SAND2018-7813PE

Development, Validation, and Benchmarking of Quantitative Risk Assessment Tools for Hydrogen Refueling Stations

Brian Ehrhart

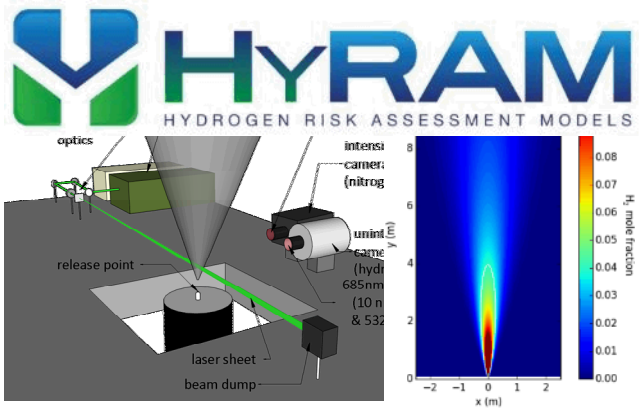
Sandia National Laboratories

PI: Alice Muna

Project Team: Ethan Hecht, Chris LaFleur, Bikram Roy Chowdhury, Anthony McDaniel, Scott Bisson

H2@Scale Group Kickoff Meeting

August 2, 2018



SAND2018-4092 D

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Overview

Timeline

- Project start date: TBD
- Project end date: One year after start date

Barriers

A. Safety Data and Information: Limited Access and Availability
F. Enabling national and international markets requires consistent RCS
G. Insufficient Technical Data to Revise Standards

Budget

- FY18 DOE Funding: $250k
- FY18 Air Liquide Funding: $250k
- FY18 Air Liquide In-Kind Contribution: $75k
- Total DOE Funds Received to Date: $250k

Partners

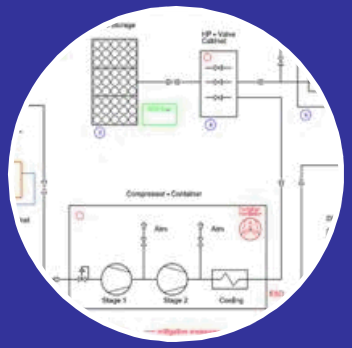
- Air Liquide
- NFPA H2 Liquid Separation Distance Task Group

Relevance

Objective: Utilize SNL's hydrogen behavior models and quantitative risk assessment (QRA) methodology to defensibly revise safety codes and standards.

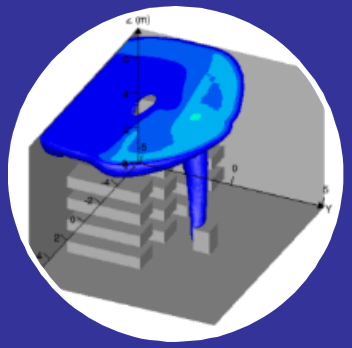
Barrier from 2015 SCS MYRDD	SNL Goal
A. Safety Data and Information: Limited Access and Availability	Build validated H2 behavior physics models that enable industry-led C&S revision and Quantitative Risk Assessment (QRA).
F. Enabling national and international markets requires consistent RCS	Develop H_2-specific QRA tools & methods which support SCS decisions.
G. Insufficient Technical Data to Revise Standards	Provide tools and validated models to enable better informed codes and standards revisions.

Approach: Benchmark HyRAM software

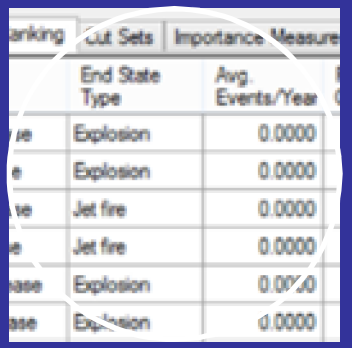


1. Select station designs to analyze

2. Perform risk analysis of stations using HyRAM while AL performs analysis using their models



3. Analyze and characterize differences between HyRAM and AL internal risk tool results



4. Document results

Approach: Develop a diagnostic tool for capturing high-fidelity quantitative data for large scale LH_2 experiments

- **Required**: quantitative concentration measurements with < 1 m resolution
- **Desired**: non-intrusive concentration, temperature and velocity measurements in 3-dimensions + time

sensors

- low cost
- straightforward implementation

- placed in flow, or suction, disturbs flow
- point measurement (challenging to get spatial resolution)
- usually slow response time (poor temporal resolution)
- can be affected by environmental factors (not specific to only H_2)

optical diagnostic

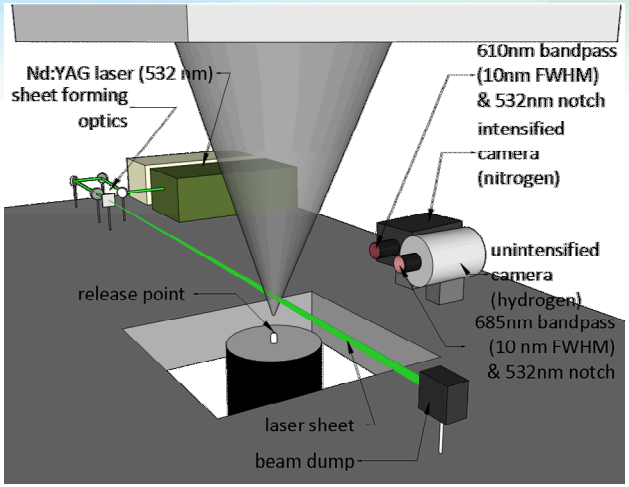
- high spatial resolution possible
- high temporal resolution possible
- non-intrusive

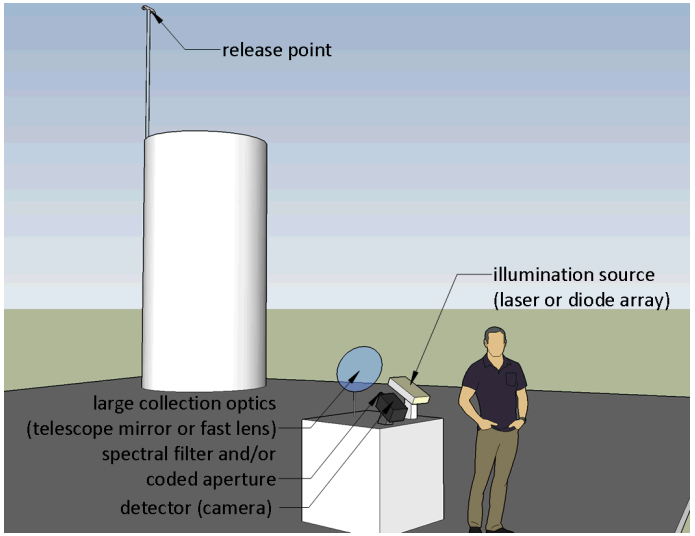
- H_2 is difficult to measure optically (no strong absorption features, no fluorescence transitions)

➢ Chosen technology

Approach: We will scale-up our lab scale Raman imaging technique

- Need large light collection area to capture the small number of photons emitted
  - Reflective optics (large telescope mirror)
  - Refractive optics (Fresnel lens)
- High-powered light source required to excite as many molecules as possible
  - High-power laser with volumetric illumination
  - High-repetition rate laser scanned across the area quickly
  - High-power diodes
- Effective background light suppression is key (both sunlight and illumination source that reflects off of condensed water vapor)
  - Time gating
  - Spectral gating
- Potentially use coded aperture sensing to improve temporal, spectral, or spatial resolution





Collaboration & coordination

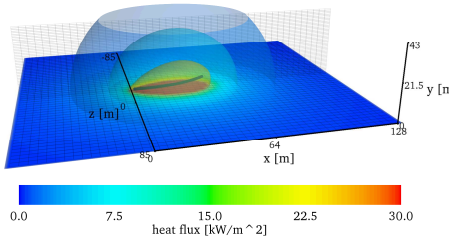
For the Benchmarking HyRAM Task:

- AL: Select up to 10 scenarios, use internal risk tool to analyze scenarios, compare with HyRAM results, review final report.
- SNL: Analyze up to 10 scenarios with HyRAM and compare results, develop final report.

For the Developing a Diagnostic Tool for a LH2 Release Task:

- AL: Support experimental design by providing industry experience, conduct periodic advisory panel meetings, review final report.
- SNL: Develop optical diagnostic to measure dispersion of cold gaseous hydrogen from a LH2 release plume in at least 2-dimensions,design validation testing, develop final report.

HyRAM
HYDROGEN RISK ASSESSMENT MODELS



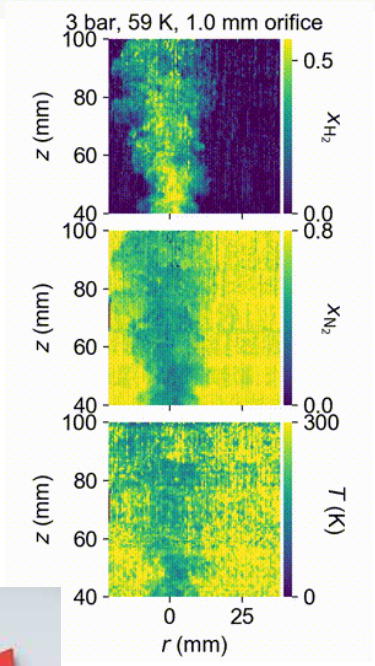
Remaining challenges & barriers

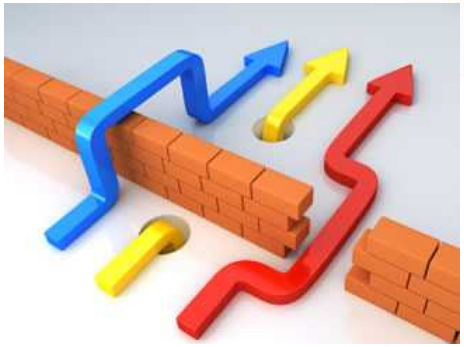
Task 1 - Benchmarking HyRAM:

- All scenarios might not be able to be analyzed in the current form of HyRAM. However, work is being conducted to alter the code to more easily analyze unique scenarios.

Task 2 - Developing a Diagnostic Tool for a LH2 Release:

- This is a challenging problem requiring high-powered illumination and atypical light collection optics. Finding components that can provide these features at reasonable cost will be difficult.





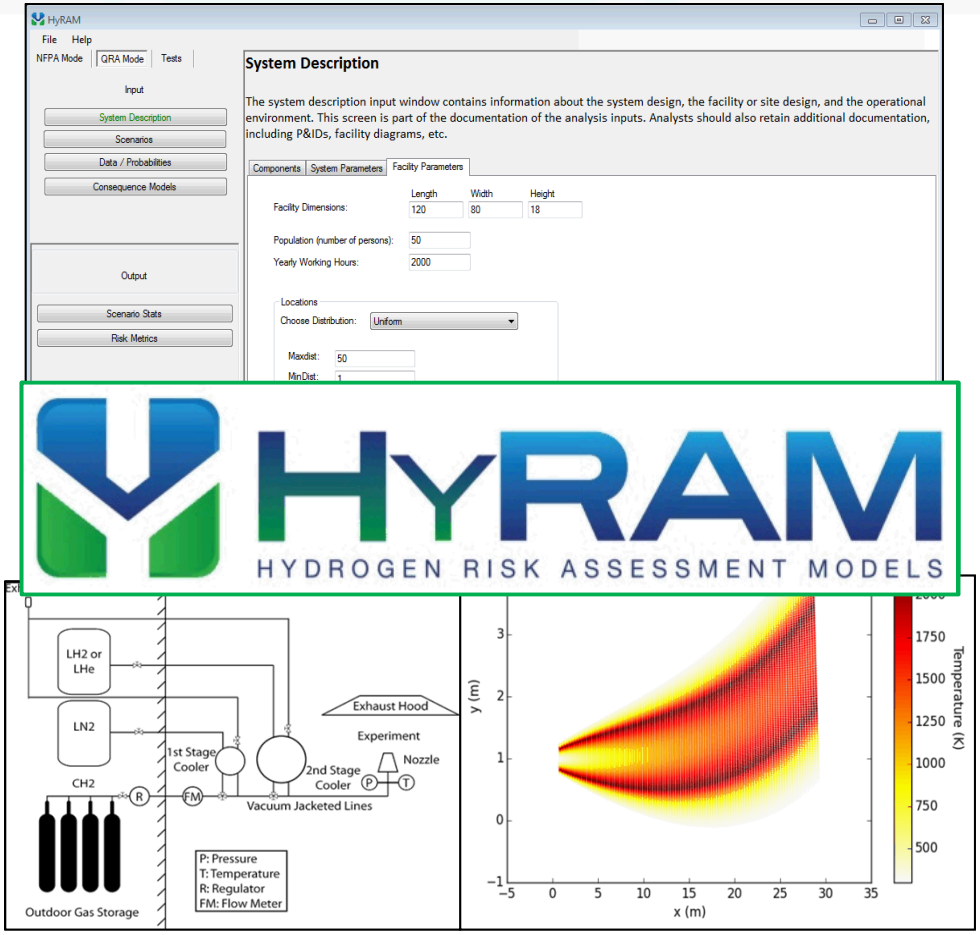
Proposed future work

- FY18:
  - Benchmark HyRAM Software
  - Develop a diagnostic tool for capturing three-dimensional (3D) data for large scale hydrogen experiments
- FY19:
  - Refine characterization of LH2 releases with validated cold plume release and identify full scale modeling needs to provide sound scientific basis for revised bulk LH2 separation distances in NFPA 2/55
  - Develop GUIs & source code for cold-plume model based on experimental results
  - Update HyRAM with lessons-learned from AL internal risk and consequence modeling tool

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

Technology transfer activities

- Technology transfer strategies are tied to the accessibility of HyRAM QRA tool kit to other users (AHJs, station designers, etc.) to analyze station risks or consequences-only
- Free HyRAM download at http://hyram.sandia.gov



Current release is version 1.1.1.1249

Summary

Relevance: Build validated H2 behavior physics models and QRA tools that enable industry-led C&S revision.

Approach: *Benchmark HyRAM:* 1. Select station designs to analyze. 2. Perform risk analysis of stations using HyRAM. 3. Analyze results between HyRAM and AL internal risk tool. 4. Document results.

Developing Diagnostic: 1. Calculate hardware (illumination and light collection) needed. 2. Build diagnostic system. 3. Prove functionality by applying diagnostic to real-world release 4. Document results.

Progress: Work has not yet begun on this project.

Technical Back-Up Slides

HyRAM: Making hydrogen safety science accessible through integrated tools

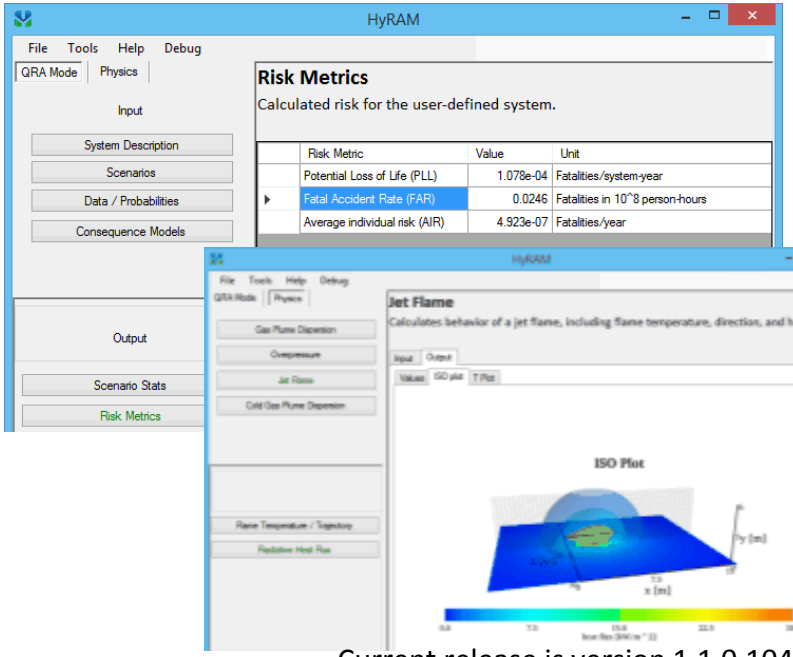
First-of-its-kind integration platform for state-of-the-art hydrogen safety models & data - **built to put the R&D into the hands of industry safety experts**

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



Current release is version 1.1.0.1047

Free download at http://hyram.sandia.gov