

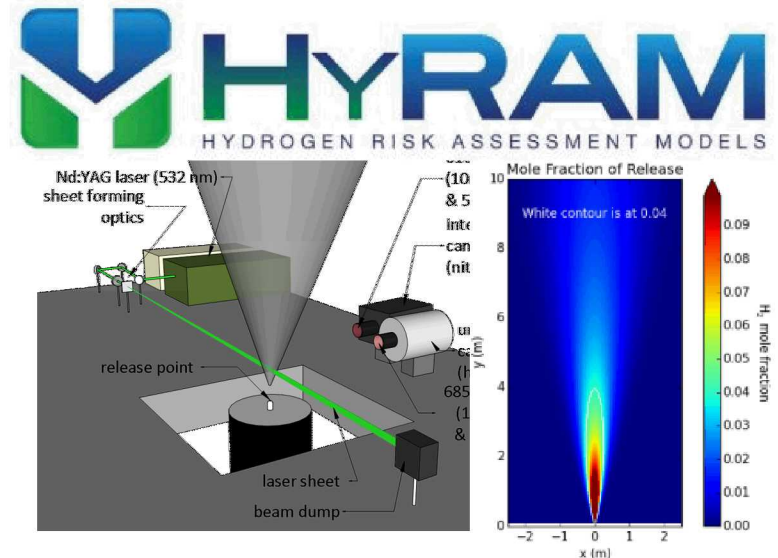


Development, Validation, and Benchmarking of Quantitative Risk Assessment Tools for Hydrogen Refueling Stations

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H2@Scale Workshop

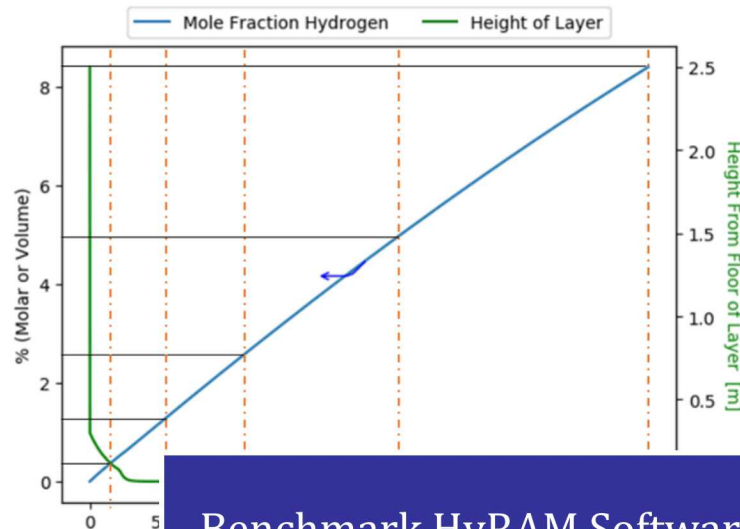
June 26, 2019

SAND2019-XXXX



CRADA Tasks

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



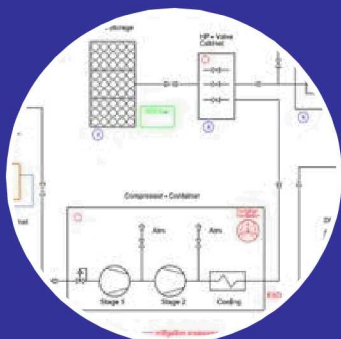
Benchmark HyRAM Software



Develop diagnostic tool for 3D data for large scale experiments



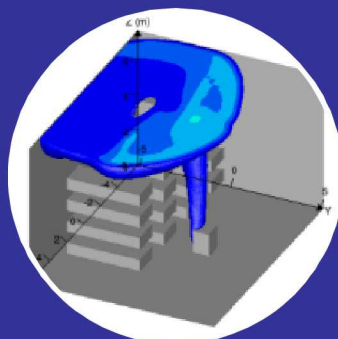
Approach: Benchmark HyRAM software



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

Ranking	Out Sets	Importance Measure
	End State Type	Avg. Events/Year
1st	Explosion	0.0000
2nd	Explosion	0.0000
3rd	Jet fire	0.0000
4th	Jet fire	0.0000
5th	Explosion	0.0000
6th	Explosion	0.0000

4. Document results





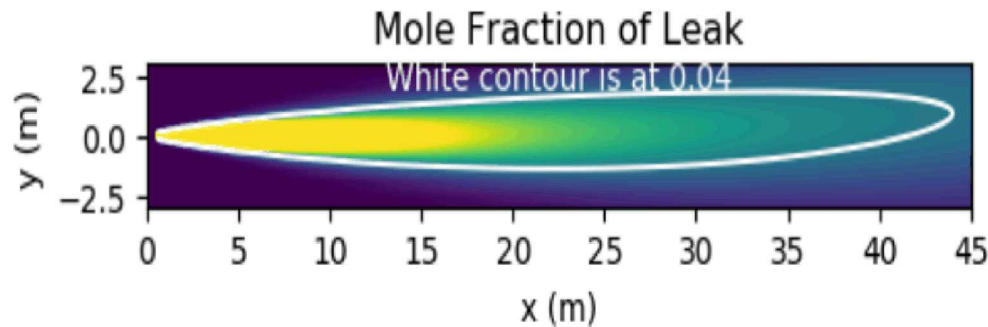
Example scenario: GH2 release

- Inputs:
 - Leak orientation
 - Pressure
 - Size of breach
 - Continuous release
 - No wind
- Outputs:
 - Mass flow
 - Distance at 4% and 10% concentration
 - Width of plume at 4% and 10%
 - Flame length
 - Distances at heat fluxes

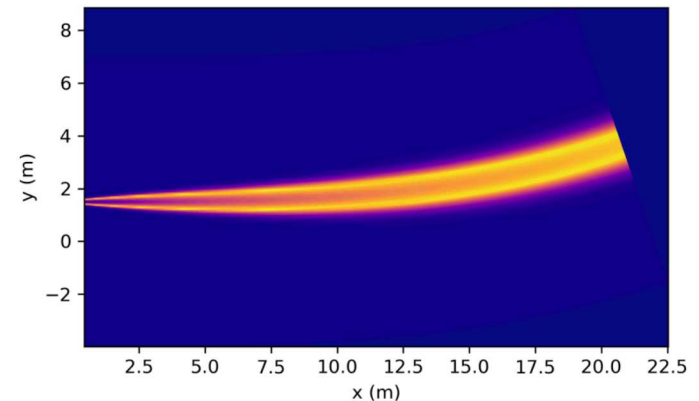


HyRAM models

- Engineering Toolkit was used to calculate mass flow rate
- Gas plume dispersion model was used to calculate horizontal distance and maximum width of the cloud for 4% and 10%
- Jet flame and radiative heat flux model was used to calculate flame length and horizontal distance of heat flux values



Gas plume model



Jet flame and radiative heat flux model



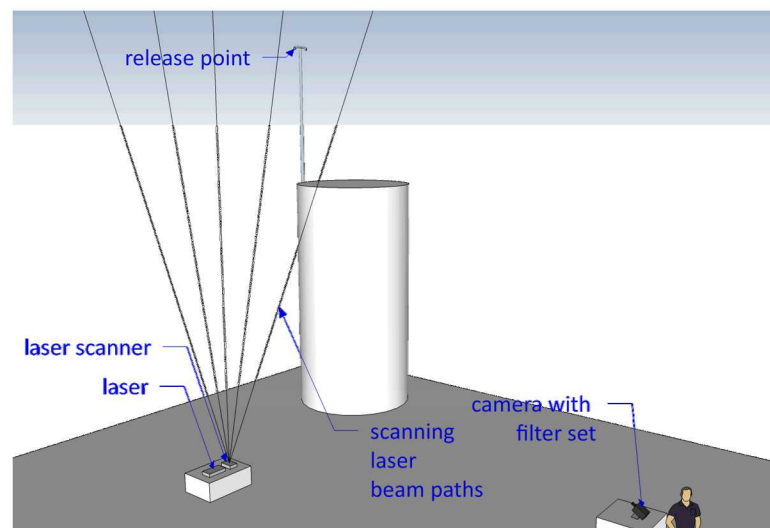
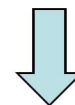
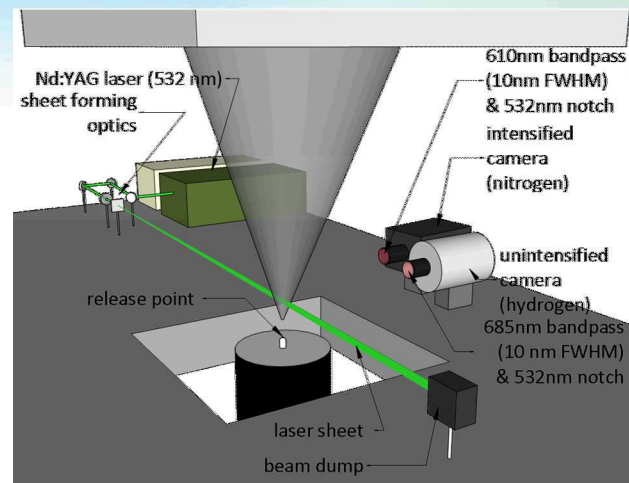
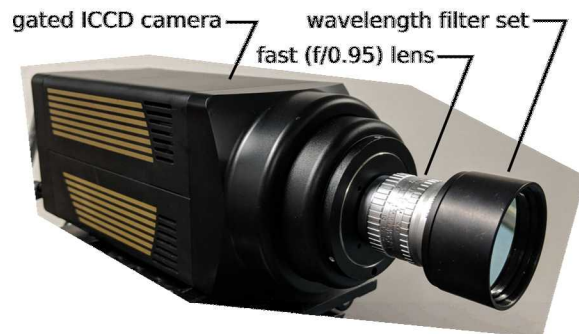
Make quantitative measurements from large LH₂ experiments that enable defensible codes/QRA

- Support CGA G-5.5 testing task force measurements of LH₂ 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 LH₂ vent stacks
 - Develop a diagnostic tool for capturing high-fidelity quantitative data for large scale unignited LH₂ 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



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





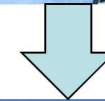
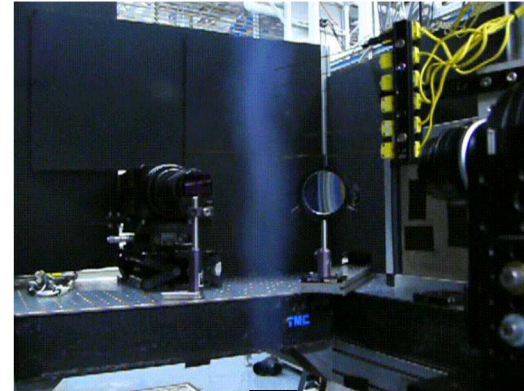
Remaining challenges & barriers

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:

- Executing outdoor experiments require approvals from LLNL, proper procedures to operate the laser outdoors, and appropriate weather conditions (i.e. high- and low-wind conditions)





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



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 LH₂ 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 begun to run scenarios using HyRAM. Experimental work is also in development.



Thank you

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