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Another Means of Worksite Analysis – NFPA 652's Standard on Dust Hazard Analysis (DHA)

Another Means of Worksite Analysis – NFPA 652's Standard on Dust Hazard Analysis (DHA)

Presented by:

Scott E. Genta, Director, Southwest Operations

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Me

Scott E. Genta is a chemical engineer with 22 years of experience in the practical application of technical safety disciplines in the hazardous chemical and explosives industries. Experience includes OSHA's "Process Safety Management" (PSM) regulation, and EPA's "Risk Management Program" (RMP). Currently an Ambassador with OSHA's Voluntary Protection Program (VPP) for the Region 9 Participants Association.

Mr. Genta has provided Process Safety Management and Process Hazard Analysis Training for many different companies and annually at the TCI Consulting course for DOD contractors

Project Highlights Include

- PHA for High Pressure Water Washout of 155mm Munitions in the Ukraine and Belarus
- PHA for the Alaskan Pipeline
- Site Safety Support for Munitions Manufacturing Facility Start-up in Mulwala, Australia

SMS Capabilities

- **Risk Management and Process Hazards Analysis Methodologies**
  - Qualitative (HAZOP, FMEA, etc.)
  - Quantitative (Fault Tree, Probabilistic Analyses, etc.)
- **Compliance**
  - OSHA PSM, EPA RMP, DOD, VPP
- **Material Characterization Testing**
  - Sensitivity & Reactivity Testing
  - DOT Classification Testing and Analysis
  - Test Equipment
- **Facility Siting & Design**
  - Quantity Distances, Venting, Barricades, Workstation Protection, etc.
- **Training**
  - Risk Management
  - Explosives Safety

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Introduction FAI & SMS Teams

- ISO/IEC Accredited Laboratory
- US Department of Transportation (DOT) Competent Authority
- DOT approved and authorized Examining Agency to perform explosives and other hazardous materials examination services
- Chairperson of the ASTM E27.05 Subcommittee on Dust
- NFPA Committee membership and contribution (NFPA 654, 655, 91, 664, 61 and 484).
- Delegate to the United Nations (SAAMI Delegation)
- Transport of Dangerous Goods Subcommittee
  - Explosives
- Global Harmonization Subcommittee
  - Explosives Chapter 2.1
  - Dusts
- UN Explosives Working Group Delegate
- Participant with IGUS - International Group of Experts on the Explosion Risks of Unstable Substances
- Founder & Chair of the Explosives Testing Users Group
- Test sites in Burr Ridge, Illinois, Tooele, Utah, and Geleen, the Netherlands

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Risk Management Heritage

Explosives Manufacturing Risk Management Heritage

1912	1960	1970	1980	1990	Present
Hercules Dupont Others NG Manufacture	Risk Methods Improved Material Characterization Testing Explosives Safety Standards	Fault Trees FMEA Probit Analysis In-Process Simulation	Specialized Testing & Modeling	OSHA 29 CFR 1910.119 EPA RMP	Dust Incidents and OSHA Emphasis

Incidents

Dust explosions are a serious hazard, recent incidents include:

- January 2003 - West Pharmaceuticals Services – Kinston, North Carolina – Fine plastic dust - 6 fatalities many injured
- February 2003 – CTA Acoustics – Corbin, Kentucky – fiberglass binder dust – 1 fatality several injured
- October 2003 – Heyes Lemmerz – Huntington, Indiana – Aluminum Dust – 1 fatality several injured
- February 2008 – Imperial Sugar – Port Wentworth, Georgia – Sugar dust – 14 Fatalities 38 Injured

Explosion Example

West Pharmaceutical - Operation kept clean - it was the fine plastic dust collecting above the false ceiling that propagated the reaction

Overview of NFPA 652

Standard on the Fundamentals of Combustible Dust

Why?

- **Why was NFPA 652 Created**
  - There are multiple commodity specific NFPA standards
  - Requirements are sometimes inconsistent between industry sectors and dust types
  - Defines the relationship between this standard and others to address gaps or conflicts with requirements
  - Aims to simplify OSHA compliance and enforcement

Dust Occupancy Standards

- NFPA 652 “Fundamentals”
  - Wood/Cellulosic Dust – NFPA 664
  - Metallic Dust – NFPA 484
  - Agricultural Dust – NFPA 61
  - Sulfur – NFPA 655
  - Pulverized Fuels – NFPA 85
  - Coal – NFPA 120
  - Chemical Dust – NFPA 654

When?

- When does this take effect?
  - Unless otherwise specified, the provisions of this standard shall not apply to facilities, equipment, structures, or installations that existed or were approved for construction or installation prior to the effective date of the standard
  - What is retroactive?
    - » Dust Hazard Analysis – Chapter 7
    - » Housekeeping – Section 8.4
    - » Ignition Source Control – Section 8.5
    - » Management – Chapter 9

NFPA 652
Chapter 8: Hazard Management – Mitigation & Prevention

- **Housekeeping**
  - A facility must have documented housekeeping procedures that include:
    - » Cleaning methods
    - » Frequency and goal
    - » Training

NFPA 652
Chapter 8: Hazard Management – Mitigation & Prevention

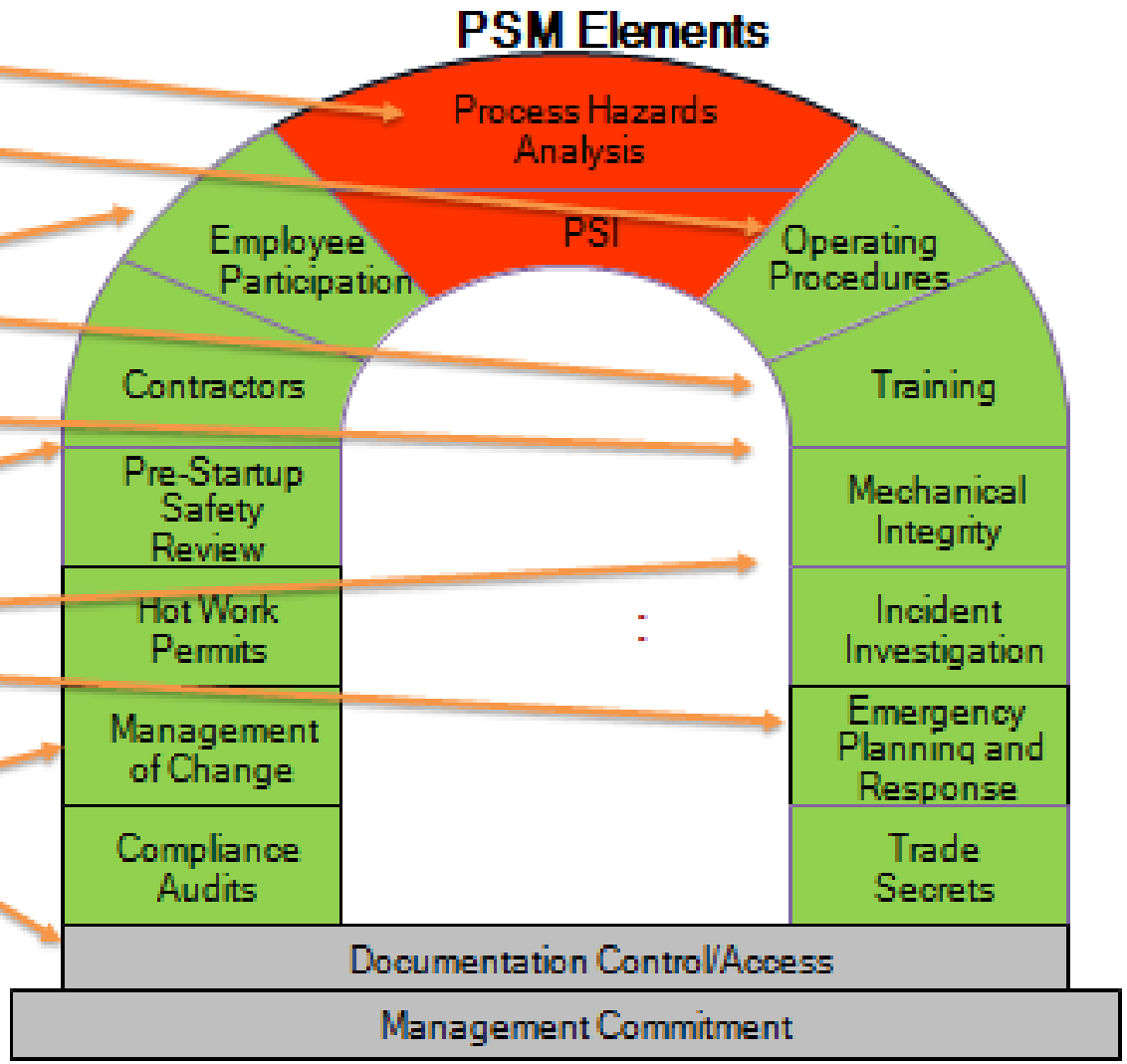
- **Ignition Source Control**
  - Hot work
  - Hot surfaces
  - Bearings
  - Electrical Equipment and Wiring
  - Electrostatic Discharges (portions are retroactive requirements)
  - Open Flames
  - Industrial Trucks
  - Electrostatic Discharges (portions are retroactive requirements)
  - Open Flames
  - Industrial Trucks

NFPA 652
Chapter 9: Management Systems

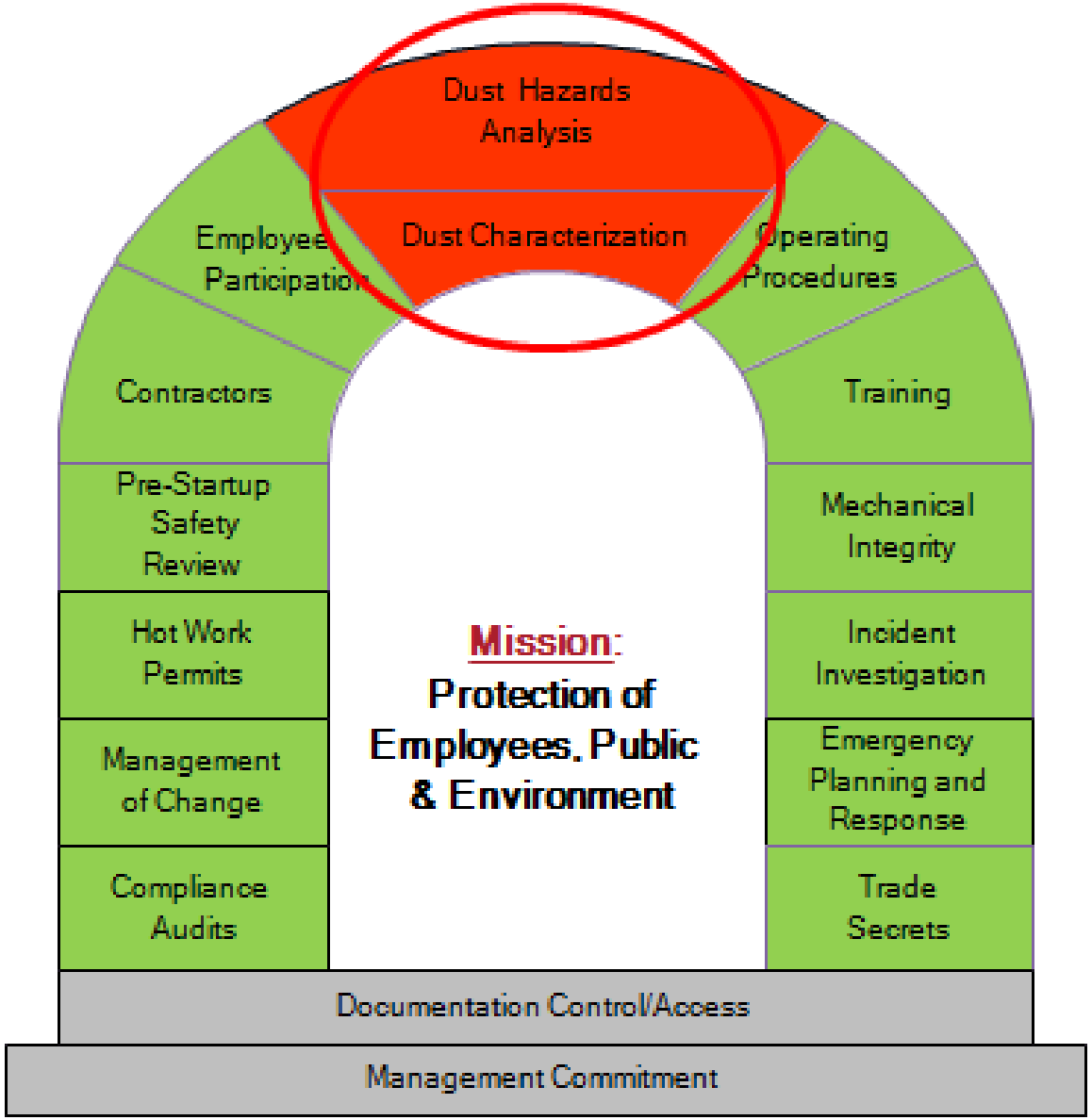
- Covers the administrative requirements needed to manage combustible dust hazards
  - Equipment Operation Procedures
  - Employee/Contractor Training Requirements (Hazard Awareness)
  - Management of Change (MOC)
  - Incident Investigation
  - Document Retention
- All requirements in this chapter apply retroactively

NFPA 652 DHA Requirements

- Dust Hazard Analysis (DHA)
- Operating Procedures and Practices
- Employee Participation
- Training and Hazard Awareness
- Inspection, Testing, and Maintenance
- Contractors
- Incident Investigation
- Emergency Planning and Response
- Management of Change
- Documentation Retention
- Management Systems Review



NFPA 652 DHA Requirements



NFPA 652
Chapter 7: Dust Hazard Analysis (DHA)

- **Owner/Operator *must* complete a DHA if facility is handling a combustible dust.**
- **This is a retroactive requirement**
  - **Existing process/facilities must schedule and complete DHA within 3 years of the effective date of NFPA 652 (9/7/2015)**

NFPA 652 DHA Requirements
(continued)

- NFPA 654 – June 2nd, 2021
- NFPA 664 – September 7th, 2018 (same as NFPA 652)
- NFPA 61 – June 2nd, 2021
- NFPA 484 – Falls under NFPA 652 (waiting on new edition)

OSHA's Voluntary Protection Programs Management Guidelines

Work Site Analysis

↓

Baseline Hazard Analysis

NFPA 652 DHA Requirements

- Defined as a <u>systematic</u> review to <u>identify</u> and <u>evaluate</u> the potential fire, flash fire, or explosion hazards associated with the presence of one or more combustible particulate solids in a process or facility
- The purpose is to identify hazards in the process and <u>document</u> how those hazards are being managed

NFPA 652 DHA Requirements

- DHA shall evaluate the fire, deflagration, and explosion hazards and provide recommendations to manage the hazards in accordance with NPFA 652, Chapter 4

- DHA shall be performed or led by a qualified person

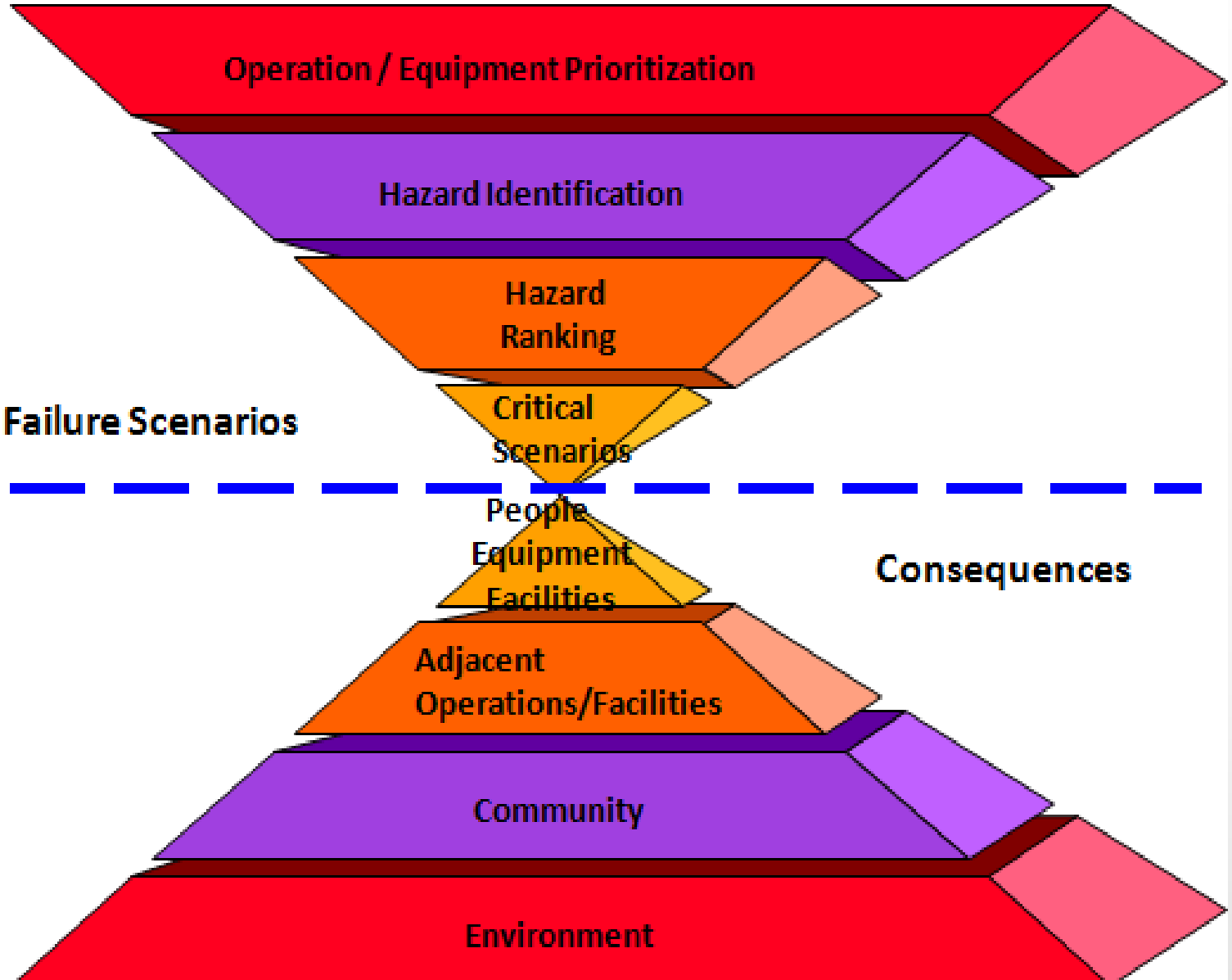
- Results of the DHA review shall be documented, including any necessary action items, a change to the process, or materials

Risk Management & DHA Philosophy

- "Safety by Design"
  - Minimize Personnel Exposure
  - Minimize Quantities of Hazardous Materials
  - Safety Specifications
- Standards
- Procedures
- Training

Level Setting
Fundamental to Risk Management & DHAs

Level Setting



Level Setting
Prioritization

- Identification of dust or potential for dust
- Testing per NFPA 652 Chapter 5 (screening)

Level Setting
Prioritization

NFPA 652, 5.2.3

"The absence of previous incidents shall not be used as the basis for deeming a particulate not to be combustible or explosive"

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Level Setting
Prioritization

Property	Definition	ASTM Test Method	Application
K_{St}	Dust deflagration index	ASTM E 1226	Measures the relative explosion severity compared to other dusts
P_{max}	Maximum explosion overpressure generated in the test chamber	ASTM E 1226	Used to design enclosures and predict the severity of the consequence
$(dP/dt)_{max}$	Maximum rate of pressure rise	ASTM E 1226	Predicts the violence of an explosion. Used to calculate K_{st}
MIE	Minimum Ignition Energy	ASTM E 2019	Predicts the ease and likelihood of ignition of a dispersed dust cloud
MEC	Minimum Explosible Concentration	ASTM E 1515	Measures the minimum amount of dust dispersed in air, required to spread an explosion Analogous to the lower flammability limit (LFL) for gas/air mixtures
LOC	Limiting Oxygen Concentration	ASTM E2931	Determines the least amount of oxygen required for explosion propagation through the dust cloud
ECT	Electrostatic Charging Tendency	No ASTM standard	Predicts the likelihood of the material to develop and discharge sufficient static electricity to ignite a dispersed dust cloud

Material Characterization Testing: Sensitivity and Reactivity

- Sensitivity
  - MIE, MEC, MIT, Resistivity

- Reactivity
  - Explosive Severity – K_{st}, dp/dt, P_{max}

Not all dusts are the same

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Level Setting
Prioritization

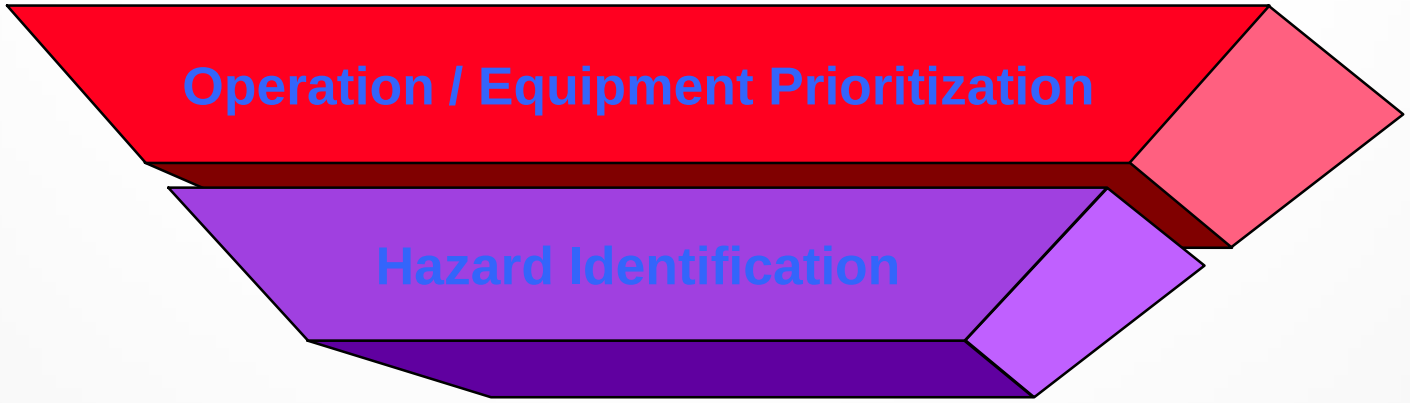
NPA 652 - Each process system where combustible dust is present or where particulate solids could cause combustible dust to be present shall be evaluated

Level Setting
Prioritization

- **May use a simple table:**

Operation/ Item	Explosible Dust Present (Fuel)	Possible MEC (Dispersion)	Oxygen	Possible MIE (Ignition)	Confinement	Further Assessment
Bulk Storage	In Packaging	No	Yes	No	No	No
Mixing Room	Yes	Upset	Yes	Yes	Yes	Yes
Drum Loading of Tank	Yes	Upset	Yes	Yes	Yes	Yes
Filling Tank	Yes	Upset	Yes	Yes	Yes	Yes
Dust Collection System	Yes	Yes	Yes	Yes	Yes	Yes

Level Setting
Hazard Identification



Level Setting
Hazard Identification

The complexity of the Hazards Analysis must reflect the complexity of the process

- **NFPA 652 Appendix B**
- **OSHA 1910.119**

Level Setting
Hazard Identification

- **Methodology (continued)**
  - **Acceptable methods may include, but are not limited to:**
    - » **“What-if” analysis**
    - » **Checklist & “What-if” analysis**
    - » **Failure Modes and Effects Analysis (FMEA)**
    - » **Fault Tree Analysis**
    - » **HAZOP**

- NFPA 652 Appendix B
- OSHA 1910.119

Level Setting
Hazard Identification

NOTE From 652 Appendix B:

It is not the intent of this standard to require users to apply the PHA provisions of OSHA regulations in 29 CFR 1910.119, “Process Safety Management of Highly Hazardous Chemicals,” in developing a DHA. The example is intentionally vague to allow users to match the complexity and extent of the analysis to the complexity and extent of the facility and its process

Level Setting
Hazard Identification

<u>Example</u>: "Hazards" Checklist

Key Items For Dust

- Thermal, ESD, friction, impact, shock, etc.
- Housekeeping, Spill, Process Leak, etc.

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Level Setting
Hazard Identification

Types of Energy

Level Setting

Hazard Identification

LINE NO.	OPERATION / ITEM	FAILURE MODE	FAILURE CAUSE	POTENTIAL EFFECTS	SAFEGUARDS	HAZ CAT	RECOMMENDATIONS	HAZ CAT
2A	**Grinder (Roll Crusher)**	ESD initiation of combustible dust	Isolated and charged components in grinder (MEC is expected inside equipment)	Fire and Explosion	Bonding cables are in place Grinder is operated remotely	2D	Provide documented periodic bonding and grounding checks for the grinder equipment. At a minimum grounding should be checked after reassembly of equipment. (Rec. 6)	2E
2B		Impact/Friction/ESD/Thermal of combustible dust	Unknown initiation source in confined equipment	Fire and Explosion	Grinder appears to be open Grinder is operated remotely	2D	Provide modeling or calculations to ensure grinder will properly vent a dust cloud initiation event to prevent an explosion from confinement. (Rec. 7)	2E
2C		Friction/Impact initiation of combustible dust	Excessive force on crusher rolls due to jamming or over current	Fire and explosion due to excessive energy imparted into internal dust cloud	Wheels are spring loaded with may allow forces to be minimized	2D	Develop means to minimize operator exposure during a grinder jam/upset condition (e.g., automatic jam reversal, over-current protection with an alarm and fault). (Rec. 8)	2E
2D		Friction/Impact initiation of combustible dust	Combustible dust material migration into roll crusher chain and drive shaft equipment	Fire and Explosion	Drive mechanisms are guarded but not dust tight allowing fugitive dust to migrate MEC of 147 g/m^3 outside of equipment is unlikely	2D	Develop an inspection method to ensure guarded rotating chain driven drive equipment does not accumulate combustible dust. (Rec. 9)	2E

Level Setting

Hazard Identification

The DHA would not be complete without a review of NFPA 652 and the commodity specific standards

- Wood/Cellulosic Dust – NFPA 664
- Metallic Dust – NFPA 484
- Agricultural Dust – NFPA 61
- Sulfur – NFPA 655
- Pulverized Fuels – NFPA 85
- Coal – NFPA 120
- Chemical Dust – NFPA 654

Level Setting

Hazard Identification

Don't Forget the Design Standards:

- **NFPA 68: Standard On Explosion Protection By Deflagration Venting**
- **NFPA 69: Standard on Explosion Prevention Systems**
- **NFPA 77: Recommended Practice on Static Electricity**
- **NFPA 13: Standard for the Installation of Sprinkler Systems**
- **NFPA 15: Standard for Water Spray Fixed Systems for Fire Protection**

Level Setting

Hazard Identification

Either a separate table may be used

Standard	Observations/ Potential Deficiencies	Recommendations
NFPA 664 Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities (2017)		
3.2.3 Mechanical Conveying Systems	Roller bearings are used on each conveyor system. The bearings are on a regular PM schedule where they are inspected for wear and lubricated. The bearings are dust tight and easily accessible.	NAI
7.2 Electrical Systems	One electrical junction box was opened in the Hog building and a sizeable quantity of wood dust was found on the inside. There are other adjacent junction boxes in the area that do not have a Class II Division 2 label.	Verify proper enclosure ratings to meet Class II Division 2 requirements on all power junction boxes or electrical connections (Rec. 11)

Level Setting

Hazard Identification

Or a as a reference in the FMEA table

HAZ CAT	RECOMMENDATIONS	HAZ CAT	Additional Standard Reference
3D	Due to low MIE (21 mJ) for the tested Ti dust fines, provide proper human static prevention measures for personnel working around fines in screener and dry lab (i.e. static dissipative floor, footwear, heel stats, wrist stats, etc.) (Rec. 3)	3E	NFPA 484 8.5.7* Grounding of Personnel.
2D	Develop housekeeping maintenance plan for the Ti Sponge Dry Lab (Rec. 35)	2E	NFPA 484 16.1 General Provisions Housekeeping 7.3.1* Fugitive dust shall not be allowed to accumulate to a level that obscures the color of the surface beneath it.

Level Setting

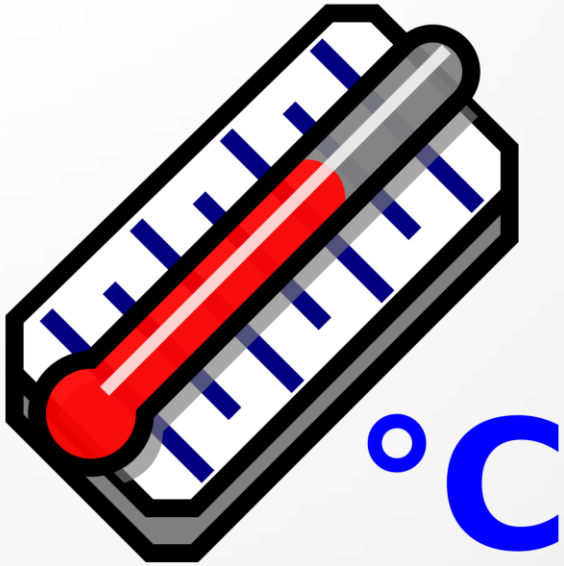
Hazard Identification

SAFEGUARDS	HAZ CAT	RECOMMENDATIONS	HAZ CAT	Additional Standard Reference
Grounding clips are being used but clamps are damage or not designed for their purpose	2D	Ensure all plastic material (boot, sight glass (e.g. ESD Lexan), etc.) material is conductive and process is bonded across plastics (Rec. 17) Include in the conductivity measurement PM an overall continuity check to ensure individual bonding is sufficient throughout the system (Rec. 20) Provide means to properly secure grounding clamp to drum grounding rod (Rec. 21) Utilize appropriate clamps that can penetrate paint coverings (e.g., FM Approved RE2960) (Rec. 22) 	2E	NFPA 484 16.2 Facility Equipment used for the processing of titanium shall be bonded and grounded.

4. Recommend Risk Mitigating Solutions & Use of Standards
(continued)

Temperature Class Maximum Surface Temperature °C (NFPA 70)

- T1 450ºC
- T2 300ºC
- T3 200ºC
- T4 135ºC
- T5 100ºC
- T6 85ºC



4. Recommend Risk Mitigating Solutions & Use of Standards (continued)

Typical Self Ignition Temperatures for Dust – Layer and Cloud

Dust	Temperature (Cloud)	Temperature (Layer)
Cellulose	490ºC	430ºC
Cocoa	500ºC	200ºC
Flour	490ºC	430ºC
Lead	460ºC	240ºC
Lignite	380ºC	225ºC
Polyacrylonitrate	540ºC	400ºC
Soya Meal	540ºC	340ºC
Zinc	570ºC	440ºC

4. Recommend Risk Mitigating Solutions & Use of Standards
(continued)

$$A_{v0} = 1 \cdot 10^{-4} \cdot \left(1 + 1.54 \cdot P_{stat}^{4/3}\right) \cdot K_{St} \cdot V^{3/4} \cdot \sqrt{\frac{P_{max}}{P_{red}} - 1} \qquad (8.2.2)$$

Source: NFPA 68

where:

A_{v0} = vent area (m^2)

P_{stat} = nominal static burst pressure of the vent (bar)

K_{St} = deflagration index (bar-m/s)

V = enclosure volume (m^3)

P_{max} = maximum pressure of a deflagration (bar-g)

P_{red} = reduced pressure after deflagration venting (bar) [115]

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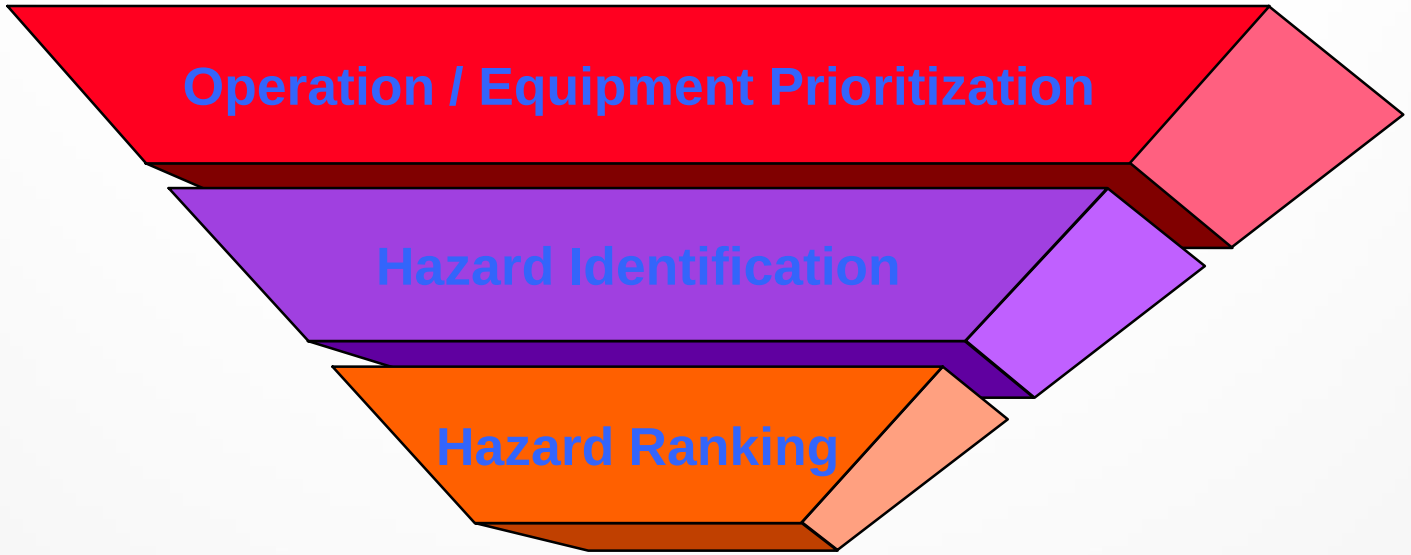
Level Setting
Hazard Ranking



- Explosibility and combustibility results (Sensitivity/Reactivity)
- Qualitative estimates based on likelihood and outcome

Hazard Risk Assessment Matrix
(MIL-STD-882E)

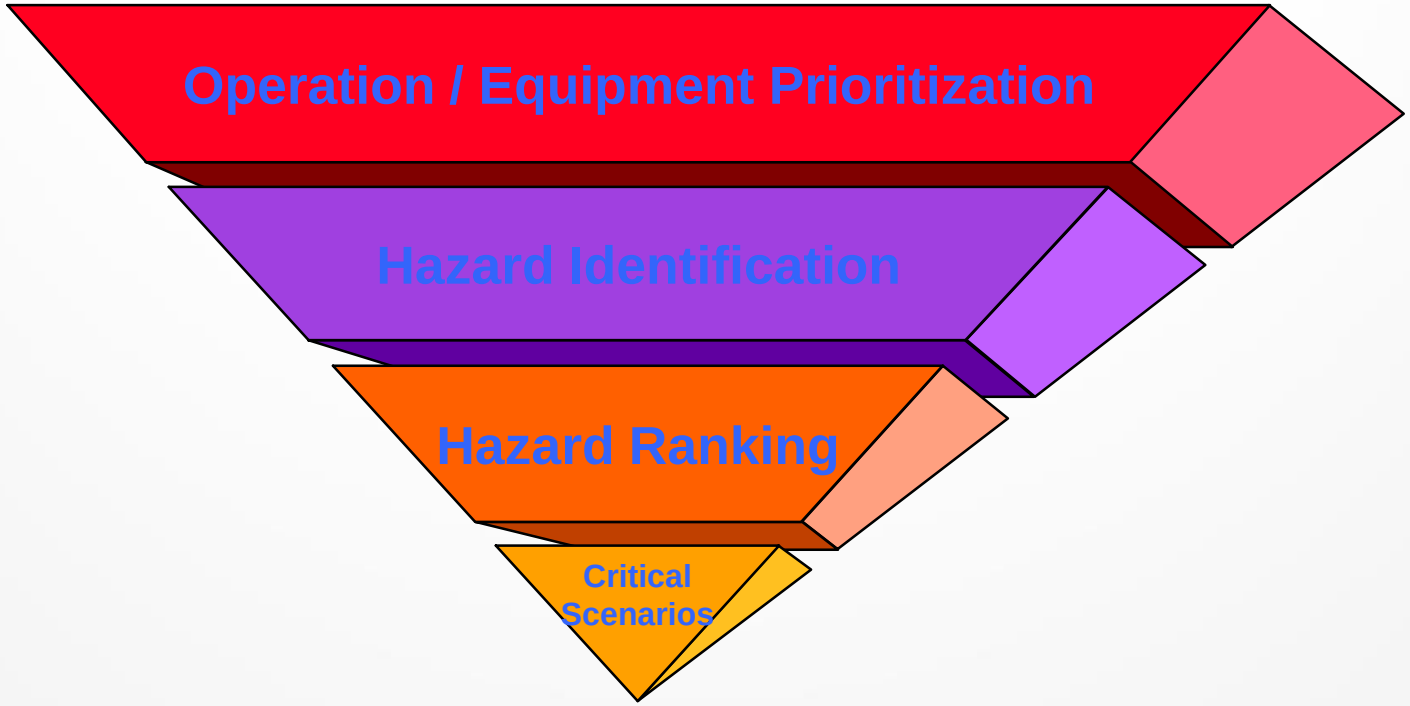
TABLE III. Risk assessment matrix

RISK ASSESSMENT MATRIX				
SEVERITY / PROBABILITY	Catastrophic (1)	Critical (2)	Marginal (3)	Negligible (4)
Frequent (A)	High	High	Serious	Medium
Probable (B)	High	High	Serious	Medium
Occasional (C)	High	Serious	Medium	Low
Remote (D)	Serious	Medium	Medium	Low
Improbable (E)	Medium	Medium	Medium	Low
Eliminated (F)	Eliminated			

Hazard Risk Assessment Matrix

SAFEGUARDS	S	L	R	RECOMMENDATIONS	S	L	R	Additional Standard Reference / Comments
Dust collection flow on system to keep 3500 to 4500 ft/min or below MEC Process interlocked to not run without dust collection Material allowed to Recirculated due to HEPA filter keeping concentrations below -PM 4653 Exhaust Test Annul N/S Furnace -PM 5107 Exhaust Test Annual Dust/Welding/Furnace -PM 5108 Exhaust Test Annual Line3/Wet Scrubbers Relief at dust collector	2	5	7	HEPA filtration needs pressure sensor with system shut off in the event of a HEPA filter failure (See A3 Action Item Summary line 29)	2	6	8	NFPA 652 8.3.5 AMS Clean Air Exhaust Recirculated Required – method for detecting AMS malfunctions that would reduce collection efficiency and allow increases in the amount of combustible particulate solids returned to the building. Filter – Provisions are incorporated to prevent transmission of flame and pressure effects from a deflagration in an AMS back to the facility unless a DHA indicates that those effects do not pose a threat to the facility or the occupants.

Level Setting
Critical Scenarios



- Highest risk areas that are difficult to manage

Level Setting
Critical Scenarios

Probabilistic Risk Assessment

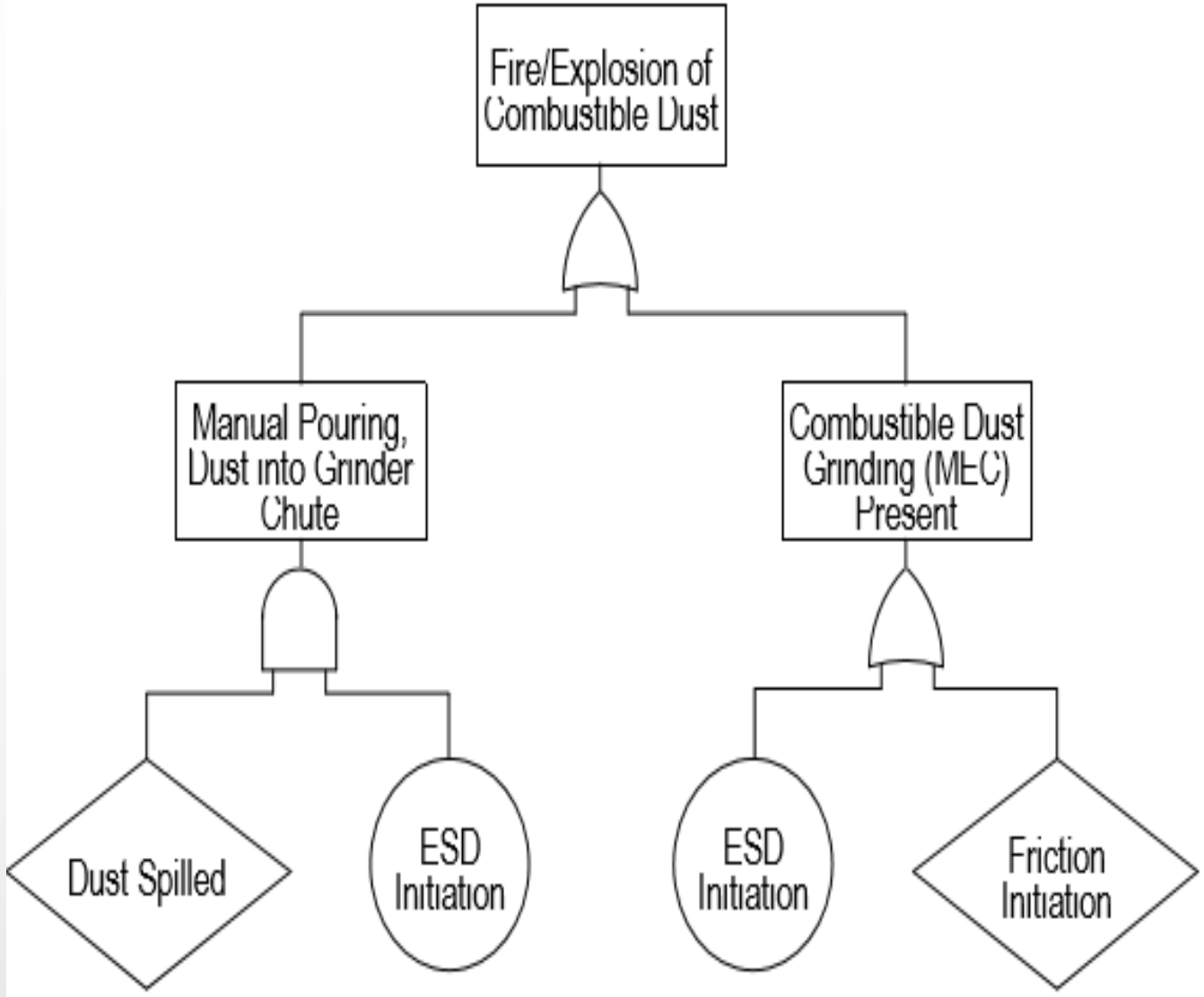
Fault Tree Analysis

- Event Probabilities
  - Equipment/Component Failure Data
  - Human Factors

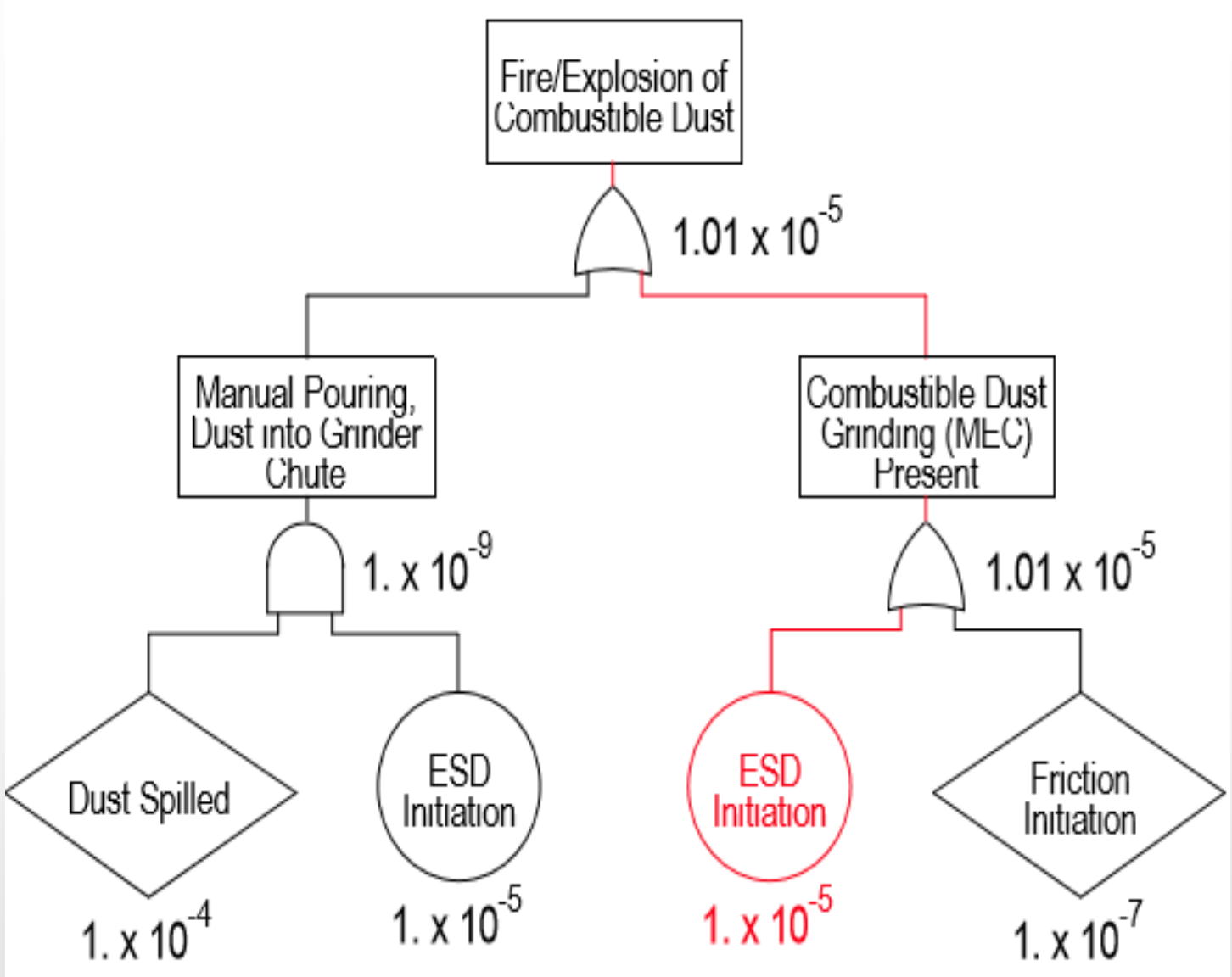
In-process/Operational Energies VS Material Response Characteristics

- Dust testing "Sensitivity" data (MIE, MIT, LIT, etc.)

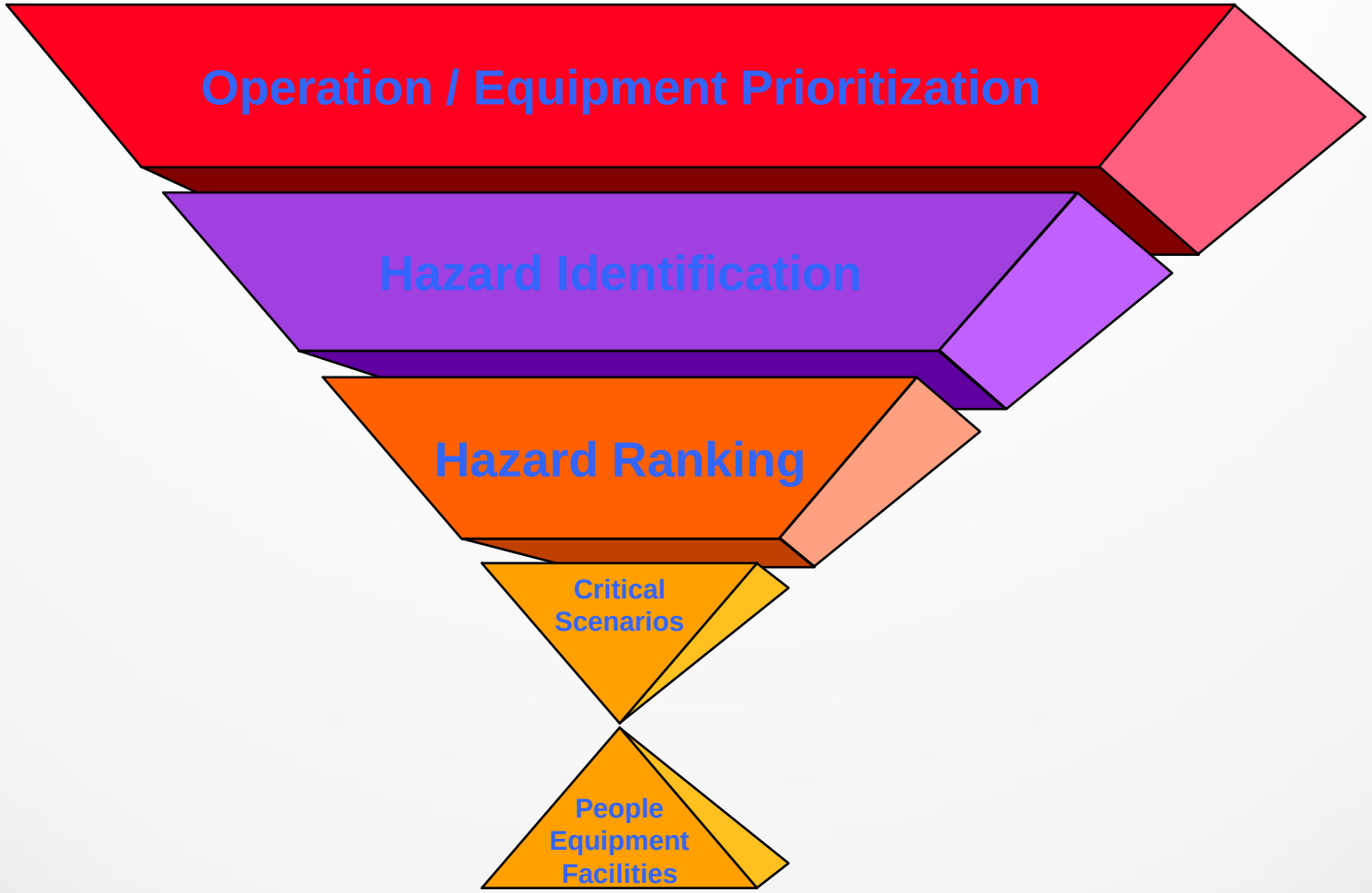
Logic Diagrams – Fault Tree



Logic Diagrams – Fault Tree



Level Setting
Consequence Analysis



Level Setting
Consequence Analysis

- Dust testing "Reactivity" (K_{st}, P_{max}, dP/dt, etc.)
- Thermal Flux
- Fragments
- Overpressure
- Equipment Design
- Facility Design

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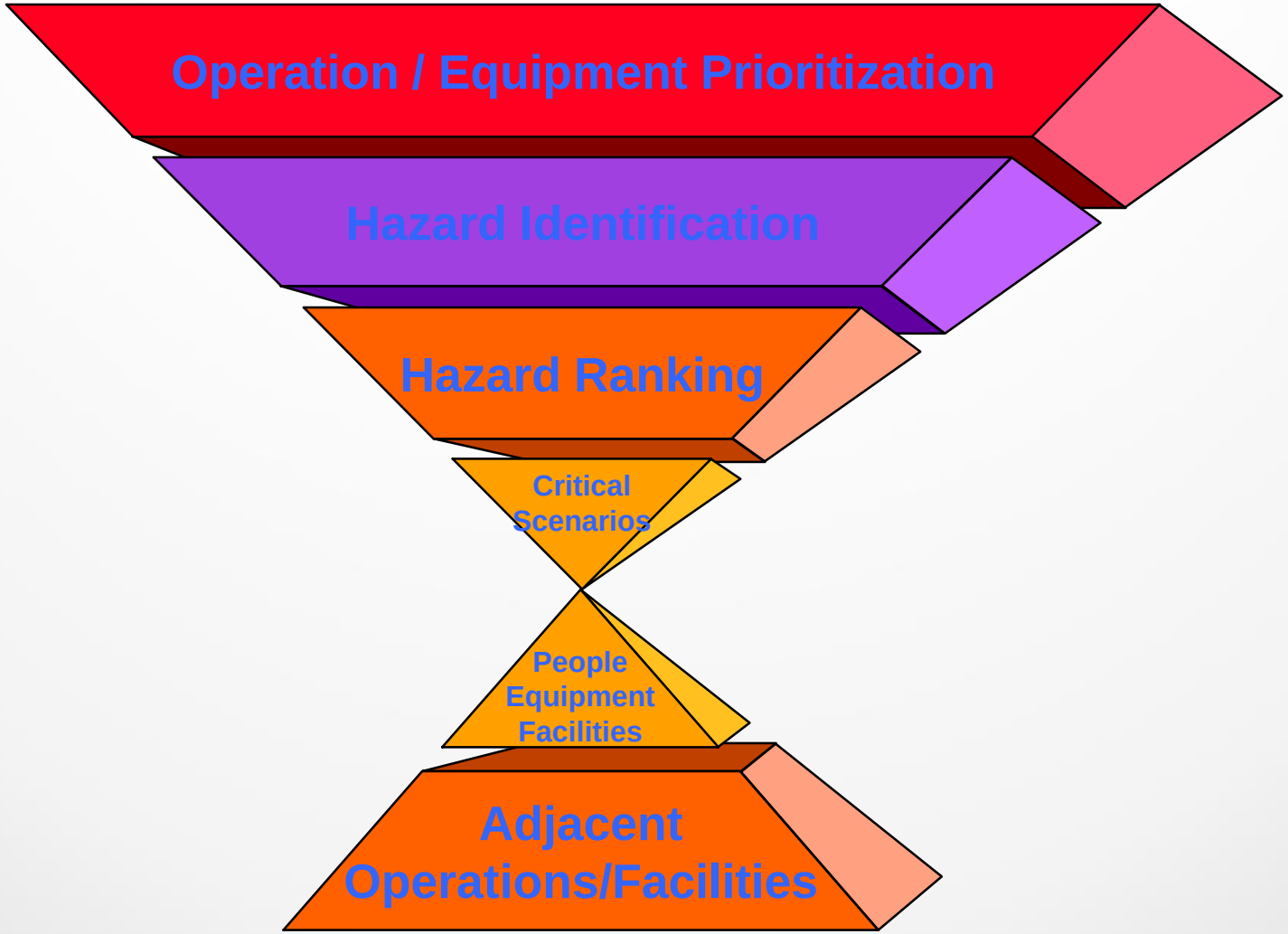
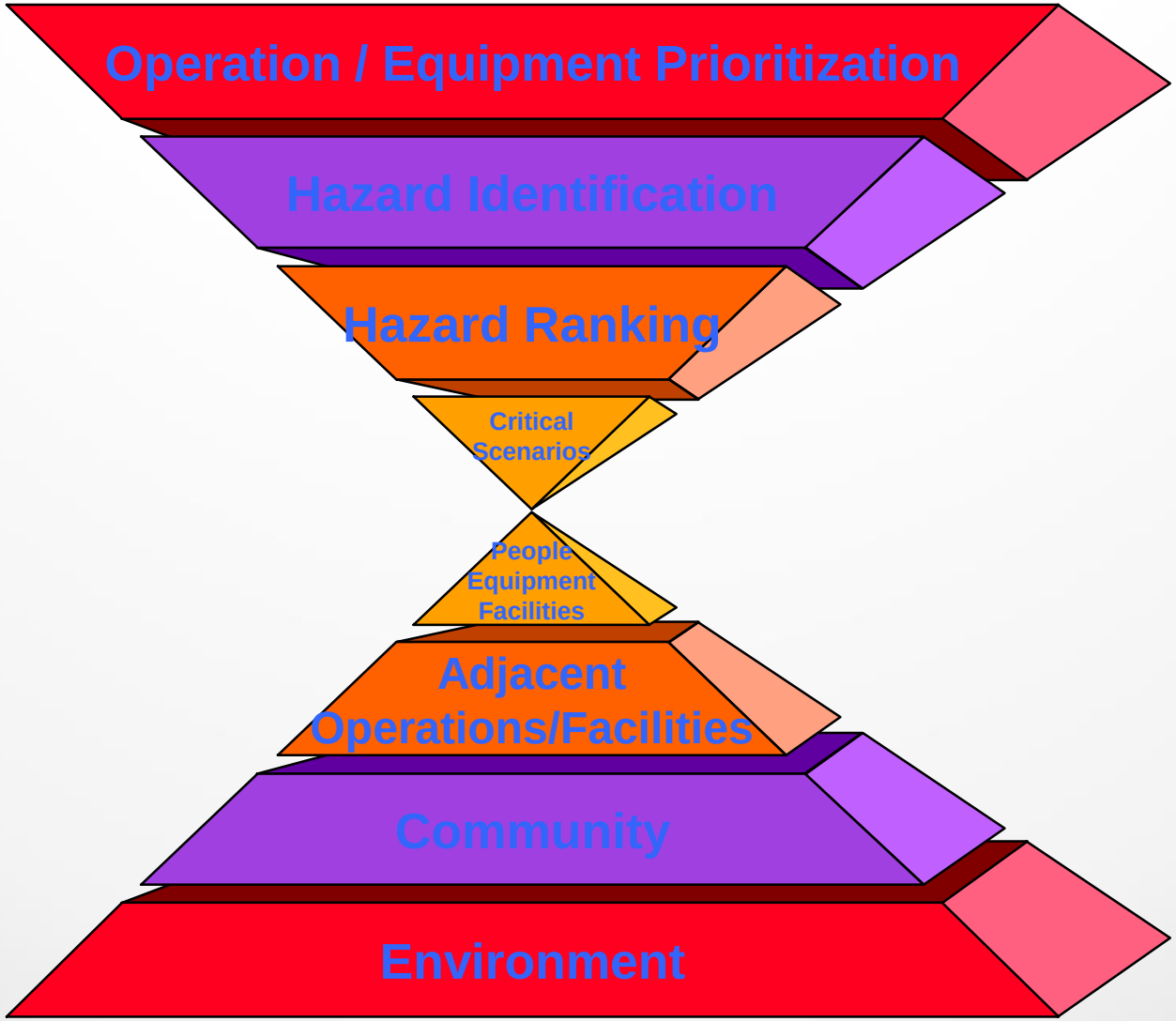
Level Setting
Consequence Analysis



Level Setting
Consequence Analysis

- Facility Design
  - Shielding
  - Venting
  - Dust migration/contamination
- Facility Siting
  - Distance
  - Location

Level Setting
Consequence Analysis

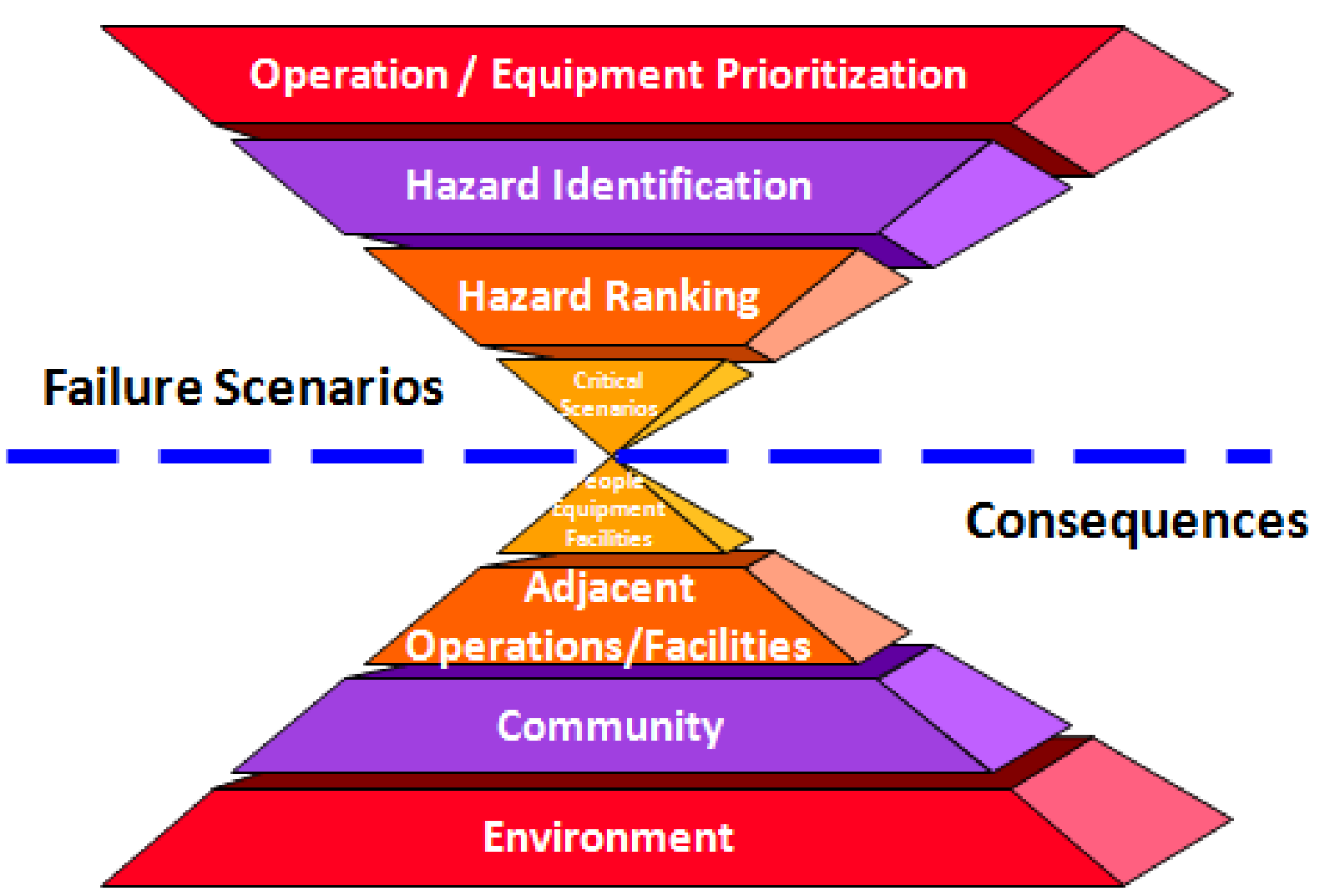


Level Setting
Consequence Analysis

Modeling

- Thermal
- Explosion
- Dispersion
  - Air
  - Ground

Level Setting
Consequence Analysis



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