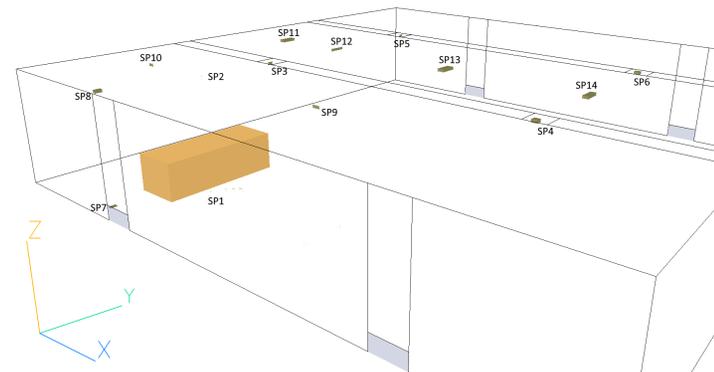
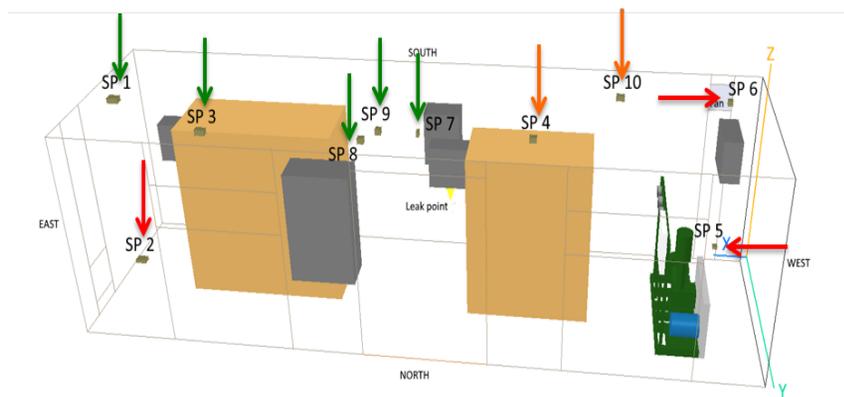


# Guidance for Indoor H<sub>2</sub> Sensor Placement

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Project ID # SCS0027

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

# Overview

## Timeline

- Project start date: 02/12/2019
- Project End Date: 04/30/2021
- \* Project continuation and direction determined annually by DOE

## Budget

- FY19 DOE funding: \$ 75,000
- FY20 planned DOE funding: \$ 75,000
- Total DOE funds received to date: \$ 150,000

## Barriers

- A. Safety Data and Information: Limited Access and Availability
- G. Insufficient Technical Data to Revise Standards
- K. No Consistent Codification Plan and Process for Synchronization of R&D and Code Development

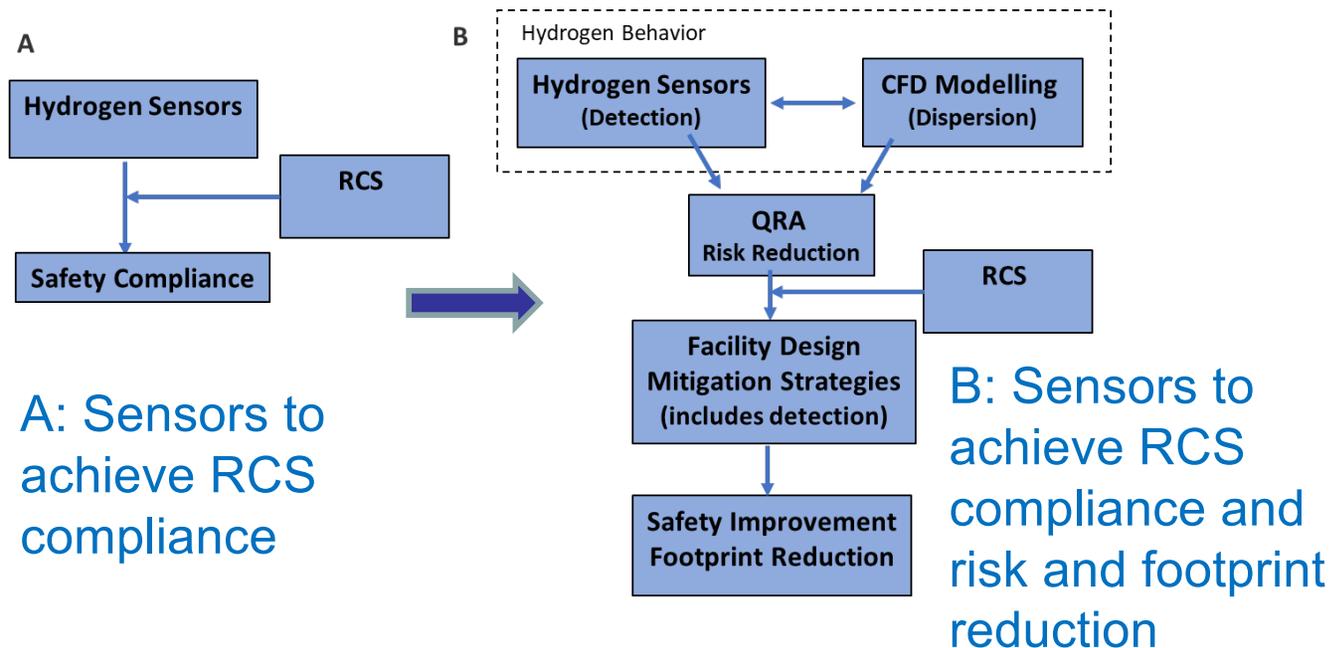
## Partners

- No partners

# Relevance

- ❑ Objective: Enable the safe use of hydrogen as an alternative renewable fuel via a cost-effective and smart hydrogen detection system
  - Provide rational guidance on hydrogen sensor deployment strategies to mitigate risks and minimize hazards associated with the inadvertent release of hydrogen.

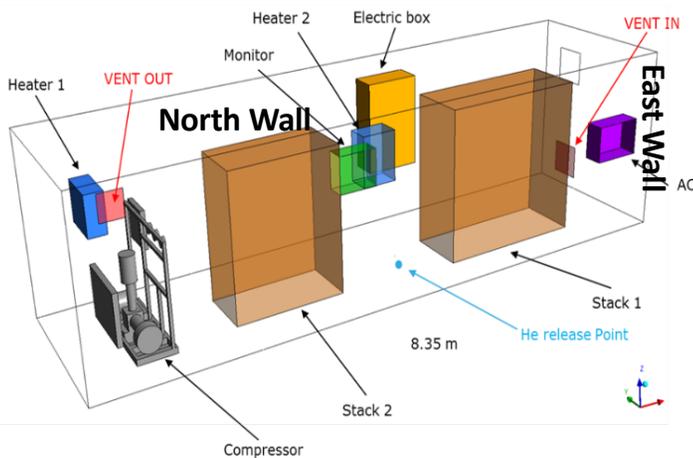
Evolution of the role of sensors:  
From A to B



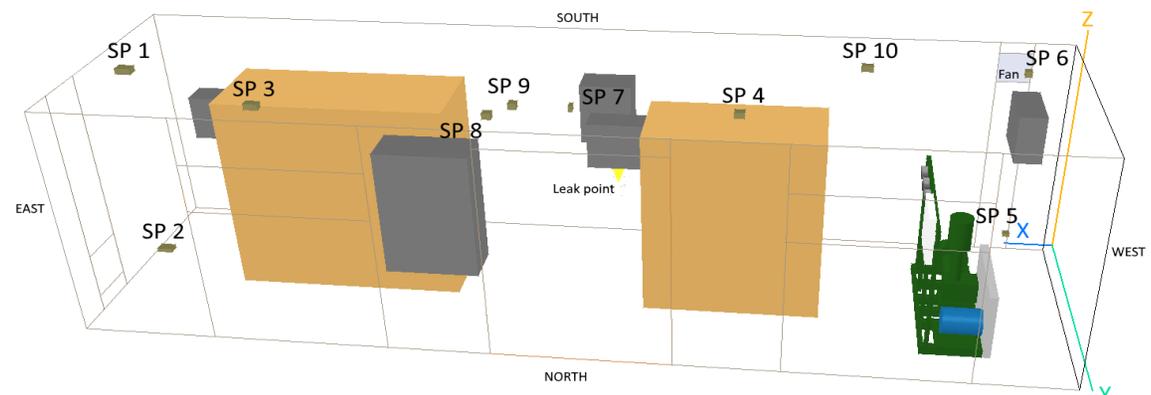
**Active monitoring for early leak detection is one mitigation strategy to assure facility safety**

# Approach – Phase 1

- ❑ Test the concept and develop draft sensor placement guidance for “small” ventilated enclosures (1):
  - Real-world hydrogen generator with compression at NREL test wind site – regular 20’ container with exhaust fan
  - HyWAM (Hydrogen Wide Area Monitoring) deployment: 10 thermo-conductivity sensors (measure ppmv H<sub>2</sub> or ppmv He) at select Sampling Points (SP)



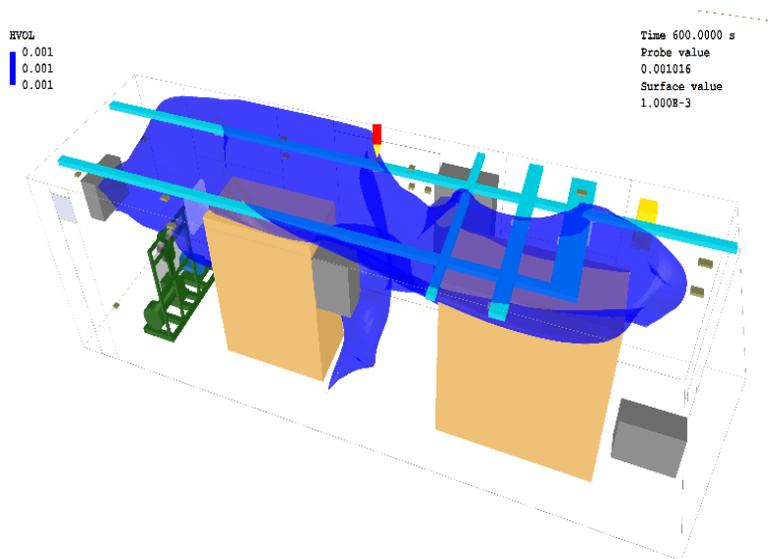
Enclosure equipment



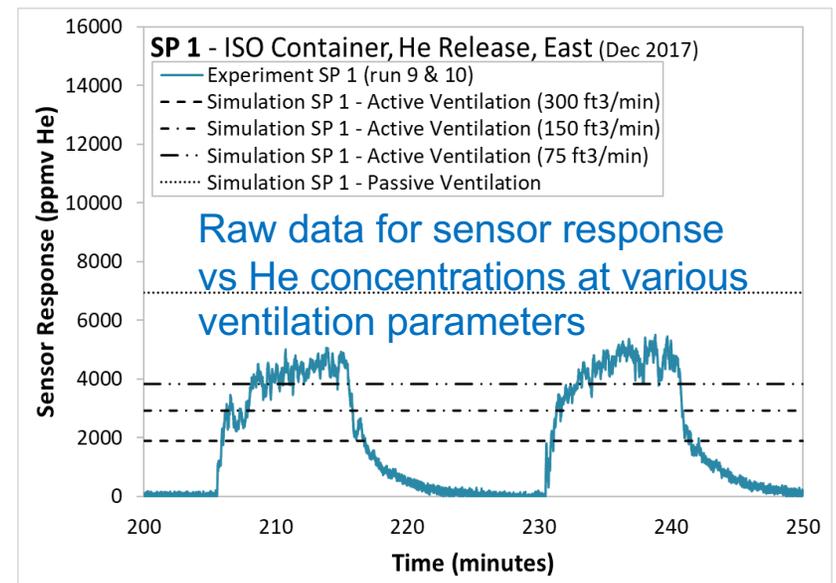
HyWAM sensor locations for He release tests.  
CFD modeling used the same sensor points.

# Approach – Phase 1

- ❑ Test the concept and develop draft sensor placement guidance for “small” ventilated enclosures (2):
  - Pre- and post-test CFD modeling (both H<sub>2</sub> and He) with variation of ventilation parameters
  - Helium release tests (in 5 directions from the leak point)



CFD Modeling



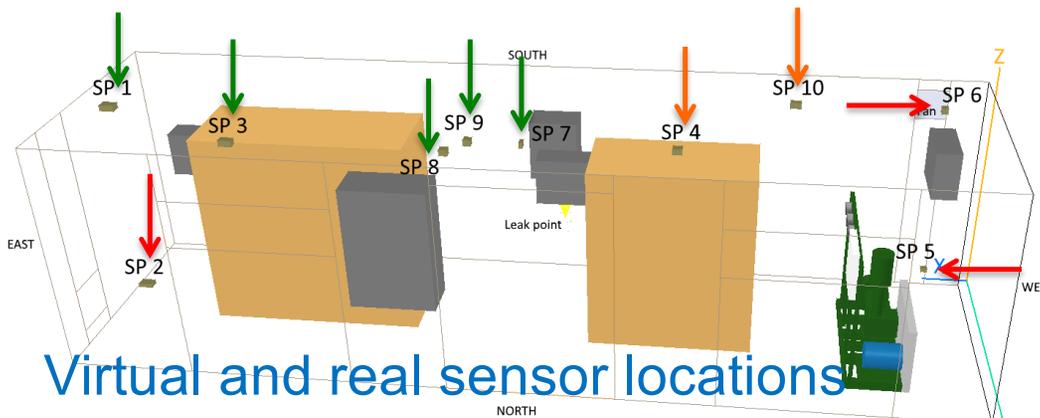
He Release Tests

Validated CFD modelling of indoor releases verified the concept for indoor H<sub>2</sub> sensor placement guidance

# Accomplishments and Progress – Phase 1

- ❑ Draft guidance for sensor placement for “small” ventilated enclosures

Sensor locations per Dec 2017 Tests–300 ft <sup>3</sup> /min ventilation										
	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SP9	SP10
NORTH	Y	N	Y	Y	N	N	Y	Y	Y	U
EAST	Y	N	Y	U	N	N	Y	Y	Y	U
UPWARD	Y	N	Y	U	N	N	Y	Y	Y	U
WEST	Y	N	Y	Y	N	Y	Y	Y	Y	Y
SOUTH	Y	N	Y	U	N	U	Y	Y	Y	U
DOWNWARD	Y	Y	Y	U	U	U	U	Y	Y	U
<b>Overall Rating</b>	Y	N	Y	U	N	N	Y	Y	Y	U



Virtual and real sensor locations

Sensor Position Markers:

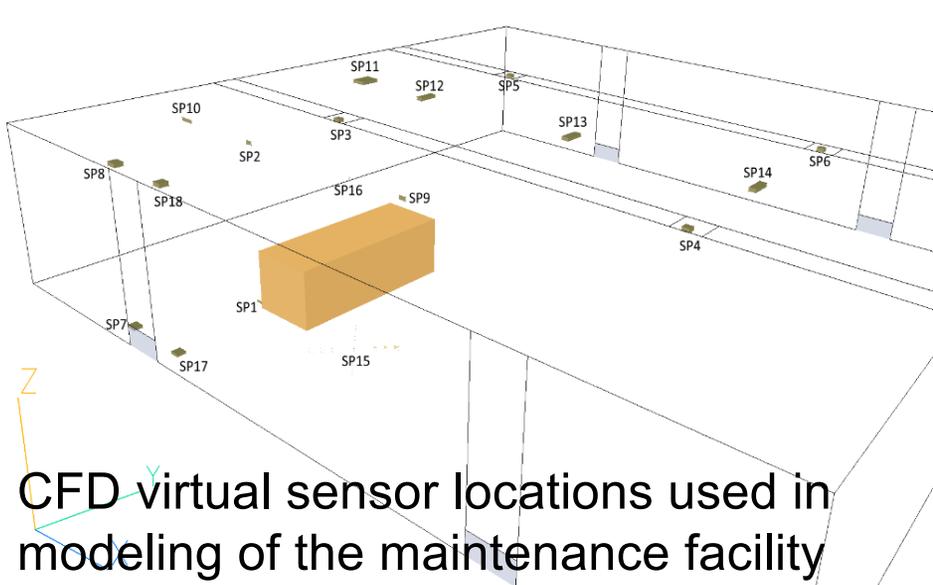
Suitable → Uncertain → Not suitable →

- ✓ Not on direct path of airflow
- ✓ Practical detection range 1,000 – 4,000 ppm (0.1 to 0.4 % vol. in air)

**Sensor placement and response level guided by ventilation parameters (small facility)**

# Approach – Phase 2

- ❑ Expand the concept to “large” ventilated enclosures and validate sensor placement guidance:
  - Real-world FCEV maintenance facility; Validated leak scenario and ventilation regimes provided by SNL (Project # H2011)
  - CFD modeling (virtual sensors)
  - Try to integrate into QRA tool (HyRAM)



CFD modeling domain

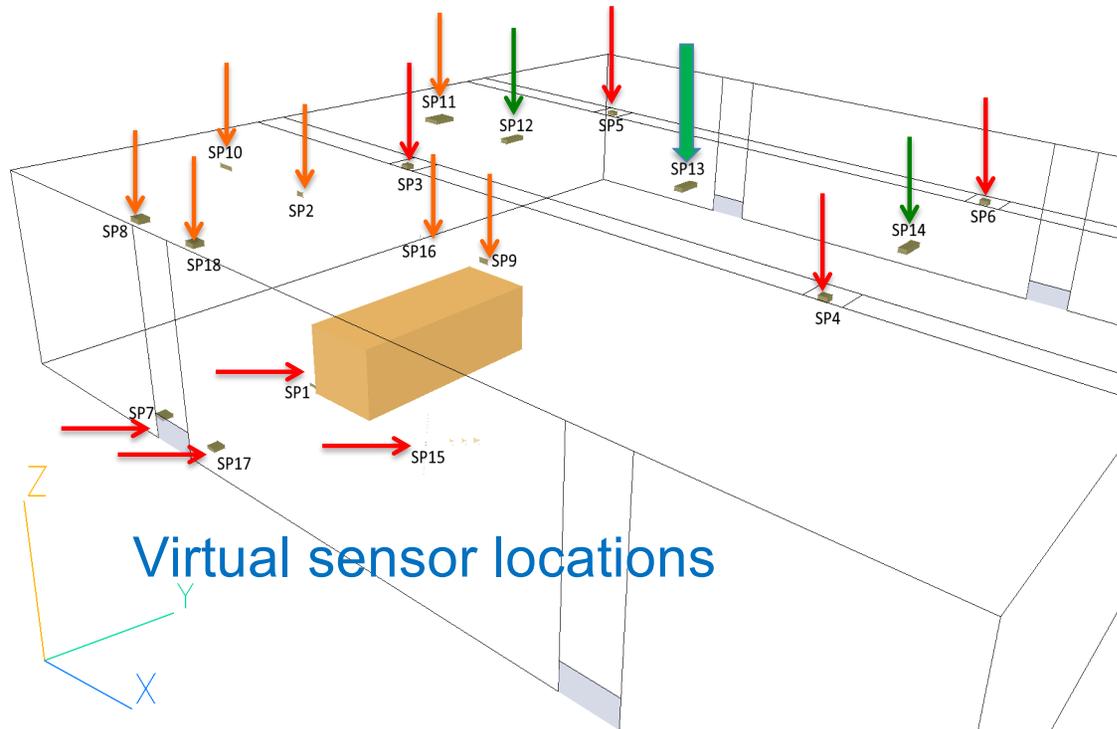


Plug-in to HyRAM

**CFD modeling was instrumental to validate sensor placement guidance for indoor facility**

# Accomplishments and Progress – Phase 2

- ❑ Validated guidance for sensor placement for “large” ventilated facilities with ceilings up to 16’ high



Sensor Position Markers:

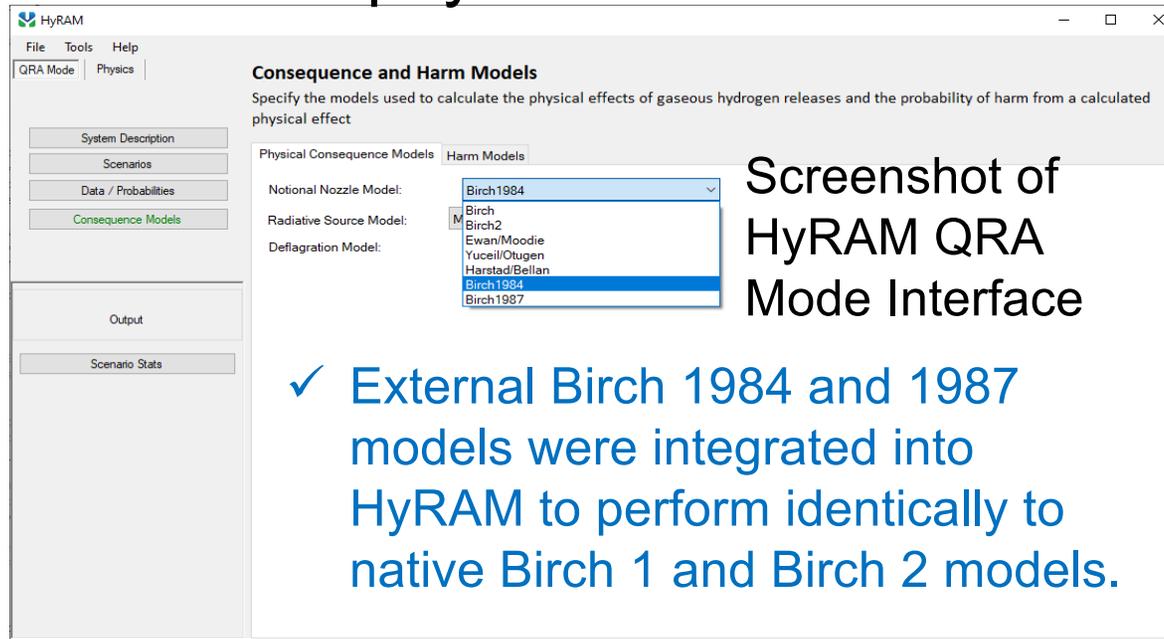
Suitable → Uncertain → Not suitable →

- ✓ Not on direct path of airflow.
- ✓ Practical detection range 1,000 – 4,000 ppm.
- ✓ Locations along the centreline of the garage (SP13, SP12 and SP14) are suitable and practical.
- ✓ For high ceiling (>16’) enclosures, sensor should be placed above potential leak points.

**Sensor placement and response level  
guided by ventilation parameters (large facility)**

# Accomplishments and Progress – Phase 2

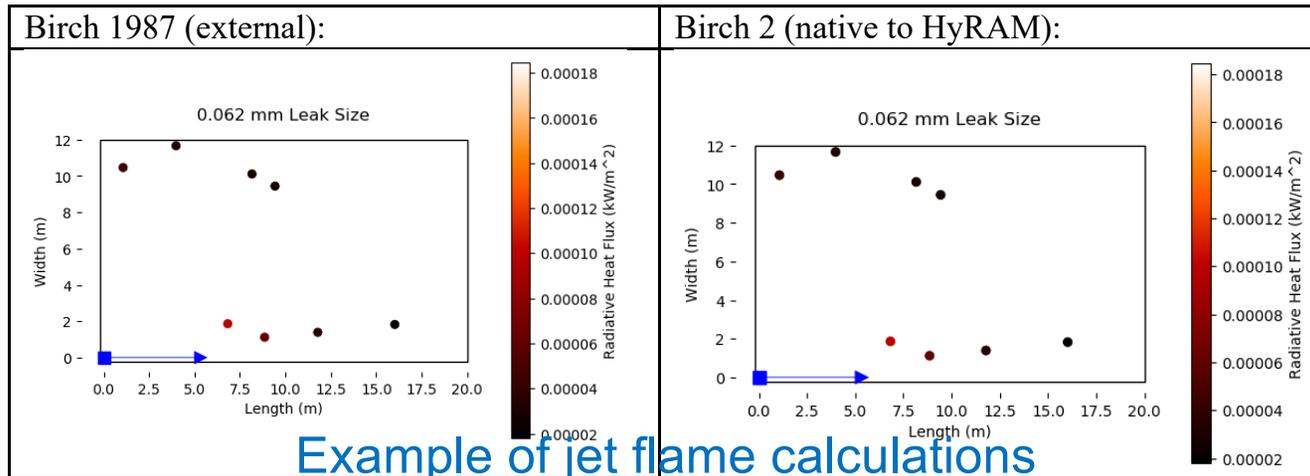
- ❑ Integrated external physical effects models into HyRAM



Screenshot of HyRAM QRA Mode Interface

- ✓ External Birch 1984 and 1987 models were integrated into HyRAM to perform identically to native Birch 1 and Birch 2 models.

Screenshot of HyRAM generated results using Birch external model

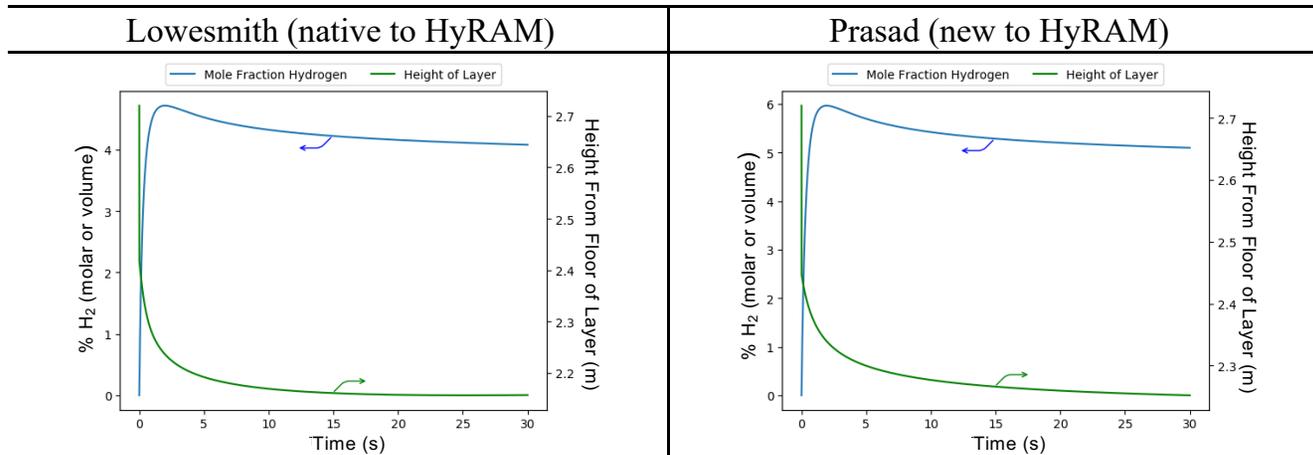


Screenshot of HyRAM generated results using Birch native model

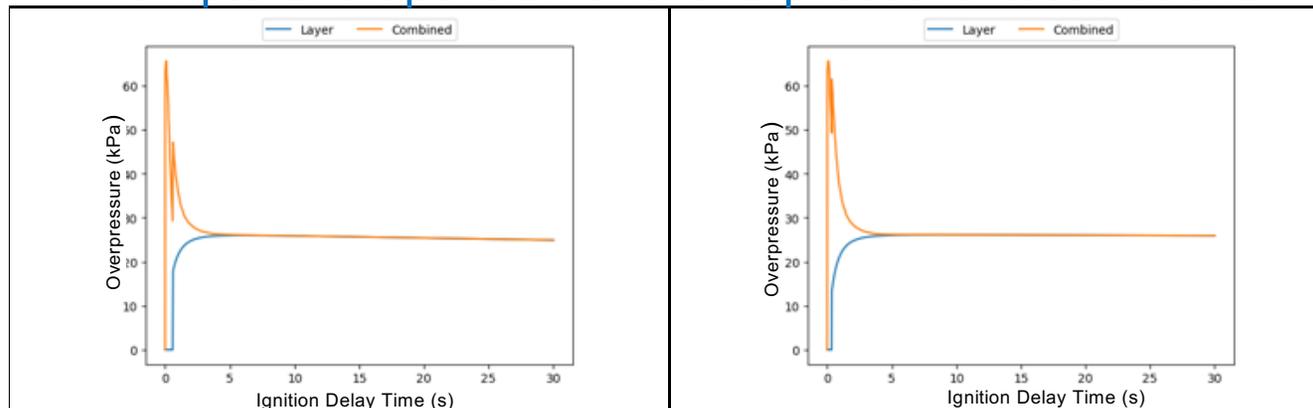
External physical effects models can be integrated into HyRAM and used in lieu of native models

# Accomplishments and Progress – Phase 2

## ❑ Integrated external enclosure model into HyRAM



### Example of dispersion and overpressure calculations



External Prasad enclosure dispersion model was integrated into HyRAM to perform in lieu of native Lowesmith model within HyRAM internal algorithm and interact with the native overpressure model.

**External enclosure models can be integrated into HyRAM and interact with other native models**

# Collaborations

Collaborators:

❑ Sandia National Laboratories:

➤ Relevant data sharing, HyRAM expertise

❑ NFPA 2 Hydrogen Technologies Code TC, HySafe, and PNNL Hydrogen Safety Panel:

➤ Feedback on sensor placement guidance

# Remaining Challenges and Barriers

For sensor placement:

- ❑ Integration into NFPA 2 next edition – buy-in on the guidance.
- ❑ Expand to confined outdoor environment.

For enhancement of physical effects models for enclosures and risk reduction credits:

- ❑ Integration of CFD modeling and test results directly into physical effects and / or QRA modes of open source HyRAM code.

**Manageable challenges for both sensor placement and integration to HyRAM**

# Proposed Future Work\*

\* Project continuation and direction determined annually by DOE

1. Contribution to NFPA 2:
  - a. Presentation of results and feedback
  - b. Submission of language to Appendix for next revision
2. Enhancement of physical effects models for enclosures / confined spaces:
  - a. Develop enhanced CFD-informed engineering enclosure model inside HyRAM
3. Expansion of indoor releases analysis to outdoor confined spaces:
  - a. Focus on facilities with outdoor compressed gas storage with fire wall barriers

**Critical tasks to contribute to best engineering safety practices and account for risk reduction**

# Summary

- ❑ Objective: Assure the safe use of hydrogen as an alternative renewable fuel via an affordable intelligent hydrogen detection system.
- ❑ Relevance: Provide rational guidance on hydrogen sensor deployment strategies to mitigate risks and minimize hazards associated with the inadvertent release of hydrogen.
- ❑ Approach: Phase 1: Test the early detection concept on “small” enclosure via CFD modeling and release experiments. Phase 2: expand to “large” facility and validate the concept via CFD modeling and try integrate into HyRAM.
- ❑ Accomplishments: Developed and validated guidance for sensor placement inside ventilated enclosures up to 16’ high. Integrated external jet and enclosure models into HyRAM.

**State-of-the-Art research to validate early leak detection guidance to improve safety of H2 facilities**