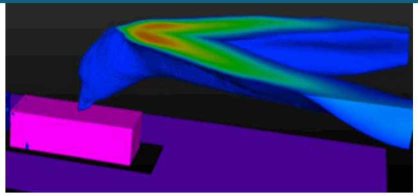
SAND2020-8731PE

Background and Current Work on Hydrogen for Rail



Presented by:

Brian Ehrhart

8/21/2020

ZEHTRANS Monthly Meeting

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SAND2020-XXXX PE

Sandia National Laboratories Overview

"Exceptional Service in the National Interest"

Multi-Mission for DOE NNSA Lab

Federally Funded Research and Development Center (FFRDC)

- Government owned, contractor operated

Main sites: Albuquerque, NM and Livermore, CA

- Other sites: Kauai, HI; WIPP, Carlsbad, NM; Pantex Plant, Amarillo, TX; Tonopah, NV

FY19 Budget: $3.8B

- Sponsors: DOE, DOD, DHS, DOT, NRC, etc.

>**14,000 employees** (>12,000 in NM; >1,600 in CA)

- Staff has grown by over 5,000 since 2009 to meet all mission needs

Sandia's Hydrogen and Fuel Cells Research Program

Sandia provides deep, quantitative understanding and a scientific basis for…

Materials – for hydrogen <u>production</u>, <u>storage</u> and <u>utilization</u>

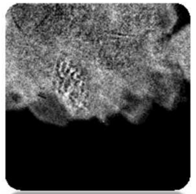
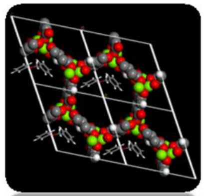
Safety – risk analysis and the creation of risk-informed standards

Hydrogen Production from Renewables


Advanced water-splitting materials and technologies for large-scale H_2 production

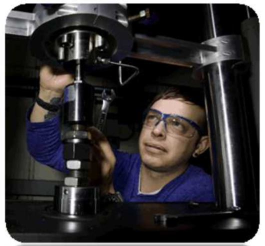
Hydrogen Storage Materials and Solutions

Discovering the behavior and performance of solid storage materials

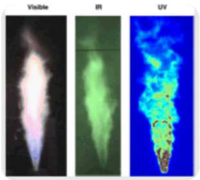

Hydrogen-Materials Compatibility





Low-cost, hydrogen-compatible materials and the science basis for their qualification

Hydrogen Fueling Infrastructure



H_2 release behavior and risk assessment to define the safety envelope for storage & delivery

Technologies for Non-Vehicle Applications

Marine and rail applications


Fuel Cells

Membrane systems for enhanced electrochemical performance

Hydrogen Risk Assessment Models (HyRAM)

Core functionality:

Quantitative risk assessment (QRA) methodology

Frequency & probability data for hydrogen component failures

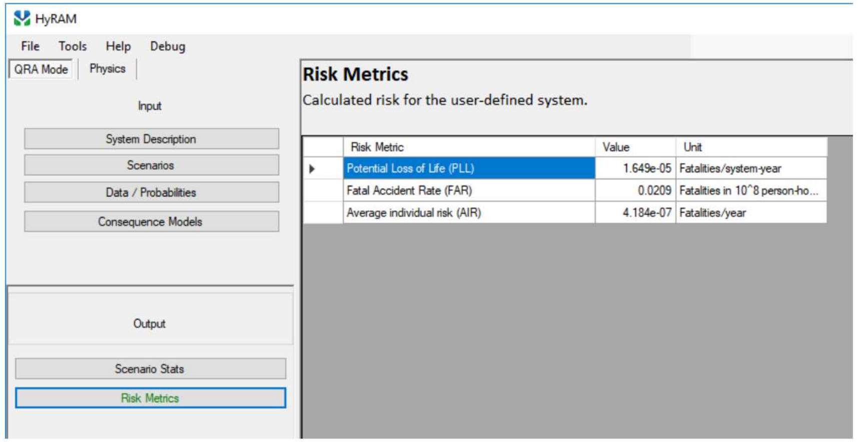
Fast-running models of hydrogen gas and flame behaviors

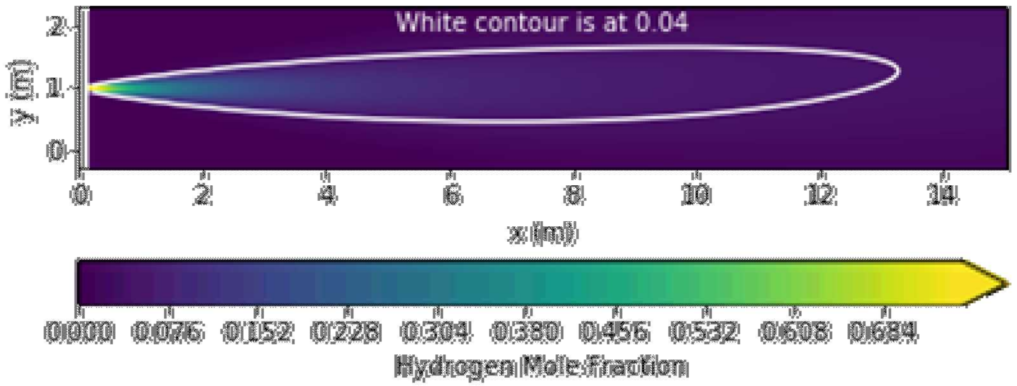
Key features:

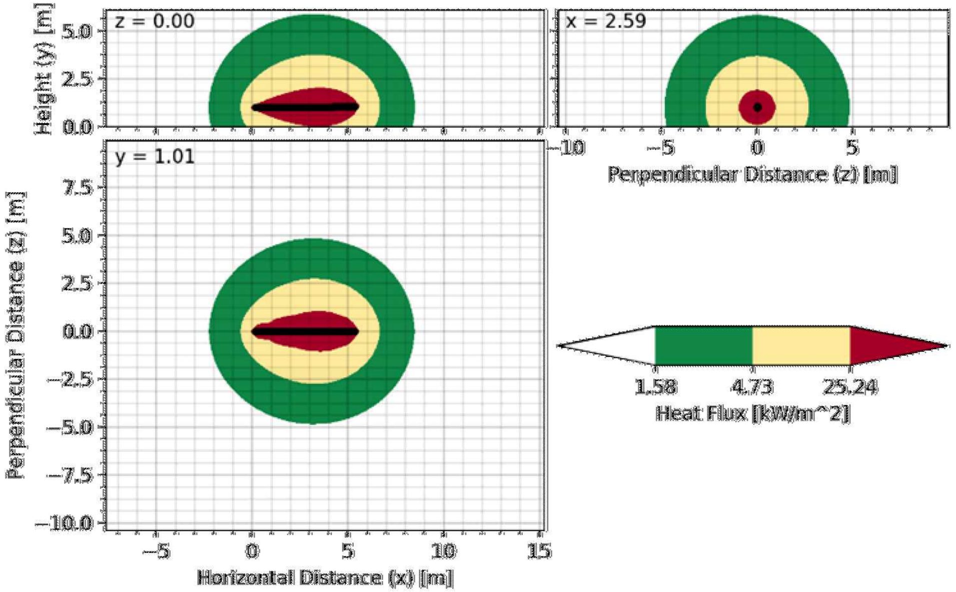
GUI & Mathematics Middleware

Documented approach, models, algorithms

Flexible and expandable framework; supported by active R&D





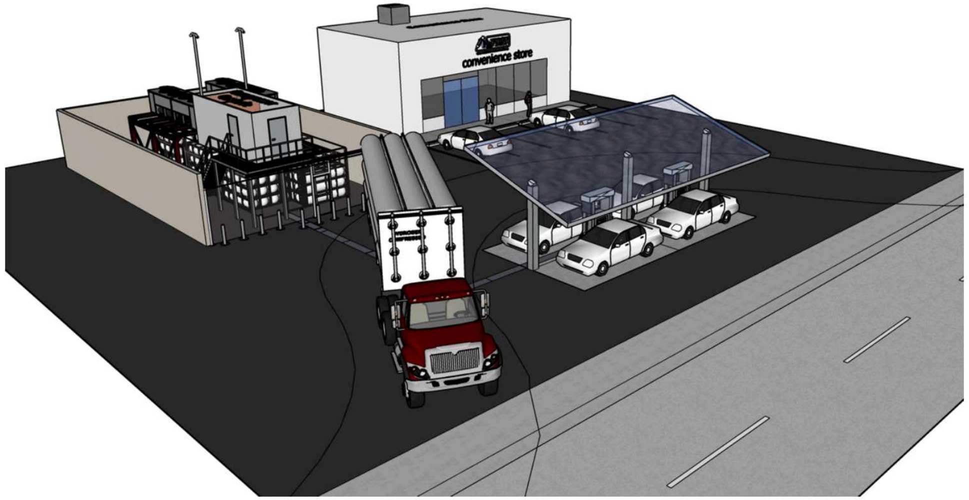


https://hyram.sandia.gov

Light-Duty Vehicle Infrastructure Studies

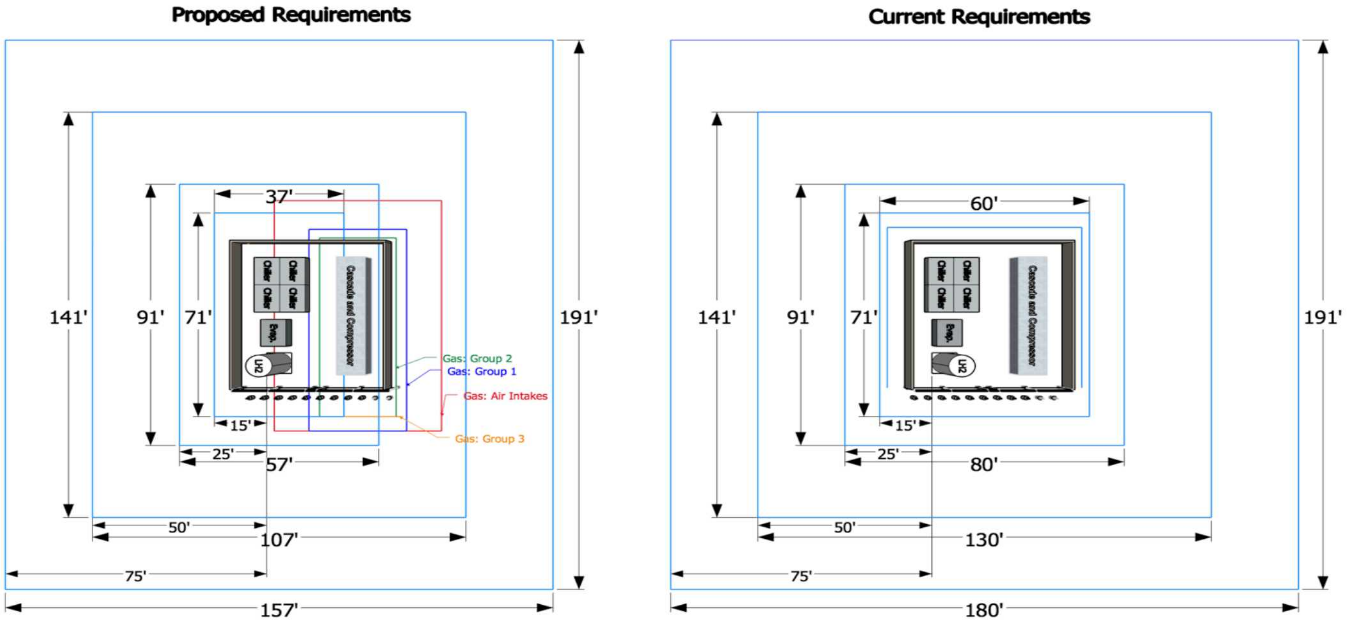
H2F1RST

Hydrogen Fueling Infrastructure Research and Station Technology

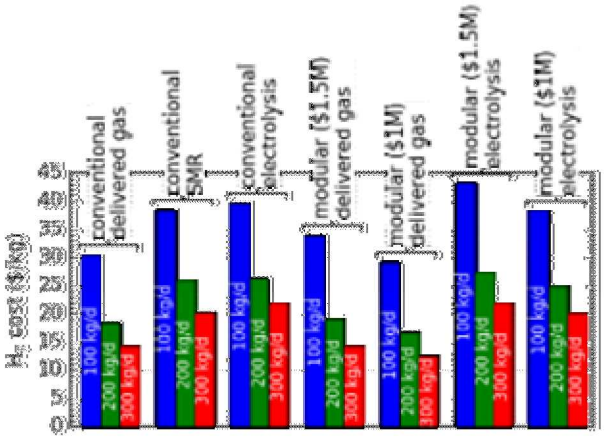


Publicly available system designs for stakeholders

Focusing on NFPA 2 code



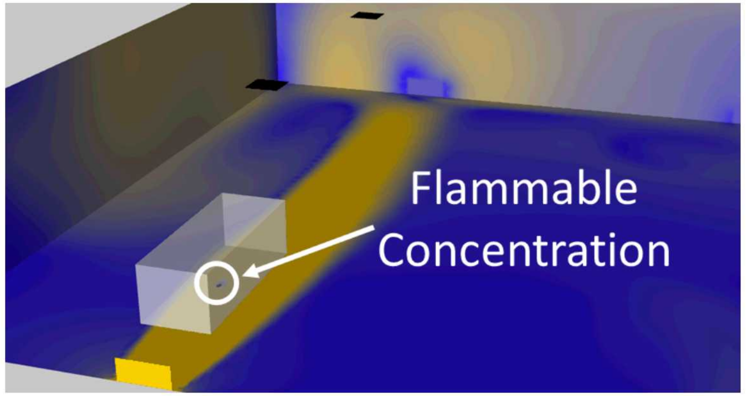
Layout footprint quantification and comparison



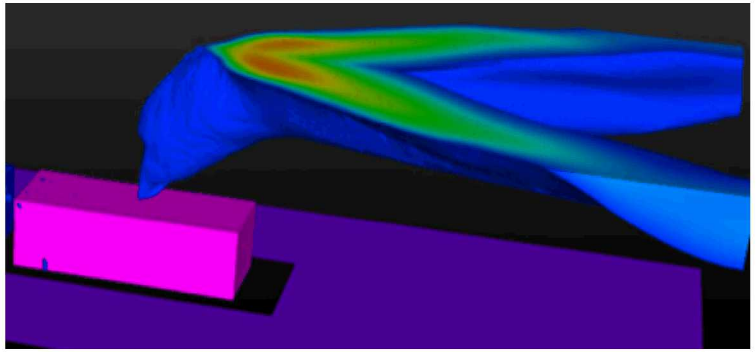
Economic Comparisons

https://energy.sandia.gov/programs/sustainable-transportation/hydrogen/infrastructure/

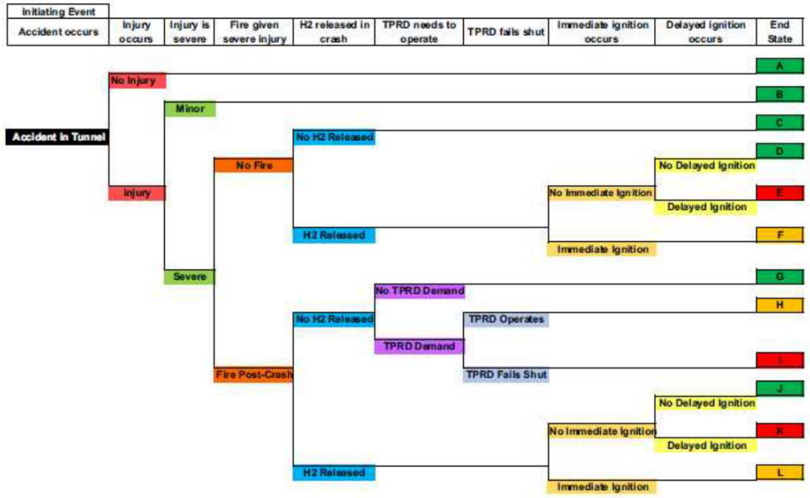
Hydrogen Risk Assessments and Consequence Modeling



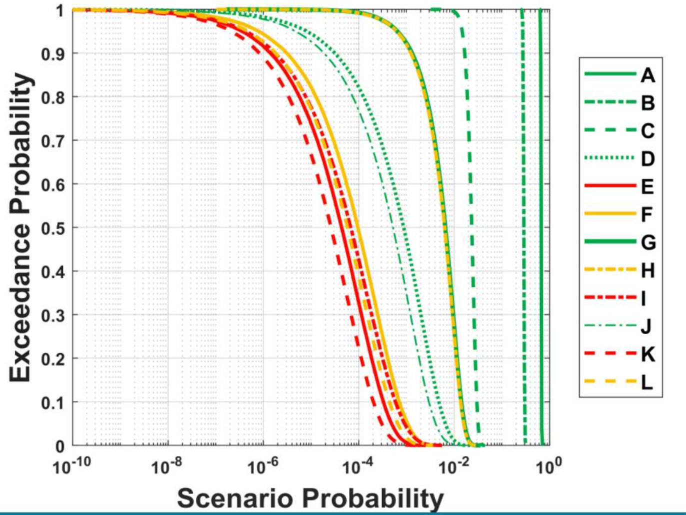
Dispersion modeling of leak with ventilation in repair garage



Jet fire modeling of effect of hydrogen leak on tunnel



Event tree for hydrogen vehicle in crash



Probability/likelihood of outcomes with uncertainty

https://energy.sandia.gov/programs/sustainable-transportation/hydrogen/quantitative-risk-assessment/

Maritime Feasibility and Safety Analyses

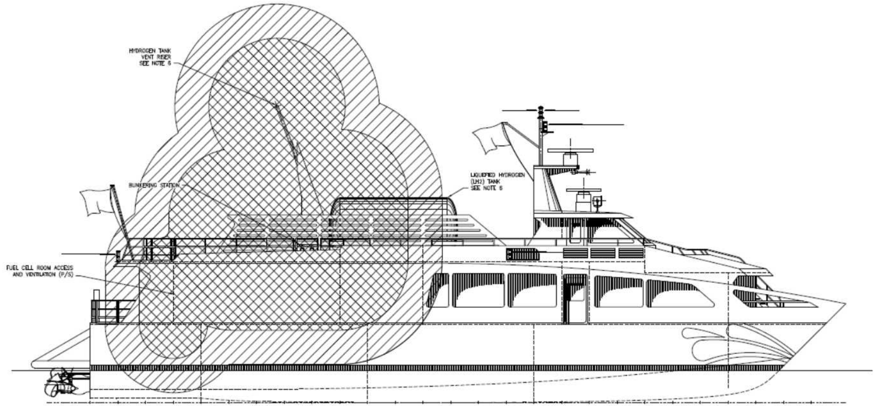
Feasibility studies funded by DOT/MARAD

SF-BREEZE high-speed hydrogen fuel cell ferry

- 1,000+ kg/day hydrogen demand

Zero-V hydrogen fuel cell coastal research vessel

- 2,400 nautical mile range
- Refueled with ~11,000 kg of LH2



https://energy.sandia.gov/programs/sustainable-transportation/hydrogen/market-transformation/maritime-fuel-cells/

Previous Work in H2@Rail – Impact Figure of Merit

Preliminary results show trade-offs between all technologies

- More refinement and exploration needed, which will change rankings

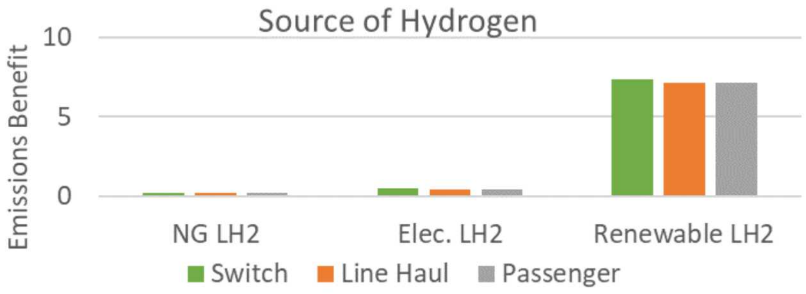
Emissions reduction benefit from hydrogen depends on the source of hydrogen

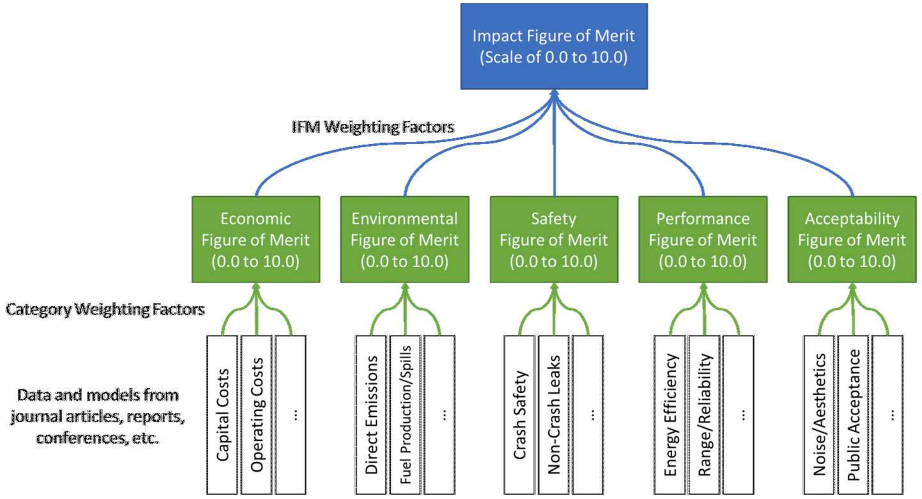
Reliability and cost of hydrogen locomotives needs to be investigated

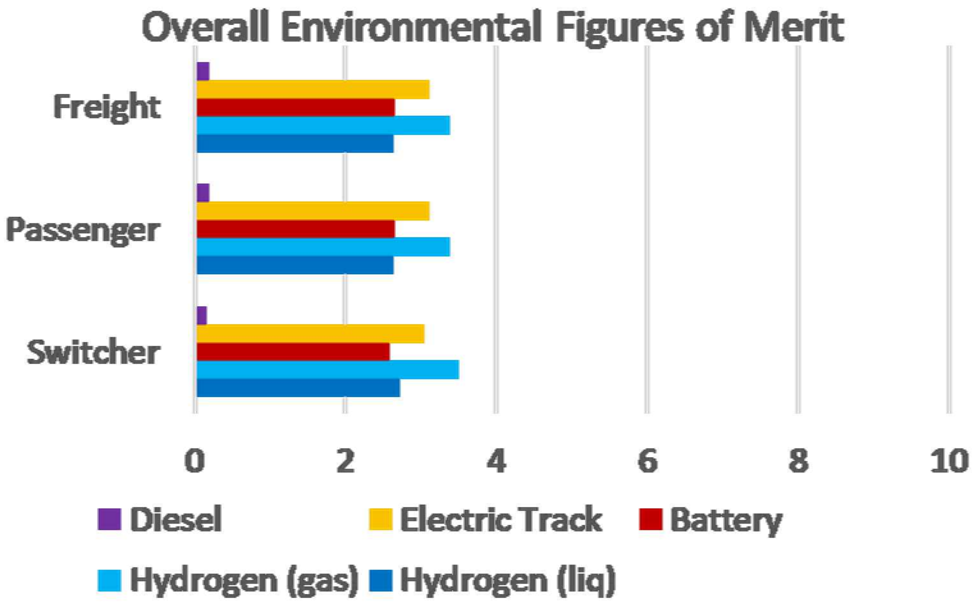
- Impacts performance and economics

Fueling infrastructure needs to be investigated further

Safety needs to be investigated further







https://www.energy.gov/sites/prod/files/2019/04/f62/fcto-h2-at-rail-workshop-2019-ehrhart.pdf

Current Work – Safety Codes and Standards (DOT FRA)

Objective: Identify, collect, and summarize relevant domestic and international codes, standards and regulations with potential applicability for storing hydrogen on-board as a locomotive fuel.

Areas of Focus:

- Assess safety and design features for *on-board hydrogen as fuel* rather than cargo
  - E.g., fuel transfer connection on side of tender rather than top of tanker
  - Freight rail specifically
- Best practices and gaps in existing safety regulations and standards will be identified

Current Work – Safety Codes and Standards (DOE HFTO)

Objective: Identify rail-specific codes and standards requirements, best practices, and gaps for the use of hydrogen fuel cells for locomotive power applications

Areas of Focus:

- Identify safety standards and regulations applicable to the storage of hydrogen for a *wide variety* of rail applications
  - Storage in compressed gas cylinders (passenger or switcher) or cryogenic tank cars (freight)
  - Storage on both rolling stock (locomotive, railcars) and stationary fueling infrastructure
- Gaps in existing safety regulations and standards will be identified and recommended actions will be described (where possible)

Current H2@Rail Work – Fueling Infrastructure (DOE HFTO)

Objective: Assess the capability of current and near-term technologies to meet the needs of freight locomotive hydrogen refueling

Areas of Focus:

- Evaluation of LH2 current fueling technologies including a determination of basic conditions (flow rate, temperature, pressure)
  - Capacity on locomotive and tender from collaborators at ANL
- Basic design of LH2 refueling facility
  - Production/delivery of H2 from collaborators at ANL
  - Three example designs with different capacities, location (urban, rural, port), and effect on similar technologies (e.g., light- and heavy-duty vehicles)
- Basic cost estimate for fueling infrastructure
  - Can be scaled or used in other analyses to estimate the overall cost of fuel

Future Work – Hydrogen Rail Safety Topics (DOT FRA)

Assessment of post-crash outcomes for passenger and freight rail

- Developing event sequence diagram with uncertainty quantification for hydrogen on both freight and passenger rail
- Modeling of consequences scenarios (CFD and/or reduced-order)

Recommendations on emergency response

- Recommendations on the minimum evacuation times and distances for passenger or freight rail following accidental release of hydrogen fuel

Recommendations on best-practices for human performance to ensure and maintain safety during refueling operations

- Review of the human factor issues surrounding refueling of hydrogen fueled train
- Develop recommendations on best practices and procedures for refueling

Identify potential mechanical loading environments experienced in railroad operations that may lead to hydrogen embrittlement concerns

- Literature review to identify where existing hydrogen studies overlap the mechanical loading conditions experienced in normal railroad operations and identify potential areas where further experimental research would be beneficial

(subject to change)

Future Work – Hydrogen Heavy-Duty Trucks (DOE HFTO)

Multiple proposals submitted on multiple projects to analyze refueling facilities for heavy-duty trucks

- Leveraging past work on H2FIRST Reference Station Projects

Stay tuned…

Thank you! Questions?

Brian Ehrhart

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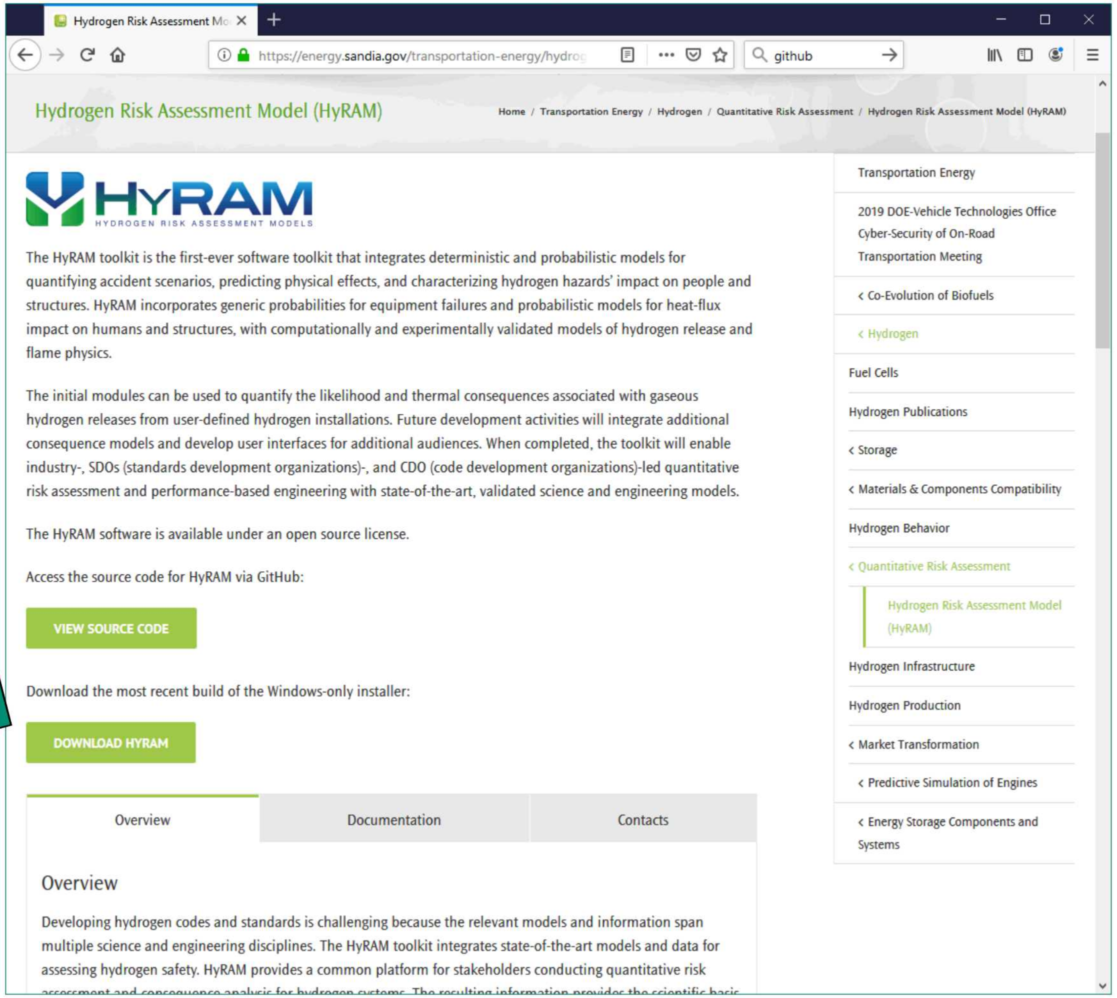
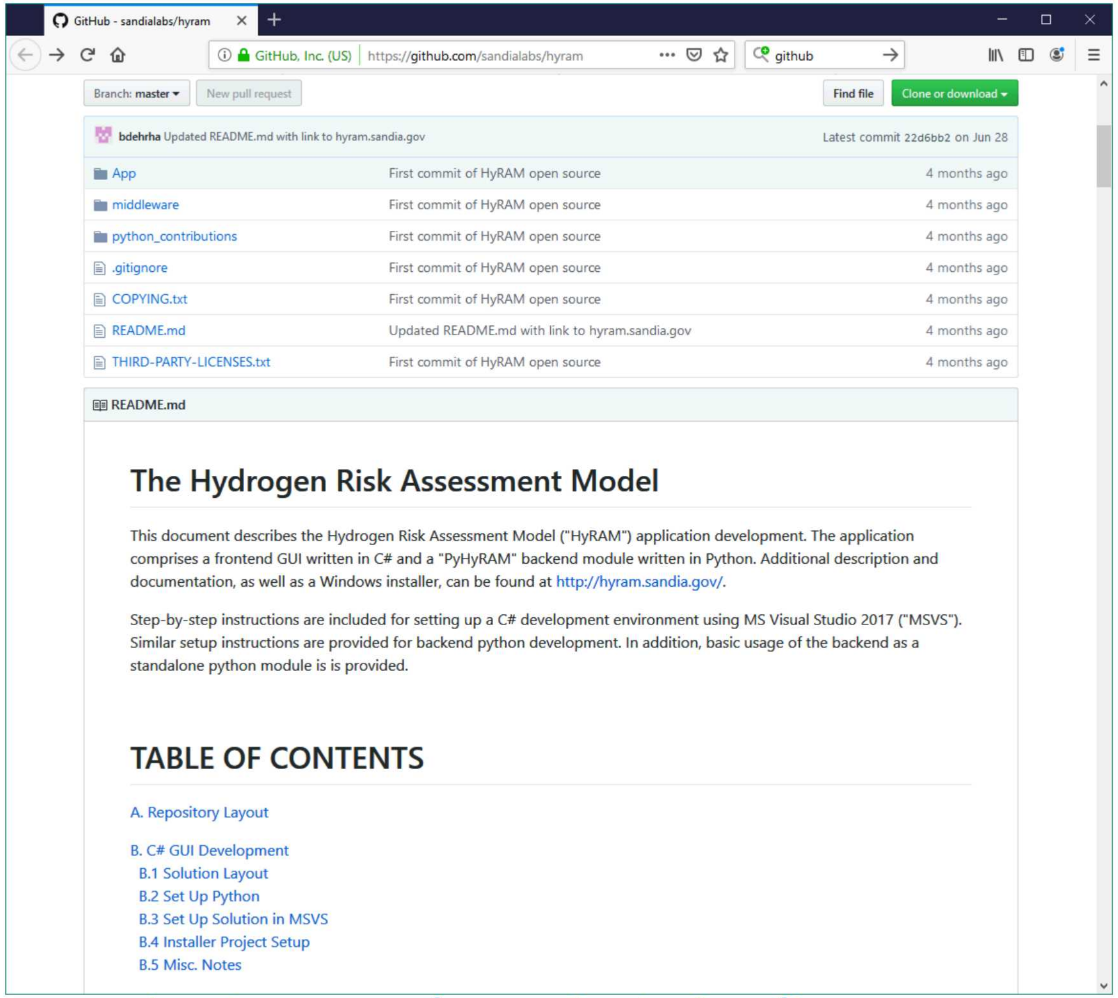
HyRAM 2.0 can be installed as a Windows executable and as an open-source software, users have access to the source code



hyram.sandia.gov



github.com/sandialabs/hyram

QRA estimates frequency and consequence for different leak sizes

Frequency of Leak

- 0.01%, 0.1%, 1%, 10%, 100%

Probability of Outcome

- Shutdown, jet fire, explosion, no ignition

Calculate Effects

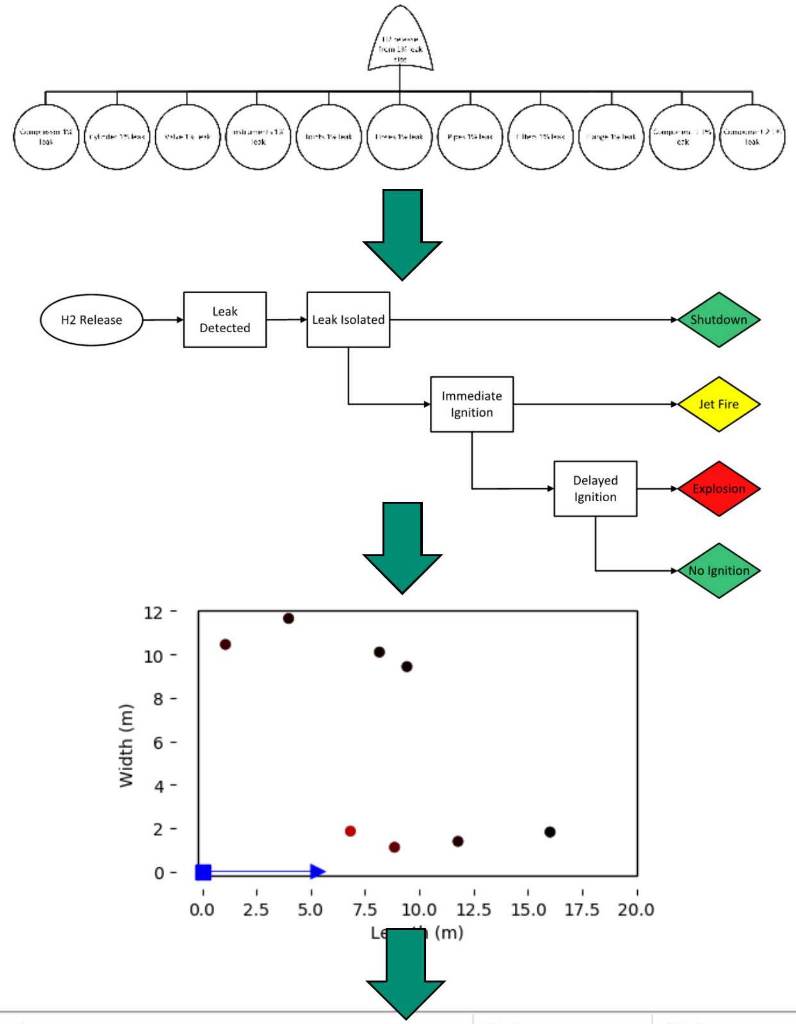
- E.g., thermal heat flux to occupant

Estimate Harm

- Probability of fatality based on effects

Risk Metrics

- 20 Scenarios



Risk Metric	Value	Unit
Potential Loss of Life (PLL)	1.246E-005	Fatalities/system-year
Fatal Accident Rate (FAR)	1.580E-002	Fatalities in 10^8 person-hours
Average individual risk (AIR)	3.160E-007	Fatalities/year

Potential SCS Gaps for Hydrogen for Rail

AAR M-1004 Tender Cars

- Temperature for testing too high (LNG)
- Wall thickness too thin (LNG)
- Means of access to inner tank
- Refueling rate limited to 400 gpm

NFPA 2

- Bonding/grounding requirements for vehicles, something needed for rail
- Vague requirements for LH2 refueling
  - Risk assessment, personnel protection
- No requirements for LH2 non-public refueling
- Maximum LH2 storage likely prohibitive