QRA Tools - Gaps, Methods, Models Tools

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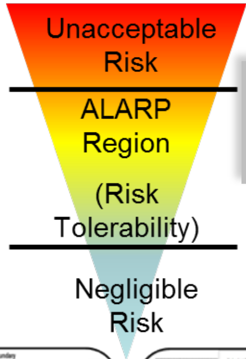
QRA Method Overview

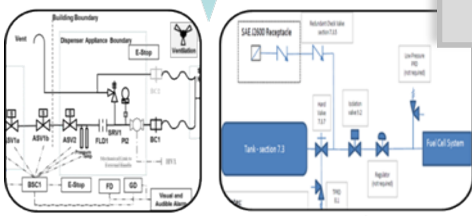
Status: The general QRA method is robust – and the hazards are known…but… the method *is only as good as* the models and tools used



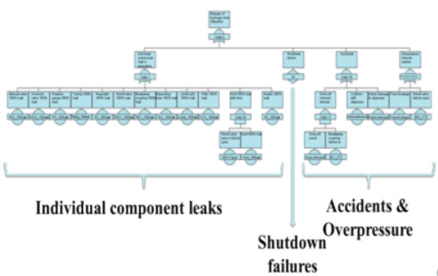
QRA Process

1. Set analysis goals

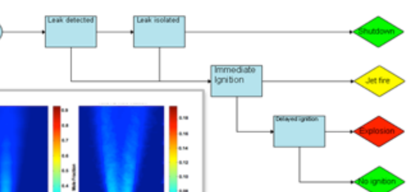
2. System & hazard description

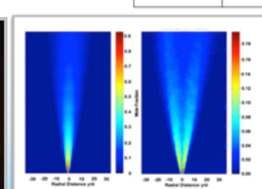


3. Cause analysis

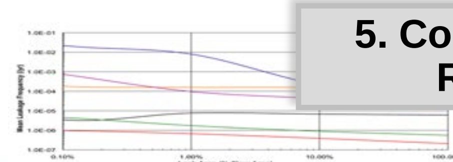


4. Consequence analysis





5. Communicate Results



Occupation	FAR
U.S. Workforce total	1.8
Construction and extraction occupations	5.9
Industrial machinery, installation, repair, and maintenance workers	10.4
Industrial truck and tractor operators	3.0
Laborers and freight, stock, and material movers, hand	3.1
Farming, fishing, and forestry occupations	13.5

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. H2-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

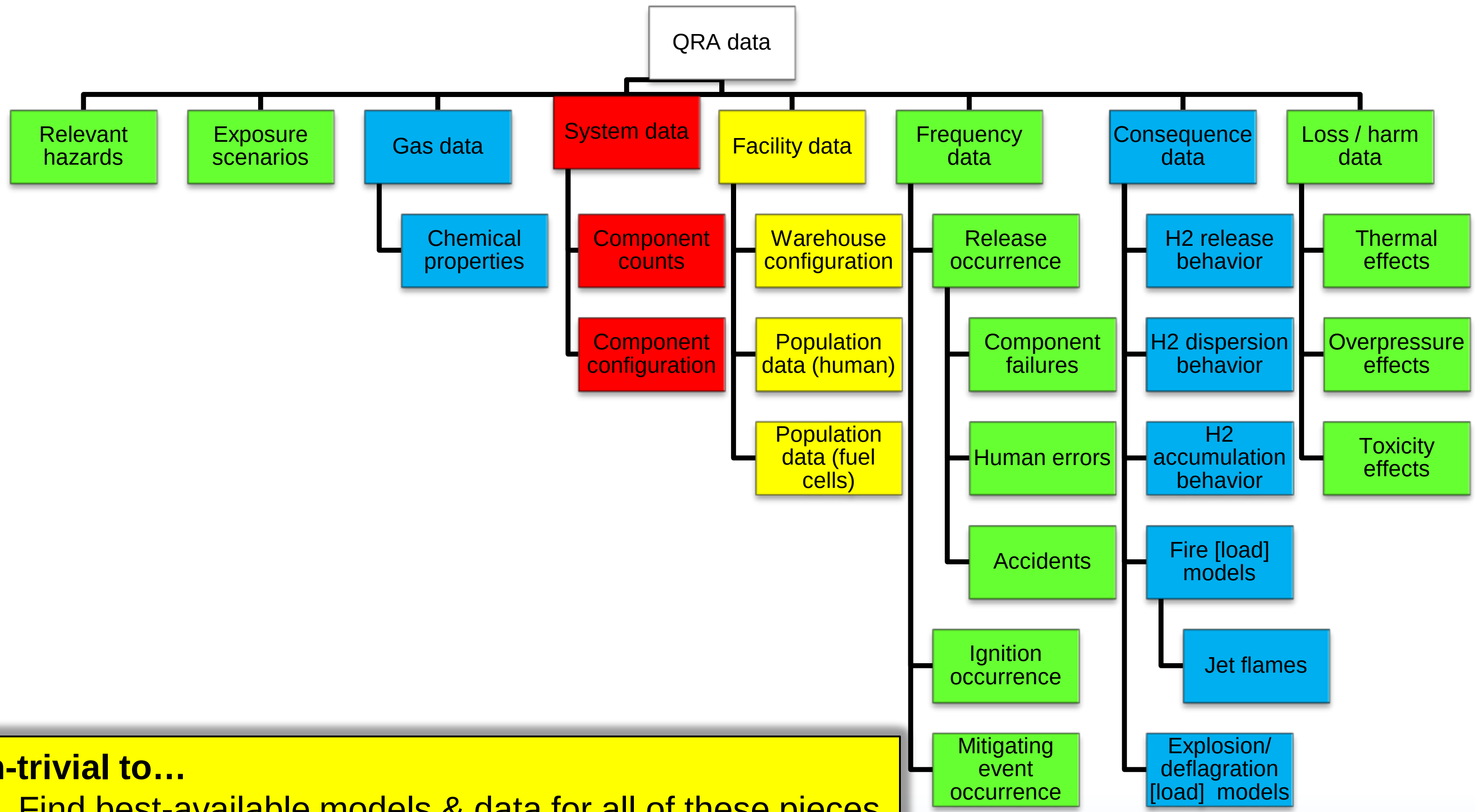
Workshop results (2): Developer needs

- Collective ownership & development among the hydrogen safety community, free license
  - International H2 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	• Use validated models (as available), standardized models if you don't. • Update models as knowledge improves
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 overpressures (Multiply by 10)	0.50
Uncertainty about ignition probability. (multiply by 100)	2.60
Uncertainty about ignition probability. (multiply by 10)	1.35
Uncertainty about the design (Multiplying # of components by 10)	1.58
Uncertainty (under-prediction) about leak rate (use 95 percentile).	0.51
Multiply number of vehicles by 10	0.27
Change leak detection probability to 0%	0.19
Change leak detection probability to 50%	0.093
Change thermal exposure time to 180s	0.21
Change thermal exposure time to 30s	0.15
Use Tsao instead of Eisenberg thermal probit model	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

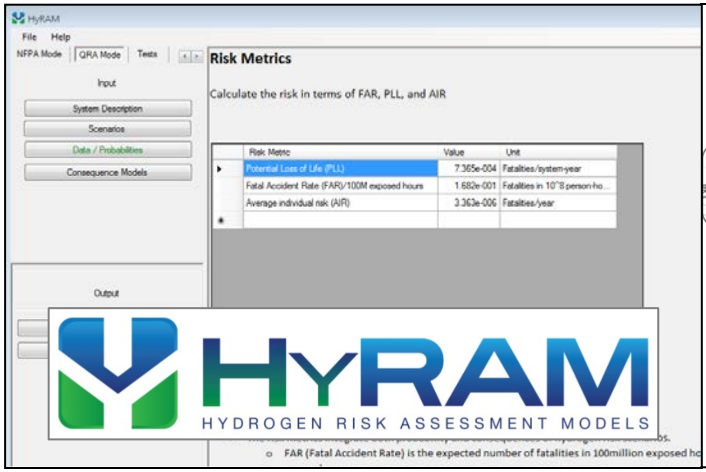
- R&D community provides user confidence in underlying models
- HyRAM needs models, statistics, and data for H2
  - Behavior models specifically developed & validated for application to hydrogen fuel cell problems
  - Lab-scale experiments, full-scale experiments, simulation
  - H2 data for improving 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)

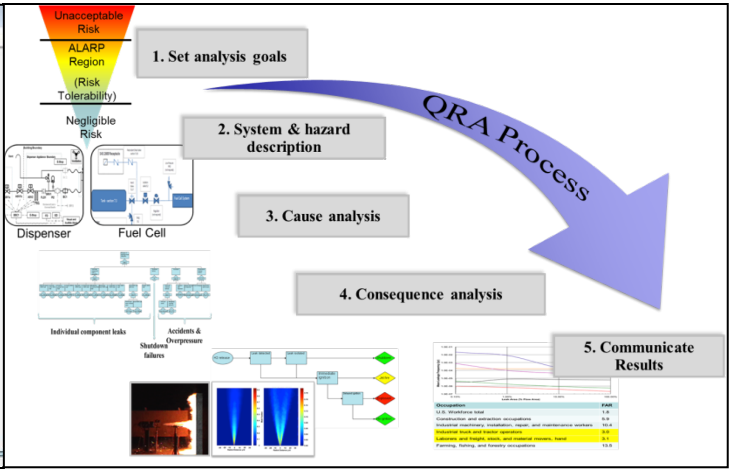
Critical gaps

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 & Verifiabl gapse**
  - 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!

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration