D-ZERO COLLISION HALL

SECTION IV CHAPTER 02 OF THE FERMILAB SAD

Revision 5 August 8, 2023

This Chapter of the Fermilab Safety Assessment Document (SAD) contains a summary of the results of the Safety Analysis for the D-Zero collision hall of the Fermilab Main Accelerator that are pertinent to understanding the risks to the workers, the public, and the environment due to its operation.

SAD Chapter Review

This Section IV, Chapter 02 of the Fermi National Accelerator Laboratory (Fermilab) Safety Assessment Document (SAD), D-Zero Collision Hall, was prepared and reviewed by the D-Zero Technical Coordinator in conjunction with 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.

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SAD Review Subcommittee Chair

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 also 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
Staff of RD D-Zero Construction Project		March 6, 1994	Initial D0 SAD Release
H.E.Fisk, D.Green, J.Christenson, P.D.Grannis, H.E.Montgomery, L.D. Spires, Staff of RD D-Zero Construction Project		September 21, 1994	Revision of D0 SAD
Staff of PPD D-Zero Upgrade Project		February 12, 2001	Safety Assessment Document Addendum Update of SAD for Run II
Angela Aparicio	4	November 13, 2014	Implement new SAD layout Revisions to the SAD for completion of operations
George Ginther	5	August 8, 2023	Implement latest SAD format Incorporation of Risk Matrix and hazard discussion

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Acronyms and Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienists
ACNET	Accelerator Control Network System
AD	Accelerator Directorate
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
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
^3H	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
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

IV-2. D-Zero Collision Hall

IV-2.1. Introduction

This Section IV, Chapter 02 of the Fermi National Accelerator Laboratory (Fermilab) Safety Assessment Document (SAD) covers the D-Zero collision hall segment of the Fermilab Main Accelerator.

IV-2.1.1 Purpose/Function

The D-Zero collision hall was designed and built to accommodate insertion of the D-Zero detector into the D-Zero straight section of the Tevatron collider ring so that the D-Zero physics collaboration could collect data resulting from collisions of protons on antiprotons at the highest available center of mass energy. The adjoining D-Zero Assembly Building was designed and built to facilitate assembly and installation of the D-Zero detector in the D-Zero collision hall, and to support operation of the D-Zero detector. The D-Zero detector is a 5,500-ton collider detector currently comprised of an inner silicon detector, a scintillating fiber tracker, preshower detectors, liquid argon sampling calorimeters, and muon detectors (consisting of wire chambers and scintillation counters).

The Run I version of the D-Zero Detector operated between 1992 and 1996. In 1995, both the Collider Detector at Fermilab (CDF) and D-Zero physics collaborations announced the discovery of the top quark. The D-Zero detector was upgraded to take advantage of improvements to the Tevatron collider prior to the start of Run II in 2001. Run II provided the data necessary to discover single top production and perform additional precision measurements of properties of W and Z bosons. D-Zero was also involved in the discovery of the exotic baryons and observation of B-meson mixing and produced many other physics results.

After the Tevatron run ended in September of 2011, the D-Zero detector was stabilized and secured, and prepared to serve as an exhibit of a general-purpose collider detector. Components of the detector that could readily be removed and re-purposed were extracted without significantly impacting the appearance of the detector (for exhibit purposes). Between 2012 and 2020, more than 8000 visitors had the opportunity to tour this exhibit in the D-Zero collision hall as escorted visitors, and more than 7000 of those escorted visitors also took advantage of the opportunity to tour the neighboring Tevatron tunnel. (Note that the D-Zero collision hall tourists are considered as co-located workers for the purposes of this hazard analysis. The tour guides escorting the visitors on these tours receive specific training to serve as tour guides for this area.)

The D-Zero Assembly Building High Bay was cleared and prepared to be used as assembly space for other detectors, including Muon g-2, the Chicagoland Observatory for Underground Particle Physics **(**COUPP), Micro Boone Neutrino Experiment (MicroBooNE) and SBND.

IV-2.1.2 Current Status

The D-Zero collision hall segment of the Fermilab Main Accelerator is currently: **Non-operational.**

IV-2.1.3 Description

The D-Zero facility is comprised of the Assembly Building (DAB) and the adjacent collision hall. The DAB offers assembly space in the pit and high bay with a large capacity (50 ton) overhead crane and office spaces within its 64,000 square feet.

The D-Zero detector resides in the D-Zero collision hall. The D-Zero detector measures about 30 feet by 30 feet by 50 feet and weighs ~5,500 tons. The D-Zero detector surrounds the D-Zero straight section of the Tevatron with layers of detectors. Precision charged tracking detectors are located closest to the collision region, surrounded by calorimeters, and then muon systems. At present there are no plans to dismantle or relocate the D-Zero detector.

Almost all operating systems for the detector have been emptied, turned off and stabilized. The LCW cooling water has been shut down. The silicon microstrip tracker (SMT) chiller has been shut down and drained and dismantled. The liquid argon was drained from the detector and storage dewars and the liquid was transferred to other experiments on-site (Long Baseline Neutrino Experiment (LBNE) 35T and MicroBooNE). The spare Visible Light Photon Counter cassettes (VLPCs) were given to the International Muon Ionization Cooling Experiment (MICE) collaboration. The muon readout electronics, some high-voltage equipment, blowers, computers, rack monitors, turbo pumps, and cryogenic components have been removed and reused by other experiments.

The main entrance to the collision hall is via a labyrinth with a personnel door in the north-east stairwell of the D-Zero Assembly Building. An additional personnel entrance is located in the center of the shield block wall that separates the D-Zero collision hall from the assembly pit in the D-Zero Assembly Building. There is also an emergency exit in the south-west corner of the D-Zero collision hall that leads into the Tevatron tunnel. The entrances are locked and access to the D-Zero collision hall is managed via supervised access keys.

IV-2.1.4 Location

The D-Zero collision hall of the Fermilab Main Accelerator is located on the Fermilab site in Batavia, IL.

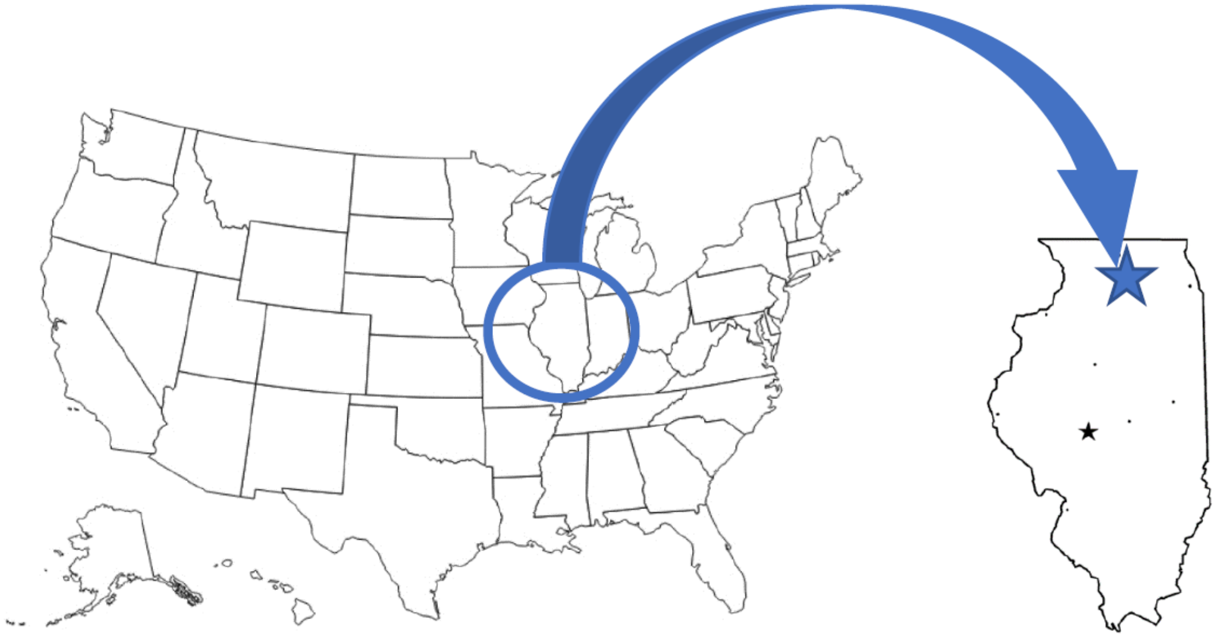

Figure 1. Regional view showing the location of the Fermilab site in Batavia, IL.

The D-Zero collision hall is located in the D-Zero straight section of the Fermilab Tevatron on the Fermilab site. The D-Zero detector operated in the collision hall west adjunct to the D-Zero Assembly Building (DAB) in a locally enlarged portion of the accelerator tunnel. A twelve-foot-thick shield block wall isolates the D-Zero collision hall from the D-Zero Assembly Building.

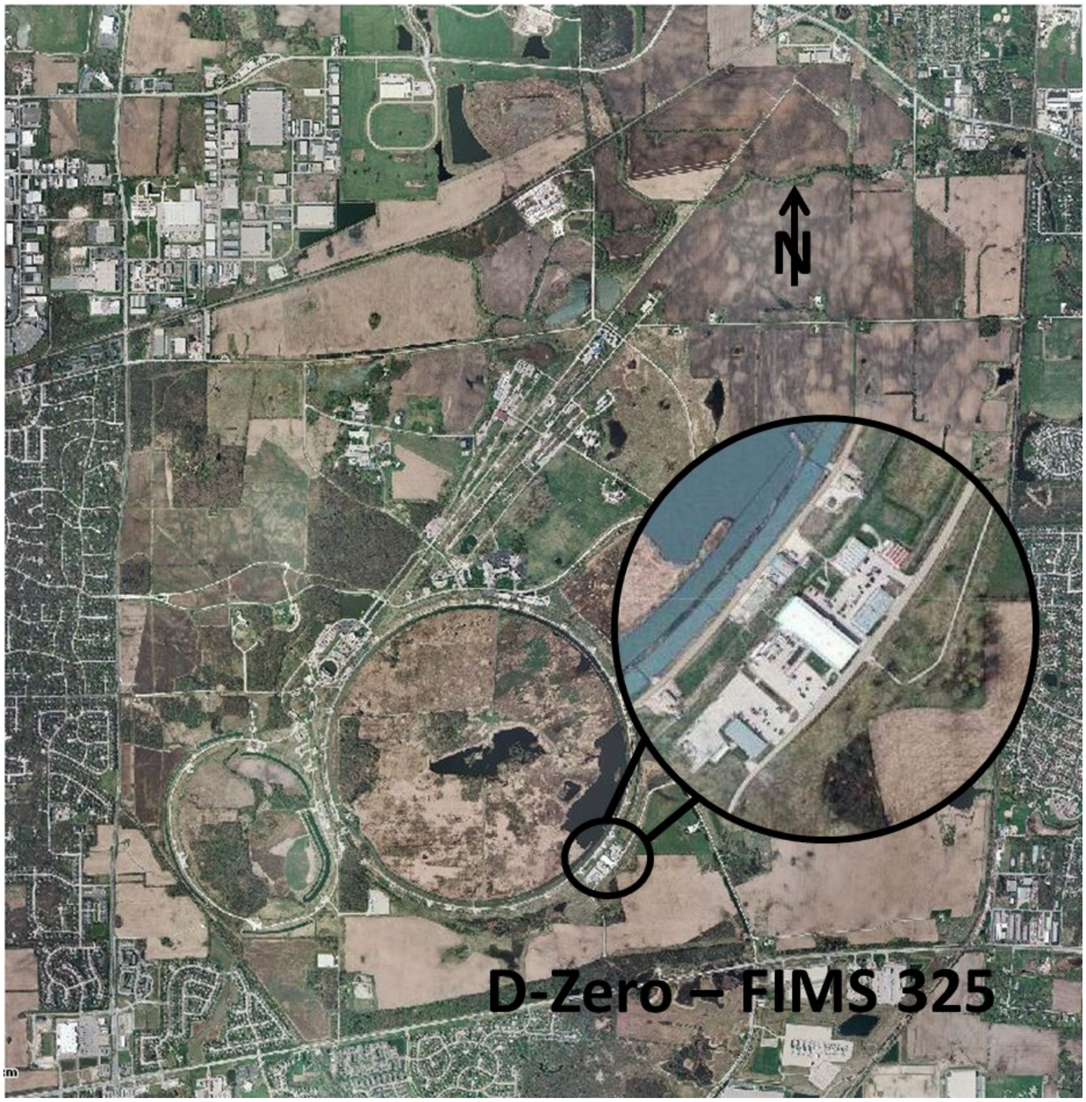

Figure 2. Aerial view of the Fermilab site, indicating the location of the D-Zero region, including the D-Zero Assembly Building with the D-Zero collision hall located in the Tevatron ring directly adjacent to the west end of the D-Zero Assembly Building.

IV-2.1.5 Management Organization

During operations, the D-Zero collision hall was managed jointly by the landlords, Particle Physics Division and Accelerator Division.

IV-2.1.6 Operating Modes

The D-Zero detector completed operations early in 2012 after the Tevatron colliding beam program ceased operations. The D-Zero detector has been stabilized and secured. The D-Zero detector is non-operational, but continues to reside within the D-Zero collision hall.

IV-2.1.7 Inventory of Hazards

The following table lists all of the identified hazards found in the D-Zero collision hall. Section I-1.10 *Appendix – Risk Matrices* describes the baseline risk (i.e., unmitigated risk in this non-operational state), any preventative controls and/or mitigative controls in place to reduce the risk, and residual risk (i.e., mitigated risk) for facility worker, co-located worker and Maximally Exposed Offsite Individual (MOI) (i.e., members of the public). A summary of these controls is described within Section I-1.2 *Safety Assessment.*

Prompt ionizing, Oxygen Deficiency Hazards due to cryogenic systems within accelerator enclosures, and fluorinert byproducts due to use of fluorinert that is subject to particle beam have been identified as accelerator specific hazards, and as such their controls are identified as Credited Controls. The analysis of these hazards and their Credited Controls are not discussed in detail within this SAD Chapter because none of these hazards is currently relevant to this area. The Credited Controls for these three hazards are summarized in the Accelerator Safety Envelope for the Fermilab Main Accelerator. Accelerator specific controls are identified as **purple/bold** throughout this Chapter.

All other hazards present in the D-Zero collision hall are safely managed by other DOE approved applicable safety and health programs and/or processes, and their analyses have been performed according to applicable DOE requirements as flowed down through the Fermilab Environment, Safety and Health Manual (FESHM). These hazards are considered to be Standard Industrial Hazards (SIH), and their analysis will be summarized in this SAD Chapter.

Table 1. Hazard inventory for the D-Zero collision hall.

	Radiological		**Toxic Materials**
☐	**Prompt Ionizing Radiation**	☒	Lead
☒	Residual Activation	☒	Beryllium
☐	Groundwater Activation	☐	**Fluorinert & Its Byproducts**
☐	Surface W☒ater 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

IV-2.2. Safety Assessment

All hazards for the D-Zero collision hall segment of the Fermilab Main Accelerator are summarized in this section, with additional details of the analyses for accelerator specific hazards.

Note that for the purposes of the risk assessments included in this chapter, the baseline configuration (without controls) is understood to be based upon the non-operational status of the D-Zero detector. As a consequence, many preventative measures implemented during the design, fabrication and operations phases are not explicitly cited in these analyses.

IV-2.2.1 Radiological Hazards

The D-Zero collision hall presents radiological hazards in the form of residual activation, radioactive sources, and nuclear material. See Section IV Chapter 2.10 Appendix for the Risk Matrix tables 2.1, 2.2, and 2.3 summarizing the analysis of the radiological hazards in the D-Zero collision hall.

IV-2.2.1.1 Prompt Ionizing Radiation

This hazard is no longer applicable to the D-Zero collision hall since the Tevatron is non-operational.

IV-2.2.1.2 Residual Activation

The D-Zero collision hall was an impacted area per FN000731 Radiological Worker - Just-in-Time Training.

Residual radiation due to beam-induced activation may still be present near the Tevatron beam pipe. Radiological surveys are performed to document radiation levels. Contamination wipes are also taken periodically in the collision call to verify that there are no contamination issues.

Due to the low levels of residual activation detected, and the inaccessibility of the location of that residual activation, the exposure to this hazard is not large, and the anticipated consequences are negligible, so the baseline qualitative risk due to this hazard is of minimal concern.

Shielding associated with the D-Zero collision hall remains unchanged.

IV-2.2.1.3 Groundwater Activation

This hazard is no longer applicable to the D-Zero collision hall since the Tevatron is non-operational.

IV-2.2.1.4 Surface Water Activation

This hazard is not applicable to the D-Zero collision hall since the Tevatron is non-operational.

IV-2.2.1.5 Radioactive Water (RAW) Systems

This hazard is not applicable to the D-Zero collision hall.

IV-2.2.1.6 Air Activation

This hazard is no longer applicable to the D-Zero collision hall since the Tevatron is non-operational.

IV-2.2.1.7 Closed Loop Air Cooling

This hazard is not applicable to the D-Zero collision hall.

IV-2.2.1.8 Soil Interactions

This hazard is no longer applicable to the D-Zero collision hall since the Tevatron is non-operational.

IV-2.2.1.9 Radioactive Waste

Radioactive waste produced in the course of D-Zero detector decommissioning will be managed within the established Radiological Protection Program (RPP) and as prescribed in the Fermilab Radiological Control Manual (FRCM) [1].

Radioactive waste is a standard radiological hazard that is managed within the established Radiological Protection Program (RPP) and as prescribed in the Fermilab Radiological Control Manual (FRCM). Waste minimization is an objective of the equipment design and operational procedures. Although production of radioactive material is not an operational function of the D-Zero detector, beam loss and, in the case of some beam diagnostics devices, intentional interception of the beam resulted in activation of beam line elements. Reuse of activated items will be carried out when feasible. Activated items that cannot be reused will be disposed of as radioactive waste in accordance with the FRCM requirements when decommissioned.

IV-2.2.1.10 Contamination

This hazard is not applicable to the current phase of the D-Zero collision hall.

IV-2.2.1.11 Beryllium-7

This hazard is no longer applicable to the D-Zero collision hall since the Tevatron is non-operational.

IV-2.2.1.12 Radioactive Sources

Twelve Ruthenium (Ru)-106 sources and twelve Americium (Am)-241 sources remain in place within the D-Zero detector. The ruthenium is a 3.5 MeV beta source with a 374-day half-life, which had an activity of 30 to 40 kBq per reference [2]), consequently these sources are now extremely weak in addition to being shielded by the calorimeter cryostat walls. The Americium is a 5 MeV alpha source, with a half-life of 432 years and an activity of <4 kBq [2]. The penetrating power of these alpha particles is extremely limited. In addition, as situated, the sources are inaccessible until the detector is decommissioned. These sources present a potential for low radiation exposures to the worker if handled improperly once they become accessible (during decommissioning).

During the course of operating the D-Zero detector, a variety of sealed radioactive sources were used for checks and calibrations of the detector, and kept in the Radioactive Source box in the pit. The source box kept the radiological materials segregated from non-radioactive materials. The Radioactive Source box is no longer located in the pit.

All sources are managed following Fermilab Radiological Control Manual (FRCM) Chapter 4: *Radioactive Materials*, and remain on the Laboratory's inventory of radioactive sources.

Due to the inaccessibility of the radioactive sources, the anticipated consequences are negligible, so the baseline qualitative risk due to this hazard is of minimal concern.

IV-2.2.1.13 Nuclear Material

3 mm and 4 mm thick depleted uranium plates are housed in the calorimeter cryostats, as are 6 mm thick uranium-niobium 2%) alloy plates [3]. The D-Zero detector contains ~200,000 kg of depleted uranium. (The prototype cryostat also contains ~20,000 kg.) The plates are contained inside welded double-walled stainless-steel cryostats, which provide some shielding. The radiological hazards associated with the D-Zero depleted uranium are small external dose rates when very near the cryostats; and the potential for small amounts of DU or DU oxide dust particulates in the argon blanket system.

At the conclusion of D-Zero detectors' operations, the liquid argon in the calorimeters was transferred back into the external liquid argon storage dewar. The calorimeters were warmed up and filled with dry argon gas with slight positive pressure (~1 psig) to minimize oxidization of the depleted uranium. (The formation of oxide powder poses a potentially serious radioactive contamination problem and the oxides can be pyrophoric.) The regulated argon gas is supplied to the underground storage vessel by a bank of argon gas cylinders in the gas shed external to the collision hall. An automated Cryogenic System Programmable Logic Controller monitors the argon gas pressures. If positive gas pressure is lost, automated messages notify personnel. The responding employee takes action to return the argon pressure to normal.

Due to the inaccessibility of the nuclear material, the anticipated consequences are negligible, so the baseline qualitative risk due to this hazard is of minimal concern.

IV-2.2.1.14 Radiation Generating Devices (RGDs)

This hazard is not applicable to the D-Zero collision hall.

IV-2.2.1.15 Non-Ionizing Radiation Hazards

This hazard is no longer applicable to the D-Zero collision hall since the calibration laser is no longer in service.

IV-2.2.2 Toxic Materials

Toxic materials in the D-Zero collision hall include lead and beryllium. Neither of these materials is readily accessible in the D-Zero detector. Access to the lead and beryllium requires dismantling elements of the detector. See Section IV Chapter 2.10 Appendix for the Risk Matrix tables 2.4, 2.5, and 2.6 summarizing the analysis of the toxic materials related hazards in the D-Zero collision hall.

IV-2.2.2.1 Lead

Lead is a toxic metal that can cause health issues if particulates are inhaled or ingested. Approximately 30 tons of lead are integrated into the forward muon shielding located along the beamline between the

End Calorimeter cryostats and the north and south walls of the collision hall. This lead, in the form of rectangular plates typically two inches thick, is encased in welded steel boxes along with polyethylene sheets. The boxes are attached to the outer surfaces of additional steel shielding blocks that reside in the north and south muon end toroids and on the north and south C-layer muon trusses. The lead shielding is purely passive and isolated from personnel.

In addition, approximately one ton of lead is integrated into the preshower detectors in the form of thin sheets approximately 0.5 cm and 1 cm thick. This lead is also passive in nature, covered with other detector elements, and therefore isolated from personnel. Should handling of any preshower lead sheets ever be necessary, procedures will be developed and appropriately trained personnel and protective clothing will be used.

Note that the baseline entries in the relevant section of the Risk Matrix of the D-Zero collision hall are based on the current phase of the detector, that is, the non-operational (but assembled) detector is interpreted as the baseline condition for this assessment. The lead in the detector will remain inaccessible until the detector is reconfigured for decommissioning. When the D-Zero detector is dismantled, all lead safety practices will be followed, per Fermilab Environment, Safety and Health Manual (FESHM) Chapter 4200: *Special Toxic Hazards – Lead-Containing Materials*. Only workers trained in Lead Handling or Lead Worker training will handle lead components.

Due to the inaccessibility of the lead in the D-Zero collision hall, the anticipated consequences are negligible, so the baseline qualitative risk due to this hazard is of minimal concern.

IV-2.2.2.2 Beryllium

Beryllium is a toxic metal that can cause health issues if its particulates are inhaled, ingested or absorbed through skin contact. The D-Zero detector contains beryllium within the beam pipe and the silicon microstrip tracker. The beryllium remains in place on the detector, but is located behind a locked configuration control gate.

Note that the baseline entries in the relevant section of the Risk Matrix of the D-Zero collision hall are based on the current phase of the detector, that is, the non-operational (but assembled) detector is interpreted as the baseline condition for this assessment. The beryllium in the detector will remain inaccessible behind a locked configuration control gate until the detector is reconfigured for decommissioning. When the detector is dismantled, proper beryllium handling precautions will be taken, following Fermilab Environment, Safety and Health Manual (FESHM) Chapter 4190: *Special Toxic Hazards - Beryllium and Beryllium Alloys Chronic Beryllium Disease Prevention Program.*

Due to the inaccessibility of the beryllium in the D-Zero collision hall, the anticipated likelihood of exposure is not large. However, the baseline consequence of beryllium exposure is rated as high, so the baseline qualitative risk due to this hazard is of major concern. Mitigations reduce the residual risk to minimal concern.

IV-2.2.2.3 Fluorinert & Its Byproducts

This hazard is not applicable to the D-Zero collision hall.

IV-2.2.2.4 Liquid Scintillator Oil

This hazard is not applicable to the D-Zero collision hall.

IV-2.2.2.5 Ammonia

This hazard is not applicable to the D-Zero collision hall.

IV-2.2.2.6 Nanoparticle Exposures

This hazard is not applicable to the D-Zero collision hall.

IV-2.2.3 Flammables and Combustibles

The D-Zero detector includes a cable plant, which remains in place in the collision hall. The collision hall is outfitted with a Very Early Smoke Detection Apparatus, and a sprinkler system and a Halon fire suppression system. The Fermilab Fire Department continues to make routine inspections of the collision hall. See Section IV Chapter 2.10 Appendix for the Risk Matrix tables 2.7, 2.8, and 2.9 summarizing the analysis of the hazards from flammable and combustible materials in the D-Zero collision hall.

IV-2.2.3.1 Combustible Materials

The services intended to support detector operations inside the collision hall remain in place. The cable selection was reviewed by the Fermilab AHJ (Jim Priest), so that the selected insulation on the cables was fire retardant.

The baseline likelihood of the hazard due to combustibles is rated as anticipated, and the consequences could be high, so the baseline risk was of major concern for facility workers and co-located workers. Mitigations reduce the residual risk to a situation of minimal concern for each category of receptor.

IV-2.2.3.2 Flammable Materials

This hazard is no longer applicable to the D-Zero collision hall since the muon gas distribution system is no longer in service.

IV-2.2.4 Electrical Energy

The conventional power distribution system for building services as well as the utilization equipment throughout the collision hall remains in place. The detector is powered down, but air handling, circulation systems and lighting continue to function. The hazards resulting from these systems are addressed in accordance with the 9000 series of the Fermilab Environment, Safety, and Health Manual.

IV-2.2.4.1 Stored Energy Exposure

This hazard is no longer applicable to the D-Zero collision hall.

IV-2.2.4.2 High Voltage Exposure

The risk of high voltage exposure in the D-Zero collision hall in the current non-operational status is attributable to the electrical power distribution system. Only properly trained and equipped personnel are allowed to service the electrical power distribution system in the D-Zero collision hall.

The baseline likelihood of the shock and arc flash hazards due to the electrical power distribution is rated as anticipated, and the consequences could be high, so the baseline risk was of major concern. Mitigations reduce the residual risk to a situation of minimal concern. (See section I chapter 04 for the Standard Industrial Hazards Risk Matrix tables applicable to the analysis of the power distribution high voltage related hazards in the D-Zero collision hall.)

IV-2.2.4.3 Low Voltage, High Current Exposure

This hazard is no longer applicable to the D-Zero collision hall since the detector is in non-operational status.

IV-2.2.5 Thermal Energy

Since the D-Zero detector is in a non-operational phase, there are no current thermal energy hazards.

IV-2.2.5.1 Bakeouts

This hazard is not applicable to the D-Zero collision hall.

IV-2.2.5.2 Hot Work

This hazard is not applicable to the D-Zero collision hall in its current status, but will need to be appropriately re-evaluated prior to decommissioning of the detector.

IV-2.2.5.3 Cryogenics

The cryogenic system at D-Zero supplied liquid nitrogen refrigeration to the three liquid argon calorimeter cryostats. The cryogenic control system enabled the automatic operation of the calorimeter cryostats at a fixed pressure and liquid argon level. A superconducting solenoid magnet and two VLPC cryostats were added to the D-Zero Detector in 2000 as part of the Run II upgrade. The solenoid and VLPCs required cryogenic services of both liquid nitrogen and liquid helium.

After the completion of the D-Zero detector operation, the liquid argon within the calorimeters was transferred into the external argon storage dewar. All three calorimeters were warmed and filled with gaseous argon to keep the depleted uranium plates within under a dry blanket.

Two liquid nitrogen storage dewars, the external liquid argon storage dewar, and the liquid helium storage dewar were emptied. The liquid was used by other experiments (*i.e.,* LBNE 35T Prototype & MicroBooNE), and the dewars have also been re-purposed.

This hazard is no longer applicable to the D-Zero collision hall since the detector is non-operational.

IV-2.2.6 Kinetic Energy

Kinetic energy hazards are not applicable to the D-Zero collision hall in its current status, but will need to be appropriately re-evaluated prior to decommissioning of the detector. See section I chapter 04 for the Standard Industrial Hazards Risk Matrix tables applicable to the analysis of the kinetic energy hazards that might be anticipated during decommissioning.

IV-2.2.6.1 Power Tools

This hazard is not applicable to the D-Zero collision hall in its current status, but will need to be appropriately re-evaluated prior to decommissioning of the detector.

IV-2.2.6.2 Pumps and Motors

This hazard is not applicable to the D-Zero collision hall in its current status, but will need to be appropriately re-evaluated prior to decommissioning of the detector.

IV-2.2.6.3 Motion Tables

This hazard is not applicable to the D-Zero collision hall in its current status, but will need to be appropriately re-evaluated prior to decommissioning of the detector.

IV-2.2.6.4 Mobile Shielding

This hazard is not applicable to the D-Zero collision hall in its current status, but will need to be appropriately re-evaluated prior to decommissioning of the detector.

IV-2.2.7 Potential Energy

Since the D-Zero detector is in a non-operational phase, there are no current potential energy hazards, but these hazards will need to be re-evaluated prior to decommissioning the D-Zero detector. See section I chapter 04 for the Standard Industrial Hazards Risk Matrix tables applicable to the analysis of the potential energy hazards that might be anticipated during decommissioning.

IV-2.2.7.1 Crane Operations

This hazard is not applicable to the D-Zero collision hall in its current status, but will need to be appropriately re-evaluated prior to decommissioning of the detector.

IV-2.2.7.2 Compressed Gasses

There are no compressed gas bottles in the D-Zero collision hall.

IV-2.2.7.3 Vacuum/Pressure Vessels/Piping

This hazard is no longer applicable to the D-Zero collision hall since the detectors are non-operational.

IV-2.2.7.4 Vacuum Pumps

This hazard is no longer applicable to the D-Zero collision hall since the detectors are non-operational.

IV-2.2.7.5 Material Handling

This hazard is not applicable to the D-Zero collision hall in its current status, but will need to be appropriately re-evaluated prior to decommissioning of the detector.

IV-2.2.8 Magnetic Fields

The D-Zero 2.0 Tesla superconducting solenoid was warmed to room temperature early in 2012. The power supply has since been re-purposed. The power supply for the toriods has been tagged and locked with configuration locks, and the reversing switch has been removed, so that toriods are also out of service. See Section IV Chapter 2.10 Appendix for the Risk Matrix tables 2.10, 2.11, and 2.12 summarizing the analysis of the hazards from the magnetic fields in the D-Zero collision hall.

IV-2.2.8.1 Fringe Fields

The residual magnetic fields in the D-Zero collision hall are well below the DOE-HDBK-1163-2020 Appendix A screening criteria for static magnetic fields (> 2T). Surveys of readily accessible areas have not detected residual magnetic fields above the FESHM 4270 thirty gauss threshold for potential projectile threats. However, the collision hall is posted as a Magnetic Field Hazard (no persons with cardiac pacemakers or electronic medical devices) due to results of a survey of the residual magnetic fields of slightly over the five-gauss posting threshold on contact in a few accessible locations in the collision hall (but not on the center of the walkway) [6].

The baseline likelihood of impact on an individual with a medical implant sensitive to a magnetic fringe field hazards is rated as anticipated, and the consequences could be high, so the baseline risk was of major concern. Mitigations reduce the residual risk to a situation of minor concern for workers and minor concern for offsite individuals.

IV-2.2.9 Other Hazards

Since the D-Zero detector is in a non-operational phase, there are no current identified hazards in this category, but these hazards will need to be re-evaluated prior to decommissioning the D-Zero detector.

IV-2.2.9.1 Confined Spaces

This hazard is not applicable to the D-Zero collision hall in its current status, but may need to be appropriately re-evaluated prior to decommissioning of the detector.

IV-2.2.9.2 Noise

This hazard is not applicable to the D-Zero collision hall in its current status, but will need to be appropriately re-evaluated prior to decommissioning of the detector.

IV-2.2.9.3 Silica

This hazard is not applicable to the D-Zero collision hall in its current status, but may need to be appropriately re-evaluated prior to decommissioning of the detector.

IV-2.2.9.4 Ergonomics

The D-Zero collision hall is in non-operational status. There are no current unusual ergonomic hazards. However, the collision hall is a posted hard hat area due to limited overhead clearances in the muon trusses and the possibility of activity on the upper levels of the detector.

IV-2.2.9.5 Asbestos

This hazard is not applicable to the D-Zero collision hall.

IV-2.2.9.6 Working at Heights

This hazard is not applicable to the D-Zero collision hall in its current status, but will need to be appropriately re-evaluated prior to decommissioning of the detector.

IV-2.2.10 Access & Egress

The main entrance to the collision hall is via a labyrinth with a personnel door in the north-east stairwell of the D-Zero Assembly Building. An additional personnel entrance is located in the center of the shield block wall that separates the D-Zero collision hall from the assembly pit in the D-Zero Assembly Building. There is also an emergency exit in the south-west corner of the D-Zero collision hall that leads into the Tevatron tunnel. The entrances are locked and access to the D-Zero collision hall is managed via supervised access keys. See section I chapter 04 for the Standard Industrial Hazards Risk Matrix tables applicable to the analysis of the access & egress hazards related to the D-Zero collision hall.

IV-2.2.10.1 Life Safety Egress

The emergency exits from the D-Zero collision hall include a labyrinth with a personnel door in the north-east stairwell of the D-Zero Assembly Building, as well as an additional emergency exit located in the center of the shield block wall that separates the D-Zero collision hall from the assembly pit in the D-Zero Assembly Building. There is also an emergency exit in the south-west corner of the D-Zero collision hall that leads into the Tevatron tunnel. Each of these personnel doors on the collision hall open out to the exiting area without the need of a key.

The exit paths around the D-Zero detector are marked with signs and emergency lighting.

The baseline likelihood of the life safety egress related hazards is rated as anticipated, and the consequences could be high for both facility workers (moderate for co-located workers), so the baseline risk was of major (moderate) concern. Mitigations reduce the residual risk to a situation of minimal concern, and this risk is not applicable to the offsite individual.

IV-2.2.11 Environmental

These hazards are not applicable to the current status of the D-Zero collision hall.

IV-2.2.11.1 Hazard to Air

This hazard is not applicable to the D-Zero collision hall.

IV-2.2.11.2 Hazard to Water

This hazard is not currently longer applicable to the D-Zero collision hall since the detectors are non-operational.

IV-2.2.11.3 Hazard to Soil

This hazard is no longer applicable to the D-Zero collision hall since the detectors are non-operational.

IV-2.3. Summary of Hazards to Members of the Public

The public does not have unescorted access to the D-Zero collision hall.

IV-2.4. Summary of Credited Controls

The D-Zero collision hall is geographically separated from the operational accelerator components and thus does not require any passive, active engineered or administrative controls that rise to the level of a Credited Control needing inclusion in the Accelerator Safety Envelope.

IV-2.4.1 Passive Credited Controls

Not applicable.

IV-2.4.1.1 Shielding

Not applicable.

IV-2.4.1.1.1 Permanent Shielding Including Labyrinths

Not applicable.

IV-2.4.1.1.2 Movable Shielding

Not applicable.

IV-2.4.1.1.3 Penetration Shielding

Not applicable.

IV-2.4.1.2 Fencing

Not applicable.

IV-2.4.1.2.1 Radiation Area Fencing

Not applicable.

IV-2.4.1.2.2 Controlled Area Fencing

Not applicable.

IV-2.4.2 Active Engineered Credited Controls

D-Zero does not currently have any active engineered credited controls.

IV-2.4.2.1 Radiation Safety Interlock System

The radiation safety interlock system for the D-Zero collision hall is non-operational. This radiation safety interlock system is no longer needed since neither the Main Ring nor the Tevatron is not currently capable of delivering beam to the D-Zero straight section.

IV-2.4.2.2 ODH Safety System

All previous ODH analyses of the D-Zero collision hall during operations resulted in classification as ODH Class 0, which is the least hazardous ODH class and requires no special precautions. Following the conclusion of D-Zero detector operations in early in 2012, the cryogenic systems were stabilized, warmed, and the cryogenic liquids were transferred for use in other experimental apparatuses.

No cryogenic liquids remain, and there are no plans to refill the vessels with cryogenic liquids. With no hazard remaining, the ODH monitoring equipment was shut down. The ODH monitoring equipment is no longer required for good engineering practice and has been disabled.

All gases that created the ODH are no longer in use, eliminating the hazard. (See D-Zero Engineering Notes #3740.510-EN-332 [4] and #3823.000-EN-585 [5].)

IV-2.4.3 Administrative Credited Controls

Not applicable.

IV-2.4.3.1 Operation Authorization Document

Not applicable.

IV-2.4.3.2 Staffing

Not applicable.

IV-2.4.3.3 Accelerator Operating Parameters

Not applicable.

IV-2.5. Defense-in-Depth Controls

Not applicable.

IV-2.6. Machine Protection Controls

Not applicable.

IV-2.7. Decommissioning

The D-Zero detector is non-operational. It remains in the collision hall. Final decommissioning of the D-Zero detector will follow the requirements of FESHM Chapter 7050: *Demolition and Decommissioning*.

DOE Field Element Manager approval shall be obtained prior to the start of any decommissioning activities in the D-Zero collision hall.

IV-2.8. Summary and Conclusion

The hazards specific to the current non-operational phase of the D-Zero detector in the D-Zero collision hall have been identified and assessed in this chapter of the Fermilab Safety Assessment. Designs, controls, and procedures to mitigate D-Zero specific hazards are identified and described. The residual risks after implementation of preventative and mitigative measures are categorized as of minor or minimal concern.

IV-2.9. References

[1] Fermilab Radiological Control Manual
[2] V. M. Abazov *et al.,* Nucl. Instr. and Meth. A 565 (2006) 463.
[3] S. Abachi *et al*., Nucl. Instr. and Meth. A 338 (1994) 185.
[4] D-Zero Detector Collision Hall Oxygen Deficiency Hazard Analysis, D-ZERO Engineering Note 3740.510-EN-332, John Wu, Revised by Dan Olis 2/12/2001.
[5] D0 Decommissioning Storage of depleted uranium modules inside D0 calorimeters after the termination of the D0 experiment, D-ZERO Engineering Note 3823.000-EN-585, Michael Sarychev, Sept 21 2011.
[6] M. Spaw, Fermilab Field Notes Form, Survey ID 11935.

IV-2.10. Appendix – Risk Matrices

Risk Assessment methodology was developed based on the methodology described in DOE-HDBK-1163-2020. Hazards and their potential events are evaluated for likelihood and potential consequence assuming no controls in place, which results in a baseline risk. A baseline risk (i.e., an unmitigated risk) value of III and IV does not require further controls based on the Handbook. Events with a baseline risk value of I or II do require prevention and/or mitigation measures to be established in order to reduce the risk value to an acceptable level of III or IV. Generally, preventive controls are applied prior to a loss event, reflecting a likelihood reduction, and mitigative controls are applied after a loss event, reflecting a consequence reduction. For each control put in place, likelihood or consequence can have a single "bin drop", resulting in a new residual risk (i.e., a mitigated risk). This risk assessment process is repeated for each hazard for Facility Workers (FW), Co-Located Workers (CLW), and Maximally-Exposed Offsite Individual (MOI).