



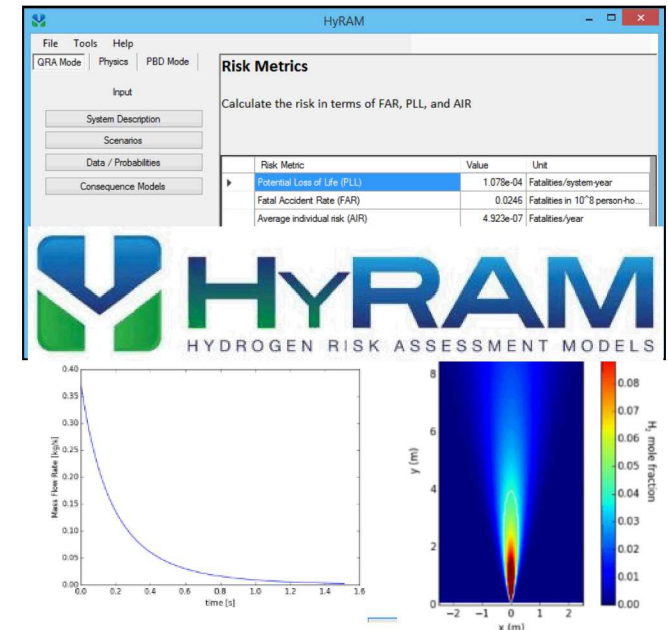
Hydrogen Safety Research Priorities: QRA and HyRAM

Alice B. Muna

Sandia National Laboratories

Project Team: Brian Ehrhart, Ethan Hecht,
Myra Blaylock, Gabriela Bran Anleu, John
Reynolds, Cieran Sims, Chris LaFleur

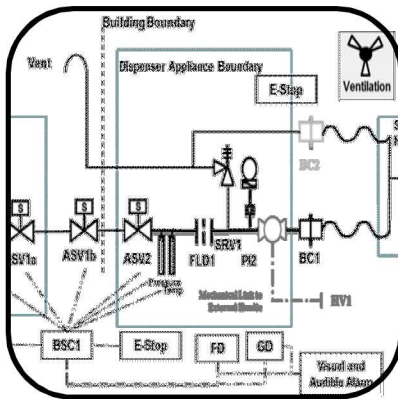
HySafe Workshop
September 19-20, 2018



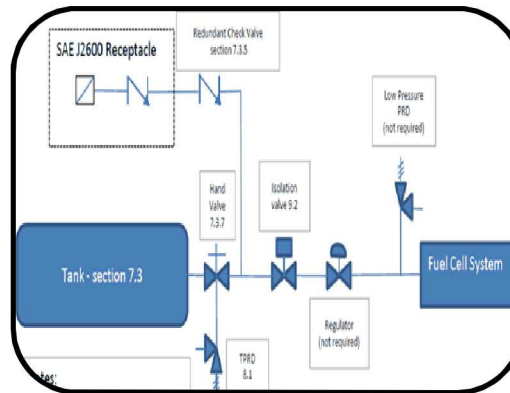


Current HyRAM QRA Analysis

- Focused on a gaseous hydrogen dispenser fueling forklifts located in a warehouse
- Analysis can be altered for generic fueling stations, but applicability is limited beyond that scope



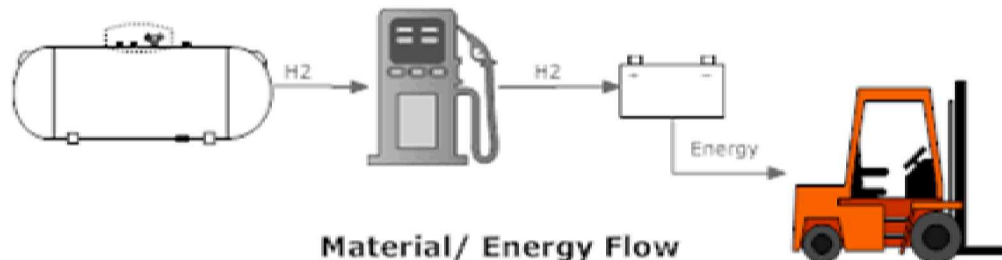
Dispenser



Fuel Cell



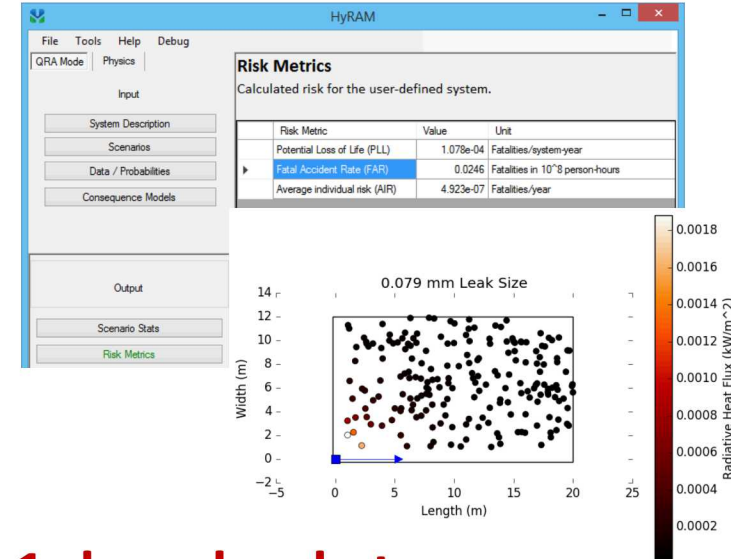
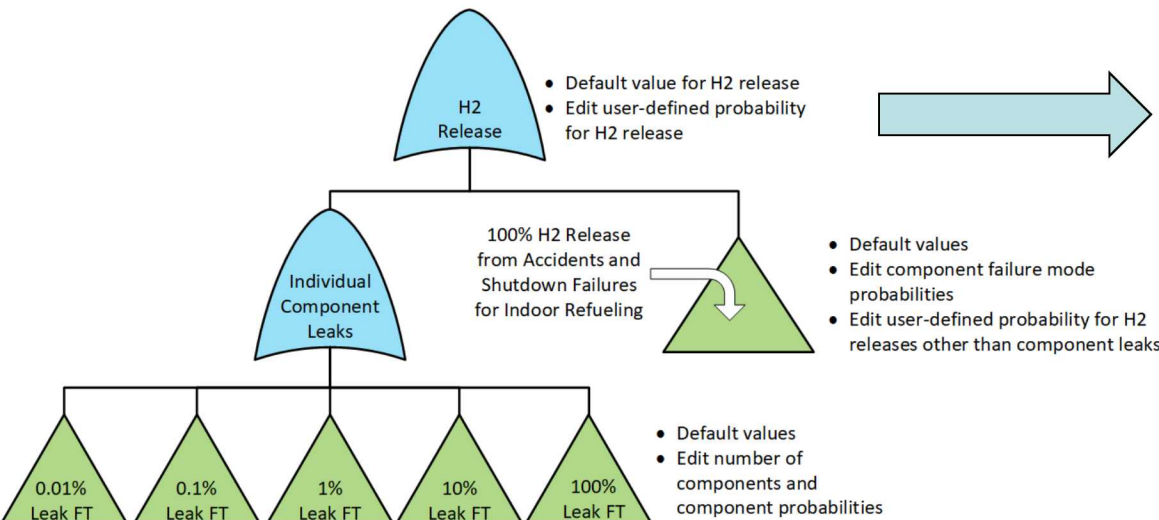
Vehicle



Material/ Energy Flow

QRA Progress: Expanding HyRAM QRA flexibility beyond hydrogen refueling stations

- Develop additional QRA capability to enable HyRAM to be applied to a larger variety of H₂ applications
 - Users will be able to edit the parameters of the existing fault tree to alter the risk analysis for different applications
 - Underlying physics-based analysis would remain the same
 - Version 2.0 expected to be released once copyright updated



Version 1.1 download at
<http://hyram.sandia.gov>



Near Term Research Direction: LH2 and Additional Fuels

- Publish HyRAM 2.0
 - Updated QRA analysis to allow for customization and fidelity
 - Critical bug fixes which improved and clarified user interface
- Incorporating LH2 models and risk analysis into HyRAM
 - Incorporate **validated liquid/cryogenic H2 release behavior model**
 - **Generate data/probabilities** for liquid hydrogen system component failures, leak frequencies, detection effectiveness, etc. based on operating experience or other information
- Expanding HyRAM to AltRAM (Alternative Fuels Risk Assessment Models)
 - Customization of the components, failure modes and accidents, will allow for the risk analysis of alternative fuels (CNG, LNG, LPG) **with the addition of appropriate physics/behavior models**



Gaps and Research Directions

- Ongoing need for safety data and models:
 - Incorporate **additional validated physics models for liquid hydrogen behaviors**, including: pooling, vaporization and flame
 - Add **deflagration** (unconfined) and **detonation** models, etc.
 - Scoping algorithms for uncertainty analysis
- Expanding risk analysis to other applications
 - Applying QRA concepts to other safety needs
 - Analysis of materials
 - Maintenance facilities
 - Parking garages
 - Residential garages