Hydrogen R&D at Sandia National Labs

SAND2009-5224C

Lennie Klebanoff (lekleba@sandia.gov)

Sandia National Laboratories

August 12, 2009

UNLV Renewable Energy Symposium

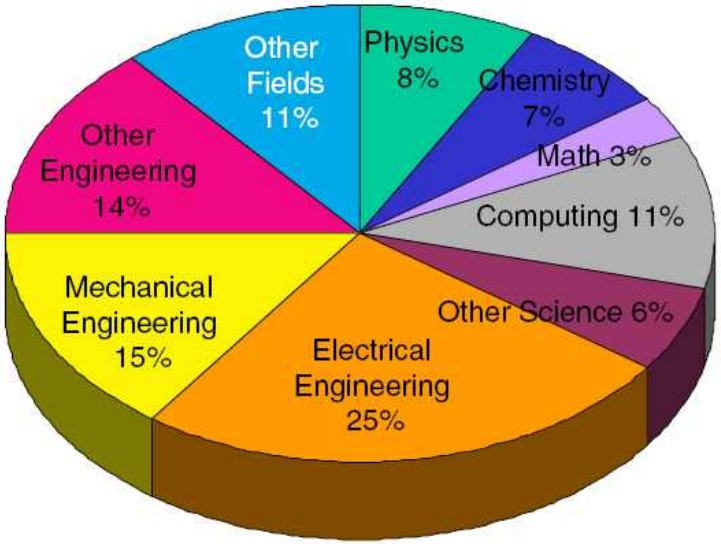
Las Vegas, Nevada

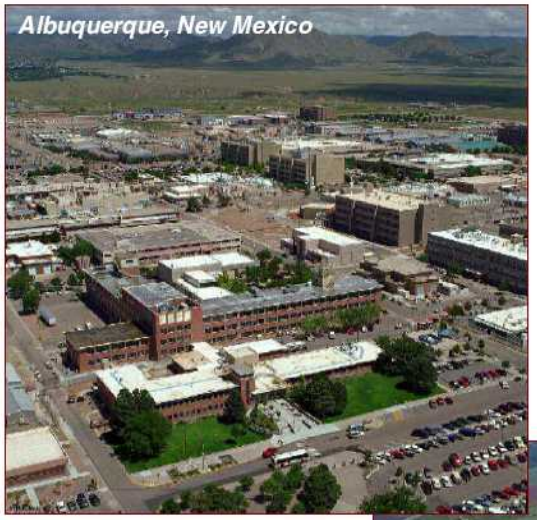
Sandia National Laboratories

"Exceptional Service in the National Interest"

Sandia National Laboratories

Sandia is a government-owned/contractor operated (GOCO) facility. Sandia Corporation, a Lockheed Martin company, manages Sandia for the U.S. Department of Energy's National Nuclear Security Administration.





- ~ 8,300 employees
- ~ 1,500 PhDs; ~2800 MS/MA
- ~ 700 on-site contractors

Website: www.sandia.gov

Sandia's National Security Missions

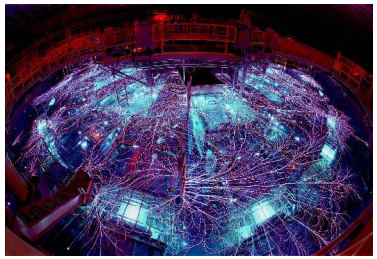
Nuclear Weapons
• Ensure a safe, secure, & reliable nuclear deterrent

Energy & Infrastructure
• Ensure clean, abundant & affordable energy and water

Nonproliferation
• Reduce proliferation of weapons of mass destruction & threat of accidents

Military Technologies & Applications
• Help maintain U.S. military weapon-systems superiority

Homeland Security
• Help protect our nation against terrorism through advanced technology



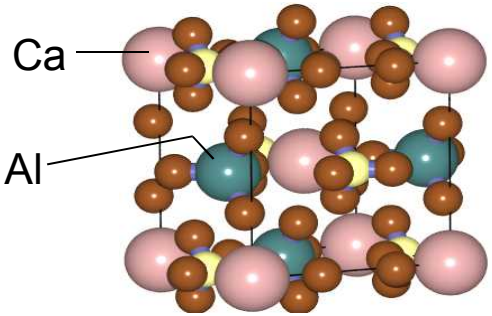
Science, Technology, & Engineering
• Conduct R&D programs to support all national security missions

Sandia's Hydrogen Program

Website: www.ca.sandia.gov/hydrogen

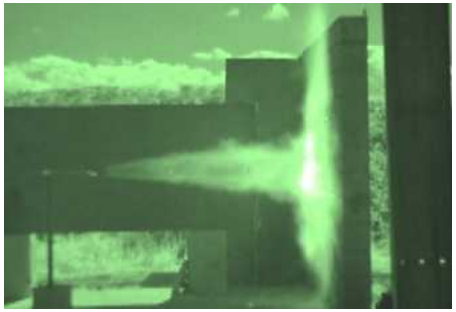
~ 50 Full Time Staff Involved

Combustion

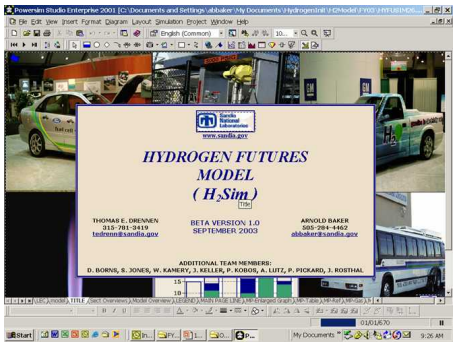


Ca $(AlH_4)(BH_4)$

H_2 Materials, Storage Engineering



H_2 Safety



Infrastructure Modeling

H_2 Storage for Ground Transportation

We all use about 10 gallons of gas in our cars

Energy in 1 Gallon of Gas ≈ Energy in 1 kg of hydrogen

Therefore,

10 gallons of gas ≈ 10 kg of hydrogen

OPTIONS FOR STORING 10 kg of H_2 on CARS:

1. **Compressed Gas (116 gallons at 5000 psi, T = 72 F)** **(V too large!)**
2. **Liquid H_2 (~ 38 gallons, T = - 420 F)** **(Too cold, boil-off, E losses)**
3. **A sponge that reversible absorbs and releases H_2:**

Ex. : $NaAlH_4$ (T = 70 F, ~ 57 gallons, wt. = ~ 440 lbs) (metal hydride)

Note: System considerations make the situation much more challenging

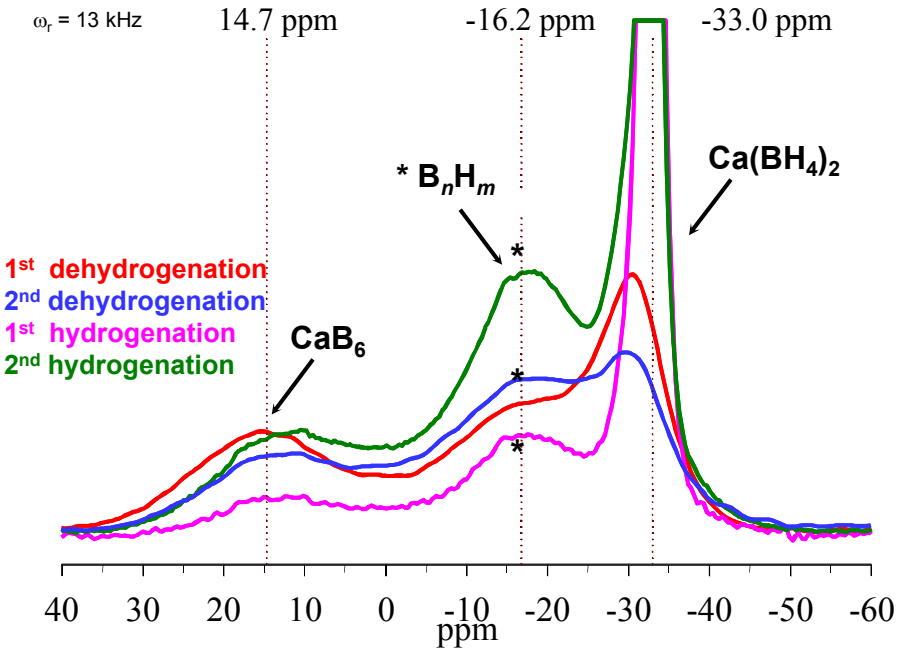
DOE Metal Hydride Center of Excellence

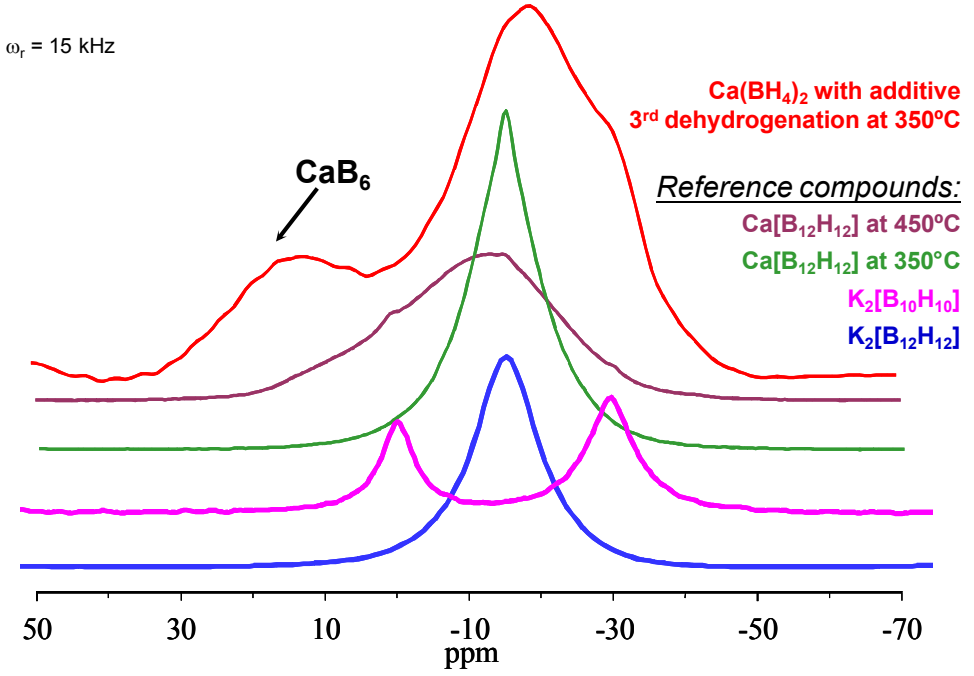
Director: Lennie Klebanoff (SNL)
Deputy Director: Jay Keller (SNL)

Investigations of $Ca(BH_4)_2$ at Sandia

Expectations: $Ca(BH_4)_2 \longrightarrow CaB_6 + 2\,CaH_2 + 10H_2$ **(9.6wt. %)**

But material does not "cycle" well, can't recharge fully to $Ca(BH_4)_2$



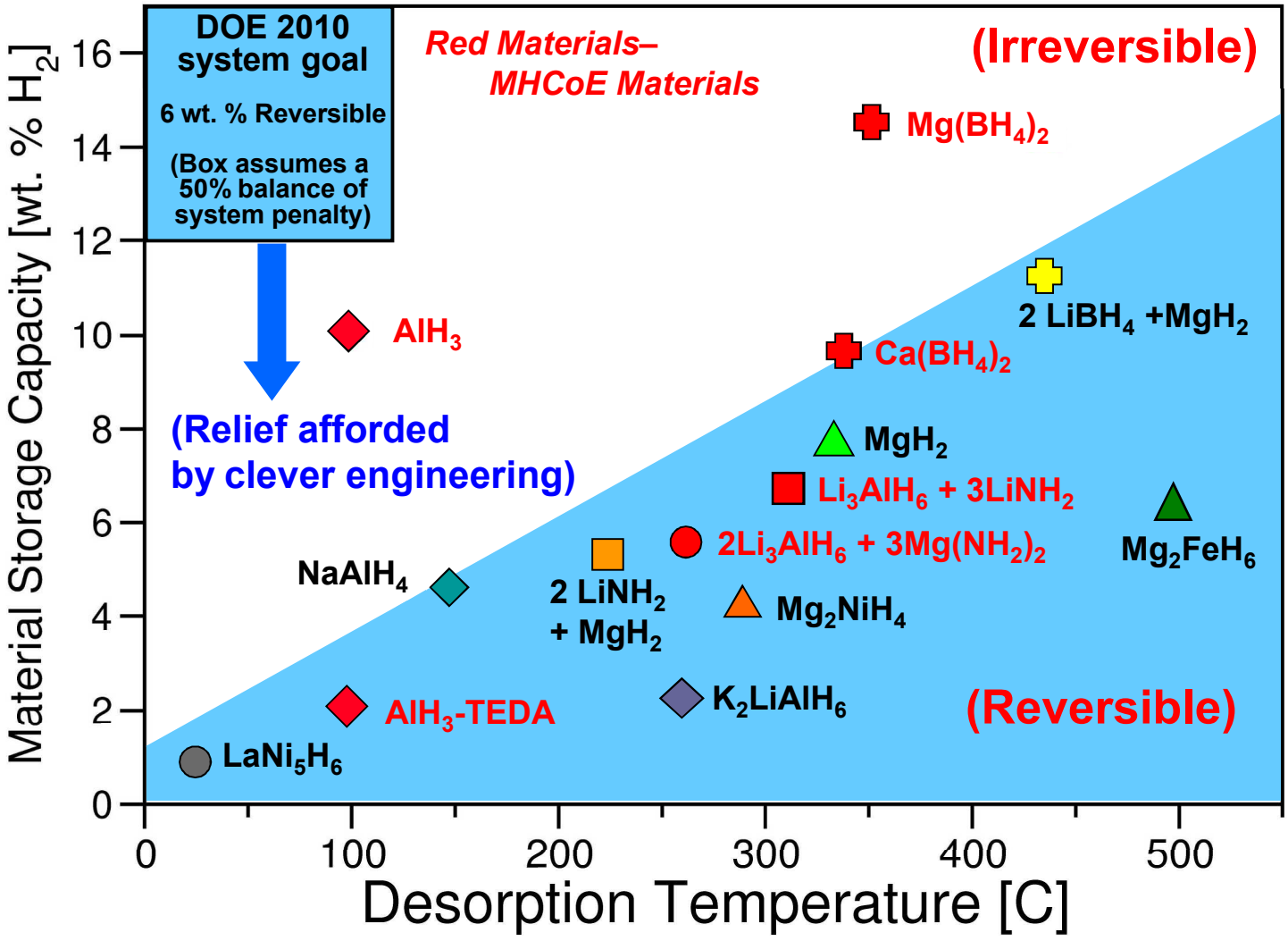


- ^{11}B NMR reveals the presence $[B_nH_m]$ species and their accumulation upon cycling

- Separate experiments show that $Ca[B_{12}H_{12}]$ cannot be hydrogenated or dehydrogenated under the conditions tested

METAL HYDRIDE CENTER OF EXCELLENCE

MHCoE Materials Relative to DOE Targets



(Original plot from GE)

Engineered Systems for Solid-State Hydrogen Storage

-- a GM funded Project…

Key program aspects:

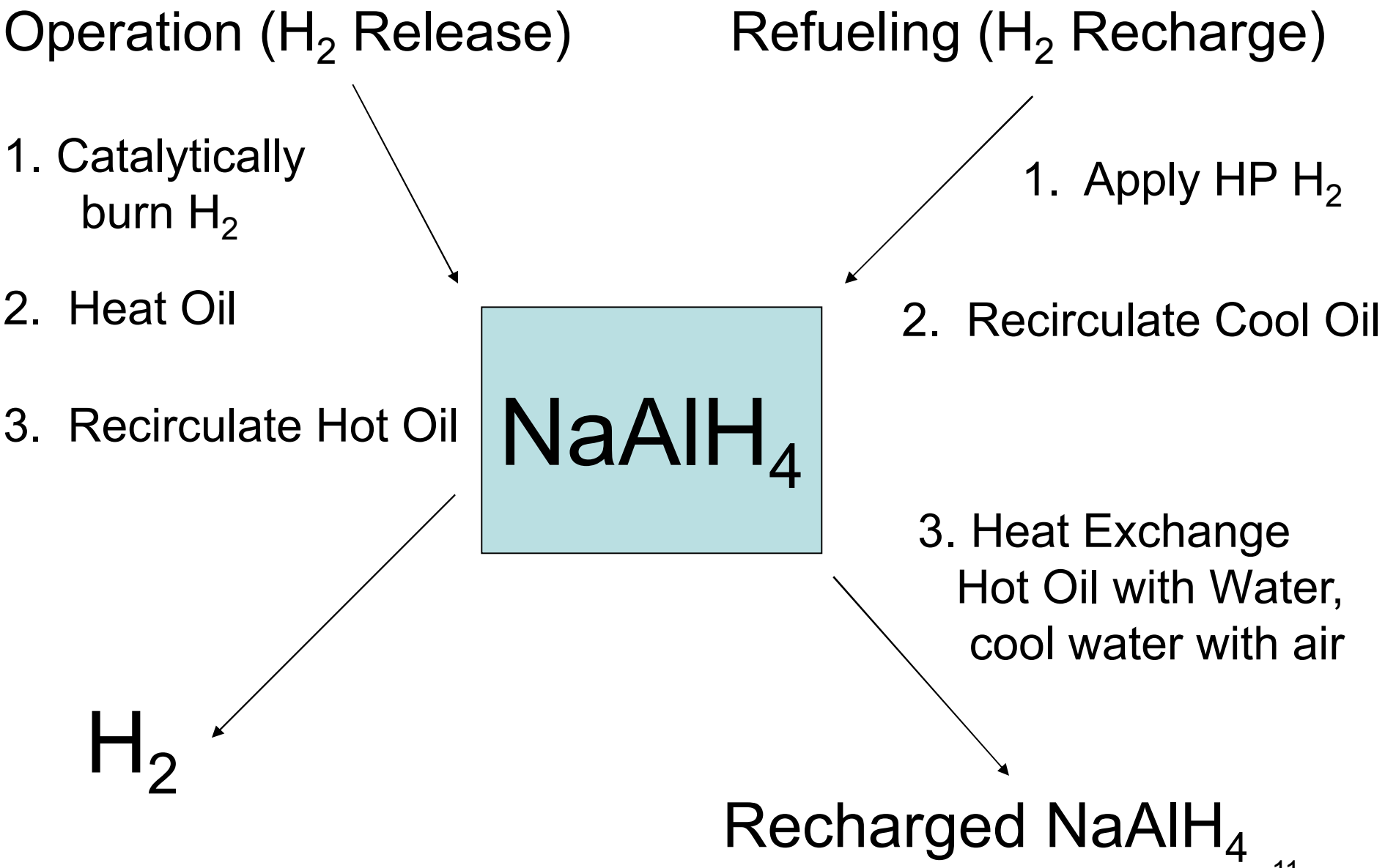
- Develop conceptual designs for reversible metal hydride storage systems
- Experimentally validate design concepts using sub-system prototypes
- Develop design tools
- Design, analyze, and optimize storage system
- Validate design tools using large-scale system

The System Is Based on $NaAlH_4$

$$NaAlH_4 \xrightarrow{\text{heat}} 1/3Na_3AlH_6 + 2/3Al + H_2$$

$$1/3Na_3AlH_6 \xrightarrow{\text{More heat}} NaH + Al + 3/2H_2$$

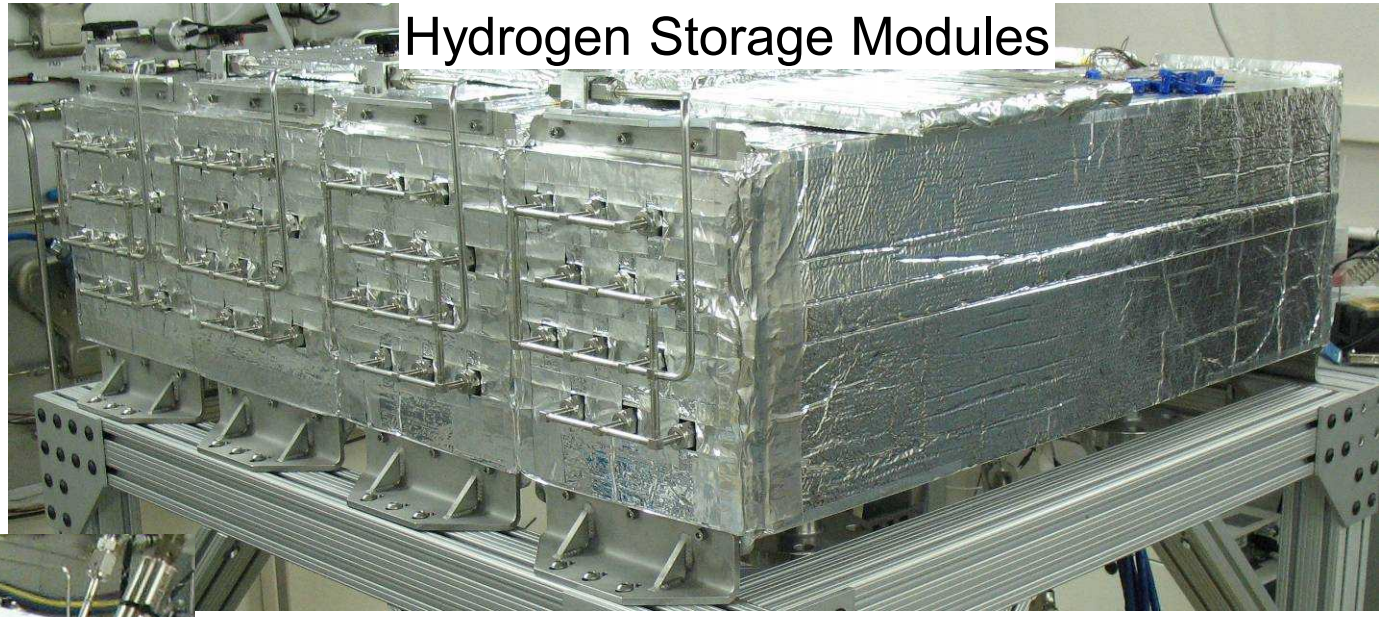
Made by ball milling NaH with Al and 3mole % $TiCl_3$, then hydrogenate

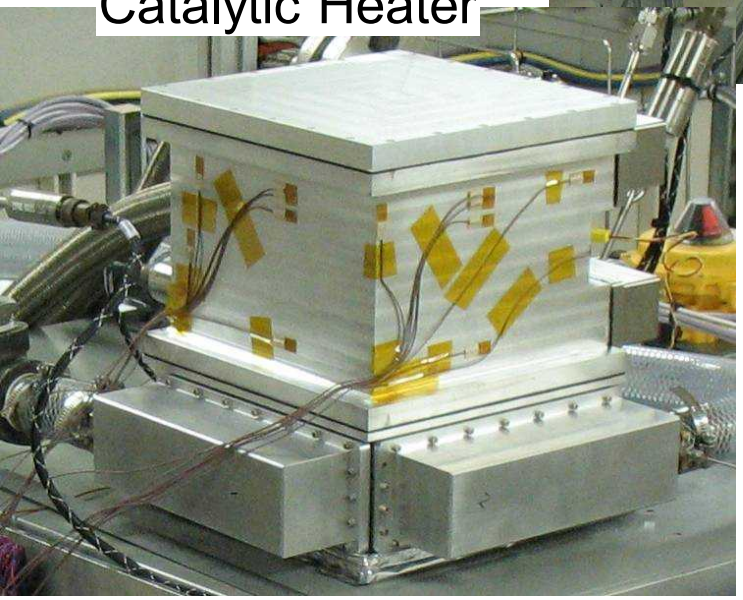

Operation (H_2 Release)
Refueling (H_2 Recharge)
1. Catalytically burn H_2
2. Heat Oil
3. Recirculate Hot Oil
$NaAlH_4$
1. Apply HP H_2
2. Recirculate Cool Oil
3. Heat Exchange Hot Oil with Water, cool water with air
H_2
Recharged $NaAlH_4$

Heat Exchanger For Refueling

Tank Size Suitable for Automotive Use

Storage System Features

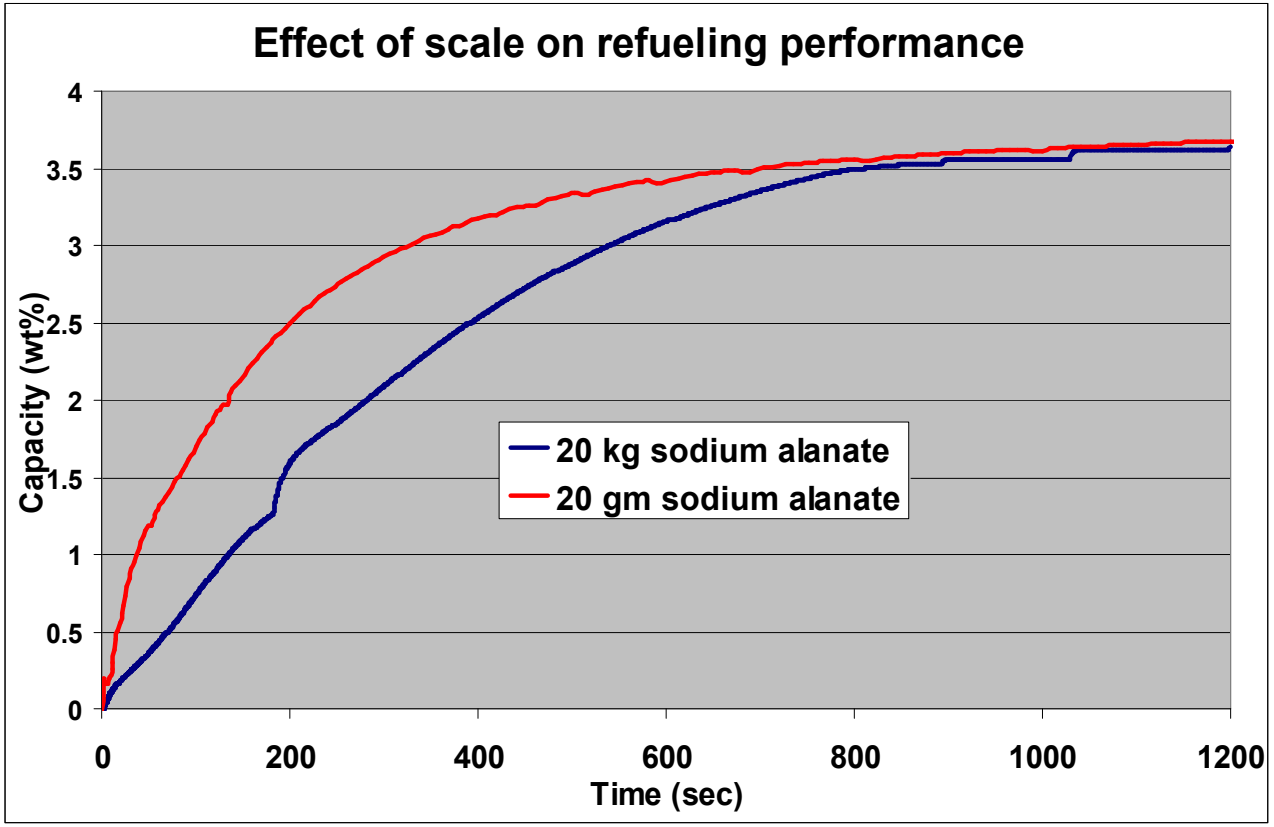




- Modular design to optimize fuel delivery performance and form factor
- 3 kg hydrogen storage using sodium alanate
- Shell and tube heat exchanger configuration
- Compact heat exchanger with catalytic heating

Engineering Project Achievements

- 3 kg capacity was achieved ✓
- Kinetic bottlenecks under control ✓
- Thermal management design validated with optimum refueling demonstrations ✓
- Real-world fuel cell drive cycles demonstrated ✓



Fuel Cell Light Stand Project

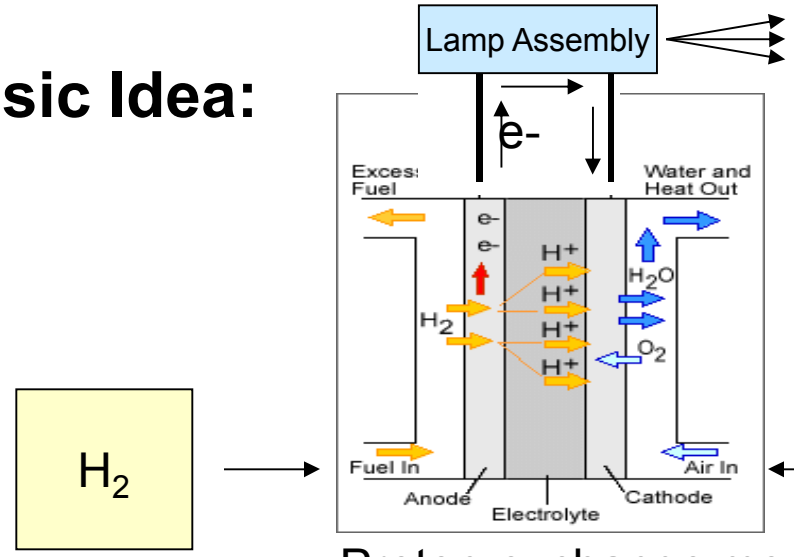
3/1/2008:

"We (Boeing) would like Sandia to lead an effort with us to bring hydrogen fuel cell technology to airport ground support equipment"

-- George Roe, Manager of Subsystems Technology, Boeing Phantom Works

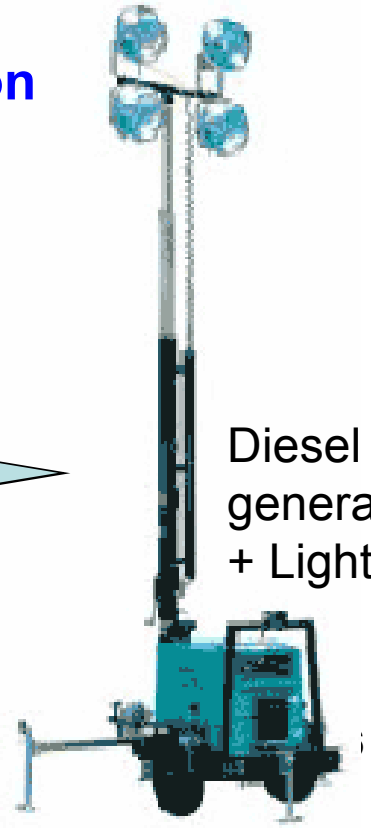
Initial discussions settle on a H_2 fuel cell demonstration for mobile 5 kW aircraft maintenance lighting:

Basic Idea:



Proton-exchange membrane (PEM) Fuel Cell

replaces….



Diesel generator + Lights

Why We Want to Do This

The project brings clean energy technology (lighting, H_2 fuel cells) to the marketplace, testing the technologies, promoting H_2 infrastructure needs.

--an opportunity for users to gain experience with these technologies, and for a demanding field test of the technologies themselves.

Great Performance Benefits:

Greatly reduced noise with use of PEM fuel cell
No diesel particulate emissions
} **Improved worker safety**

With one unit, we displace 2730 gallons of diesel fuel/year, eliminate 27.5 metric tons/year of CO_2 if "green H_2" is used } **Good for the environment, GHG reductions**

Lots of Applications for the H_2/Fuel Cell Light:

Road work, emergency roadway lighting, aircraft/airport maintenance, film industry, disaster recovery -- **commercially attractive**

Broader Technology Implications:

Improved efficiency stationary lighting for roadways, bridges, facilities
Clean portable power for equipment, communications

A Team Has Come Together to Bring This Technology to the Marketplace

Partners

Sandia National Laboratories, Technical Lead, H_2/Fuel Cell expertise

Altergy Systems (Folsom), Leading manufacturer of PEM Fuel Cells

Multiquip Inc., Leading manufacturer of construction equipment, diesel light systems

Caltrans, Transportation Expertise, Field Testing

Boeing, Technology innovation, fuel cell technology for aviation

Lumenworks/Luxim, Advanced lighting technology and design

Golden State Energy, Energy technology analysis, project coordination

California Fuel Cell Partnership, Fuel cell technology expertise

San Francisco International Airport, alternative energy and aviation

Next Steps for Fuel Cell Lighting Project

Build an “Alpha” System based on HP Storage of H_2

Build a “Beta” System based on MH Storage of H_2

Deploy Prototypes in Real World Work at Caltrans and at SFO, get feedback on performance

Design Commercial Unit, Mass Manufacture

Partners have donated > $500K in-kind
We are actively seeking full funding for project

Other Hydrogen R&D at Sandia

- Supporting the development of new model fire codes to permit the commercial and residential infrastructure for the hydrogen economy
- Measuring hydrogen effects in structural materials at challenging service conditions
- Demonstrating hydrogen production via solar thermal energy in NM
- Developing high-T OH^- conducting membranes for Alkaline Fuel Cells

Summary

We at Sandia are engaged, along with many partners, in R&D supporting the eventual transition to a hydrogen-based transportation world.

Sandia is interested in partnering with others to achieve this transition!