U.S. DEPARTMENT OF ENERGY | Office of Science

Office of Safety & Security (OSS)

Challenges in DOE Subterranean Facilities & Operations

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Introduction > Defining Need

➢The DOE/SC&NNSA underground facilities are a unique collection of large voids (e.g., facility), tunnels and shafts in which experiments, and dedicated activities are not common to general industry and have a high-risk profile which presents challenges in the selection and application of appropriate safety and health standards. Examples include;

- LBNF/DUNE, SURF/Fermi (FSO/SC) and SLAC – California (SC) and others
- WIPP – New Mexico (EM)
- U1a/U1h and Tunnels (P, T, etc.) – Nevada (NNSA)

➢The current approach to Facility Safety and Fire Protection as well as other relevant safety requirements (Chemical & Emergency Response, etc.) from various sources, differing from the approach of DOE-STD 1066-2016 Appendix D.

Note: This has created areas in which cannot be fully met (per Order & STD) due to challenges of legacy facilities and in some cases non-compliance issues with DOE O 420.1C, Facility Safety.

Introduction > Defining Need

Subterranean Ops IPT Participants

- >50 participants (*List will be generated in future*);
- DOE Feds and Contractors from HQ/Field representing EHSS, EM, NE, NNSA, SC;
- Other Governmental Organizations: MSHA, NIOSH, National Academies of Sciences, Engineering and Medicine;
- International Organizations: AWE, CERN, SNOLAB and others.
- Industry/Consultants/Universities

Phase I/II Senior Executive Sponsors

- EHSS: Kevin Dressman and Garrett Smith
- EM: Greg Sosson and Brenda Hawks
- NNSA: Dan Sigg and Ahmad Al-Daouk
- SC: Mike Weiss and Rick Verhaagen

Charter Goals & Tasks

1. Review DOE/NNSA directives and work with DOE programs & stakeholders to determine need for a DOE STD to specifically address best approach to subterranean facility safety.
2. Develop and implement guidance for such facilities.
3. Develop recommendations; conduct briefings May – June 2022
4. Develop/implement countermeasures July 2022 – June 2023

- **IPT Structure:** NNSA/IH was designated as the lead for a multifaceted **Integrated Product Team (IPT)** to review the application of safety health requirements for these subterranean facilities by leveraging expertise from within NNSA, Office of Science (SC), Environmental Management (EM), and DOE-EHSS Office of Safety who all signed the IPT charter.

- **There are also Sub-Teams for FP and IH** who met regularly to review, discuss and articulate issues and challenges in their specific functional areas of expertise. These Sub-Teams will then meet in the larger IPT meetings to focus on common issues and areas of overlap, Fire Suppressions Systems (FSS), Ventilations, Emergency Egress, etc.

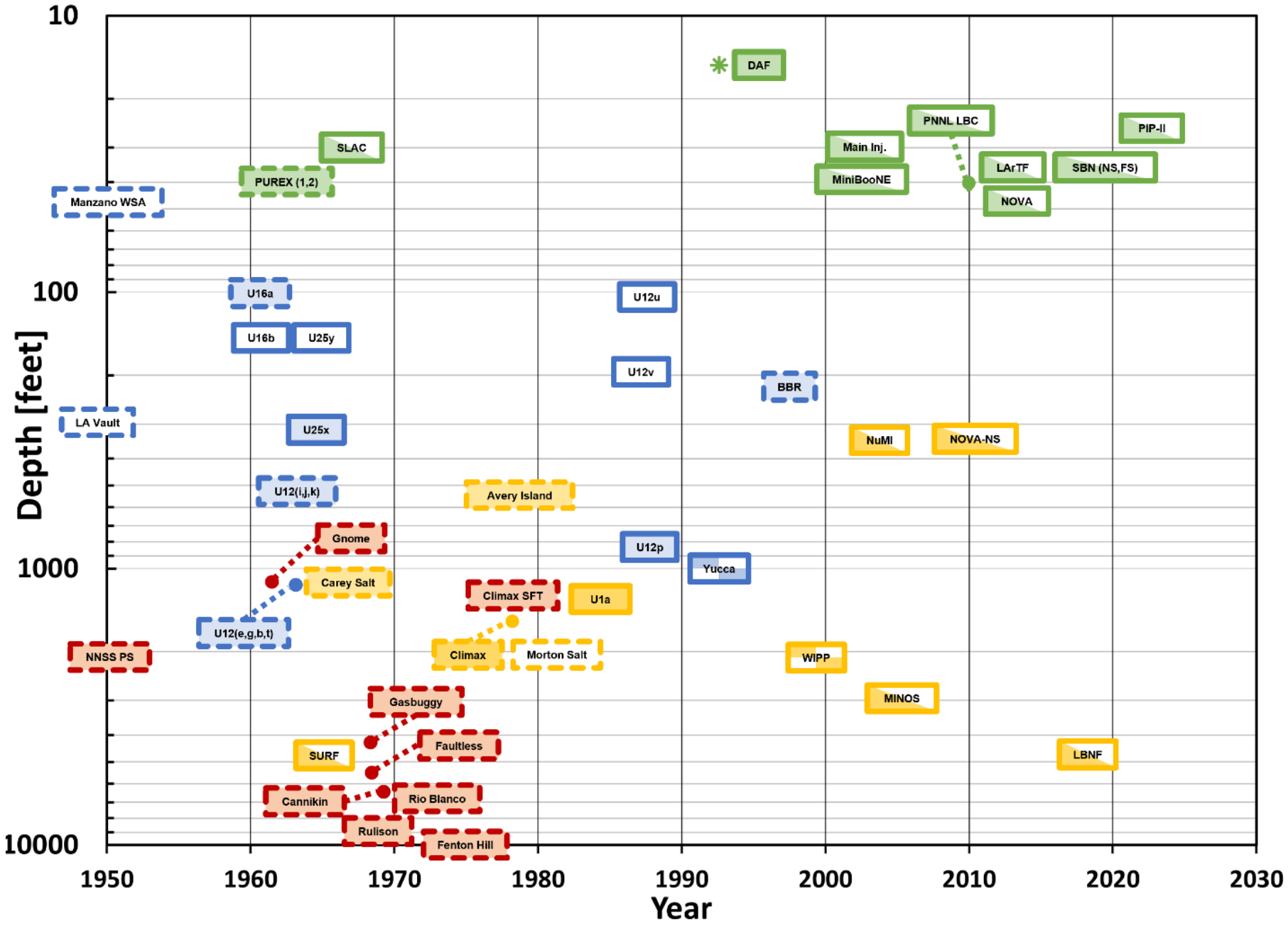
Charter Goals & Tasks (Cont.)

- The FP requirements for subterranean facilities need to also be coordinated with other relevant safety requirements (IH, NPH, Emergency Response, etc.) and provided a consistent and seamless set of requirements.

- A team of unique and experienced SME's from across DOE Programs were assembled to develop the tools, structure and guidance for selection and application of safety requirements to support subterranean safety and oversight.

- The varied and unique nature of DOE Subterranean facilities don't lend themselves to "*one size fits all*". It is believed by some members that optimum solution should be tailored site specific.

- Use of **Performance-Based Design** is being considered for Subterranean facilities. The 2021 edition, NFPA 520, *Standard on Subterranean Spaces* went through a substantial change and new chapters have been added to the previous document to address performance-based design. These new chapters allow performance-based design to be an option and provide guidance on the required considerations for performance-based design.



Relative depths and initial years of operation of subterranean facilities owned, leased, and operated by DOE.

Table of DOE Subterranean Facilities

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able 1. DOE Subsurface/Subterranean Facilities.

Facility Description						Facility Status		
Facility Name	**Location**	**DOE Office (EM/NNSA/SC)**	**DOE Owned/ Leased/ Other**	**Mission**	**Information entered by: (Name/Title/Date)**	**Project Lifecycle Status (Design/Constr/Oper/Decom)**	**Nuclear Facility (Y/N)**	**Modeling Studies (e.g., Ventilation, Fire, Evacuation, Geotechnical)**
Fermilab	Main Injector - Batavia, IL	SC	Owned	HEP	J. Niehoff, Fire Protection AHJ, 9/20/2022	2035	No	NPFA 101 Performance Measures
University of Minn	NuMI Off-axis ve Appearance (NOvA) Far Detector - Ash River, MN	SC	Grant, for a lack of a better term	HEP	J. Niehoff, Fire Protection AHJ, 9/20/2022	2025	No	IBC with Alternative Methods
Fermilab	NuMI Off-axis ve Appearance (NOvA) Near Detector - Batavia, IL	SC	Owned	HEP	J. Niehoff, Fire Protection AHJ, 9/20/2022	2025	No	Studies related to NFPA 101/520
Fermilab	NuMI (MINOS Experiment) - Batavia, IL	SC	Owned	HEP	J. Niehoff, Fire Protection AHJ, 9/20/2022	2025	No	Studies related to NFPA 101/520
SURF	LBNF/ US DUNE - City of Lead, SD	SC	Leased	HEP	J. Niehoff, Fire Protection AHJ, 9/20/2022	2035?	No	Complete
Fermilab	International Linear Collider (ILC) - DuPage County IL	SC	Not Built	HEP	J. Niehoff, Fire Protection AHJ, 9/20/2022	N/A	No	Complete

Modeling Task Team

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Insights from Task Team Initiatives:

- Modeling was determined to be very important to subterranean operations. It supports a performance-based approach for unique facilities in which prescriptive codes and standards are inadequate to address safety hazards.
- An initial categorization of models by model type, usage, and applicability to subterranean facilities was completed. Functional areas and types include:

- Fire and Life Safety
- Ventilation
- Geotechnical / Ground Control
- Seismic
- Industrial Hygiene
- Natural Phenomena Hazards
- Emergency Response

- Models currently in use by some DOE sites could not be verified or validated for use for subterranean facilities. Although the tasl team did a cursory review, an in-depth review of modeling software was not completed to determine if they are valid for use in subterranean facilities. Much of software is used commercially for subterranean, mining and tunneling used by NIOSH and NIST

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Modeling Task Team

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Summary of Results

- Modeling is very important to subterranean operations supporting a **performance-based approach** for unique facilities in which prescriptive codes and standards are inadequate to address safety hazards.

- Current DOE regulations do not require the use of models as input for either nuclear safety or non-nuclear safety applications.

- Subterranean facilities with nuclear facilities utilized various types of models as input to the DSA. Depending on the software, models had various requirements for the level of Software Quality Assurance, although much of the modeling is utilized commercially by mining, design firms, NIST, MSHA, and NIOSH.

- The use of modeling for performance-based design and operations is a relatively new approach (~last 10-15 years). Current regulatory requirements have not caught up to the new methodology and approaches.

- International organizations, such as CERN, have created their own safety/risk assessment guidelines which govern the use of models and implemented models in their decision-making process to justify the occupancy and use of their subterranean facilities

Recommendations

- Develop high level guidance outlining the usage of models in subterranean facilities.
  - Depending on the future requirements for DOE subterranean facilities, a framework needs to be created to ensure that proper selection and use of models is achieved.
- Create a process to ensure that a proper peer review is conducted for critical usage of model for subterranean facilities.
  - For example, require the use of a peer review team for software models that involves life safety or structural stability of critical facilities.
  - Utilizing the Subterranean Ops IPT as a permanent committee or group of SMEs could provide the framework for a review team to ensure that models are valid for use and models don’t provide unrealistic results

Review of DOE NPH Directives and Available Site Information

- Directives are generally applicable to subterranean facilities and relevant NPH events should be considered in the design and analysis of underground SSCs.
- Design and analysis criteria outlined in DOE-STD-1020-2016 were developed for surface facilities, and specific criteria may not be applicable to underground SSCs.
- Sites have been using engineering judgement to develop site-specific NPH design criteria

Summary of Results

- DOE currently lacks high-level guidance tailored for NPH design and analysis of underground facilities.
- Difficult for sites to provide their specific NPH design criteria.
- Office of Science facilities, which are non-nuclear, are not utilizing DOE O 420.1C, Chg 3 and DOE-STD-1020-2016 because they do not provide much guidance beyond the IBC - if no safety SSCs are defined.
- DOE has internal expertise but could utilize experts in the mining and tunneling industries (ex. Mine Safety and Health and Industry, NIOSH) to develop and review guidance.

Recommendations

- Develop high-level guidance for NPH design and analysis of underground facilities.
- Employ experts in the mining and tunneling industries (ex. Mine Safety and Health and Industry, NIOSH) to develop and review guidance.
- Develop requirements for a cognizant Mining Engineer and federal oversight to assist in applying high-level guidance at a site-specific level

Phase II Conclusions

Conclusions:

- IPT Task Teams evaluated DOE Regulations/Directives and identified/analyzed gaps with respec to subterranean facilities;
- IPT completed visits to EM (WIPP), NE (Yucca Mountain), NNSA (U1a, Tunnels), and SC (LBNF-DUNE/SURF/Fermilab) Sites;
- Phase II activities completed in June;
- July 2023, IPT will provide informed recommendations to Senior Executive IPT Sponsors from EHSS, EM, NNSA and SC

Phase II Recommendations

Recommendations:

- Endorse Phase III IPT Activities.
  - Establish Repository for DOE Subterranean Facility information.
  - Develop appropriate NPH Guidance.
  - Develop appropriate Modeling Guidance.
  - Develop appropriate WSH Guidance (includes international codes and standards).

- Create a DOE Policy for Subterranean Facilities.

- Institutionalize the Subterranean Ops IPT as a permanent multi-disciplinary committee.

- Endorse NIOSH-SMRD MOU (Establish OPI Signatory) and other external partnerships

International Codes & Standards

DOE Office of Science increasingly conducts research with International Collaborators who make major contributions to scientific experiments (e.g., LBNF/DUNE, Proton Improvement Plan II (PIP-II) at Fermilab)

- Partners and vendors provide specialized capabilities and equipment (contributions in kind)
- Other SC Labs involved in such partnerships include but may not be limited to SLAC and LBNL
- This collaboration often involves using European or other International processes such as pressure vessels, systems & components – that may be designed, constructed, and tested in accordance with the European Pressure Equipment Directive (PED)
- Non-ASME pressure codes are not recognized by 10 CFR 851 unless certain exception criteria are met.

Issue?

10 CFR 851 DOE Worker Safety and Health Program

- Requires contractors to comply with codes and standards incorporated by reference, including the American Society of Mechanical Engineers (ASME) boiler and pressure vessel and piping codes.
- Unlike other national consensus codes, ASME does not include an explicit process for Authority Having Jurisdiction (AHJ) nor local engineering judgement to determine an equivalent (as-good-as)level of safety.
- Appendix A to Part 851 has a very narrow exception process which addresses only pressure-range, vessel geometry, use of special materials, etc.
- Specifies a required version of American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC) 2004 with the following exception:

WHY (Continued)?

- 10 CFR Part 851 Specifies a required version of American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC) 2004 with the following exception:

- *"When national consensus codes are not applicable (because of pressure range, vessel geometry, use of special materials, etc.), contractors must implement measures to provide equivalent protection and ensure a level of safety greater than or equal to the level of protection afforded by the ASME or applicable state or local code. Measures must include the following: (1) Design drawings, sketches, and calculations must be reviewed and approved by a qualified independent design professional (i.e., professional engineer). Documented organizational peer review is acceptable. (2) Qualified personnel must be used to perform examinations and inspections of materials, in-process fabrications, non-destructive tests, and acceptance test. (3) Documentation, traceability, and accountability must be maintained for each unique pressure vessel or system, including descriptions of design, pressure conditions, testing, inspection, operation, repair, and maintenance"*

10 CFR 851 Technical Amendment Q&A22(d)

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Q: Research projects are increasingly becoming international in nature. Many contractors use pressure equipment that conforms to the applicable harmonized EN standards of the European Pressure Equipment Directive 2014/68/EU in place of the ASME standards listed in 4(b)

A: Contractors may apply for a variance to provide an equivalent level of safety and protection provided by the ASME standards listed in 4(b) by using the process provided in 10 CFR § 851.31, Variance process. Per 10 § 851.31(d)(2)(ii), the contactor is required to provide:

"*A statement showing how the conditions, practices, means, methods, operations, or processes used or proposed to be used would provide workers a place of employment, which is as safe and healthful as would result from compliance with the standard from which a variance is sought.*"

Not Unique Problem to US/DOE

- The need for international codes is not unique to the U.S. DOE or other U.S. Executive Departments requiring unique pressure systems that do not conform to ASME standards.
- Department of Defense (DOD) and the Department of Interior's National Aeronautics & Space Administration (NASA) also have non-ASME pressure systems in use or planned for construction.
- In addition, forty-six states, including Illinois and South Dakota, have instituted an exemption or variance process to accept non-ASME pressure systems.

Appendix A to Part 851 – Pressure Safety (c)

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Exception to ASME

- When national consensus codes are not applicable (because of pressure range, vessel geometry, use of special materials, etc.), contractors must implement measures to provide equivalent protection and ensure a level of safety greater than or equal to the level of protection afforded by the ASME or applicable state or local code. Measures must include the following:
- Design drawings, sketches, and calculations must be reviewed and approved by a qualified independent design professional (i.e., professional engineer). Documented organizational peer review is acceptable.
- Qualified personnel must be used to perform examinations and inspections of materials, in-process fabrications, non-destructive tests, and acceptance test.
- Documentation, traceability, and accountability must be maintained for each unique pressure vessel or system, including descriptions of design, pressure conditions, testing, inspection, operation, repair, and maintenance.