Sandia National Laboratories

H2FC Hydrogen and Fuel Cells Program

Hydrogen Safety, Risk Assessment, and Material Compatibility R&D

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Sandia National Laboratories

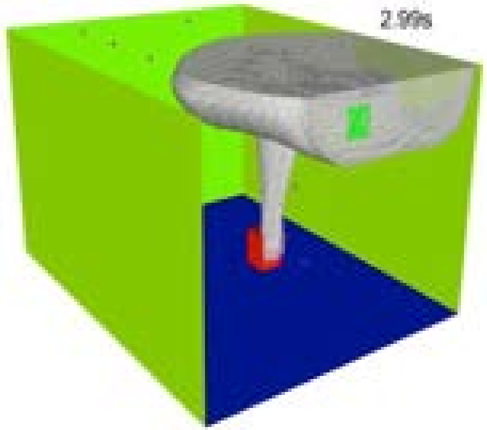
U.S. Department of Energy H2@Scale Workshop

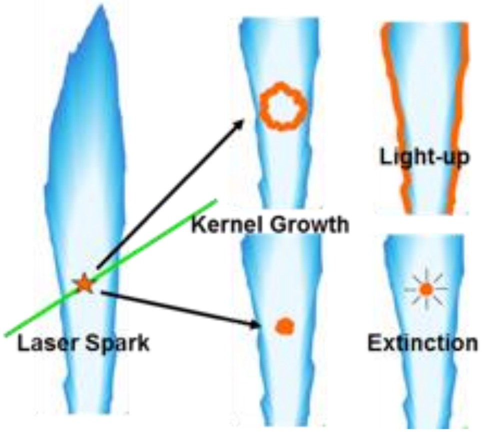
May 23 -- 24, 2017

Defensible safety standards for hydrogen technology

Goal

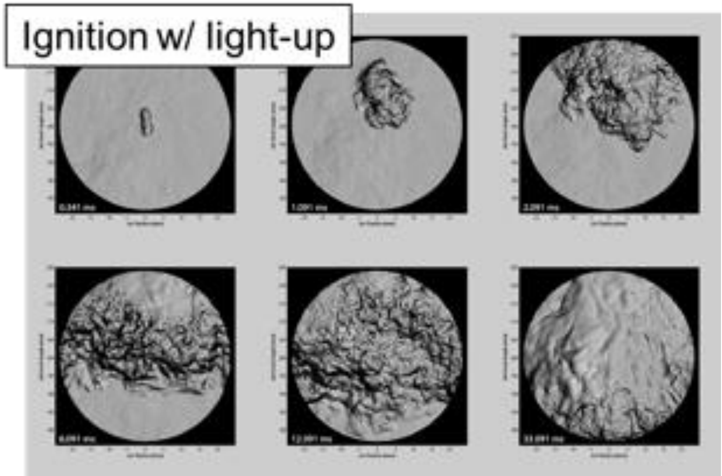
Facilitate the safe use of hydrogen technologies by understanding and mitigating risk





Demonstrated Impact

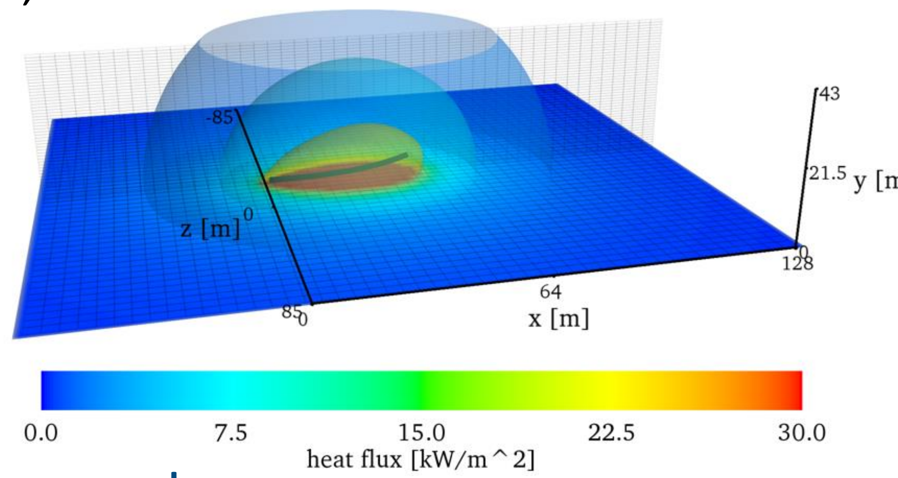
- Enabling the deployment of refueling stations by developing science-based, risk-informed decision making processes for specification of safety distances.
- Sandia's analysis has enabled the indoor use of fuel cell powered vehicles.



Risk framework incorporates science basis for safety

Hydrogen Behavior Models

Validated mathematical models to accurately predict hazards and harm from liquid releases, flames, etc.



Quantitative Risk Assessment

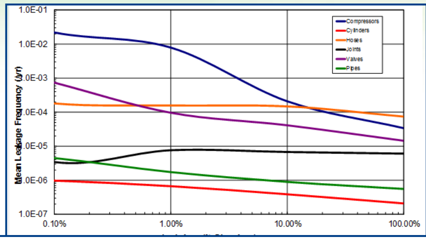
Develop integrated methods and algorithms enabling consistent, traceable, and rigorous QRA (Quantitative Risk Assessment) for hydrogen facilities and vehicles

Decision Support for Standards Development

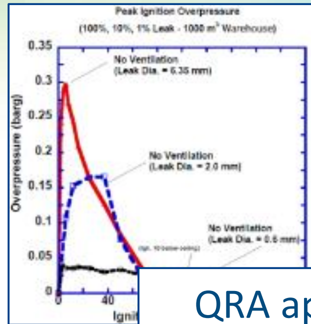
Provide physics models and risk calculations to address real problems in hydrogen infrastructure and emerging technology

HYRAM
HYDROGEN RISK ASSESSMENT MODELS

Evolution of quantitative risk assessment in standards

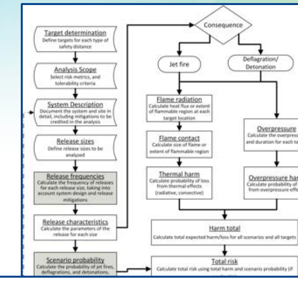


Established risk-informed processes for separation distances



QRA applied to indoor refueling to inform code revision

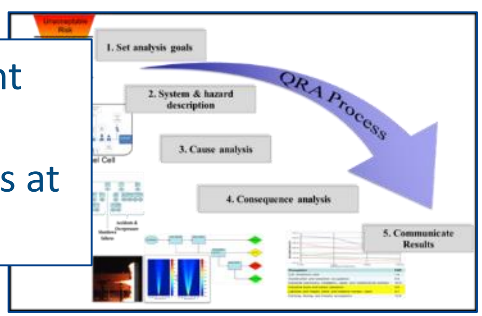
Performance-based system layout demonstrated



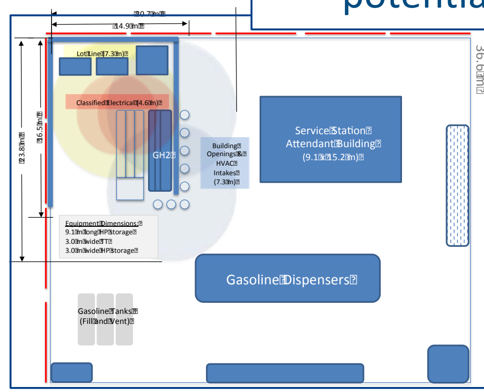
ISO TC197 WG24 incorporating QRA and behavior modeling

2005 | 2007 | 2009 | 2011 | 2013 | 2015 | 2017

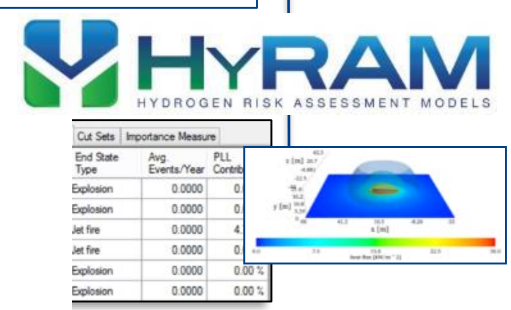
Risk assessment proposed for hydrogen systems at ICHS



QRA-informed separation distances in NFPA 2

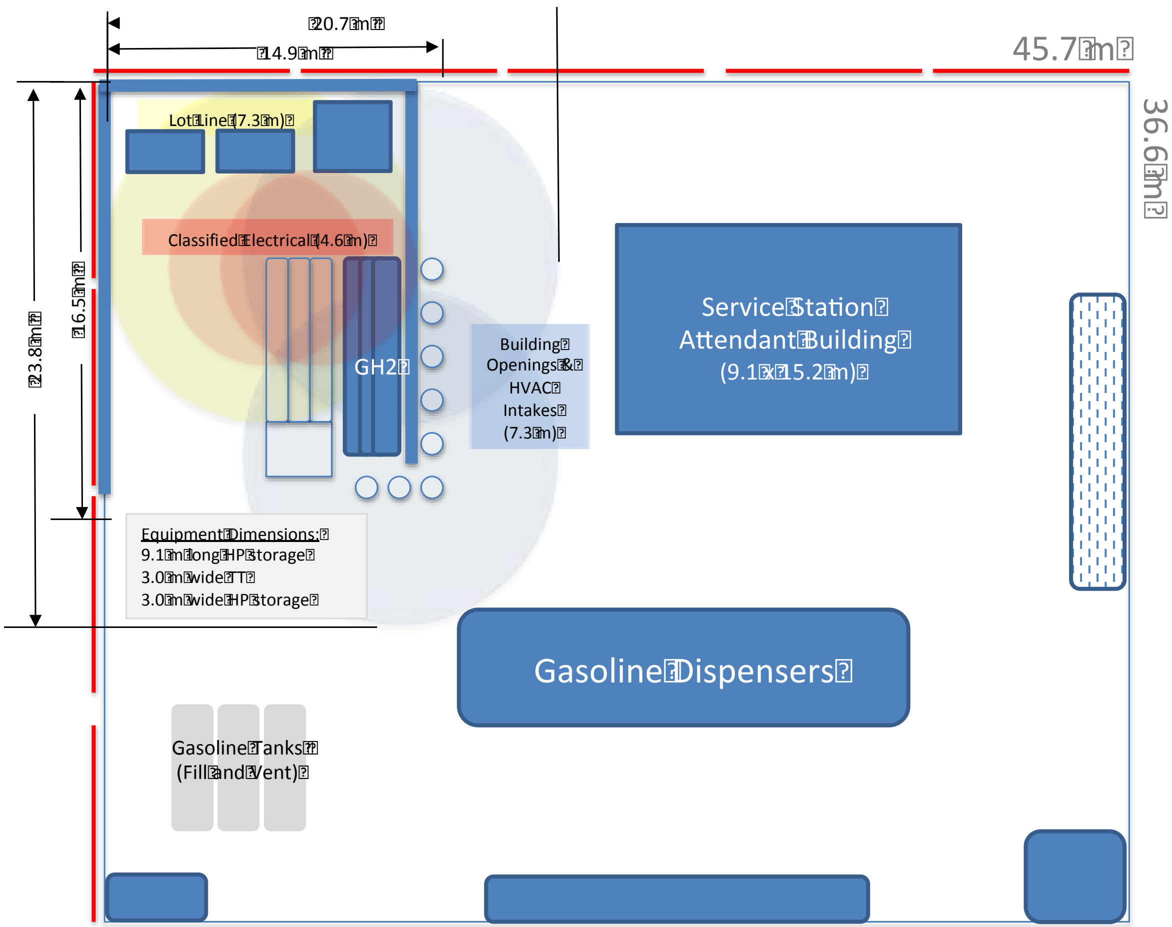


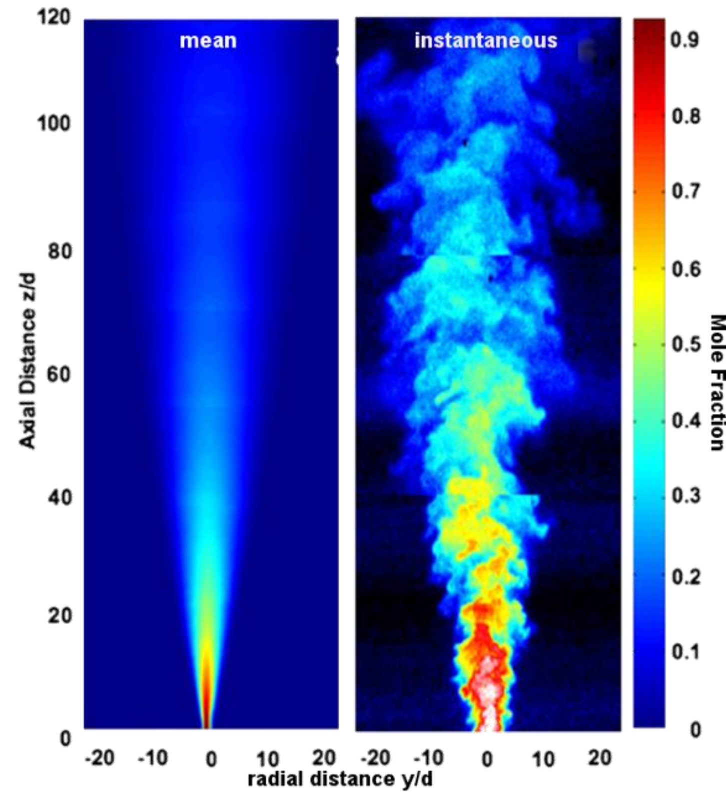
20% station penetration potential due to QRA



Public release of HyRAM

2011 NFPA 2 risk approach results in 20% of gasoline fueling stations able to integrate with hydrogen



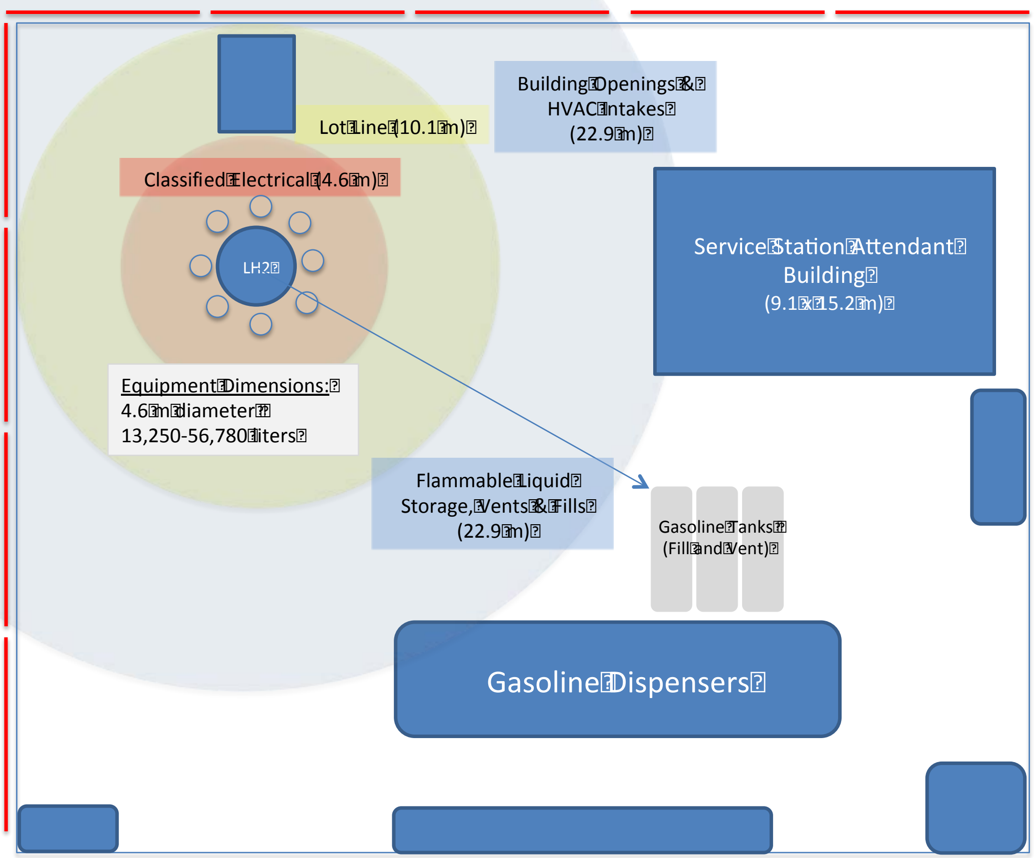


GH_2 storage

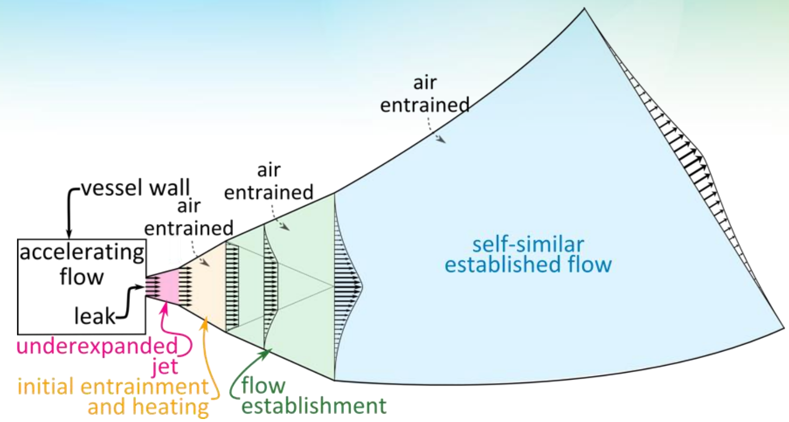
Harris et al. SAND2014-3416

Developing risk models for liquid hydrogen storage

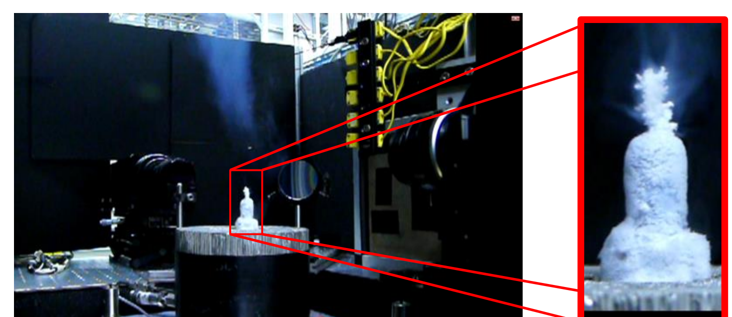
Temperature of LH_2 = 20K (-253˚C)



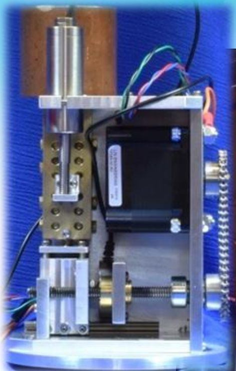
LH_2 storage

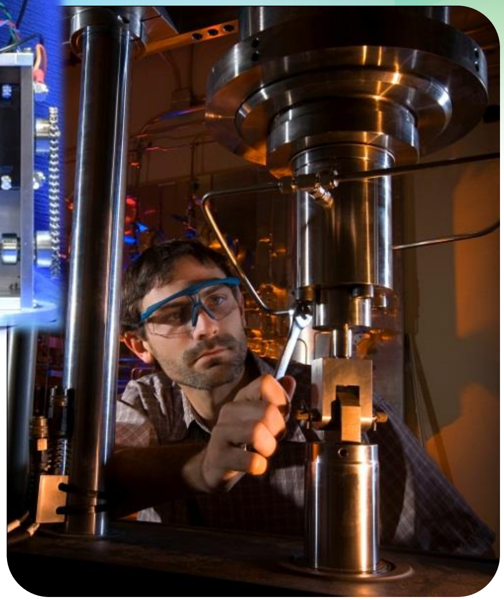


Laboratory experiments and validated models of cryogenic hydrogen releases inform safety requirements for LH_2 storage



Leadership in materials and components for hydrogen service





Goals

- Develop and characterize high-performance, hydrogen containment materials and structures to lower capital cost of hydrogen infrastructure, systems and components

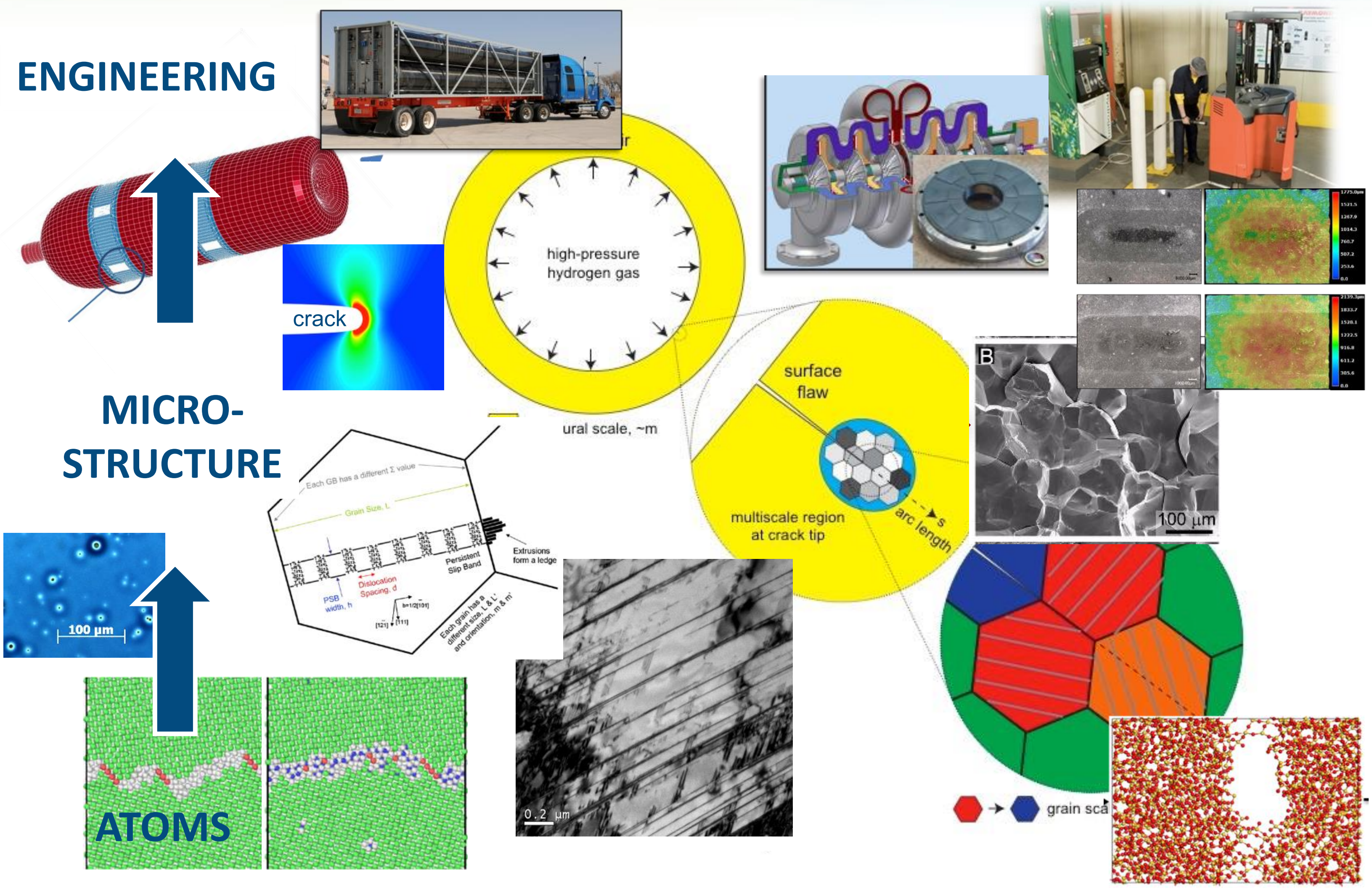
- Understand fundamentals of hydrogen interactions with metals and polymers to enable materials selection and mitigation strategies for hydrogen-enhanced degradation

Demonstrated Impact

- Enabled worldwide deployment of hydrogen and fuel cell systems by developing test methodologies for science-based standards

GRANTA MI

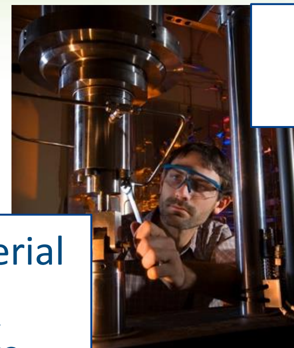
Foundational materials science for hydrogen systems engineering: *Atoms to Engineering concept*



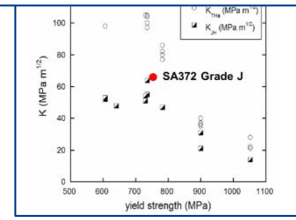
Evaluation of *Materials Compatibility* enables hydrogen technology innovation

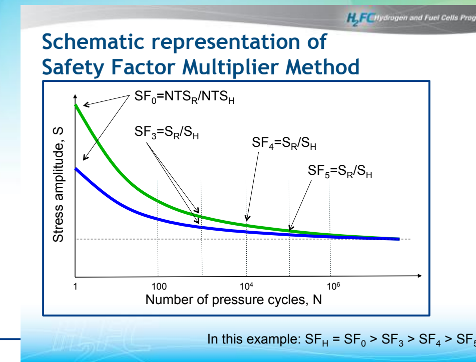
ASME article KD-10 input on test methodology

Platform for material testing in GH_2 at high pressure



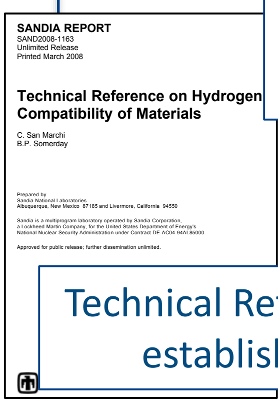
Critical assessment of statically loaded cracks





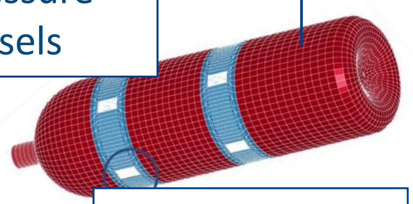
CSA CHMC1 test methods and material qualification

2005 2007 2009 2011 2013 2015 2017

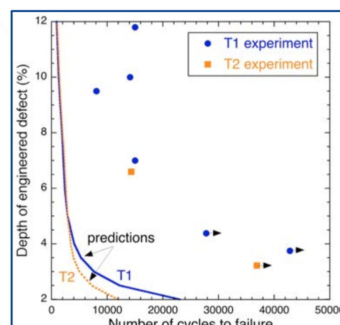


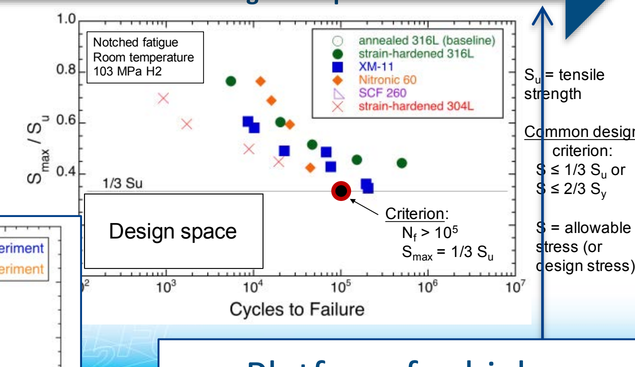
Technical Reference established

First qualification data for high-pressure ASME vessels



Full-scale tank testing
CSA HPIT1
SAE J2579

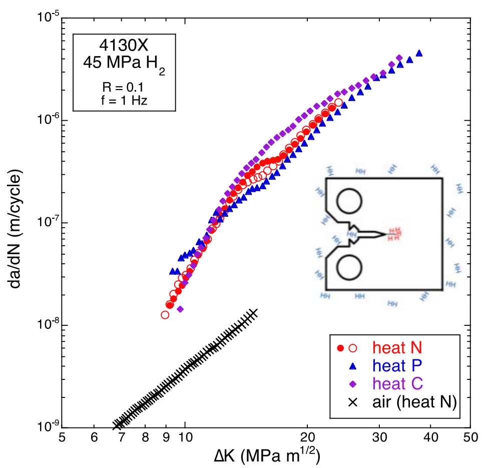


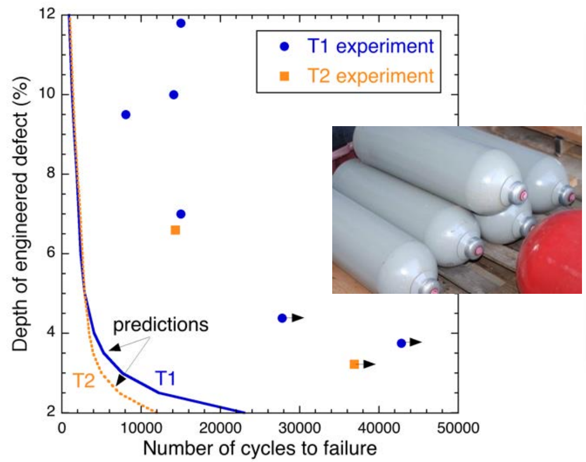


Platform for high-pressure GH_2 over temperature range (-40˚C to +85˚C)

Full-scale testing of pressure vessels enabled deployment of safe, low-cost fuel cell forklifts

Material failure characterization → Component testing → Lifetime prediction and code development





- Quantified uncertainties in the cycle life of hydrogen storage tanks for the lift-truck application
- Enhanced safety and market growth enabled through standards development (CSA HPIT1)
- Today, there are >10,000 clean and efficient fuel cell forklifts in service (and growing!)

plug power
NUVERA FUEL CELLS
NORRIS CYLINDER
CSA

International testing collaboration to develop

SAE

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This presentation is based on

Stefan's presentation reported

Safety, Codes and Standards needs for H2@Scale

- Protocols for distributed production and power systems integration
- Oxygen management in distributed systems
- Metrology at scale (metering for geologic storage and pipelines)
- Purity requirements and purification
- Gas segregation in mixed gas systems
- Leakage in geologic storage and pipeline systems
- Materials compatibility in existing infrastructure (PVC, cast iron, *etc*)
- Combustion requirements (*e.g.*, burners)
- Safety requirements for underground storage at point of use
- Maritime standards for international shipping and transport over waterways
- Safety standards for conveyance of LH_2