

# QRA Tools - Gaps, Methods, Models Tools

**Katrina M. Groth, Ph.D.**

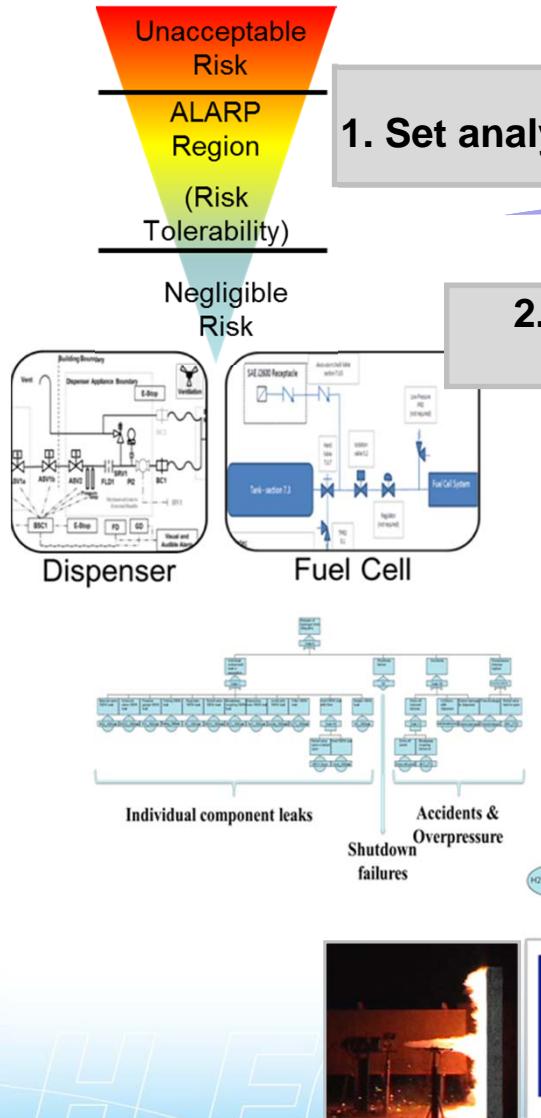
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2014 HySafe Research Priorities workshop  
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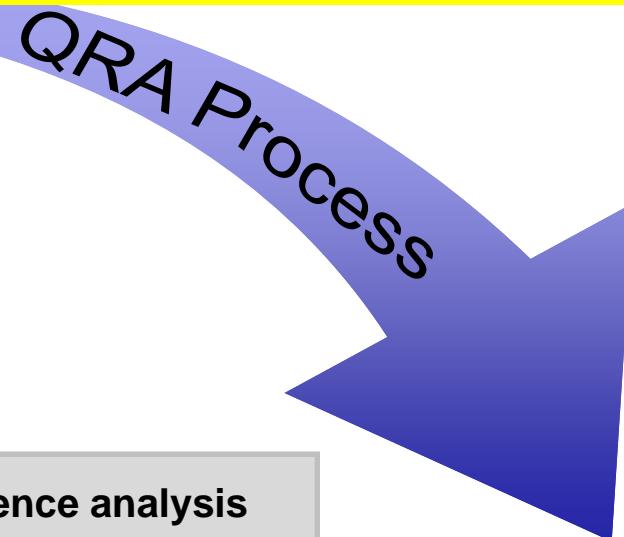


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# QRA Method Overview



Status: The general QRA method is robust – and the hazards are known...**but...**  
**the method is only as good as the models and tools used**



## Previously: Gaps from 2012 HySafe document

1. Hydrogen-specific data for updating probability models
  - Component leak frequencies
  - Gas and flame detection probability
2. A credible probability model for ignition occurrence
3. Simplified models of physical effects for deflagration/detonations
4. Inclusion of human, software, & organizational failures
5. Pilot study of external hazards (e.g., earthquakes, high winds)
6. H<sub>2</sub>-specific harm models (deterministic criteria, probit models)
7. Guidance on the use of risk insights in decision making
8. Uniform cost-benefit criteria for use in evaluating acceptable risk levels

## New approach to thinking about gaps

- Approach:
  - SNL/HySAFE QRA gap analysis workshop to identify gaps & set priorities
  - Sensitivity analysis of gaps with HyRAM
  - Added (and ongoing) focus on *impact* of the gaps
    - Framing out “QRA success”

# Sandia/HySafe H2 QRA needs workshop

- **Specifics:**

- Hosted by **Sandia (SNL)** and **HySafe** – Washington DC, June, 2013
- Attendees from industry, academia, research, C&S, government
- Final report: *K. Groth & A. Harris (Sept, 2013). Hydrogen Quantitative Risk Assessment Workshop Proceedings. SAND2013-7888.*

- **Objectives:**

- Understand the goals & needs of early (non-research) users of H2 QRA
- Introduce Sandia QRA methodology and toolkit
- Establish specific user needs and priorities for QRA

- **Results:**

- Identified key priorities for improving H2 QRA; Summarized in SAND2013-7888

## Workshop results (1): User needs

- User groups interested multiple types of analysis:
  - High level, generic insights for C&S developers, regulators, etc.;
  - Detailed, site-specific QRA insights for system designers, insurers authorities having jurisdiction (AHJs)
- Most users interested in: relative risk comparisons; graphical output
- Many different preferred risk metrics
- Need for guidance, training for different users
- Established timeline for updates to “user” version

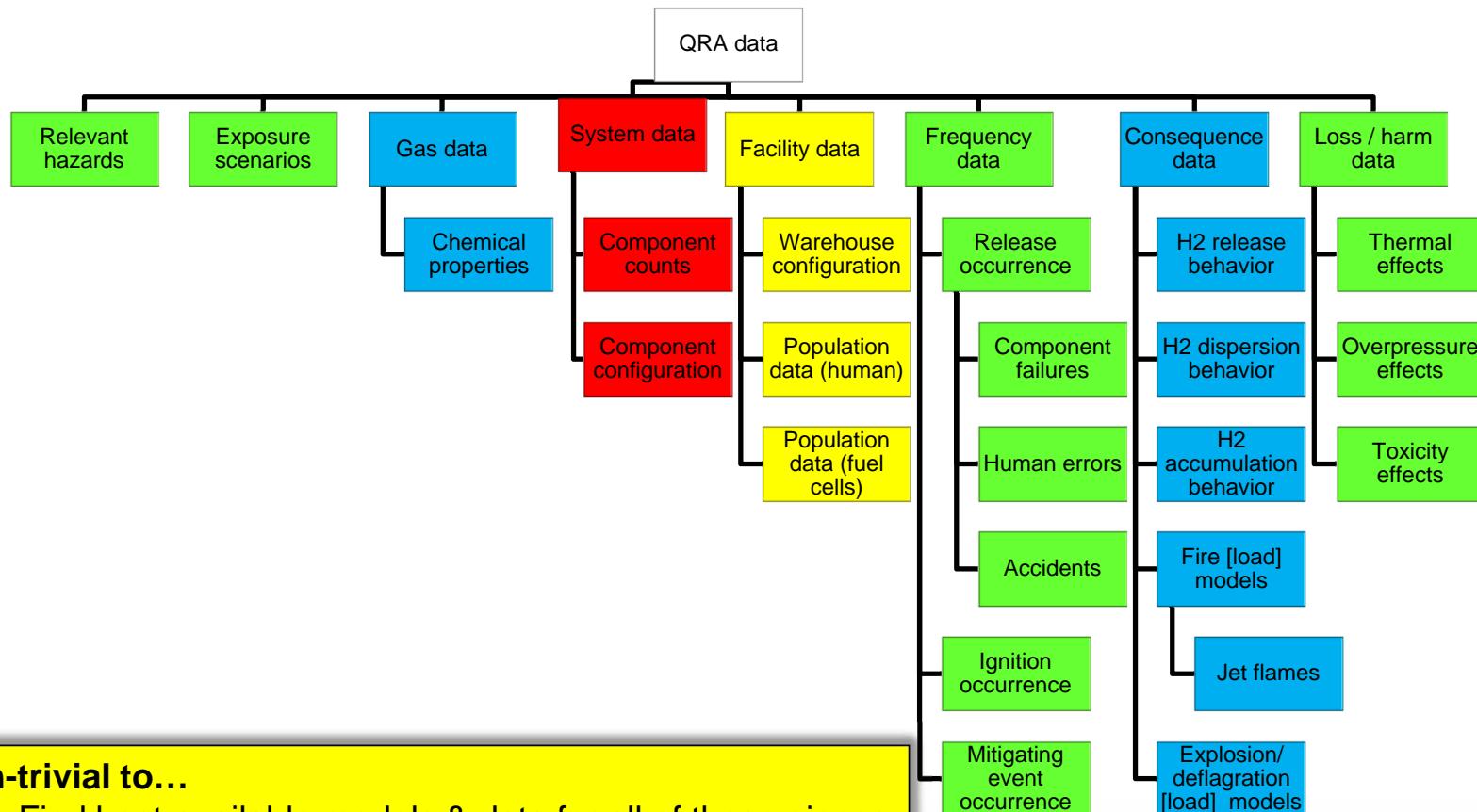
## Workshop results (2): Developer needs

- Collective ownership & development among the hydrogen safety community, free license
  - International H<sub>2</sub> community (e.g, SNL, H2CAN, KIT) as developers
- Current QRA tools lack *validated* models and data for hydrogen fuel cell analyses.
  - Datasets must be developed specifically for use in the toolkit – **both users and developers can contribute**
  - Need behavior models to enable consideration of: gas dispersion, overpressure, buoyancy-dominate releases
  - Need to handle duration and timing aspects (e.g., of release and ignition)

# QRA– What does success look like?

- **Complete** – Encompasses all hazards and consequences, entire system (as-built and as-operated),
- **Comparable** - Differences in QRA results should be due to differences in designs, not due to model choices
- **Robust**
  - **Validated** – Experimentally validated, simulation-supported physical models; and system-specific data
    - Or at least **Standardized** set of models and data (if unable to validate)
    - **Relevant** – To this system, in the range of use of the models
- **Repeatable & Verifiable** – Different teams should be able to produce the same result
  - Requires: Defined objectives and scope
  - Requires: Clear definitions of failure modes, consequences, the system, and criteria (or data used) to assign severity and likelihood
  - Requires: System, data, models, and analysis are sufficiently documented for a peer reviewer to evaluate correctness

## Challenge: A quality QRA incorporates a large body of information from different areas



## It is non-trivial to...

- Find best-available models & data for all of these pieces
- Validate those models
- And combine those all into a single framework
- ...And still work your day job

## Specific data needs

- Statistical information, Physical models, Expert analyses
- a. Identify accident scenarios
- b. Quantify accident scenarios
  - Release frequencies – leaks, accidents, etc.
  - Component failures
  - Ignition probabilities, timing
  - Detection, Isolation probabilities and timing
- c. Physical consequences (For a range of parameters relevant to hydrogen systems)
  - Fluid release, dispersion & accumulation
  - Fire properties (jet flames, flash fires)
  - Heat fluxes
  - Overpressures (Confined space , Propagation in open )

## Motivation for HyRAM: Enable QRA success

Goal	Means
Completeness	Use comprehensive modeling tool
Comparability	Use standard, flexible modeling tool
Robustness	<ul style="list-style-type: none"><li>• Use validated models (as available), standardized models if you don't.</li><li>• Update models as knowledge improves</li></ul>
Repeatability	Document the analysis
Verifiability	Use the same tool throughout the industry

Motivates building a unifying framework  
HyRAM + H2 R&D community

# Quantifying gaps with HyRAM: Sensitivity analysis (Indoor fueling model, single param.)

Case	FAR
Baseline indoor fueling analysis	0.17
Uncertainty about modeled <u>overpressures</u> (Multiply by 10)	0.50
Uncertainty about <u>ignition probability</u> . (multiply by 100)	2.60
Uncertainty about <u>ignition probability</u> . (multiply by 10)	1.35
Uncertainty about the <u>design</u> (Multiplying # of components by 10)	1.58
Uncertainty (under-prediction) about <u>leak rate</u> (use 95 percentile).	0.51
Multiply <u>number of vehicles</u> by 10	0.27
Change <u>leak detection probability</u> to 0%	0.19
Change <u>leak detection probability</u> to 50%	0.093
Change <u>thermal exposure time</u> to 180s	0.21
Change <u>thermal exposure time</u> to 30s	0.15
Use Tsao instead of Eisenberg <u>thermal probit model</u>	0.20

**Goal: Identify which uncertainties matter the most**

Yellow denotes FAR > 0.3, which means the risk that exceeds tolerable threshold

**Impact: Being wrong here changes the decision**

Less critical uncertainties  
(Being uncertain doesn't change the decision)

Disclaimer: These are model-specific results from a small model – need to run additional cases to verify

## HyRAM needs from R&D community

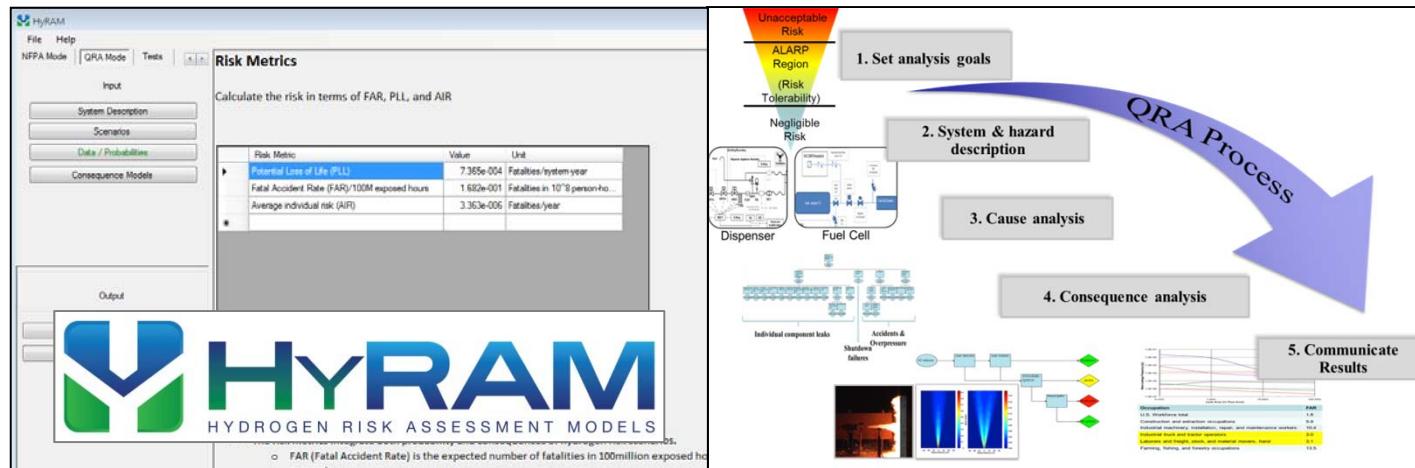
- R&D community provides user confidence in underlying models
- HyRAM needs models, statistics, and data for H<sub>2</sub>
  - Behavior models specifically developed & validated for application to hydrogen fuel cell problems
  - Lab-scale experiments, full-scale experiments, simulation
  - H<sub>2</sub> data for improving credibility of probabilistic event models (e.g., release frequencies, harm)
  - Validation activities to enhance credibility of behavior models and data originating from non-fuel-cell applications.
- Engagement with partners to refine QRA approach, standardize, review & adopt models (international and domestic, research and application)

## Critical gaps

1. User-friendly, industry-focused software tools (with strong scientific foundation & rigorous documentation) to enable risk-informed decision making
2. Guidance on the use of risk insights in decision making
3. Simplified models for predicting overpressures; cryo-release behavior, barrier walls
4. A validated probabilistic model for ignition occurrence
5. Hydrogen-specific data for updating probability models
  - Leak & release data
    - Component failure rates
    - Component leak frequencies
    - Accidents
  - Human, software, & organizational failures
  - Gas and flame detection probability

# ...And why they matter

- **Completeness gaps:**
  - Simplified models for predicting overpressures
  - Simplified models for predicting cryo-release behavior,
  - Simplified models for predicting impact of barrier walls
  - Human, software, & organizational failures
  - Comprehensive software tool
- **Comparability gaps:**
  - Need for software tools to enable comparable analyses
- **Robustness gaps:**
  - A validated probability model for ignition occurrence
  - Validation for models for overpressures; cryo-release behavior; barrier walls
  - Hydrogen-specific data
- **Repeatable & Verifiable gaps:**
  - Guidance on the use of risk insights in decision making
  - Software tools to enable standardized analyses & rigorous documentation of the models used in those tools



# Thank you!

Katrina Groth  
 Sandia National Laboratories  
[kgroth@sandia.gov](mailto:kgroth@sandia.gov)

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