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Large-scale Hydrogen Storage Risk Assessment

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DOE WBS 6.2.0.803

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DOE Hydrogen Program
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AMR Project ID #
SCS034

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Project Goal:
Risk Assessment of Large-Scale Hydrogen Storage

- The projects helps Ports and Utilities in undertaking risk assessments that yield public safety risk metrics and in effective stakeholder engagement

- The project applies a series of risk assessment techniques from ISO 31010 towards understanding hydrogen plant systems, their failure modes, and safety risks.

Photo: [eakkarat rangram | Shutterstock]

Project Overview:
Q3 Underway, Manageable Barriers, On Target

Timeline and Budget

- Project Start Date: 09/30/2022
- Project End Date: 10/16/2024

- Total Project Budget: $880,000
  - Total DOE Share: $770,000
  - Total Cost Share: $110,000

- Project Resource Allocation
  - PNNL: $400,000
  - SNL: $370,000
  - SCL (Cost Share): $75,000
  - Port (Cost Share): $35,000

- Total FY23 DOE Funds Spent*: $115,876
- Total Cost Share Funds Spent*: $12,473

* As of 04/07/2023

Barriers

- Exact system architecture is unavailable.
- There is need for increasing public confidence and understanding in hydrogen as a fuel.
- There is lack of integrated risk assessment software.

Targets

- Public safety risk metrics, gaps in codes and standards, stakeholder engagement plan

Partners

- Arun Veeramany(PI, PNNL)
- Todd Wall (Co-PI, PNNL)
- Ben Schroeder (PI- Cascading failure analysis, SNL)
- Port of Seattle
- Seattle City Light

Potential Impacts:
Decarbonization, Risk Assessment, Stakeholder Engagement

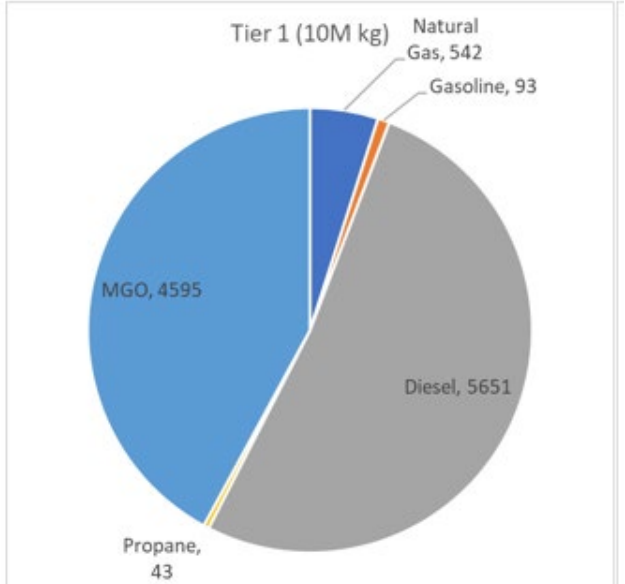
Barriers	Impacts
Exact system architecture is unavailable	We are using existing reference station design from past literature and revising it to meet the project needs.
Public confidence and understanding in hydrogen as a fuel	We are setting up a stakeholder engagement plan to improve public confidence and potential technology adoption.
Lack of integrated opensource risk assessment software	We are integrating capabilities from INL Saphire, SNL HyRAM, and PNNL extensions.

Decarbonization The project is supporting the decarbonization goals of the Port and SCL by determining the hydrogen equivalent of their current fossil fuel needs.

Risk Assessment

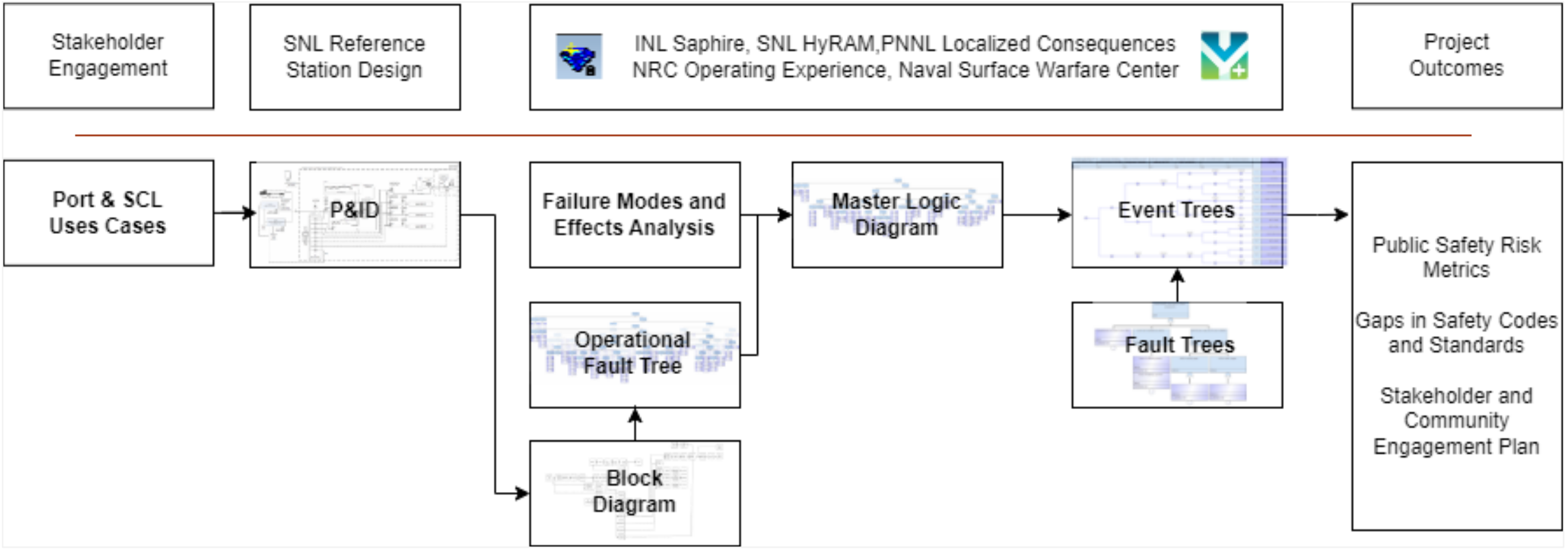
- Increases awareness of Probabilistic Risk Assessment (PRA) jobs in hydrogen industry.
- Promotes direct uptake of hydrogen storage risk assessment methodology in the private sector.
- Pools together national lab capabilities from INL, SNL, and PNNL to solve real-world Port problems.

Stakeholder Engagement task of this project is supporting community and stakeholder outreach.



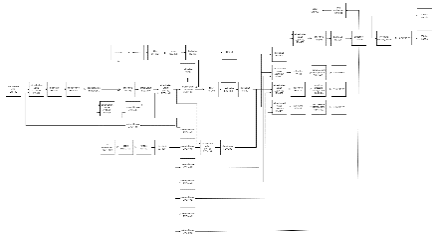
Fossil fuels: in 1000s of gallons

An Integrated Approach to Risk Assessment of Large-Scale Hydrogen Storage Systems and Plants

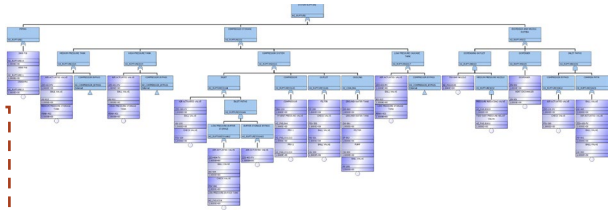


- **Prior work** done through HFTO includes reference station design and optimal sizing of nodes.
- **Major barriers** on the critical path are alleviated by leveraging prior work as needed.
- **Uniqueness**: risk assessment methodology is scaled up and tailored to the needs of the real-world.

Accomplishments and Progress (new award):
Identified System Design, Critical Safety Components, and Accident Progression

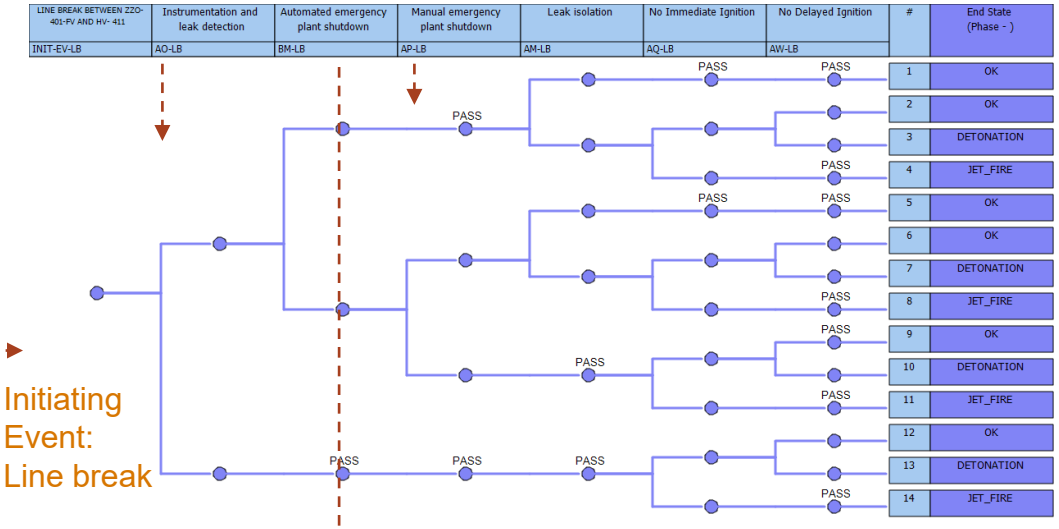


Block diagram from P&ID



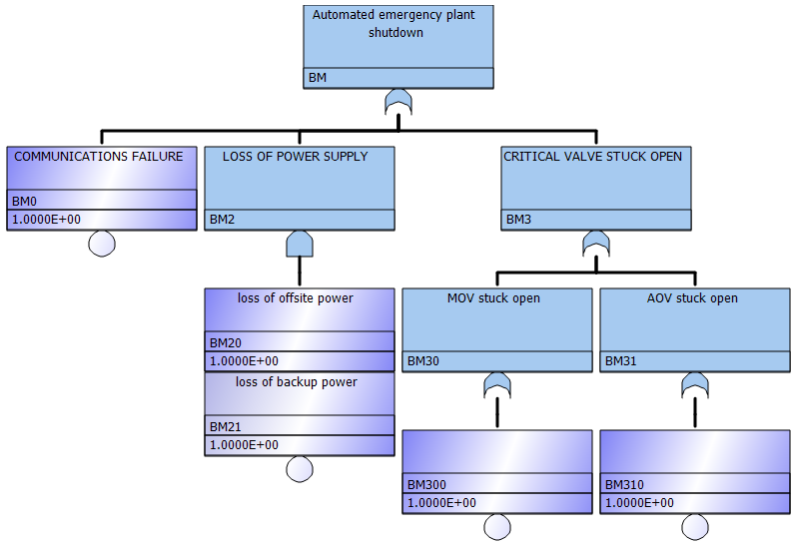
Master Logic Diagram

Initiating Event: Line break



Event Tree

Milestone	End Date
M1 Data collection	12/31/2022
M2 Conceptualization	03/31/2023
M3 Risk model	06/30/2023
M4 Validation and documentation	09/30/2023
Go/No-Go Workshop	10/15/2023
M5 Cybersecurity risk assessment	12/31/2023
M6 Future needs system assessment	03/30/2024
M7 Future needs risk assessment	06/30/2024
M8 Validation and documentation	09/30/2024



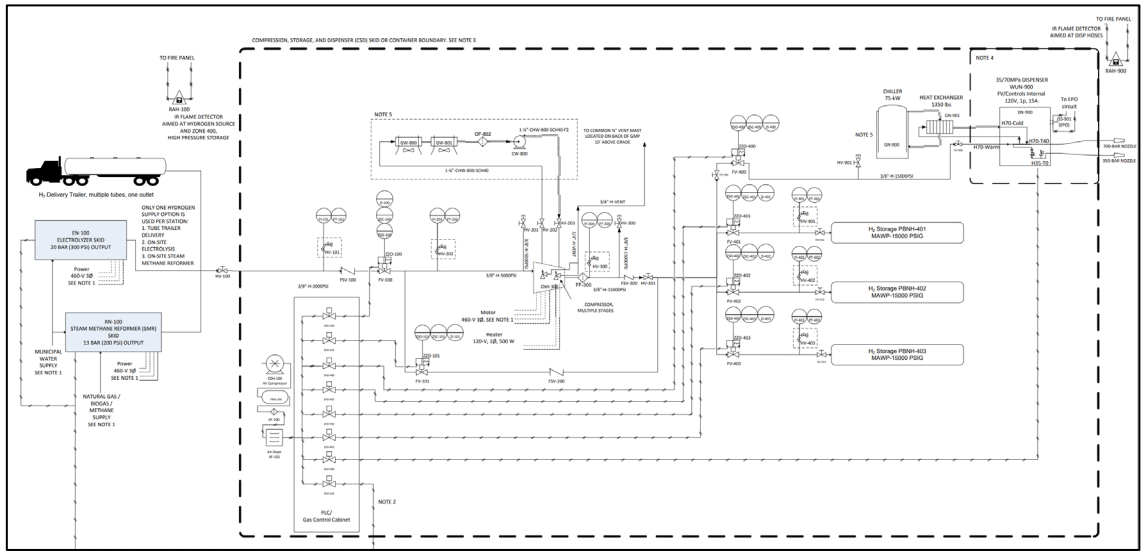
Fault Tree

Progress: Quantitative Risk Assessment

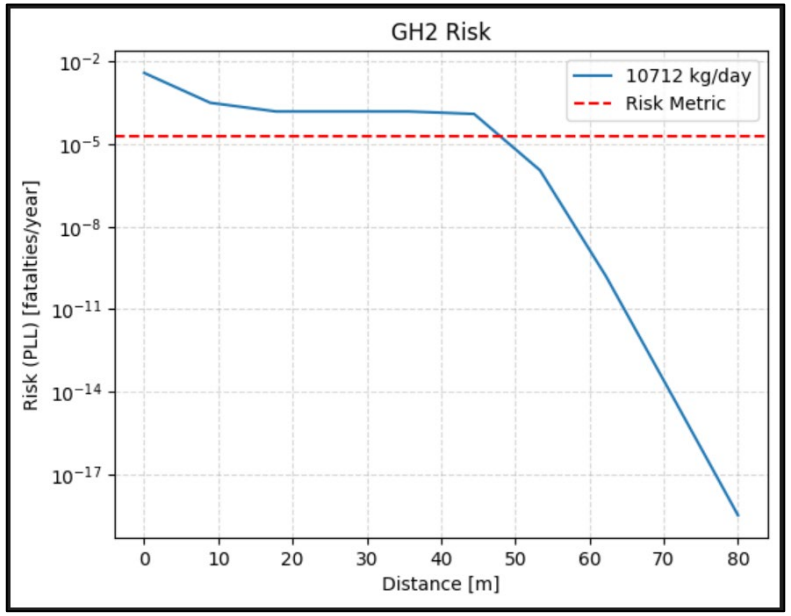
Applying **quantitative risk analysis** to large scale gaseous and liquid H_2 storage using the Hydrogen Plus Other Alternative Fuels Risk Assessment Models (HyRAM+) software toolkit

- Identified potentially representative system piping and instrumentation diagrams (P&ID).
- Estimated risk profiles for representative systems.
- Began developing framework for quantifying cascading failure risk.

Representative gaseous storage system P&ID [*]



Example risk profile generated by HyRAM+ for a representative gaseous storage system



HyRAM+ Hydrogen Plus Other Alternative Fuels Risk Assessment Models

[*] Hecht, E.S., Pratt, J. Comparison of conventional vs. modular hydrogen refueling stations, and on-site production vs delivery, Sandia National Laboratories Technical Report SAND2017-2832.

Sandia National Laboratories

Progress: Safety Codes and Standards Gap Assessment

Initial review and internal discussion of gaps for applying safety codes and standards to **large scale H_2 storage**

- Identifying **maximum quantities** considered in National Fire Protection Association's Hydrogen Technologies Code (NFPA 2) bulk storage sections
- Considering if specifications account for potential **large scale hazards**

National Fire Protection Association's Hydrogen Technologies Code

Image: https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=2

Accomplishments and Progress: Responses to Previous Year Reviewers' Comments

- This project "Large-scale hydrogen storage risk assessment" was not reviewed at a previous AMR

Collaboration and Coordination:

Stakeholder Engagement Far and Wide

- FFRDC Partners
  - Sandia National Laboratories (Cascading failure analysis)
- Cost Sharing Industry Partners
  - Seattle City Light, Port of Seattle (Operational needs)
- Advisory Board
  - Industry
  - Academia (WSU, Univ. of Maryland, Leibniz Univ.)
  - Agencies (Port of Portland, Long Beach, Tacoma)
  - Consortia (CHARGE)
  - Alliances (NWSP: Northwest Seaport Alliance)
- Review Panel
  - Hydrogen Safety Panel (HSP)
- Codes and Standards Committees
  - ASME Hydrogen Steering Committee
- Conference Management
  - ASME, PNNL

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Remaining Challenges and Barriers:
Uncertainties in Use Cases, Scaled Up P&ID, and Validation

- Challenge: Determining hydrogen cyclic loading risk from various Port and SCL use cases towards operational risk assessment.
  - Barrier: Uncertainty in timing and duration of future use case scenarios.
  - Proposed solution: Expert judgment and extensive stakeholder engagement.

- Challenge: Scaling up the risk assessment methodology.
  - Barrier: Scaling up the risk assessment in the absence of a scaled up P&ID.
  - Proposed solution: The ongoing HFTO hydrogen node sizing project is being influenced to produce a scaled up P&ID. The node and risk assessment project members attend each others project meetings.

- Challenge: Validation of risk assessment approach and results.
  - Barrier: Lack of parameters such as risk tolerance and risk appetite.
  - Proposed solution: The hydrogen safety panel (HSP) is being engaged to review the approach to synchronize findings with real-world observations.

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Proposed Future Work:
Quantification, Cybersecurity Risk, Technical Report

- Fault and event trees have been built qualitatively. These will be quantified during rest of FY 2023.
- Cybersecurity risk assessment will be initiated in FY 2023 and eventually incorporated into the main stream large-scale hydrogen storage risk assessment.
- Work performed in FY 2023 will result in a technical report outlining the baseline risk assessment results. The baseline is a hydrogen plant targeted to produce about 300 kg hydrogen per day.

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Any proposed future work is subject to change based on funding levels

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Summary:
Scaling Up Hydrogen Storage Risk Assessment Methodology is Impactful to Ports, Utilities and DOE HFTO

Goal, Impacts, Approach, Accomplishments, Collaboration, Challenges, Future	
Goal	Helps Ports and Utilities in undertaking risk assessments that yield public safety risk metrics and in effective stakeholder engagement
Impacts	Decarbonization, risk assessment, and stakeholder engagement
Approach	Applies a series of risk assessment techniques from ISO 31010 towards understanding hydrogen plant systems, their failure modes, and safety risks.
Accomplishments	Identified system design, critical safety components, and accident progression
Collaboration	Port of Seattle, Seattle City Light, Sandia National Laboratory, Advisory Board, Code and Standards Committees, and Hydrogen Safety Panel
Challenges	Uncertainties in use cases, scaled up P&ID, and validation
Future Work	Quantification, cybersecurity risk assessment, technical report