by the SRSO, and documented using the USI Process, prior to implementation.

Section 7. Summary of Credited Controls for the FAST Accelerator

Passive – Shielding

Applicability During beam operations to the FAST Accelerator.

Basis Based on the Nominal Operating Intensities of 1.96e17 electrons/hr at 55 MeV, 3.37e18 electrons/hr at 300 MeV, injection of 3.60e13 electrons/hr at 150 MeV, and circulation of 2.00e10 electrons at 150 MeV, analyzed in the following Shielding Assessments, the shielding is required in the locations listed below.
Shielding Assessment(s):
- 2014 Shielding Assessment for the Advanced Superconducting Test Accelerator (ASTA) Injector [1]
- 2017 Shielding Assessment for the IOTA/FAST Electron Injector at 300 MeV The Shielding Assessment for the IOTA/FAST Electron Injector at 300 MeV [2]

Requirement Required shielding specified in the listed Shielding Assessments will be installed in its proper configuration during applicable beam operations.

The listed Shielding Assessment(s) utilized the more current Monte Carlo simulation methodology, required shielding is found in the listed Shielding Assessment.

Compensatory Measure(s) In lieu of required shielding, temporary controls, such as guards, fencing, ropes, and/or postings, may be utilized as approved by the SRSO. Each use of a Compensatory Measure shall be documented using the USI Process.

Required Surveillance Required shielding shall be verified annually, not to exceed twelve (12) months.

Response Beam operation to the FAST Accelerator will be terminated. Beam operation to the FAST Accelerator will not resume until approval is received from the AD Associate Lab Director and the DOE Field Element Manager.

Passive – Fencing

Applicability During beam operations to the FAST Accelerator.

Basis Based on the Nominal Operating Intensities of 1.96e17 electrons/hr at 55 MeV, 3.37e18 electrons/hr at 300 MeV, injection of 3.60e13 electrons/hr at 150 MeV, and circulation of 2.00e10 electrons at 150 MeV, analyzed in the following Shielding Assessments, the shielding is required in the locations listed below.
Shielding Assessment(s):
- 2014 Shielding Assessment for the Advanced Superconducting Test Accelerator (ASTA) Injector [1]

- 2017 Shielding Assessment for the IOTA/FAST Electron Injector at 300 MeV The Shielding Assessment for the IOTA/FAST Electron Injector at 300 MeV [2]

Requirement Required fencing specified in the listed Shielding Assessments will be installed in its proper configuration during applicable beam operations.

Radiation Area Fencing

Fence Location	Required Posting	Gates (if applicable)	Configuration
West side of NML running north south along building	Radiation Area	MTAPA2 MTAPA3	• 4 ft height • Standing upright between 60-120° • No missing or bent pieces creating a person-sized hole (~1ft^2) • Gates locked with Rad Fence Padlock
West of NML running east west from NML to north south fence	Radiation Area	None	• 4 ft height • Standing upright between 60-120° • No missing or bent pieces creating a person-sized hole (~1ft^2)
North of NML running east west form north south fence across the Fast enclosure	Radiation Area	MTAPA1	• 4 ft height • Standing upright between 60-120°

			• No missing or bent pieces creating a person-sized hole (~1ft^2) • Gates locked with Rad Fence Padlock

Controlled Area Fencing
none

Compensatory Measure(s) In lieu of required fencing, temporary controls, such as guards, ropes, and/or postings, may be utilized as approved by the SRSO. Each use of a Compensatory Measure shall be documented using the USI Process.

Required Surveillance Required fencing shall be verified annually, not to exceed twelve (12) months.

Response Beam operation to the FAST Accelerator will be terminated. Beam operation to the FAST Accelerator will not resume until approval is received from the AD Associate Lab Director and the DOE Field Element Manager.

Active Engineered – Radiation Safety Interlock System (RSIS)

Applicability During beam operations to the FAST Accelerator.

Basis Based on the Nominal Operating Intensities of 1.96e17 electrons/hr at 55 MeV, 3.37e18 electrons/hr at 300 MeV, injection of 3.60e13 electrons/hr at 150 MeV, and circulation of 2.00e10 electrons at 150 MeV, analyzed in the following Shielding Assessments, the RSIS is established with interlocked barriers around the Exclusion Area, as well as inclusion of required interlocked radiation monitors.

Shielding Assessment(s):
- 2014 Shielding Assessment for the Advanced Superconducting Test Accelerator (ASTA) Injector [1]
- 2017 Shielding Assessment for the IOTA/FAST Electron Injector at 300 MeV The Shielding Assessment for the IOTA/FAST Electron Injector at 300 MeV [2]

Requirement The Radiation Safety Interlock System (RSIS) must prevent entry into the following Exclusion Area(s) during appliable beam operation:

- FAST

Required components of the RSIS shall be specified in the FAST Accelerator's Operation Authorization Document.

The following components of the Radiation Safety Interlock System (RSIS) shall be in place, with no known loss of safety function, during applicable beam operations.

Radiation Safety System – Interlocked Radiation Monitors
Required radiation monitors specified in the listed Shielding Assessments, or as required by the assigned Radiation Safety Officer (RSO), must be interlocked to the RSIS.

Type	Location
Chipmunk	NML NW Catwalk Railing
Chipmunk	NML Q460 Column J Roof
Chipmunk	NML North Labyrinth Gate
Chipmunk	NML N Catwalk Railing
Chipmunk	NML NE Catwalk Gate
Chipmunk	NML ESB South Wall
Chipmunk	NML ESB North Wall
Chipmunk	NML ESB Top Stairwell
Chipmunk	NML ESB Bottom Stairwell
Chipmunk	NML S Catwalk Gate
Chipmunk	NML E-Gun
Chipmunk	NML East Penetration 1
Chipmunk	NML East Penetration 2
Chipmunk	NML CC1/2 Roof
Chipmunk	NML SE Cave Gate
Chipmunk	NML Roof Column C
Chipmunk	NML SW Stairwell Gate
Chipmunk	NML Roof Column D
Chipmunk	NML West Pen 3 Column E
Chipmunk	NML Roof Column F
Chipmunk	NML East Penetration 5
Chipmunk	NML West Penetration 4
Chipmunk	NML Q450 Column G
Chipmunk	NML West Penetration 2

Compensatory Measure(s) In lieu of required interlocked detectors, temporary controls, such as guards, fencing, ropes, and/or postings, may be utilized as approved by the SRSO. Each use of a Compensatory Measure shall be documented using the USI Process.

Required Surveillance The RSIS for the FAST Accelerator shall undergo certification annually, not to exceed twelve (12) months.

Response Beam operation to the FAST Accelerator will be terminated. Beam operation to the FAST Accelerator will not resume until approval is received from the AD Associate Lab Director and the DOE Field Element Manager.

Active Engineered – Oxygen Deficiency Hazard (ODH) Safety System

Applicability During personnel access into the FAST

Basis Based on the ODH Analysis, the ODH Safety System is established with specified required components.

Requirement The following components of the Oxygen Deficiency Hazard (ODH) Safety System shall be in place, with no known loss of safety function, during personnel access into applicable areas.

- 1 area/fixed oxygen monitors
- ODH fans

Compensatory Measure(s) Temporary updated ODH postings and associated requirements and/or restrictions may be implemented following a component failure to allow reentry to fix failed components based on either: (1) an existing and approved out-of-service policy, or (2) an updated ODH analysis approved by the Cryogenic Safety Subcommittee (CSS).

Required Surveillance

- Testing area/fixed oxygen monitors every six (6) months per established procedure
- ODH Safety System performs self-checks of the ODH fans daily, logged within the system

Response Beam operation to the Neutrino Muon will be terminated. Beam operation to the Neutrino Muon will not resume until approval is received from the AD Associate Lab Director and the DOE Field Element Manager.

Administrative – Operation Authorization Document

Applicability During beam operations to the FAST Accelerator.

Basis To summarize the bounding conditions for safe operation of the FAST Accelerator, and to provide explicit approval for operations of the FAST Accelerator.

Requirement An approved FAST Beam Permit & Running Condition shall be issued prior to applicable beam operations.

Compensatory Measure(s) none

Required Surveillance The FAST Beam Permit and Running Condition shall be verified annually, not to exceed twelve (12) months.

Response Beam operation to the FAST Accelerator will be terminated. Beam operation to the FAST Accelerator will not resume until approval is received from the AD Associate Lab Director and the DOE Field Element Manager.

Administrative – Staffing

Applicability During beam operations to the FAST Accelerator.

Basis To disable beam operations to the FAST Accelerator and initiate an immediate response in the event of a determined ASE violation.

Requirement The following staffing shall be in place during applicable beam operation:

- At least one member of the AD Operations Department who has achieved the rank of Operator II or higher shall be on shift.
- At least one member of the AD Operations Department shall be present in the Main Control Room (MCR).
- At least one FAST Facility Qualified Operator shall be present in the FAST footprint (New Muon Lab Building (NML) or Electrical Service Building (ESB)).

Compensatory Measure(s) none

Required Surveillance none

Response Beam operation to the FAST Accelerator will be terminated. Beam operation to the FAST Accelerator will not resume until approval is received from the AD Associate Lab Director and the DOE Field Element Manager.

Administrative – Accelerator Operating Parameters

Applicability During beam operations to the FAST Accelerator.

Basis The FAST Facility is shielded to less than a 5 mrem accident condition dose on the enclosure walls and access labyrinths through the use of interlocked detectors. The assessment concludes that the instantaneous beam intensity shall not exceed 5.45×10^{13} electrons/second. Using criteria 1 and scaling for dose rates on the NML equipment floor, unenclosed catwalks, loading dock, and laser room roof to a 500 mrem accident condition is a factor of 100. $5.45 \times 10^{13} * 3600 * 100 = 1.96 \times 10^{19}$ electrons/hour.

Requirement The FAST Accelerator will be operated within the following parameters:

Mode	Intensity	Energy
55 MeV electrons to Low Energy Absorber (LEA)	1.96e19 electrons/hr	55 MeV
Up to 300 MeV electrons to High Energy Absorber (HEA)	1.96e19 electrons/hr	300 MeV
Injection of 150 MeV electrons to IOTA	1.96e19 electrons/hr	150 MeV
Circulation of 150 MeV elections in IOTA	n/a – ASE limit is based on injection	150 MeV

These parameters are further specified in the Operation Authorization Document.

FAST Accelerator intensity is monitored via:

- N:T124 for 55 MeV electrons to LEA
- N:T612 for 300 MeV electrons to HEA
- N:IBEAMW for 150 MeV electrons injected into IOTA
- N:IBEAM for 150 MeV electrons circulating in IOTA

Compensatory Measure(s) Alternative methods of monitoring intensity may be used.

Required Surveillance none

Response Beam operation to the FAST Accelerator will be terminated. Beam operation to the FAST Accelerator will not resume until approval is received from the AD Associate Lab Director and the DOE Field Element Manager.

Section 8. References

[1] Shielding Assessment for the Advanced Superconducting Test Accelerator (ASTA) Injector. December 12, 2014. Web link: https://fermipoint.fnal.gov/org/eshq/sa/Shared%20Documents/ASTA%20Injector%20Shielding%20Assessment/Shielding_Assessment_injector_v7.8_eh.pdf

[2] Shielding Assessment for the IOTA/FAST Electron Injector at 300 MeV. August 23, 2017. Web link: https://fermipoint.fnal.gov/org/eshq/sa/Shared%20Documents/FAST%20Electron%20Injector%20at%20300%20MeV%20Shielding%20Assessment/FAST%20Shielding%20Assessment%2008-23-17.pdf