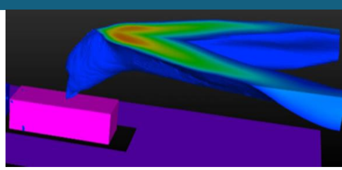
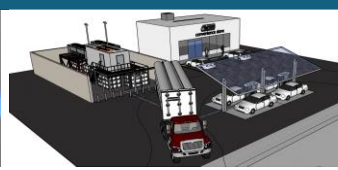
Sandia National Laboratories

Hydrogen Safety Codes and Standards





Presented by:

Brian Ehrhart

November 4, 2020

H2@Airports Workshop

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

SAND2020-11250 PE

Sandia National Laboratories Overview

"Exceptional Service in the National Interest"

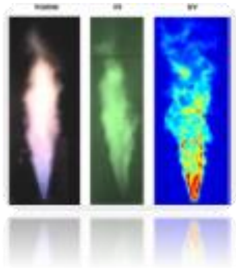
Multi-Mission DOE NNSA Lab

Federally Funded Research and Development Center (FFRDC)
- Government owned, contractor operated

Main Sites: Albuquerque, NM and Livermore, CA

Sandia Hydrogen Program

Sandia provides deep, quantitative understanding and a scientific basis for:
- **Materials** – for hydrogen production, storage and utilization
- **Safety** – risk analysis and the creation of risk-informed standards



Basis for New Safety Requirements

Existing technologies/applications have established requirements and extensive experience
- Prescriptive requirements, performance-based requirements, risk assessments

Quantitative risk assessment can be useful for analyzing a new system/application
- Needs a lot of data
- How to assess the results of a risk assessment?

Risk acceptability criteria
- Requires authority having jurisdiction (AHJ) to specific criteria
- Can make acceptance much more sensitive to calculation or design changes

Comparison to accepted hazards
- Replacement of existing hazards
- E.g., hydrogen refueling station compared to a gasoline station

Safety is Application Specific

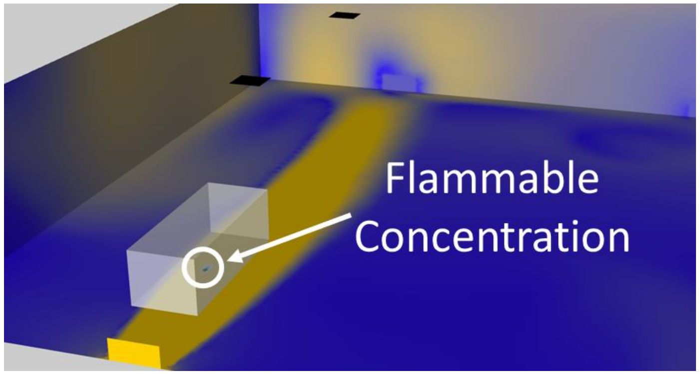
Different applications have different requirements for safety

- Automatic H_2 shutoff: Is it safe for an aircraft to shutoff fuel source mid-flight?
- Is it safe for an aircraft in-flight to vent perpendicular to flight path?
- Is it safe for systems at airports to vent upwards in the path of aircraft?

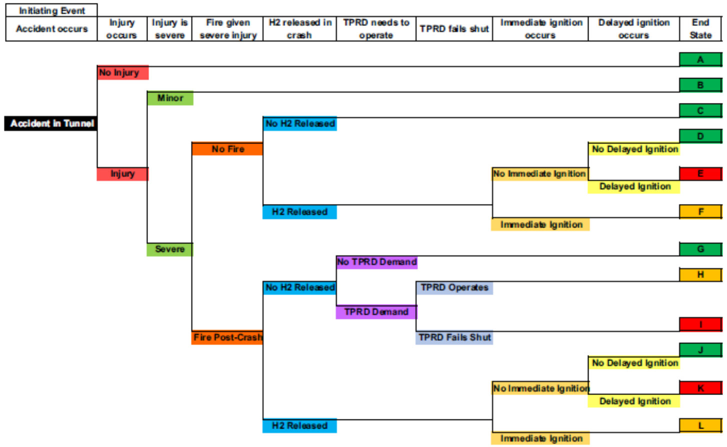
Lack of operational/performance data in new environment makes assessment uncertain

- Systems leaks can vary widely between different conditions (e.g., GH2 vs LH2)
- Different applications have different operating environments
  - Shock/vibration, temperatures/pressures, pressure cycles, crash environments

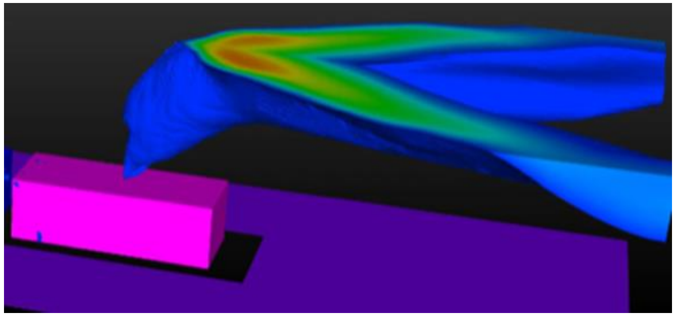
Hydrogen Risk Assessments and Consequence Modeling



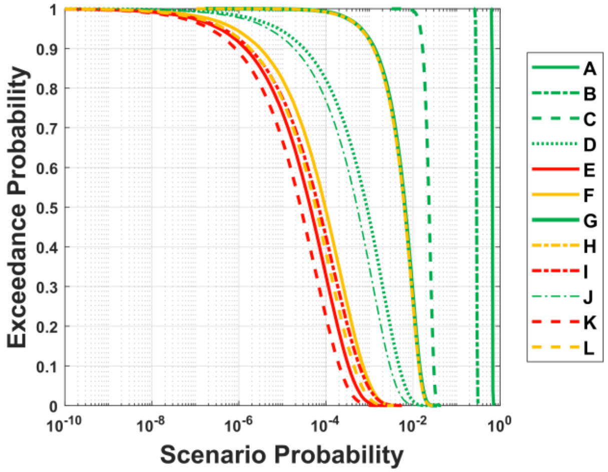
Dispersion modeling of leak with ventilation in repair garage



Event tree for hydrogen vehicle in crash

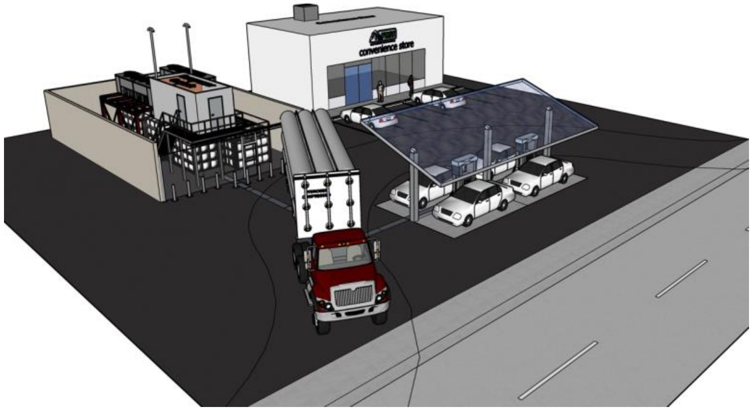


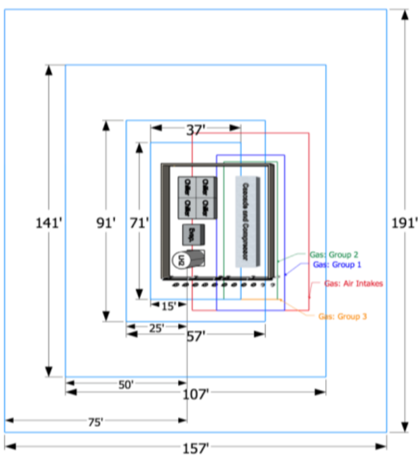
Jet fire modeling of effect of hydrogen leak on tunnel

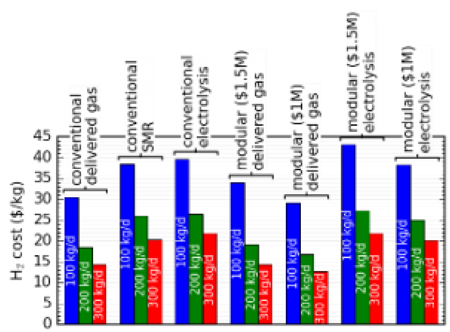


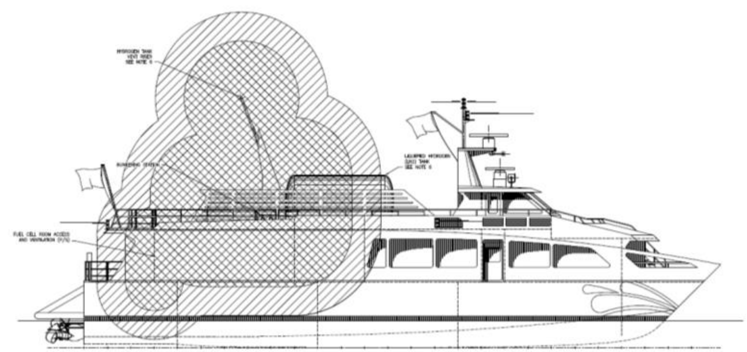
Probability/likelihood of outcomes with uncertainty

Feasibility, Economic, and Hazard Assessments









Layout Footprint and Economic Comparisons

Feasibility/Design Studies and Hazard Area Assessments

What Should be the Basis for Safety Requirements for H2@Airports?

Historical scenario?

Worst-case scenario?

Most likely scenario?

Highest risk scenario?

Thank you! Questions?

Brian Ehrhart

bdehrha@sandia.gov

Hydrogen Risk Assessment Models (HyRAM)

Core functionality:

Quantitative risk assessment (QRA) methodology

Frequency & probability data for hydrogen component failures

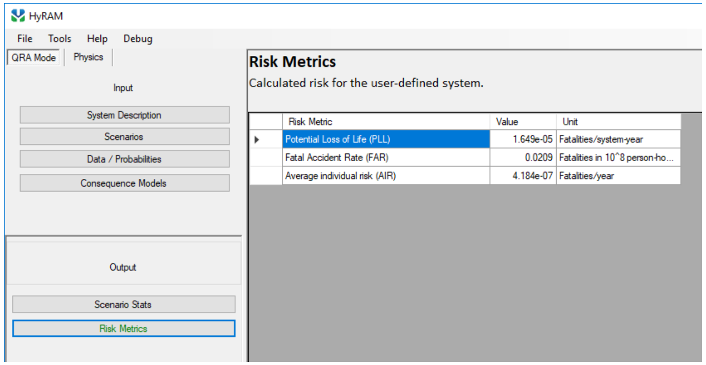
Fast-running models of hydrogen gas and flame behaviors

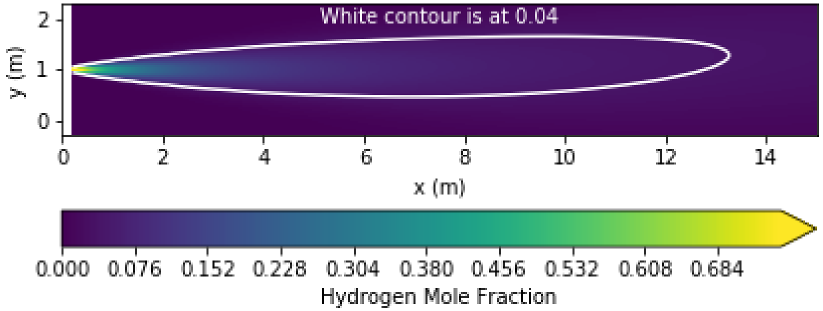
Key features:

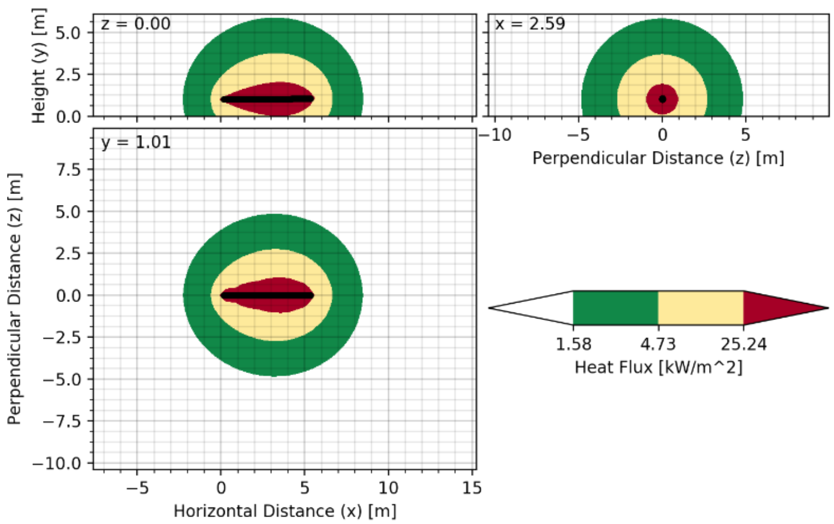
GUI & Mathematics Middleware

Documented approach, models, algorithms

Flexible and expandable framework; supported by active R&D







https://hyram.sandia.gov

QRA estimates frequency and consequence for different leak sizes

Frequency of Leak

- 0.01%, 0.1%, 1%, 10%, 100%

Probability of Outcome

- Shutdown, jet fire, explosion, no ignition

Calculate Effects

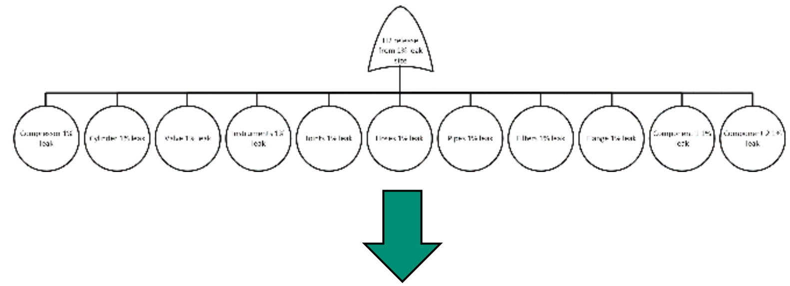
- E.g., thermal heat flux to occupant

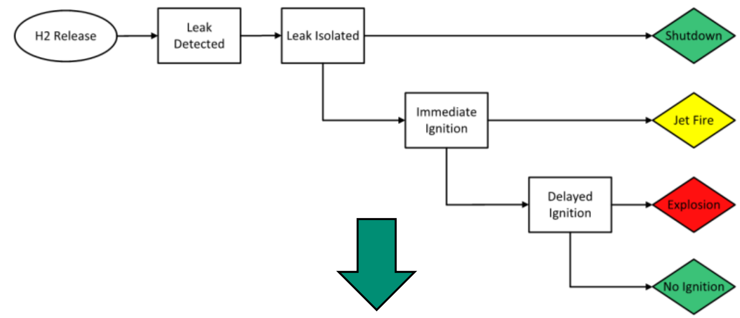
Estimate Harm

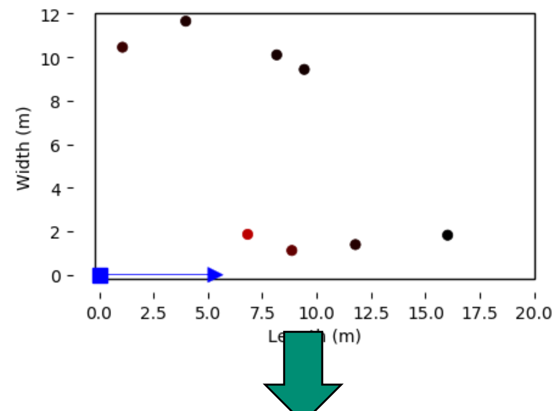
- Probability of fatality based on effects

Risk Metrics

- 20 Scenarios







Risk Metric	Value	Unit
Potential Loss of Life (PLL)	1.246E-005	Fatalities/system-year
Fatal Accident Rate (FAR)	1.580E-002	Fatalities in 10^8 person-hours
Average individual risk (AIR)	3.160E-007	Fatalities/year

Airplane Auxiliary Power Feasibility Study (2013)

Several load cases and locations were compared.

All cases saved CO_2 emissions, and most also saved Jet-A fuel use.

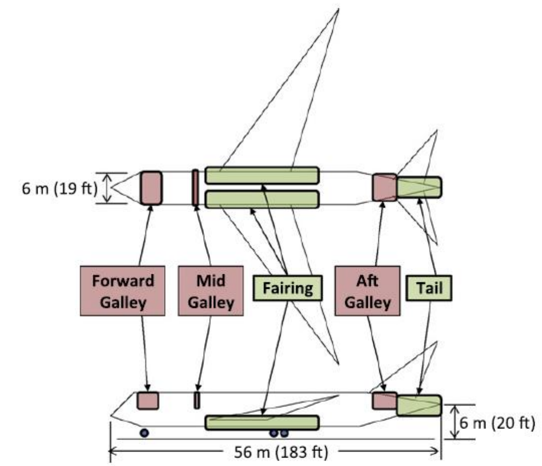


Fig. 5. Outline sketch of the 787-8, showing location of the galleys and options for the fuel cell and hydrogen storage. Airplane shape and dimensions are approximate, from [18].

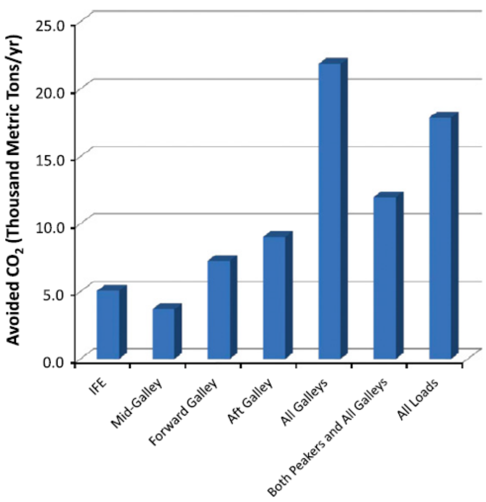


Fig. 21. Yearly avoided CO_2 emissions for a fleet of 1000 fuel cell-equipped airplanes operating 750 h/yr, using a fuel cooled fuel cell system (Case 6a) and renewable hydrogen, and comparing to the base airplane generating electricity via the main engines at 34% efficiency.

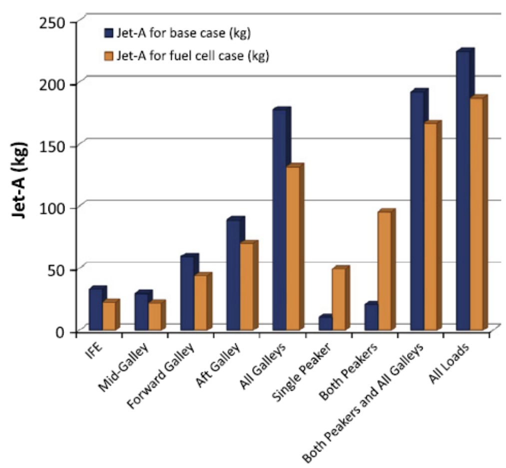
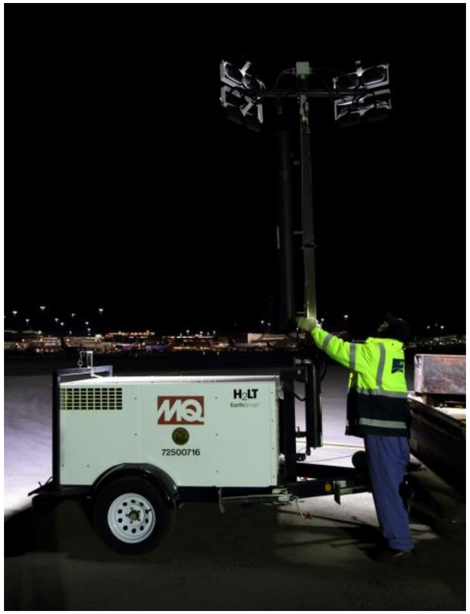


Fig. 20. The amount of fuel required by the base airplane and the airplane with the fuel cell to generate electricity and heat for the different load scenarios. The base airplane uses the main engine generator with a fuel-to-electricity efficiency of 34%, while the fuel cell assumes the fuel cooled configuration with DOE target technology. The numbers are presented in Table 7.

Table 1
Specifications of the base airplane and flight mission used in this study.

Airplane specifications [18]	
Model	Boeing 787-8 derivative
Max design takeoff weight	227,930 kg (502,500 lb)
Length	56.72 m (186.1 ft)
Wingspan	60.12 m (197.25 ft)
Seating configuration	Short to medium range, dual class
Passengers as configured	291
Maximum passengers (for system design)	375
Mission specifications	
Route	SFO ↔ JFK
Distance	4139 km (2235 nm)
Total duration	5 h
Fuel required for mission, including reserves	22,680 kg (50,000 lb)
Segments and durations	Ground taxi: 8 min Takeoff and climb: 20 min Cruise: 4 h Descent and landing: 25 min Ground taxi: 7 min

SFO Fuel Cell Mobile Light Project



The H_2LT (Hydrogen Light Tower) technology was fully reviewed and approved by SFO Fire & Safety and equipment staff on 2-27-13.

Two units have been in use since then.

Multiquip assembled the units; Altergy Systems provided the fuel cells.

H_2LT Uses at SFO:

- Aircraft maintenance
- Repair of land-based and water-based fire-fighting equipment
- Airfield plumbing repair
- Runway repair
- Special event lighting
- General security lighting

Runway repair operations 7-28-14