Frontera Space Prevention Program Hazard Management Plan

Revision: 01

Frontera Space Document: 000011

1 PURPOSE

The purpose of the Frontera Prevention Program and Hazard Management Plan is to establish a complete and defensible set of controls that prevent chemical, mechanical, operational, and environmental hazards associated with hypergolic propulsion testing at the PTSD (Portable Test Stand by Dan). This program defines how Frontera identifies hazards, mitigates risks, structures safe operating procedures, trains personnel, manages detection and monitoring systems, and coordinates emergency response to ensure the protection of workers, the public, and surrounding property.

The Prevention Program consolidates all elements required for safe operations—including engineering controls, administrative controls, operational limits, PPE posture, emergency planning integration, regulatory compliance, and documentation requirements—into a single governing framework. It aligns with the expectations of EPA's Risk Management Program (40 CFR Part 68), EPCRA chemical inventory and planning requirements, and state-level Tier II and emissions obligations.

This section establishes the foundation for the broader safety architecture that governs all hypergolic activities at the Frontera PTSD stand and defines the principles upon which operating procedures and hazard controls are built.

mechanical, structural, and environmental hazards associated with hypergolic propulsion testing at the Frontera PTSD hypergolic stand. This report consolidates process safety information, hazard controls, SOP requirements, personnel safety posture, emergency integration, and administrative systems into one comprehensive prevention framework.

The report is structured to align with regulatory expectations under EPA RMP Part 68, EPCRA, and state-level Tier II requirements, while matching the engineering analysis style demonstrated in GigEngineer Document 000010.

2 SCOPE AND APPLICABILITY

Scope

This Prevention Program governs all hazardous operations at the PTSD involving monomethylhydrazine (MMH), MON-3/N_2O_4, and associated pressurants and support chemicals. It applies to all activities where chemical exposure, system activation, or hardware contact may occur.

Activities Covered

The Prevention Program applies to the following operational phases:

1. **Chemical Handling:** receipt, storage, staging, transfer, and controlled movement of MMH, MON-3/N_2O_4, and related substances.

2. **Test Operations:** pre-test verification, system energization, ignition/start, engine run, shutdown, purge, and post-test safeing.
3. **Maintenance:** inspection, troubleshooting, valve/hardware replacement, and any task involving potential contaminated-surface or wetted-component interaction.
4. **Monitoring & Detection:** operation, calibration, and data logging for all fixed and portable toxic-gas detectors.
5. **Abnormal Conditions:** spills, leaks, vapor events, power loss, over-pressure, emergency shutdowns, and any condition affecting safe operations.
6. **Personnel Safety:** PPE posture, technician roles, training, qualification, and exposure-response expectations.
7. **Documentation & Reporting:** hazard identification, incident investigation, regulatory filing support, and emissions/safety data retention.
8. **Emergency Interface:** alignment with internal emergency response procedures and external coordination with Williamson County LEPC, fire/EMS, and state/federal reporting channels.

Applicability

This program applies to:

- All Frontera Space personnel, contractors, and visitors working within or adjacent to the PTSD operational area.
- All systems, components, and equipment used in hypergolic test operations, including tanks, transfer lines, valves, regulators, instrumentation, purge systems, fire suppression, PPE stations, and decontamination systems.
- All locations associated with PTSD operations, including the test pad, control room, chemical storage areas, PPE staging areas, and decontamination zones.

Regulatory Alignment

This Prevention Program fulfills the prevention component required under:

- EPA Risk Management Program (RMP) – Program
- EPCRA emergency planning and Tier II chemical inventory reporting
- State chemical reporting, emissions planning, and spill-notification requirements
- OSHA Hazard Communication and applicable elements of 29 CFR 1910 for chemical operations

3 FACILITY DESCRIPTION

Overview

PTSD is an atmospheric hypergolic propulsion test facility designed for engine development, system checkout, and component-level firing using monomethylhydrazine (MMH) and MON-3/N_2O_4. The facility is configured to support controlled hazardous operations with engineered containment, remote actuation capability, and dedicated detection and emergency systems.

Location	Distance from test stand (ft)
Frontera	300
183	450
business	750
138	900
residence	1050

Location & Layout

PTSD is located on approximately 20 acres under Frontera Space control. The test area includes:

1. **Test Pad:** reinforced open-air pad supporting the engine test article, thrust frame, and instrumented test hardware.
2. **Propellant Storage & Feed System:** hardened tanks, transfer lines, isolation valves, pressurant interface, and secondary containment.
3. **Control Area:** remote-operated control station equipped with displays, communication systems, and integrated alarm/monitoring.

4. **PPE & Safety Zone:** staging area for PPE donning/doffing, SCAPE gear, breathing air packs, and emergency shower/eyewash.
5. **Decontamination & Waste Area:** washdown zone, neutralizer storage, waste drums, and controlled disposal interface.
6. **Detector Network:** fixed Dreagor MMH and NO_2/N_2O_4 detectors positioned at tank farm, valve panels, test article, and PPE space.
7. **Support Infrastructure:** nitrogen and helium bottle banks, purge systems, fire extinguishers, spill kits, lighting, and environmental monitoring.

Chemical Inventory (Maximum On-Site for PTSD)

- **MMH:** 735 lb
- **MON-3/N_2O_4:** 1,200 lb
- **IPA:** 815lbs
- **Pressurants:** Nitrogen 1-12pack K bottles (2736cuft) Helium 1-6 pack K Bottles (1314 cuft)
- **Deionized Water:** for purge, cool-down, and decontamination operations 1042lbs
- **Propane:**1000 gallons/4200lbs

These inventories exceed federal EPCRA Threshold Planning Quantities (TPQs) and RMP thresholds for MMH and N_2O_4, requiring structured Prevention and Emergency Response programs.

Operational Characteristics

PTSD is engineered for:

- Remote actuation of valves, ignition systems, and emergency shutdown equipment
- Full inert-gas purge capability for lines, manifolds, and engine cavities
- Controlled fuel/oxidizer interface with minimal exposed hardware
- Rapid isolation of propellant systems (target ≤5 seconds from command)
- Constant atmospheric monitoring for MMH and N_2O_4 vapors
- Integrated fire and heat-detection elements tied to shutdown logic

Environmental Context

PTSD operations are open-air but controlled within a defined exclusion radius. Hypergolic vapor propagation is strongly wind-direction dependent, and operations must comply with exclusion zones identified by plume-modeling analysis. Weather conditions—wind direction, temperature, and approach of freezing conditions—are actively monitored prior to hazardous operations.

Personnel Presence

PTSD is staffed at minimum operational manning levels:

- Primary Technician
- Secondary Technician

- Safety Observer
  Additional PPE-equipped responders are staged near, but outside, the hot zone.

Personnel operate under defined PPE Postures A/B/C depending on contact risk, contamination potential, and operational phase.

4 Hazard Identification & Analysis Summary

Overview

Hazard identification for PTSD incorporates chemical behavior, system-level failure modes, historical hypergolic handling data, and validated dispersion modeling. The analysis focuses on credible failure scenarios involving MMH and MON-3/N_2O_4, both of which present acute inhalation and contact hazards. The goal of the hazard review is to determine the controlling accident cases, define the operational boundaries required for safe testing, and identify engineering and administrative controls necessary to prevent exposure.

Analytical Basis

Hazard characterization is derived from the following sources:

1. **Hypergolic Dispersion Analysis** (GigEngineer Document 000010) — ALOHA/CAMEO modeling for vapor propagation under varying meteorological conditions.
2. **Component Failure Modes & Effects Analysis (CFMEA) —** evaluates single-point failures in tanks, lines, valves, pressurant systems, and ignition hardware.
3. **Operational Hazard Review —** identifies risks originating from transfer operations, purge/vent sequencing, ignition, shutdown, and contaminated-surface interaction.
4. **Chemical Properties & Reactivity —** vapor pressures, boiling behavior, decomposition modes, and incompatibilities of MMH and MON-3/N_2O_4.
5. **Environmental Conditions —** wind speed, wind direction, temperature, and potential for freezing or stratification.

Primary Hazard Drivers

Key hazard categories for PTSD include:

- **Toxic vapor release** from MMH or NO_2/N_2O_4
- **Liquid spills and pool evaporation**
- **Pressurant-system failure or over-pressurization**
- **High-temperature ignition sources** in proximity to reactive chemicals
- **Incompatible material exposure** leading to violent reaction
- **Emergency system failures** such as loss of purge capability or valve non-closure
- **Weather-driven propagation** of toxic vapors into occupied areas

These hazards are controlled through engineered shutdown mechanisms, administrative boundaries, PPE posture, and real-time detection.

Controlling Accident Cases

Two scenarios govern the upper bound of vapor propagation and personnel impact:

Case 1: Steady-State Leak

- 0.050 in^2 effective breach in a tank or line
- Atmospheric-pressure release with continuous vaporization
- Produces a narrow but elongated downwind AEGL plume

Case 2: Line Burst / Pool Formation

- ½-inch line rupture at MEOP
- ~1 gallon/second release for 5 seconds (5-gallon pool)
- Rapid oxidizer boil-off; full evaporation in <5 minutes
- Represents the worst-case toxic exposure scenario
- Dispersion modeling shows that hazardous vapor regions are highly directional, forming narrow plumes aligned with the wind vector and limited to approximately ±10° from centerline.

Wind-Direction Exclusion Zones

To prevent downwind exposure, hazardous operations may not proceed when the wind is within the exclusion sectors defined by plume modeling:

- **Sector 1: 70°–90°**
- **Sector 2: 190°–340°**

No test, fuel transfer, or pressurized operation may begin if sustained winds fall inside these sectors. Compliance is verified during pre-ops and monitored continuously.

Key Findings

- AEGL-2 and AEGL-3 exposure distances do **not** reach off-site public receptors under any modeled scenario.
- AEGL-1 exposure is possible downwind if exclusion zones are not enforced.
- Toxic propagation is dominated by **wind direction**, not ambient temperature or humidity.
- MMH evaporates more slowly than N_2O_4; oxidizer releases define the controlling toxic endpoint.
- Worst-case evaporation events dissipate rapidly (<5 minutes), but still require immediate evacuation and remote shutdown.

Implications for Prevention Program

The hazard analysis defines:

- Required exclusion sectors

- Required response times for valve isolation
- Minimum PPE posture for each phase
- Detector placement and alarm thresholds
- SOP boundaries for transfer, purge, and ignition
- Training and emergency planning priorities
- Documentation needed to satisfy RMP hazard-review expectations

5 PREVENTATIVE ENGINEERING CONTROLS

Overview

Preventative engineering controls at PTSD are designed to eliminate, isolate, or mitigate hazards associated with MMH and MON-3/N_2O_4 handling, transfer, and engine testing. These controls form the primary physical barrier against toxic release, over-pressure, ignition, and contamination events. Each engineered safeguard is integrated into the system architecture to reduce reliance on human intervention and ensure predictable, fail-safe behavior.

5.1 Propellant Storage, Transfer, and Containment

- **316 Stainless Steel Propellant Lines**
  All wetted components carrying MMH or MON-3/N_2O_4 are constructed from ½-inch, 0.035-wall 316 stainless steel tubing, with a burst rating of 15,000 psi against a maximum operating pressure of 1,000 psi. This provides substantial structural margin and protects against mechanical damage, abrasion, vibration loading, and inadvertent impact.
- **Remote Isolation Valves (≤5-second closure target)**
  All primary and secondary isolation valves are remotely actuated and tied directly into the emergency-shutdown logic. The system is designed to cut off propellant flow within five seconds of a leak indication, toxic-gas alarm, or abnormal operating condition.
- **Secondary Containment at Tanks and Manifolds**
  Tanks, feed manifolds, and wetted interface components are located within engineered spill basins and rigid secondary containment barriers. These structures prevent soil penetration, uncontrolled pooling, or runoff in the event of a liquid spill, and support rapid neutralization and collection during decontamination.
- **High-Integrity Seals and Fittings**
  All threaded connections, flanges, and quick-disconnect fittings are rated for hypergolic compatibility, pressure cycling, and chemical resistance. Components are selected to minimize leak probability and provide repeatable sealing under thermal and mechanical loading.
- **Flare Stacks for Controlled Release and Passivation**
  All burst disks, vent lines, emergency depressurization paths, and isolation-vent circuits terminate at either the oxidizer-side or fuel-side flare stack. Each flare stack incorporates a 2,950-watt thermal passivator coupled with propane-fired flare capability to safely combust or thermally neutralize MMH or MON-3 vapors during emergency venting or controlled releases.

5.2 Pressure, Flow, and Thermal Protection

- **Pressure Relief Systems**
  Each tank, manifold, and transfer line is protected with pressure relief valves or burst disks sized to prevent over-pressure under abnormal conditions, including thermal expansion, line plugging, regulator malfunction, or inadvertent valve closure. Relief devices are selected to ensure predictable, fail-safe venting behavior and are tied into controlled vent paths leading to the flare stacks for safe neutralization.
- **Pressurant-System Isolation**
  Pressurant interfaces incorporate check valves, regulators, relief valves, and full physical down stream segregation between fuel, oxidizer, and inert-gas systems. The pressurant Source is segregated with triple redundancy check valves with a failsafe interlock. These measures prevent any backflow of MMH or MON-3/N_2O_4 into nitrogen or helium lines, eliminating the risk of high-energy reactions or contamination that could compromise pressurant integrity or control authority.
- **Temperature Protection and Freeze Hardening**
  Heat-tracing, environmental shielding, or temperature-controlled enclosures are used to prevent cold-weather solidification or viscosity shifts in MON-3/N_2O_4 and ensure predictable flow, valve response, and leak-detection behavior. These controls maintain chemical stability, reduce mechanical stress on seals and lines, and ensure reliable system performance during low-temperature operations.

5.3 Purge, Vent, and Inerting Systems

- **Dedicated Purge Paths**
  All wetted volumes—including transfer lines, injector passages, tank outlets, manifolds, and isolation-valve cavities—are routed through dedicated purge lines. Standard purge sequencing is:

  GN_2 → Deionized Water → IPA → GN_2 → Vacuum

  This sequence ensures removal of trapped oxidizer or fuel, dissolution and displacement of residual contaminants, solvent-assisted drying, and final inerting prior to maintenance, reconfiguration, or safeing. All purge effluent is directed to the appropriate fuel-side or oxidizer-side flare stack for controlled thermal passivation.
- **Controlled Vent Paths**
  All vent paths—including burst disk outlets, depressurization circuits, and purge exhausts—terminate at designated elevated flare stacks equipped with 2950-watt thermal passivators and propane-fired flare capability. Vent routing prevents ground-level vapor accumulation, minimizes recirculation, and ensures consistent dispersion behavior under varying environmental conditions.
- **Trickle Purge (5 psig GN_2)**
  After the standard purge sequence is completed, all applicable circuits are maintained under a continuous 5 psig GN_2 trickle purge. This prevents ambient air ingress, inhibits moisture absorption, and maintains long-term chemical isolation between MMH and MON-3/N_2O_4 systems.

- **Backflow Prevention**
  Non-return valves, flow-direction hardware, and purge interlocks are installed throughout the purge and vent network to eliminate cross-contamination between fuel, oxidizer, and inert-gas systems. These controls ensure one-way flow integrity during all purge, transfer, and depressurization operations.

5.4 Fire and Ignition Protection

Integrated Fire Detection

PTSD employs high-optical-zoom PTZ cameras positioned to provide continuous remote observation of the test article, propellant interfaces, feed systems, and surrounding structures during all hazardous operations. These cameras enable real-time identification of flame onset, abnormal thermal behavior, smoke evolution, and other ignition indicators. Remote visual monitoring supports rapid confirmation of alarms and automated-shutdown events while keeping personnel out of the hot zone.

Fire Suppression Systems

PTSD incorporates two independent fire-suppression systems designed to address both localized ignition hazards and broader area fires during steady-state and extended-duration testing.

1. Local Test Stand Suppression System

A dedicated suppression system is mounted directly on the test stand and provides immediate fire knockdown and cooling at the point of ignition. System attributes include:

- 125 gallons of deionized water as the suppression medium
- Inert-gas pressurization for rapid discharge
- Spray and deluge nozzles directed at the engine, feed system, valves, and wetted components

This system mitigates ignition from line failures, hardware overheating, or localized flame exposure. Activation is either manual (Test Director or Safety Observer) or software controled (pending final design).

2. Full-Area Fire Suppression / Wet-Down System

A secondary suppression system covers the entire test-site operational footprint and is manually triggered by the Test Director. The system provides:

- Large-area application for test-stand wet-down
- Vapor suppression for oxidizer or fuel vapor clouds
- Cooling of adjacent structures, ground surfaces, and hardware
- Containment for spreading fires or ignition events beyond the local system's reach

This system is employed as a full-stand wetdown for emergency containment. This is a hardwired trigger for manual control and safety.

System Compatibility

Both fire-suppression systems utilize agents, valves, and distribution hardware that are compatible with MMH and MON-3/N_2O_4, ensuring that no suppression action exacerbates combustion, reactivity, or thermal decomposition.

Ignition Source Control

All electrical enclosures, wiring harnesses, instrumentation lines, grounding systems, and power sources associated with PTSD are engineered to prevent arcing, sparking, or excessive surface heating capable of igniting hypergolic vapors.

- Ignition-source mitigation includes:
- Comprehensive grounding and bonding throughout the test stand
- Static-control measures on tooling and equipment
- Isolation of all non-essential electrical power during hazardous operations
- Verification that all tools, devices, and temporary equipment introduced into the hot zone meet ignition-control requirements

These measures ensure that no unintended ignition source is present during fuel/oxidizer operations, minimizing the likelihood of fire initiation.

5.5 Toxic Gas Detection and Automated Interlocks

Fixed Detection Network

PTSD employs a multi-layer fixed toxic-gas detection system using Dräger PointGard 3100 industrial detectors, configured in three paired sets with:

- One NO_2 sensor for MON-3/N_2O_4 detection
- One MMH / hydrazine-class sensor for fuel vapor detection

Detectors are installed at critical hazard zones where vapor generation or leakage is most likely:

- Tank storage and valve panel
- Test article interface and feed system region
- Hardware decontamination and bake-out oven area

This configuration provides continuous, redundancy-backed monitoring of oxidizer and fuel vapor concentrations throughout all operational phases.

Personnel-Worn Gas Detectors

All personnel entering hazardous or potentially contaminated areas are equipped with Dräger X-am series detectors, providing individual exposure protection and redundant sensing:

- X-am 5800 units configured with NO_2 sensors for oxidizer monitoring
- X-am 5100 units configured with hydrazine/MMH sensors for fuel monitoring

These detectors provide near-body detection of local vapor concentrations and serve as the final protective layer during operations near wetted components or recently decontaminated hardware.

Automated Shutdown Logic

The toxic-gas detection network interfaces directly with PTSD's safety architecture. A Tier-3 alarm from any Dräger PointGard 3100 detector triggers an immediate facility alarm. Upon Tier-3 activation, the Test Director executes the automated shutdown procedure to autonomously safe the stand. The automated safeing sequence includes:

- **Remote isolation** of all propellant feed lines
- **Automatic GN_2 purge initiation** through all connected purge paths
- **Mandatory evacuation** of all personnel and control-room lockout
- **Automated alarm notifications** to the Test Director, Safety Observer
- **Tier-1 and Tier-2 alarms** require operator acknowledgement and verification actions, with responses scaled based on the measured concentration relative to safe-exposure limits.

Regulatory Exposure Limits and Alarm Tiers

Substance (CAS)	Regulatory limits (representative)	Tier 1 Limit	Tier 2 Limit	Tier 3 Limit
Monomethylhydrazine (CH_3NHNH_2) (CAS 60-34-4)	OSHA PEL: C 0.2 ppm	0.05 ppm	0.10ppm	0.2 ppm
MON-3 (N_2O_4/NO + reported as NO_2 equivalents) (NO_2 CAS 10102-44-0)	OSHA PEL: C 5 ppm	1.25 ppm	2.5ppm	5 ppm

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Alarm Tier Definitions

Tier 1 Alarm — 25% of Safe Exposure Limit

- Alarm annunciated locally on Dräger 3100
- Notification to Test Operator and test team
- Indicates early presence of hazardous vapors
- Operations continue while source is identified and monitored
- No personnel evacuation required, but increased readiness is expected

Tier 2 Alarm — 50% of Safe Exposure Limit

- Alarm annunciated locally and in the control system

- Indicates a significant concentration of hazardous chemical
- All personnel in the hazard zone must immediately exit
- Stand should be placed in a safe, non-flow configuration
- Test Director prepares for potential Tier-3 escalation

Tier 3 Alarm — 100% of Safe Exposure Limit

- Full-facility alarm activates
- Mandatory immediate evacuation of all personnel
- Only personnel in full SCAPE Level-A encapsulation may enter the hazard area
- Automated emergency shutdown procedure is initiated by the Test Director
- Stand cannot be re-entered until cleared by gas-monitoring verification

Continuous Data Logging

All fixed toxic-gas detection systems report into a centralized monitoring and logging framework that records:

- Time-stamped concentration measurements
- Alarm-event logs and operator acknowledgements
- Detector calibration status and sensor-health diagnostics
- Real-time test-site wind direction and wind speed for plume-behavior correlation and hazard-zone validation

This data is retained in accordance with Frontera documentation policy to support:

- Regulatory compliance
- EPA RMP Prevention Program audits
- Incident reconstruction and root-cause analysis
- Long-term performance trending and sensor reliability assessment

5.6 Emergency Shutdown and System Safeing Capability

Manual and Automated E-Stop

Redundant E-Stop systems allow either remote or local initiation of:

- Valve closure
- Power shutdown
- Pressurant isolation
- Forced inert purge

Fail-Safe Valve Positions

Valves revert to a closed or isolated state upon loss of power, control signal, or communication.

Backup Power for Critical Systems

PTSD is equipped with 30 minutes of backup electrical power supplying both the test stand and the operations center. This power reserve provides more than sufficient time to execute all required safeing actions following a loss of primary power.

Backup power maintains functionality for:

- Remote valve isolation
- GN_2 purge initiation and sustained purge flow
- Toxic-gas detection systems
- Control-system interfaces and alarm annunciation
- PTZ camera monitoring
- Communication and command systems

The stand is engineered to reach a fully safe configuration under backup power and also supports several intermediate safeing states. In these conditions, any residual propellant, vapors, or contaminated purge effluent can be temporarily routed and stored in a dedicated accumulator system if the thermal passivator or flare stack becomes inoperative.

This ensures that even in multi-fault scenarios—loss of power combined with loss of flare capability—PTSD maintains a controlled, non-hazardous configuration until full systems restoration or manual intervention under SCAPE conditions.

Engineering Control Intent — SEMP-Formatted

The engineering controls described in this section collectively establish the physical, mechanical, and automated safety foundation for PTSD operations. Together, these controls ensure:

- **Minimization of leak probability** through robust materials, redundant isolation, and high-integrity fittings
- **Rapid containment and isolation** of any release via abort/automated shutdown sequencing, purge capability, and controlled vent routing
- **Prevention of fuel/oxidizer mixing** outside the engine through strict system segregation, backflow protection, and inerting protocols
- **Protection of personnel** from acute exposure through fixed and portable detection systems, structural separation, and safe-zone enforcement
- **Protection of the public and environment** by preventing off-site vapor transport and ensuring controlled neutralization of all vented materials
- **Full alignment with EPA RMP Prevention Program requirements**, EPCRA planning standards, and Frontera Space internal safety criteria

These engineering controls form the primary barrier against chemical release, ignition, or exposure and define the baseline operational safety envelope for all hypergolic testing at PTSD.

6 ADMINISTRATIVE CONTROLS

Administrative controls establish the procedural, organizational, and personnel-based safeguards required to support the engineering controls described in Section 5. These controls define how personnel operate the PTSD safely, ensure consistent execution of critical tasks, and maintain compliance with regulatory and internal safety standards.

6.1 Required Standard Operating Procedure (SOP) Categories

The following SOPs are required for all hazardous operations at PTSD. Each SOP must clearly define scope, responsibilities, required PPE posture, step-by-step actions, verification points, and contingency actions.

- **Chemical Transfer & Fill Procedures**
  Defines methods for receipt, storage, transfer, controlled fill, and pressurization of MMH and MON-3/N_2O_4 systems.
- **Verification Steps and Pre-Test Checklist**
  Covers pre-operational inspections, sensor verification, weather checks, readiness confirmation, leak checks, and system activation criteria.
- **Two-Person Rule Enforcement**
  Ensures no technician performs hazardous operations alone and establishes communication and supervision requirements.
- **Lockout/Tagout Procedures**
  Controls hazardous energy isolation, safe disconnection of systems, electrical isolation, and mechanical lockout steps.
- **Go/No-Go Criteria and Readiness Confirmation**
  Establishes pass/fail checkpoints required before progressing to ignition/start. Includes wind-sector validation per hazard modeling.
- **Ignition / Start Sequencing**
  Defines procedural steps for controlled activation of the test article, timing of pressurant engagement, telemetry verification, and safety interlocks.
- **Controlled Shutdown and Purge**
  Defines standard and emergency shutdown actions, purge sequence (GN_2 → DI Water → IPA → GN_2 → Vacuum), and return-to-safe-state criteria.
- **Leak Isolation and Contamination Control**
  Covers immediate response actions, hot-zone isolation, SCAPE-entry criteria, vapor monitoring, and stabilization of compromised systems.
- **Maintenance of Wetted Components**
  Defines procedures for inspection, decontamination, drying, purge validation, pressure testing, and reassembly of wetted systems.

- **Cold-Weather Operations**
  Establishes freeze protection steps, heat-trace verification, MON-3 temperature stabilization requirements, and cold-weather hazard mitigations.
- **Decontamination and Decommissioning**
  Details methods for hardware washdown, neutralizer use, waste segregation, bake-out operations, safe disposal, and long-term storage criteria.

All SOPs must undergo annual review or immediate revision following equipment changes, procedural changes, or incident lessons learned.

6.2 Training Requirements

All personnel participating in or supporting PTSD operations must complete a comprehensive training program covering emergency preparedness, hazardous-material handling, and hypergolic safety. These training requirements ensure personnel are qualified to safely support operations involving MMH and MON-3/N_2O_4.

- **Emergency and Fire Preparedness Training**
  Covers emergency alarm recognition, toxic vapor response, fire behavior, firefighting limitations in hypergolic environments, muster procedures, evacuation routes, and Test Director communication protocols.
- **Hazardous Chemical Communication (GHS)**
  Training on Global Harmonized System (GHS) classifications, label interpretation, Safety Data Sheet (SDS) navigation, hazard pictograms, and chemical compatibility requirements.
- **HAZWOPER — Hazardous Waste Operations and Emergency Response**
  Provides regulatory training for hazardous-material handling, contaminated hardware management, spill response fundamentals, decontamination methods, hazardous waste classification, and emergency response roles under 29 CFR 1910.120.
- **Hazardous Waste Operations (on-site implementation)**
  Covers handling of contaminated DI water, IPA waste streams, purge residue, bake-out oven off-gas management, containerization, labeling, and compliant storage and disposal procedures.
- **Lockout/Tagout (LOTO)**
  Required when electrical interactions, mechanical isolation, pressure-system isolation, or stored-energy interactions occur during maintenance or stand configuration. Includes identification of energy sources, lockout devices, and authorized-personnel requirements.
- **PPE and Respirator Fit Testing**
  Ensures personnel are properly fitted and qualified for using full-face respirators, supplied-air systems, and emergency-use respirators. Includes annual fit-testing and medical clearance as required by OSHA 1910.134.
- **SCBA Pack Operation**

Hands-on training in the safe use of supplied-air breathing apparatus including donning, pre-use checks, operational procedures, emergency bottle switching, and post-use inspection.

- **SCAPE Suit Operation (Level A Encapsulated Suit)**
  Training for working in fully encapsulated SCAPE suits during maximum-hazard conditions, including mobility limitations, heat-stress management, air-management protocols, and safe decontamination/egress procedures.
- **Hypergolic Safety Training**
  Comprehensive instruction in the properties of MMH and MON-3/N_2O_4, vapor behavior, reactivity, physiological effects, spill characteristics, incompatibilities, and operational hazards specific to PTSD.
  Includes ignition-source avoidance, situational awareness, and scenario-based emergency decision-making.

Training Documentation Requirements

All training must be documented, maintained, and verified prior to authorizing personnel for operational roles.
Refresher training is required annually, or sooner if:

- Systems or procedures change
- New hazards are introduced
- An incident or near-miss necessitates retraining
- Regulatory requirements change

7 Personnel Protection Posture (PPE Matrix)

Personnel PPE requirements at PTSD are organized into three operational postures (A, B, and C), each defining the minimum protective equipment required based on hazard level, proximity to wetted systems, and likelihood of vapor or liquid exposure. The Test Director determines posture requirements before each operation based on activity type and prevailing conditions.

Posture A — Low-Contact Activation & Monitoring

Posture A applies to operations where personnel are not in direct contact with wetted hardware or interacting with any single fault hardware and where only routine activation, observation, or control-room duties are being performed. Routine activation is limited to pressurant mechanical valve safeing/opening while other redundant safey systems closed. Software or IT hardware interaction only when disconnected from stand. Minimal exposure potential exists, but readiness for escalation is required.

Required PPE:

- Splash-resistant clothing
- Safety observer with supplied-air respirator equipped with escape bottle on standby

Posture B — Moderate-Contact Hardware Interaction

Posture B applies to maintenance, connection, inspection, or configuration activities involving potential contact with wetted components, purge lines, or hardware recently exposed to MMH or MON-3/N_2O_4. including energized click checks or wetted component testing or interaction with the stand. Safety Observer must be on standby and work procedures need to be filed with Test Director or Stand Safey Officer.

Required PPE:

- Full chemical-protective clothing
- Chemical-resistant boots
- Butyl/Viton double layer gloves
- Full face SCBA or supplied-air respirator

Posture C — Known Contamination or Spill Environment

Posture C is the maximum-protection posture and is used under confirmed contamination, spill response, vapor intrusion, abnormal alarm conditions, or during entry into the hot zone after a Tier-3 event. Safety Observer must be on standby with work procedures needing to be filed with Test Director or Safety Officer.

Required PPE:

- Full SCAPE / Level A fully encapsulated suit
- Independent supplied-air system with communications pack
- Redundant air-supply verification prior to entry
- Only trained SCAPE-qualified personnel are permitted to operate under Posture C.

Emergency Decontamination Resources

PTSD maintains comprehensive decontamination assets to support all PPE postures and emergency scenarios:

- **Shower/eyewash systems** located near the hot zone and personnel staging areas
- **Neutralizing absorbents** for hypergolic spill mitigation
- **Containment drums** for holding contaminated PPE, foils, absorbents, and hardware

- **Waste-segregation capability** compliant with hazardous waste, incompatible materials, and hypergolic byproduct requirements

8 DETECTION, MONITORING & ALARM STRATEGY

See Section 5.4

9 EMERGENCY RESPONSE PROGRAM INTEGRATION

The Emergency Response Program (ERP) defines the coordinated actions required to protect personnel, equipment, and the public during abnormal, alarm, or emergency conditions at the PTSD. The ERP integrates internal response procedures with external emergency agencies to ensure a unified and compliant response to hazardous-material incidents.

9.1 Internal Emergency Response Coverage

The ERP addresses all credible emergency scenarios associated with MMH and MON-3/N_2O_4 operations, including:

- **Liquid Spill / Pool Formation**
  Response procedures for contained and uncontained liquid releases, including isolation, neutralization, and contamination control.
- **Vapor Cloud Release**
  Actions for toxic-vapor alarms, plume tracking based on wind-sector data, evacuation, shelter-in-place decisions, and external notification.
- **Long-Dwell Contamination**
  Protocols for handling hardware or areas with sustained chemical presence, including SCAPE-entry requirements and decontamination workflows.
- **Fire and Explosion Events**
  Covers ignition events, hypergolic fire behavior, suppression activation, stand safeing, and post-event cooldown requirements.
- **Electrical Fires**
  Response steps for energized-equipment fires, isolation, safe re-entry, and interface with lockout/tagout procedures.
- **Power Loss or Critical Systems Failure**
  Ensures safe transition to backup power, stand safeing, and facility evacuation if required.
- **Toxic Gas Alarms**

Tier-based escalation for monitoring, egress, stand isolation, notification, and confirmation of all-clear conditions.

- **Over-Pressure Events**
  Response to burst-disk activation, uncommanded venting, or abnormal pressure-rise in propellant or pressurant systems.
- **Pressurant Release & Oxygen Deficiency Hazard (ODH)**
  Mitigation of GN_2 / pressurant releases, ODH monitoring, exclusion zones, and personnel rescue posture.
- **Emergency Stop (E-Stop) and Equipment Safeing**
  Immediate stand isolation, purge initiation, and lockout of all hazardous energy systems.
- **Personnel Injury and Rescue**
  Protocols for first aid, SCAPE-assisted rescue, EMS activation, and incident documentation.

9.2 External Integration and Coordination

PTSD operations interface with external safety, regulatory, and emergency-response stakeholders to ensure a unified and compliant approach to hazard communication, emergency planning, and incident response. Coordination with these agencies ensures readiness for all credible emergency scenarios involving MMH and MON-3/N_2O_4.

Williamson County LEPC

A formal coordination meeting with the Williamson County Local Emergency Planning Committee (LEPC) is scheduled for 12/5.
This engagement establishes alignment on:

- Plume modeling assumptions and hazard zones
- Alarm-notification pathways
- Community hazard-communication protocols and reporting expectations

Local Fire Department & EMS

PTSD integrates with local Fire and EMS services by providing:

- Site layout and access routes
- Chemical inventories and storage locations
- PPE posture requirements for external responders
- Rescue considerations for SCAPE-required entries

This integration supports rapid, coordinated response to fire, vapor releases, and personnel-injury events.

Regulatory Spill-Reporting Channels

PTSD maintains defined pathways for state and federal spill-reporting requirements, including:

- State environmental-protection agencies
- EPA/EPCRA reportable-quantity thresholds
- STEERS chemical-reporting submissions when required

These external interfaces ensure that all emergency and regulatory notifications occur within required timelines and formats.

10 Regulatory Programs & Reporting

PTSD operations involve the handling and use of MMH and MON-3/N_2O_4 oxidizer systems, requiring compliance with multiple federal and state regulatory frameworks. The following programs establish mandatory reporting, hazard documentation, notification requirements, and operational obligations.

10.1 EPA Risk Management Program (RMP) — 40 CFR 68

- Monomethylhydrazine (MMH) is listed under 40 CFR 68.130 with a Threshold Quantity (TQ) of 15,000 lb.
- Only MMH contributes toward RMP applicability; N_2O_4/MON-3 is not an RMP-listed substance.
- If total on-site MMH inventory exceeds 15,000 lb (pure active ingredient weight), RMP Program 2 requirements apply.

If triggered, PTSD must maintain:

- Offsite consequence analysis (hazard assessment)
- Prevention Program documentation
- Emergency Response Program
- Five-year accident history and required updates

10.2 EPCRA (Emergency Planning and Community Right-to-Know Act)

PTSD operations involve MMH and MON-3/N_2O_4 in quantities that exceed Emergency Planning and Community Right-to-Know Act (EPCRA) thresholds. These thresholds trigger mandatory planning, reporting, and coordination requirements.

EPCRA Section 302 — Extremely Hazardous Substances (EHS)

Threshold Planning Quantity (TPQ):

- Monomethylhydrazine (MMH): 500 lb TPQ *(EHS listing)*
- Nitrogen tetroxide (N_2O_4): 100 lb TPQ *(listed as “Nitrogen Dioxide” in the EHS table)*

PTSD Applicability Justification:

- PTSD stores and uses quantities of MMH and MON-3/N_2O_4 greater than the 500 lb and 100 lb TPQs, respectively.
- Exceeding TPQ requires:
- Facility emergency planning notification to the LEPC and State Emergency Response Commission
- Inclusion of MMH and MON-3/N_2O_4 in local emergency planning (12/5 LEPC meeting)

EPCRA Sections 311–312 — SDS Submission & Tier II Reporting

Threshold for reporting:

- ≥500 lb OR the threshold planning quantity (whichever is lower)
- For both MMH (500 lb) and N_2O_4 (100 lb), the applicable threshold is the TPQ, meaning:
    - MMH reporting threshold = 500 lb
    - N_2O_4 reporting threshold = 100 lb

PTSD Applicability Justification:

- PTSD stores *more* than 500 lb of MMH and *more* than 100 lb of N_2O_4.
- Therefore, annual Tier II chemical inventory reporting via STEERS is required.
- Copies must be provided to LEPC and local fire authority.

10.3 CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act)

CERCLA requires immediate federal notification for releases at or above Reportable Quantities (RQ).

CERCLA Reportable Quantities (RQ):

- Monomethylhydrazine (MMH): RQ = 10 lb
- Nitrogen dioxide (NO_2) — primary dissociation product of N_2O_4: RQ = 10 lb

PTSD Applicability Justification:

- MON-3/N_2O_4 decomposes into NO_2 upon release; EPA assigns NO_2's 10 lb RQ as the governing threshold for oxidizer spill-reporting
- PTSD uses quantities well above the RQ; therefore even small-scale liquid or vapor releases may meet or exceed the 10 lb RQ depending on:
    - Concentration
    - Release duration
    - Vapor-phase conversion

CERCLA-required notifications for releases ≥10 lb:

- National Response Center (NRC) — immediate verbal notification
- TCEQ — state-level reporting
- Documentation must be included in the facility's incident reporting system and used to update the Prevention Program as required.

Summary of Thresholds (for your SEMP table)

Regulation	Chemical	Threshold	Why PTSD Is Covered
EPCRA 302 (TPQ)	**MMH**	**500 lb**	**PTSD stores > 500 lb**
	N_2O_4/NO_2	**100 lb**	**PTSD stores > 100 lb**
EPCRA 311/312	**MMH, N_2O_4**	**TPQ (lower of 500/100 lb)**	**SDS + Tier II required**
CERCLA	**MMH**	**10 lb RQ**	**Any release ≥10 lb = immediate federal reporting**
	NO_2 (from N_2O_4)	**10 lb RQ**	**MON-3 converts to NO_2, same reporting rule**

11 Documentation, Records & Quality Assurance (QA)

PTSD maintains comprehensive documentation and quality-assurance records to support compliance with federal, state, and internal safety requirements. Recordkeeping ensures traceability, audit readiness, and continuous improvement across all hazardous operations involving MMH and MON-3/N_2O_4.

11.1 Required Documentation and Records

The following documentation must be maintained, controlled, and retained in accordance with applicable regulations and internal QA standards:

- **Detector Calibration Logs**
  Verification of performance, calibration status, and sensor health for all fixed and portable detection systems.
- **Standard Operating Procedures (SOPs)**
  Controlled versions of all operational, maintenance, and emergency procedures.
- **Training Records**
  Documentation of required training, refresher completion, SCAPE/respirator qualification, and competency verification.

- **Medical Surveillance Records**
  Tracking of medical clearance, respirator fit testing, and exposure evaluations where required.
- **Incident and Corrective-Action Reports**
  Records of all incidents, near-misses, investigations, root-cause analyses, and corrective actions implemented.
- **Regulatory Filings**
  Including but not limited to:
- **Annual Tier II (STEERS) chemical inventory**
- **Emissions inventories and supporting data**
- **SDS Library and Chemical Inventory Logs**
  Maintained and accessible for all hazardous materials on site.

11.2 Audits and Review Requirements — SEMP-Formatted

PTSD conducts scheduled audits and emergency preparedness exercises to verify program effectiveness, ensure operational discipline, and maintain compliance with federal, state, and internal safety requirements.

Quarterly Internal Safety Audit

The internal audit evaluates:
– SOP compliance and procedural adherence
– Detector performance, calibration status, and alarm functionality
– PPE posture readiness and equipment condition
– Chemical storage and inventory management
– Overall facility configuration and housekeeping standards

Annual Emergency Response Drill

The annual drill is conducted in coordination with **Local Fire and EMS** to validate:
– Alarm-response procedures for MMH and MON-3/N_2O_4 events
– Evacuation routes and assembly-point effectiveness
– SCAPE suit deployment and rescue-readiness posture
– Communications processes and command hierarchy
– Interoperability with the **Williamson County LEPC** and external emergency responders

Continuous Improvement Requirement

All audit findings, drill evaluations, and identified deficiencies must be formally documented. Corrective actions are tracked to closure and used to update SOPs, training programs, and emergency-response procedures as part of the PTSD Prevention Program's continuous-improvement framework.

12 POST-INCIDENT RECOVERY

Post-incident recovery ensures safe re-entry, contamination removal, and procedural improvement following any spill, vapor release, alarm escalation, equipment failure, or emergency response action at the PTSD. Recovery actions must be executed under the direction of the Test Director, Safety Officer, or designated Incident Commander.

12.1 Contamination Neutralization and Waste Management

- Neutralize all chemical residues using approved hypergolic-compatible neutralizers.
- Collect and segregate contaminated solids, absorbents, PPE, and wash-down fluids as hazardous waste.
- Store and label waste in compliance with state and federal hazardous-waste regulations.

12.2 Air Monitoring and Re-Entry Authorization

- Conduct continuous air monitoring using fixed sensors and handheld verification units.
- Confirm that vapor concentrations are below re-entry thresholds for MMH and NO_2/N_2O_4.
- Only the Incident Commander may authorize re-entry into the affected area.

12.2 Incident Investigation and Root-Cause Analysis

- Initiate a formal investigation immediately after stabilization of the incident.
- Document the event timeline, system performance, personnel actions, and environmental conditions.
- Perform a root-cause analysis (RCA) to identify initiating factors and systemic contributors.
- Produce a written incident report for internal records and regulatory agencies as required.

12.3 Corrective Action and Program Updates

- Implement corrective actions addressing engineering controls, procedures, and training gaps.
- Verify timely closure of corrective actions through follow-up audits.
- Update SOPs, Prevention Program documentation, and emergency-response procedures to reflect lessons learned.

13 PROGRAM MAINTENANCE & UPDATES

The Prevention Program must be:

- Reviewed annually
- Updated upon any process, chemical, equipment, or facility change
- Revised following incidents or regulatory changes