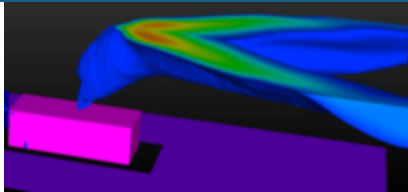




# Hydrogen Safety Codes and Standards



*Presented by:*

Brian Ehrhart

November 4, 2020

H2@Airports Workshop



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# Sandia National Laboratories Overview

***“Exceptional Service in the National Interest”***

Multi-Mission DOE NNSA Lab

Federally Funded Research and Development Center (FFRDC)

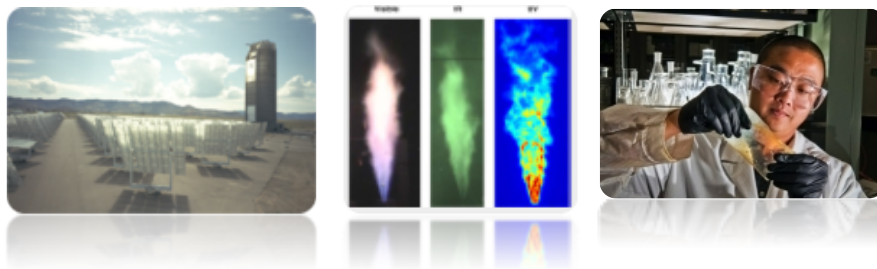
- Government owned, contractor operated

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<sub>2</sub> 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?

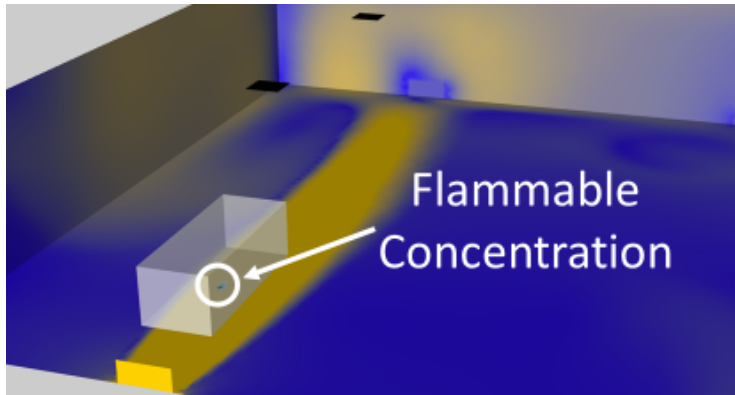
Lack of operational/performance data in new environment makes assessment uncertain

- 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

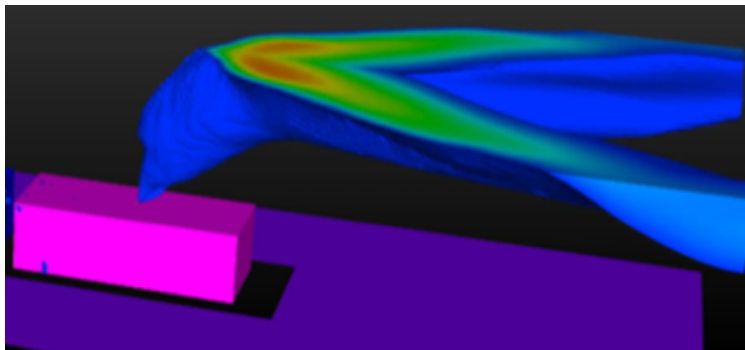




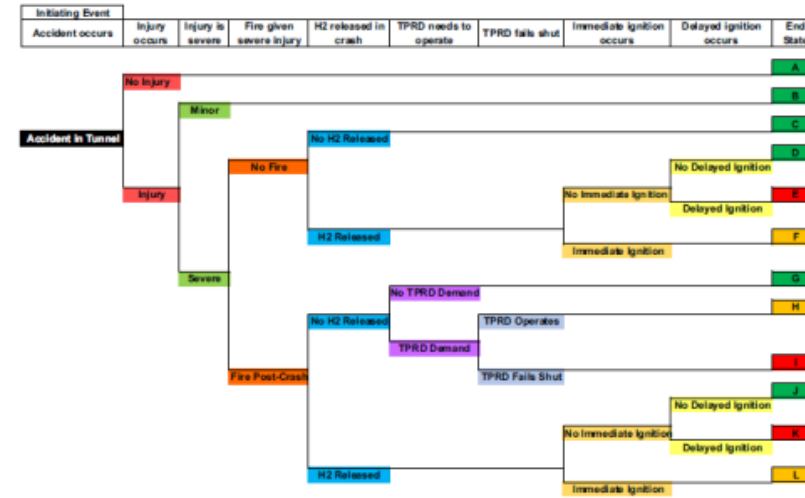
# Hydrogen Risk Assessments and Consequence Modeling



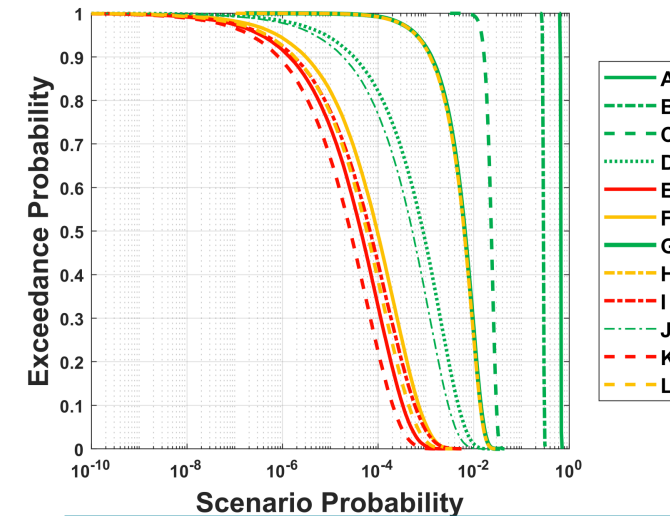
Dispersion modeling of leak with ventilation in repair garage



Jet fire modeling of effect of hydrogen leak on tunnel

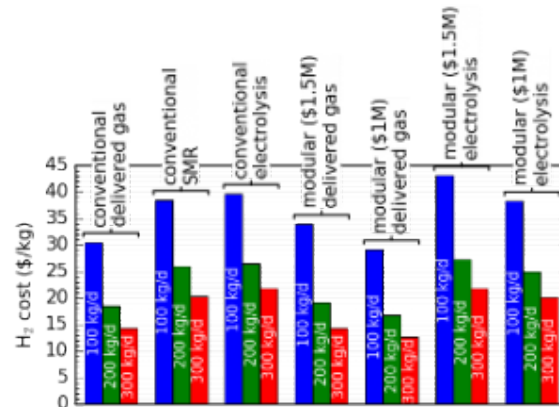
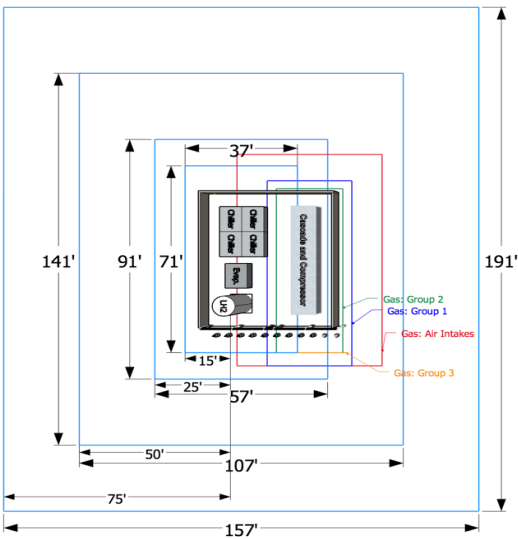
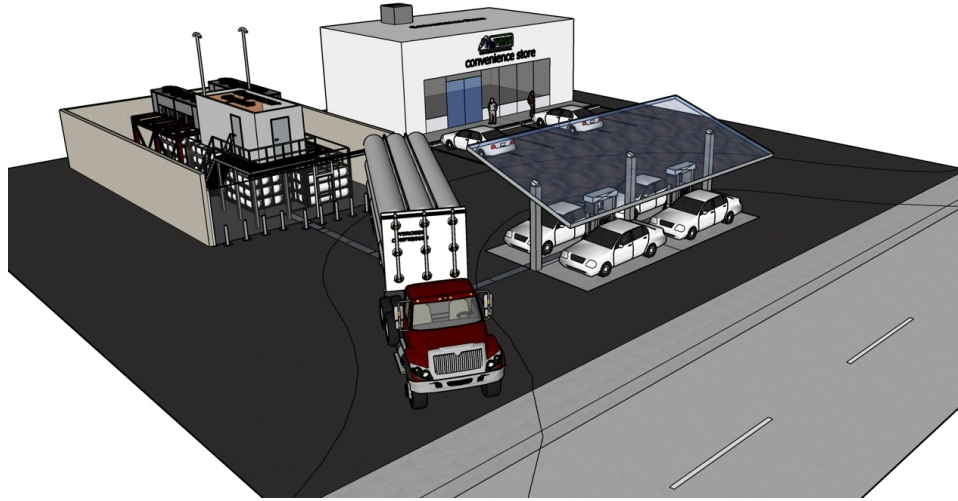


Event tree for hydrogen vehicle in crash

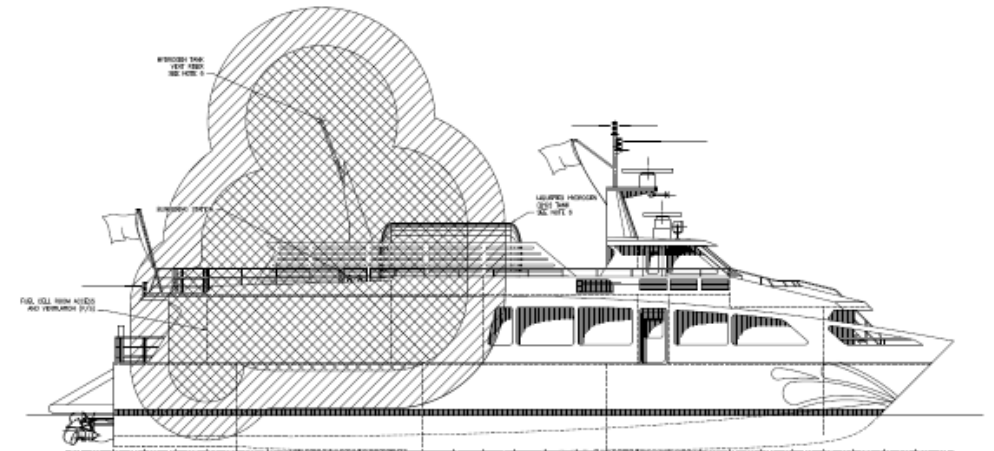


Probability/likelihood of outcomes with uncertainty

# 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?

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# Hydrogen Risk Assessment Models (HyRAM)

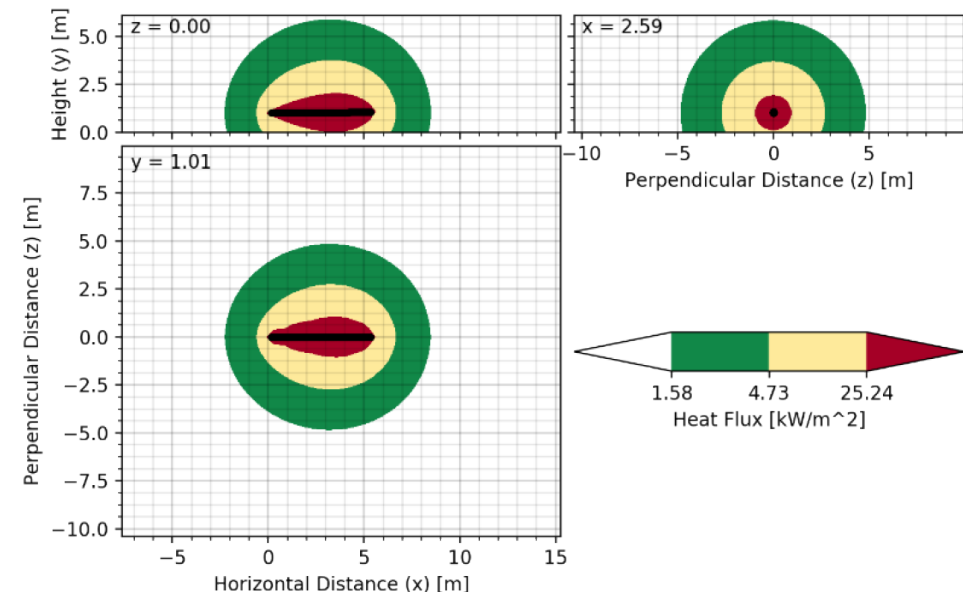
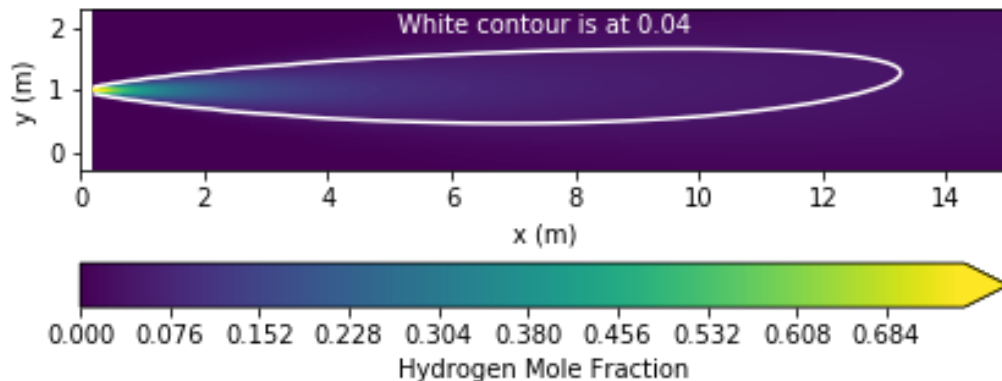
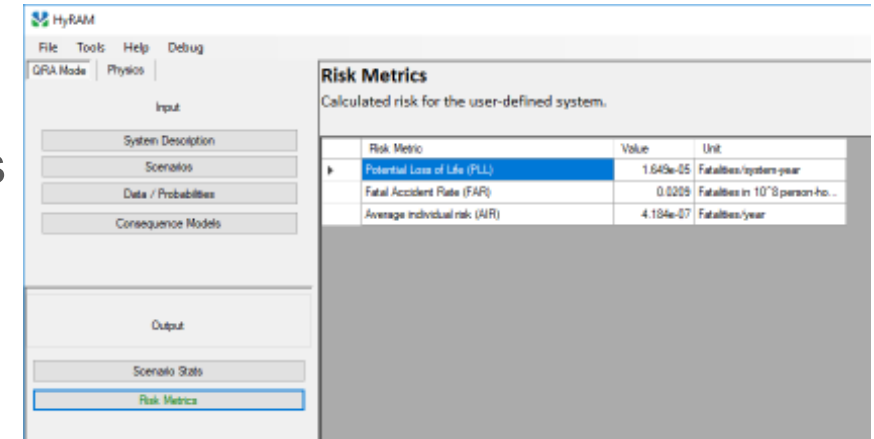


## Core functionality:

- 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

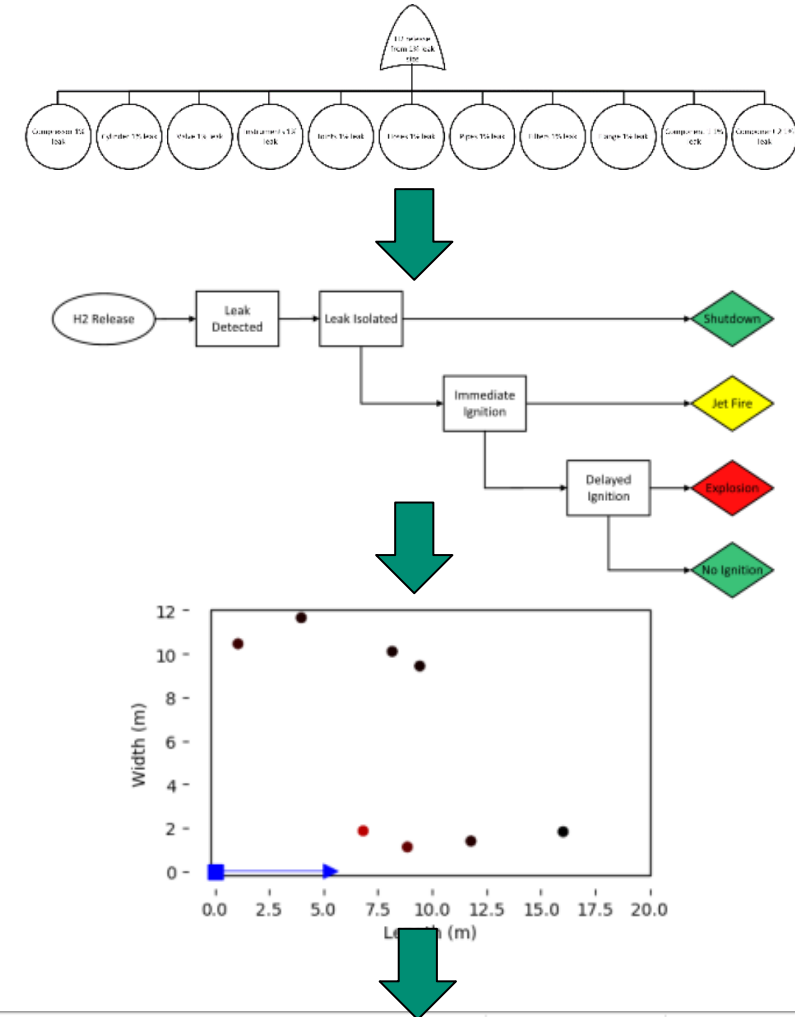
- E.g., thermal heat flux to occupant

## 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 <sup>8</sup> person-hours
Average individual risk (AIR)	3.160E-007	Fatalities/year

# Airplane Auxiliary Power Feasibility Study (20



Several load cases and locations were compared.

All cases saved CO<sub>2</sub> emissions, and most also saved Jet-A fuel use.

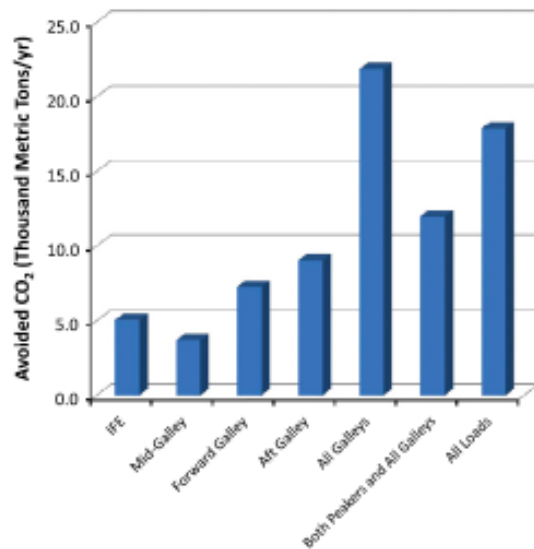


Fig. 21. Yearly avoided CO<sub>2</sub> emissions for a fleet of 1000 fuel cell-equipped airplanes operating 750 h/yr, using a fuel cooled fuel cell system (Case 6a) and renewable hydrogen, and comparing to the base airplane generating electricity via the main engines at 34% efficiency.

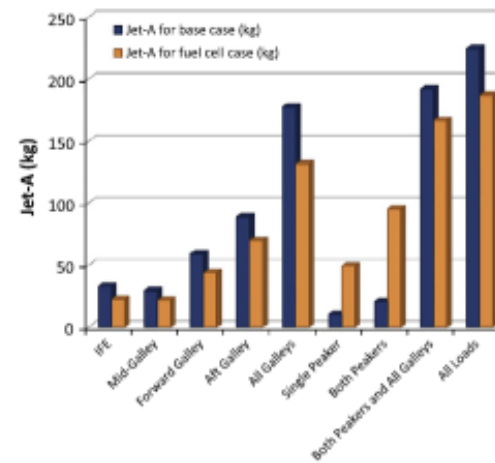


Fig. 20. The amount of fuel required by the base airplane and the airplane with the fuel cell to generate electricity and heat for the different load scenarios. The base airplane uses the main engine generator with a fuel-to-electricity efficiency of 34%, while the fuel cell assumes the fuel cooled configuration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

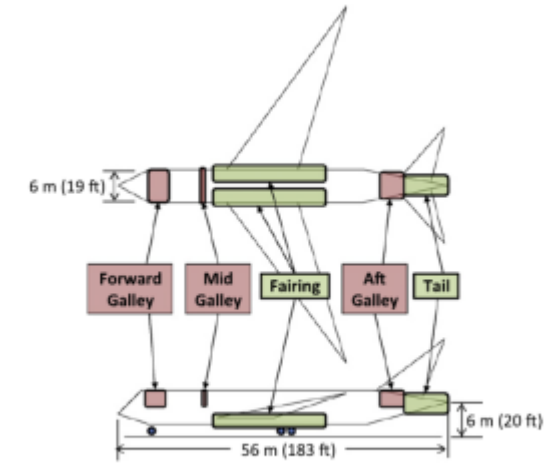


Fig. 5. Outline sketch of the 787-8, showing location of the galleys and options for the fuel cell and hydrogen storage. Airplane shape and dimensions are approximate, from [18].

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

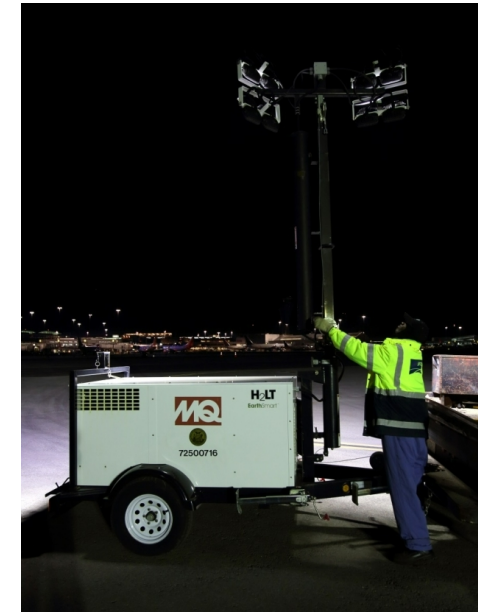
<i>Airplane specifications [18]</i>	
Model	Boeing 787-8 derivative
Max design takeoff weight	227,930 kg (502,500 lb)
Length	56.72 m (186.1 ft)
Wingspan	60.12 m (197.25 ft)
Seating configuration	Short to medium range, dual class
Passengers as configured	291
Maximum passengers (for system design)	375
<i>Mission specifications</i>	
Route	SFO ↔ JFK
Distance	4139 km (2235 nm)
Total duration	5 h
Fuel required for mission, including reserves	22,680 kg (50,000 lb)
<i>Segments and durations</i>	
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<sub>2</sub>LT (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; Alteryg Systems provided the fuel cells.



## H<sub>2</sub>LT 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

