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

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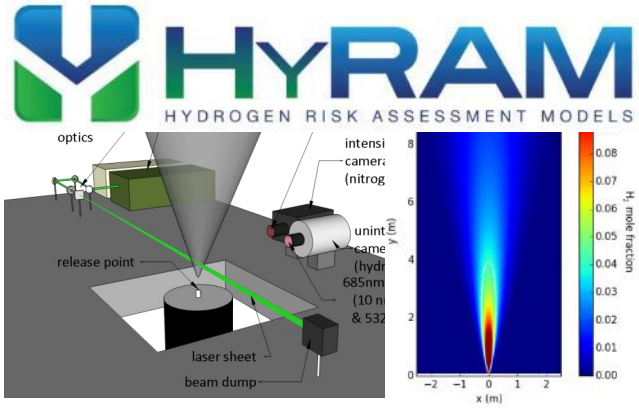
2019 DOE Hydrogen and Fuel Cells Annual Merit Review
April 30, 2019



Project # h2013
SAND2019-2319

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Overview

Timeline

- Project start date: Jan 2019
- Project end date: Jan 2020

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

- FY19 DOE Funding: $250k
- FY19 Air Liquide Funding: $250k
- FY19 Air Liquide In-Kind Contribution: $75k
- Total DOE Funds Received to Date: $250k
- Total DOE Funds Spent: $0k

Partners

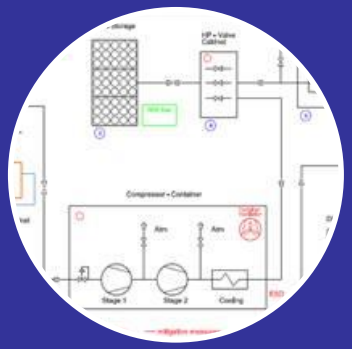
- Air Liquide (AL)
- NFPA H2 Storage Task Group
- CGA G-5.5 Testing Task Force

Relevance

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

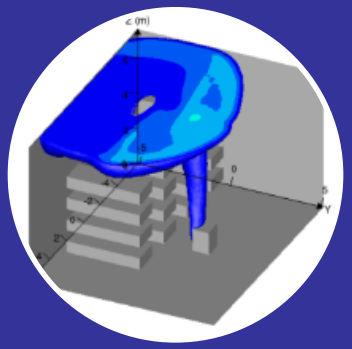
Barrier from 2015 SCS MYRDD	SNL Goal
A. Safety Data and Information: Limited Access and Availability	Build validated H_2 behavior physics models that enable industry-led C&S revision and Quantitative Risk Assessment (QRA).
F. Enabling national and international markets requires consistent Regulations, Codes and Standards	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

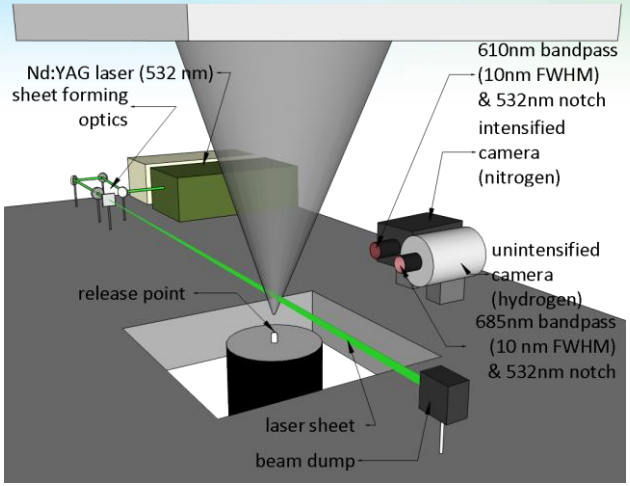
4. Document results

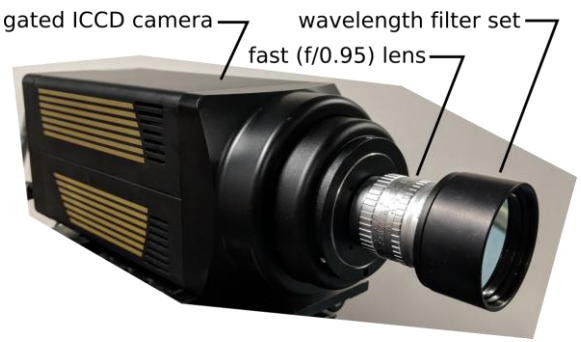
Approach: Make quantitative measurements from large LH_2 experiments that enable defensible codes/QRA

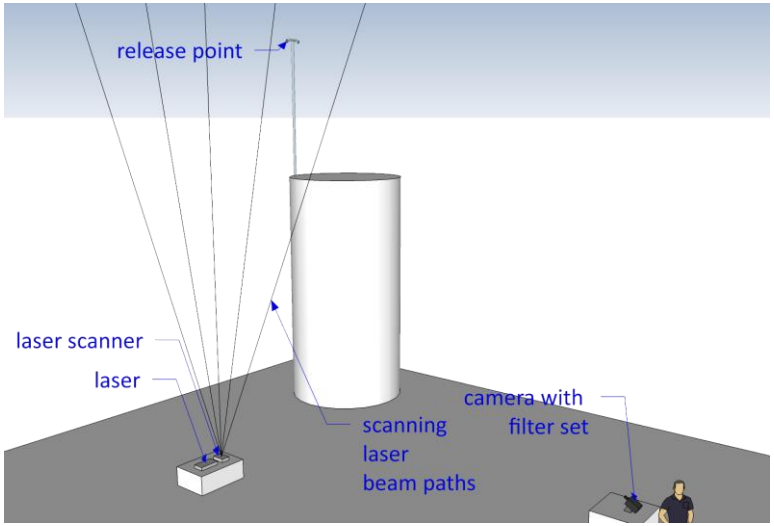
- Support CGA G-5.5 testing task force measurements of LH_2 vent stack flames
  - Hardware support (providing Sandia owned sensors to support the work)
  - Analysis support (Sandia expertise in data analysis and documentation)
- Experimentally measure unignited hydrogen dispersion from LH_2 vent stacks
  - Develop a diagnostic tool for capturing high-fidelity quantitative data for large scale unignited LH_2 experiments
    - Non-intrusive (optical diagnostic)
    - Measure concentration in at least 2-dimensions with good temporal resolution
  - Measure vent stack dispersion for a range of flow rates and weather conditions

Approach: Scale-up our lab scale Raman imaging technique

- Use high-speed (low f-number) optics to collect as much light as possible with large field of view to measure entire plume
- High-powered light source required to excite as many molecules as possible
  - High-power laser scanning in space
  - Concentrations measured along a series of lines
- Effective background light suppression is key (both sunlight and illumination source that reflects off of condensed water vapor)
  - Time gating
  - Spectral gating







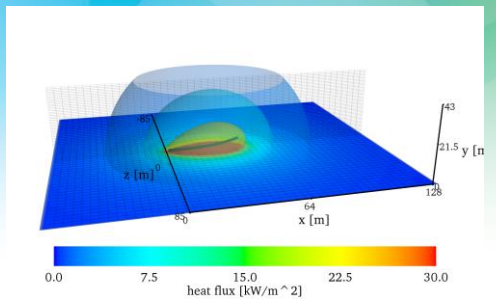
Progress & Accomplishments

- This project has not started

Response to previous year reviewer's comments

- This project was not reviewed last year

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 experimental tasks:

- AL: Support experimental design by providing industry experience, conduct periodic advisory panel meetings, review final report.
- CGA G-5.5 testing task force: Coordinate LH2 vent stack flame experiments with industrial and national laboratory partners.
- 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

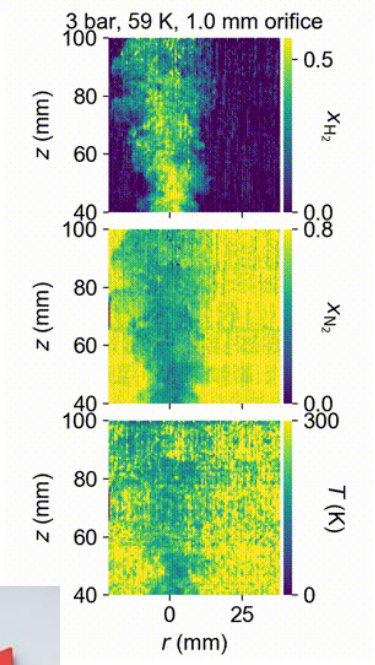
Remaining challenges & barriers

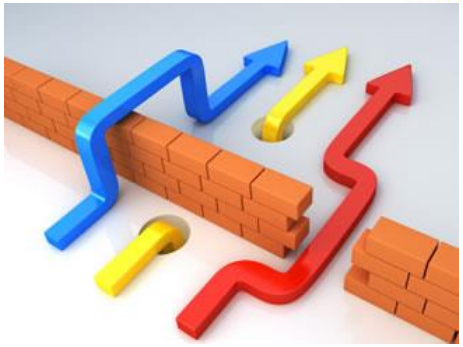
Task 1 - Benchmarking HyRAM:

- 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 - Experimental work:

- Developing a diagnostic tool to measure LH2 vent stack dispersion 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.





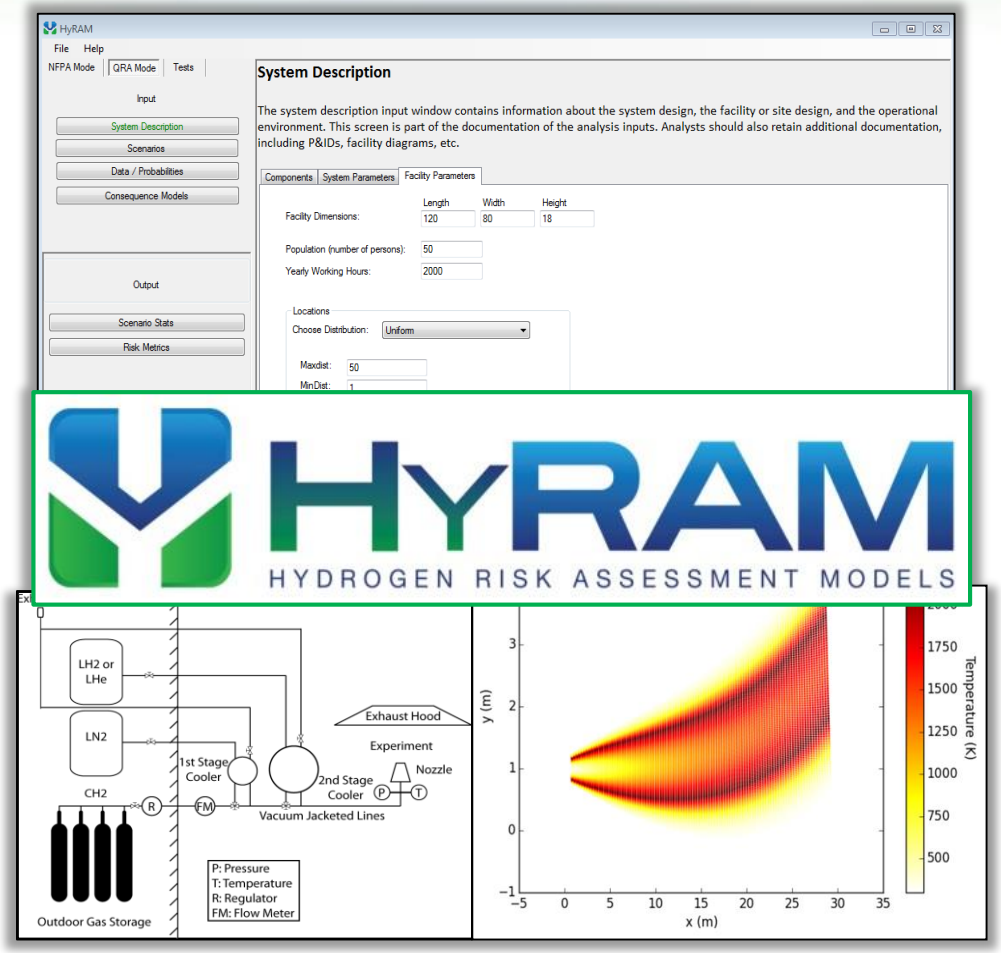
Proposed future work

- FY19:
  - Benchmark HyRAM Software
  - Provide measurement and analysis support of CGA G-5.5 testing task force data collection on H2 vent stack flame experiments
  - Develop and perform experiments with a diagnostic tool for capturing three-dimensional (3D) data for large scale hydrogen experiments
- FY20:
  - 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.

Experimental work: 1a. Support CGA G-5.5 testing task force experiments of LH_2 vent stack flame measurements. 1b. Finalize hardware build (illumination and light collection) needed for unignited dispersion diagnostic. 2b. Prove functionality by applying diagnostic to real-world releases. 3. Document results.

Progress: Work has not yet begun on this project but it is anticipated to begin by AMR.

Technical Back-Up Slides

HyRAM: Making hydrogen safety science accessible through integrated tools

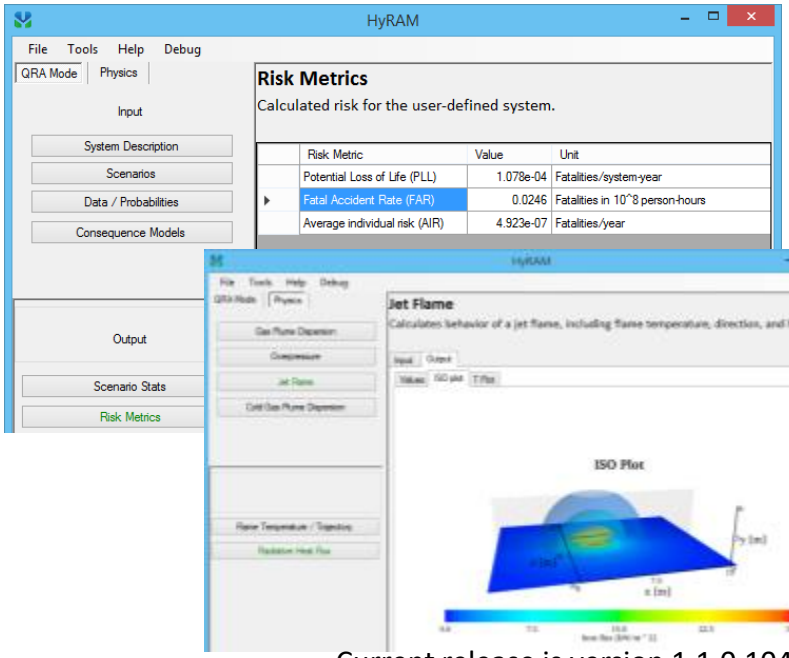
First-of-its-kind integration platform for state-of-the-art hydrogen safety models & data - **built to put the R&D into the hands of industry safety experts**

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