

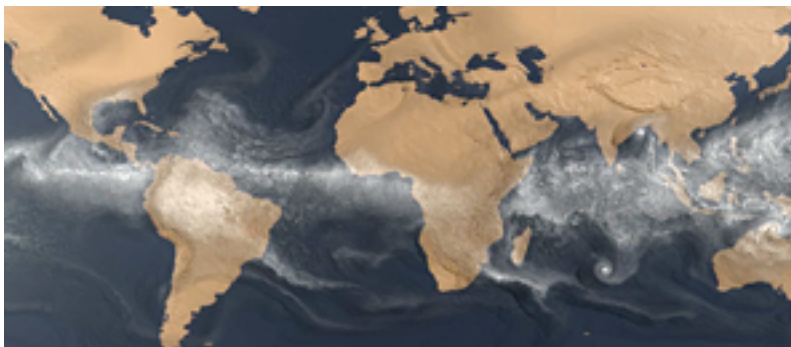
Exceptional service in the national interest



Twitter: @SandiaEnergy



Website: energy.sandia.gov



Sandia Hydrogen and Fuel Cell Technology Strategy Meeting

Jon Zimmerman, Hydrogen and Fuel Cell (H₂FC) Program Manager

Chris Moen, Senior Manager

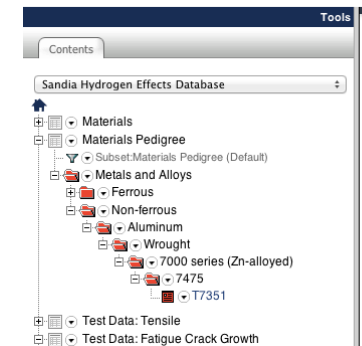
Bob Hwang, Director



Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND2016-0090 PE

Value Proposition to FCTO

- We provide deep, quantitative understanding and a scientific basis for...
 - Materials – methods for discovery and evaluating their properties and performance for hydrogen production, storage and utilization
 - Safety – innovations in risk analysis and the creation of risk-informed standards
- We build on our science and engineering R&D to perform innovative systems engineering and develop technologies that enlarge hydrogen and fuel cell application space



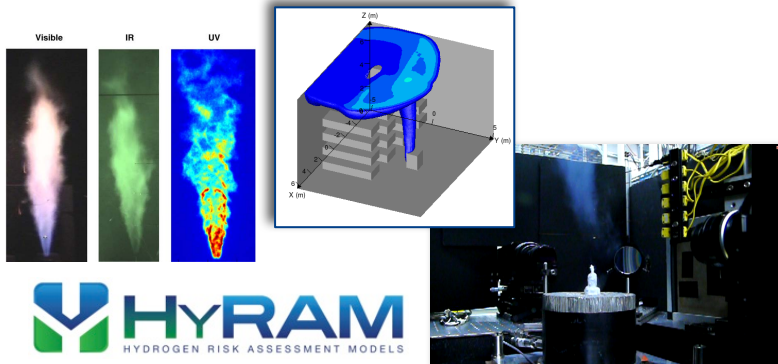
FCTO Core and Enabling Capabilities



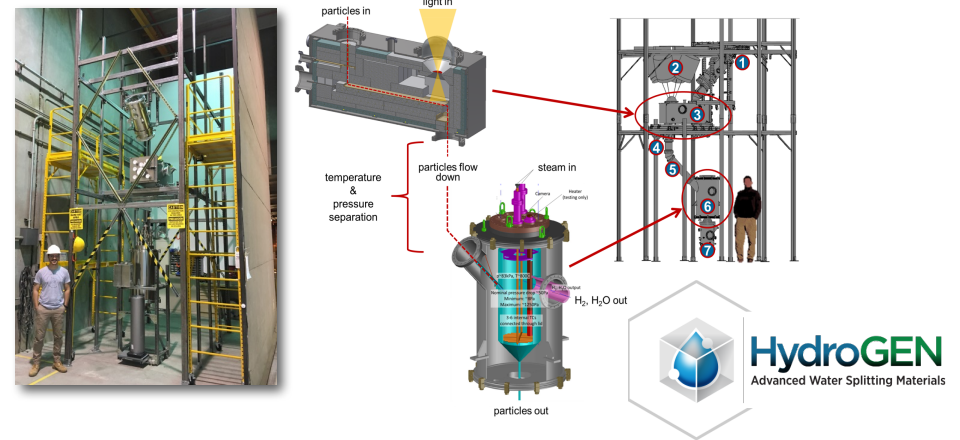
Capability	State	Cross-Walk to DOE Core Capabilities	Related Facility	Ames	ANL	BNL	INL	LANL	LBNL	LLNL	NETL	NREL	ORNL	PNNL	SLAC	SNL	SRNL	Comments
Solar Thermochemical Hydrogen Production and Storage	Existing	17, 18														●		Core capability includes the National Solar Thermal Test Facility
Hydrogen behavior and risk evaluation	Existing	17														●		SNL has developed QRA methods
Materials Compatibility in High Pressure Hydrogen	Existing	17														●		Capability provides "science basis" for flaw tolerance/stability, sub-critical crack growth and burst in hydrogen applications, e.g., tank life cycles
Alkaline exchange membranes/ electrolytes	Existing	6, 18					◐				◐					◐		Alkaline exchange membrane design, synthesis, development and testing
Polymer composite testing and evaluation	Existing	22										◐	◐			◐	◐	Will investigate status and plans in FY15-16 - Capabilities shared with Delivery and SCS
H2 storage materials discovery and development consortium (HyMARC)	Emerging	5,6,17,18						◐	◐							◐		Core national lab team to lead the consortium effort on hydrogen storage materials discovery and development
Prototype solid state hydrogen storage system testing, engineering and modeling	Existing	19														◐	◐	Capabilities to test and evaluate complete prototype materials-based hydrogen storage system against model predictions
Hydrogen infrastructure scenario and technoeconomic analysis	Existing	23		◐		◐					◐					◐		
Hydrogen Fueling Infrastructure Research and Station Technology (H2FIRST)	Existing	19									◐					◐		This capability will be one of the most critical moving forward and leverages 2 primary labs; others may join

Core Capabilities

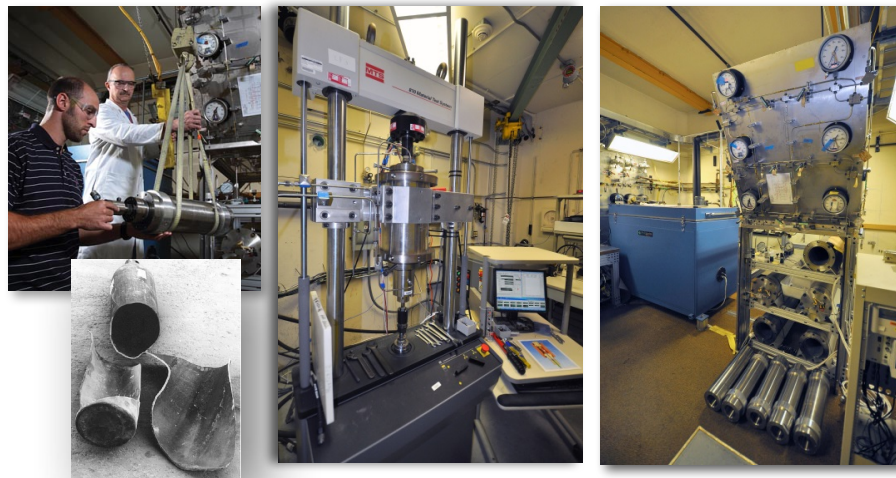
Hydrogen Behavior and Risk Assessment



Solar Thermochemical Hydrogen Production

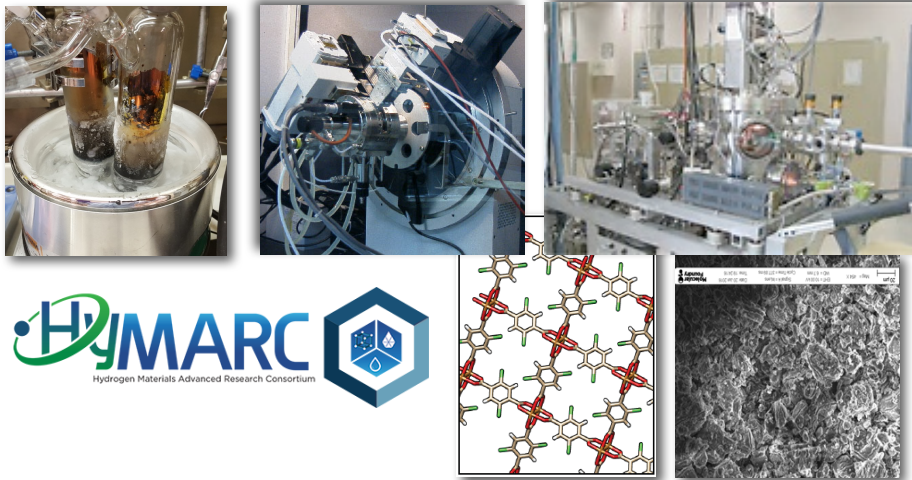


Materials Compatibility with Hydrogen

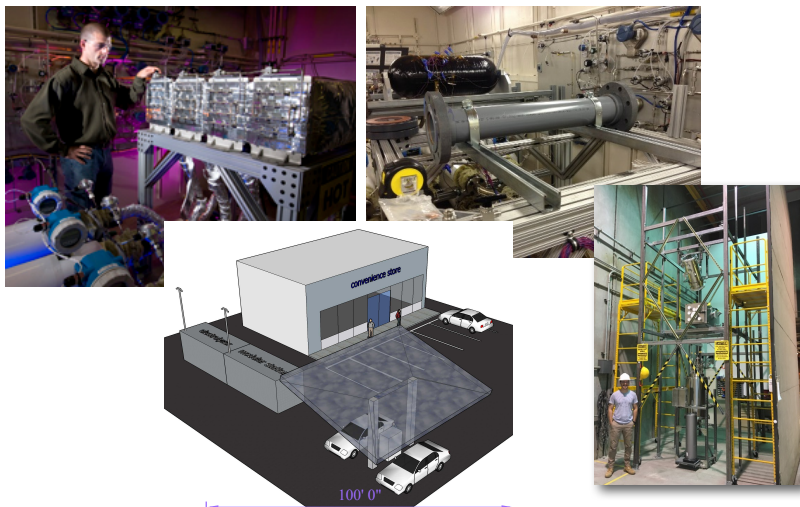


Enabling Capabilities

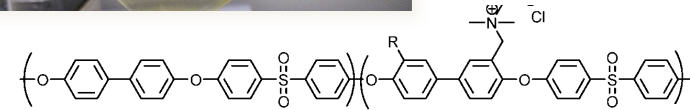
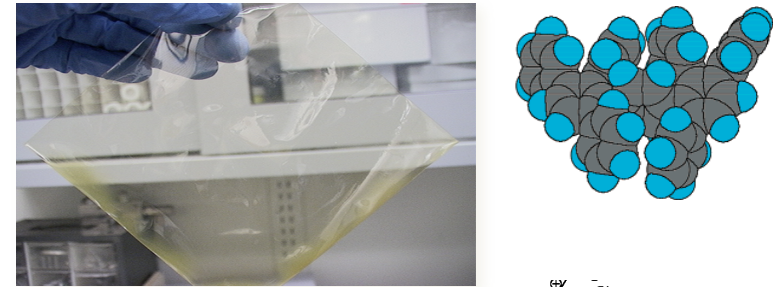
Hydrogen Storage Materials



Systems Engineering

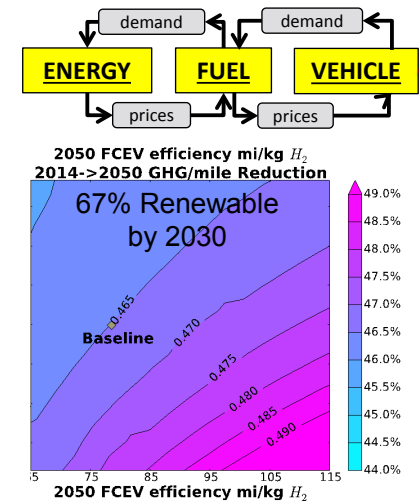
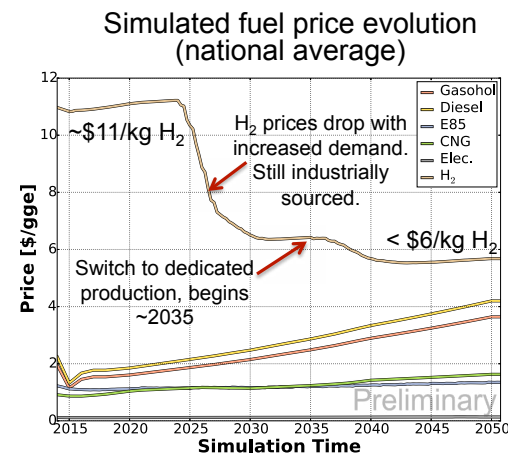


Fuel Cell Membranes



PS-AEM R = H, CH₂N(CH₃)₃

Infrastructure Scenario and Techno-economic Analysis



Enabling Capabilities

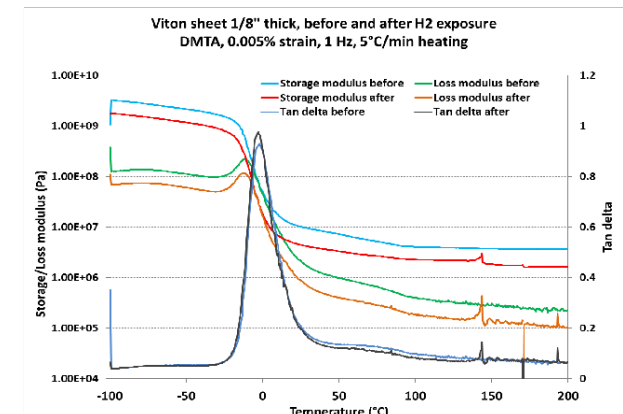
Fueling Infrastructure Research and Station Technology



Comparison of
conventional vs. modular
hydrogen refueling
stations, and on-site
production vs. delivery

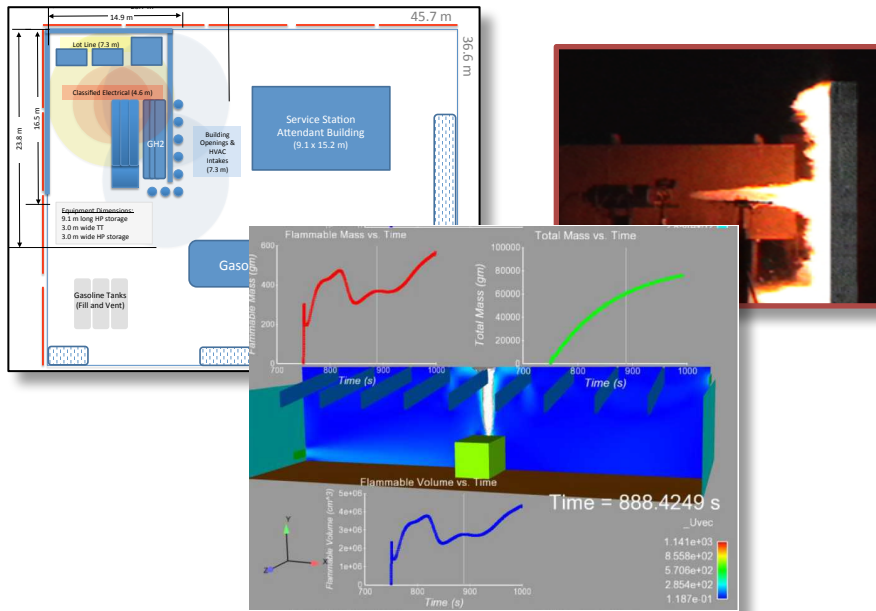
Ethan S. Hecht, Joseph Pratt
Sandia National Laboratories

Polymer and Composite Evaluation

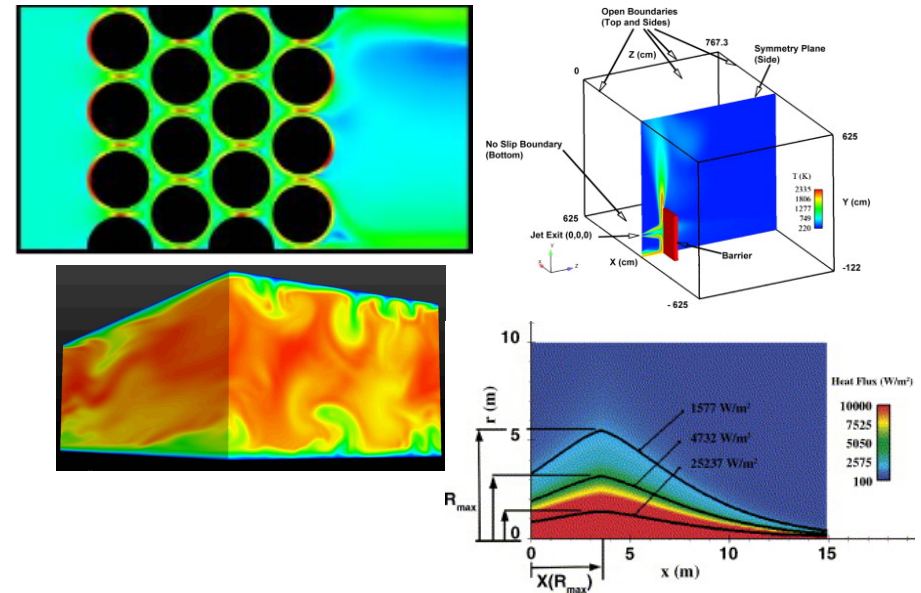


Mission-Related Capabilities

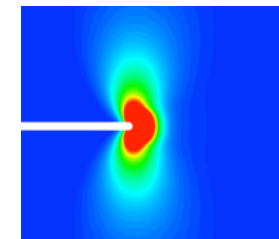
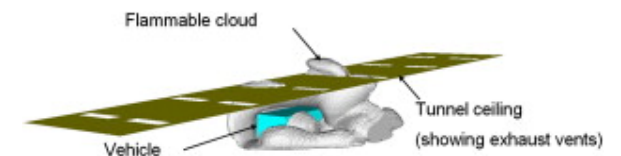
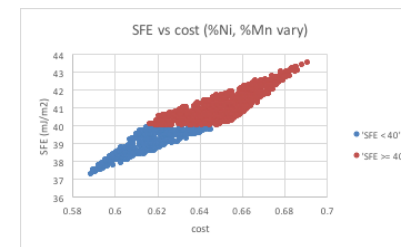
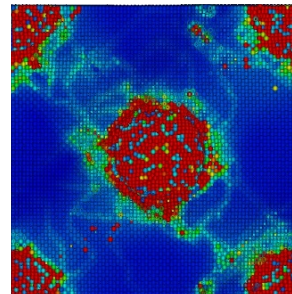
Fire Protection Engineering



Thermal/Fluids Modeling and Simulation

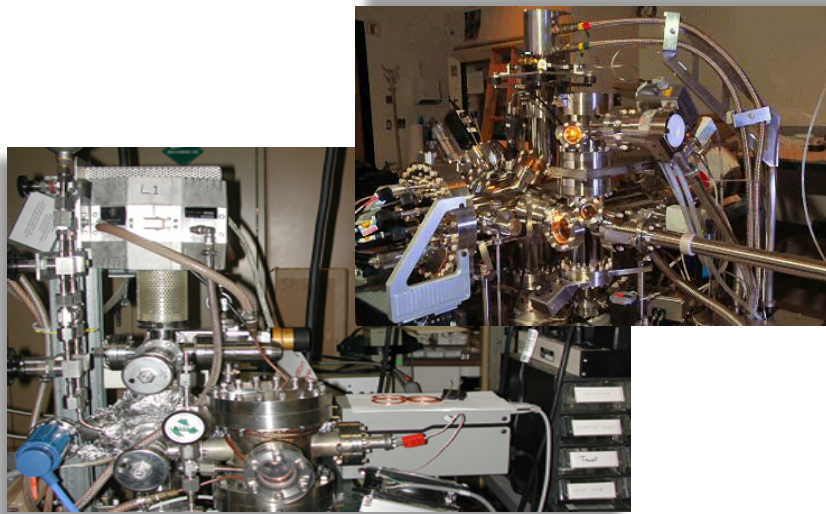


High-Performance Computing

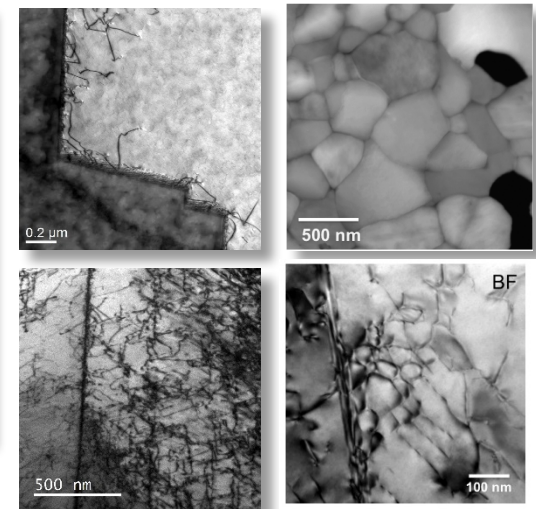


Mission-Related Capabilities

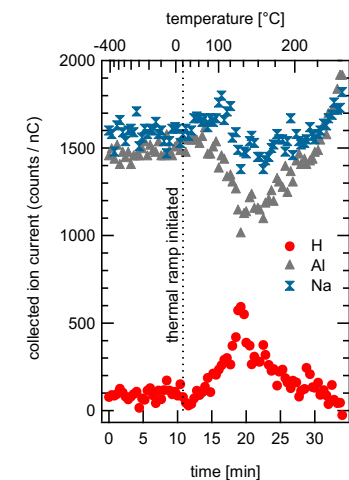
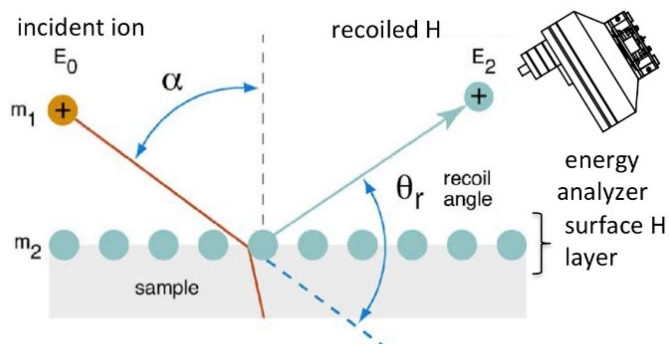
*Permeation and Thermal Desorption
Instruments and Expertise*



*Electron Microscopy-Based Expertise in
Interface Science and Material Defects*



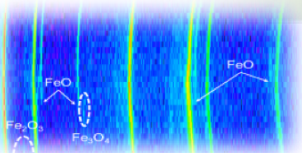
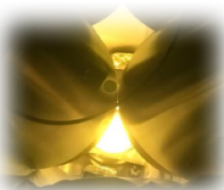
Angle-Resolved Ion Energy Spectrometry (ARIES)



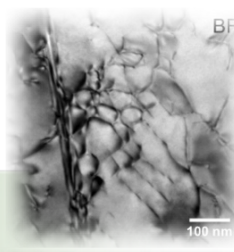
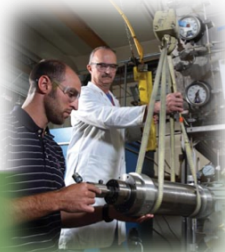
Sandia's Current Hydrogen Program

These capabilities map onto and support our work in FCTO programs

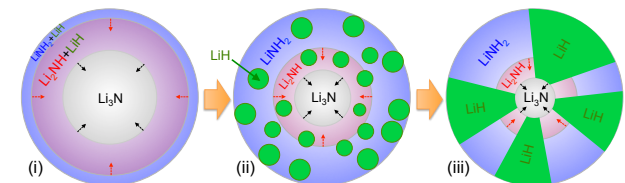
Hydrogen Production



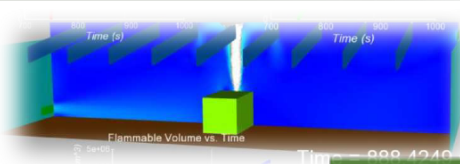
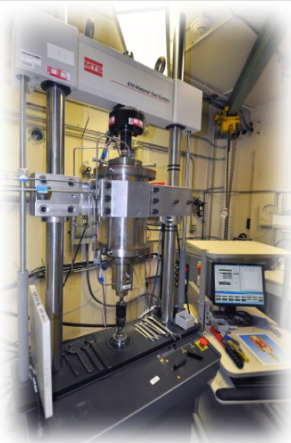
Hydrogen Delivery



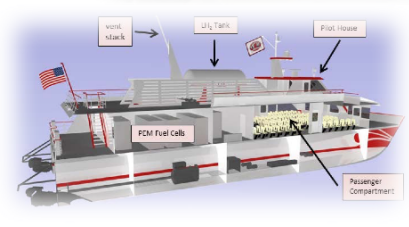
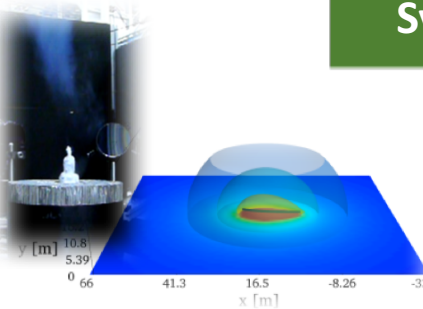
Hydrogen Storage



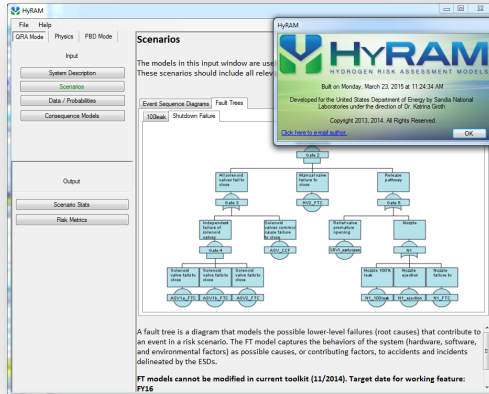
Safety, Codes and Standards



Systems Engineering



Achievement recognized by FCTO...



Safety and Design Guidance in the
Commercial Environment



Fuel Cell Generator for
Maritime/Ports



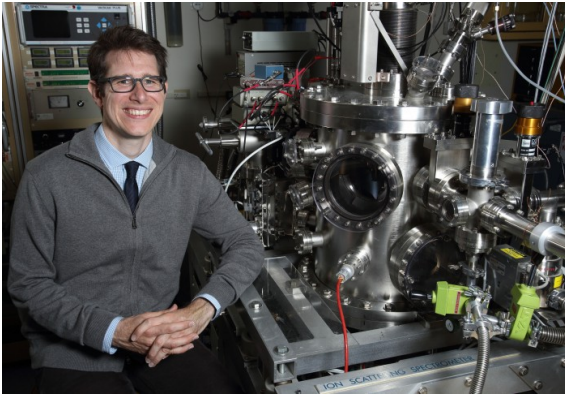
FCV Fueling Station
Performance

FCTO Annual Merit Review Awards

- 2016 – Pratt & Johnson (H2FIRST/HyStEP), Pratt (MT), Groth (SCS), Fujimoto (FC)
- 2014 – Somerday and San Marchi (H₂ Delivery & SCS)
- 2012 – Dedrick (SCS)
- 2011 – LaChance (SCS), Houf (SCS), Klebanoff (MT)
- 2010 – Klebanoff and team (MHCoE)



...and by the broader community



Rob Kolasinski – DOE Early Career Research Award for surface science supporting fusion energy



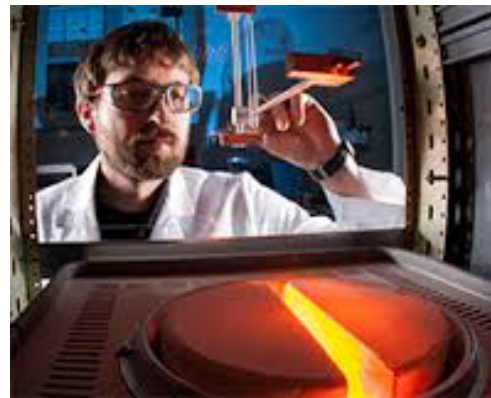
Terry Johnson and Joe Pratt – 2016 FLC West Region Outstanding Partnership Award (HyStEP)



Chris San Marchi – Award for Heki Shibata Outstanding International Technical Session at the 2015 ASME PVP Conference



Katrina Groth and Ethan Hecht - Robert Schefer Best Paper award at IA-HySafe International Conference on Hydrogen Safety



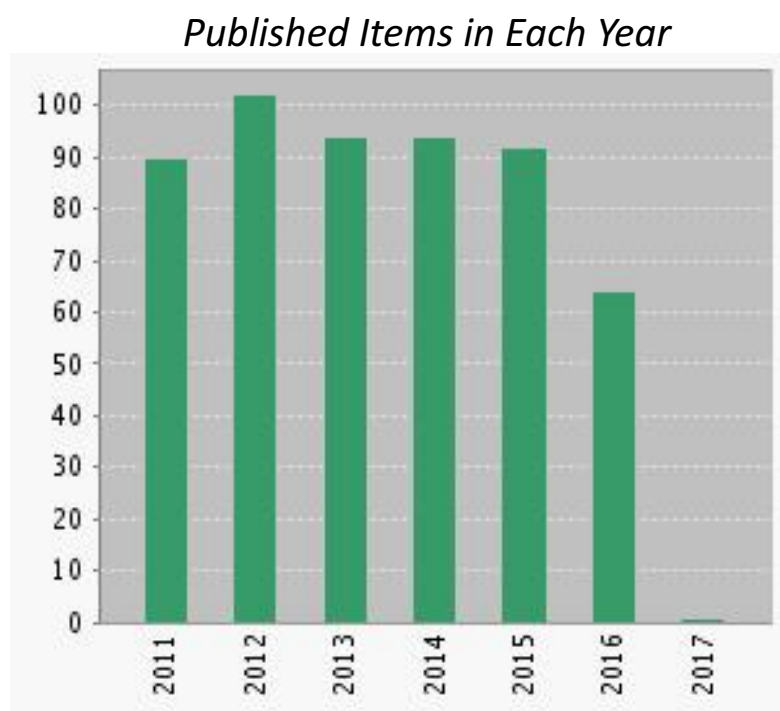
Alan Kruizenga – 2017 Presidential Early Career Award for Scientists and Engineers (PECASE)



Contributions to Codes & Standards (e.g. NFPA 2, SAE J2579)

Program outcomes

Our program has produced 145 articles sponsored by FCTO and published between 2011 and January 2017 (overall work in hydrogen science has produced over 530 articles for this same period).



\$7.2M spent → ~\$300K/article

Total Citations in 2016: ~3,000

Top Cited Articles by Allendorf, McDaniel, Hibbs, Stavila, Fujimoto, Klebanoff

Program outcomes

The next-generation of scientists and engineers for discovery and innovation...

- Early-Career staff ($\lesssim 10$ years):
 - Ronevich (CSM), Hecht (U-Utah), Kolasinski (Caltech)
 - Karnesky (Northwestern U), Reynolds (UC-Berkeley)
- Postdocs:
 - Gibbs (CSM), Lawrence (Purdue), Panda (Purdue), Albrecht (CSM)
 - Jackson (Imperial College London), Nibur (Washington State U)
 - Donovan (U-Wisconsin, Madison), Cardenas (U-Texas, Austin)
- Student Interns:
 - Harris (Boise State, U-Virginia), Hughes (Mills College, UC-Davis)
 - Shaw (Princeton), Socha (Fordham, U-RI), Yee (Carnegie Mellon U)
 - Kramer (US Naval Academy), Chan (UC-Berkeley), Carrier (UIUC)
 - Fonseca (UC-Berkeley), Biswas (UCLA), Roba (Bucknell U), Kim (Georgia Tech)
 - Huang (Columbia), Gatenby (CSU-Chico), Ling (UC-Berkeley)
 - High School: Tumma, Walkup, Zumwalt, Sena, Farmer, Patel, Liu

Vision and Strategy

- Focus on fundamental through applied research regarding the physics of hydrogen-material interactions
- Ensure safety, performance and reliability while lowering costs
- Leverage our Sandia CA location to remove roadblocks to hydrogen-based transportation adoption in collaboration with industry and government
- Partner with industries, codes and standards organizations, and international institutes to address knowledge gaps

