Fuel Cell Mobile Lighting: A Boeing-Sandia-DOE Market Transformation Activity

Lennie Klebanoff
Sandia National Laboratories
Livermore CA 94551

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Sandia National Laboratories

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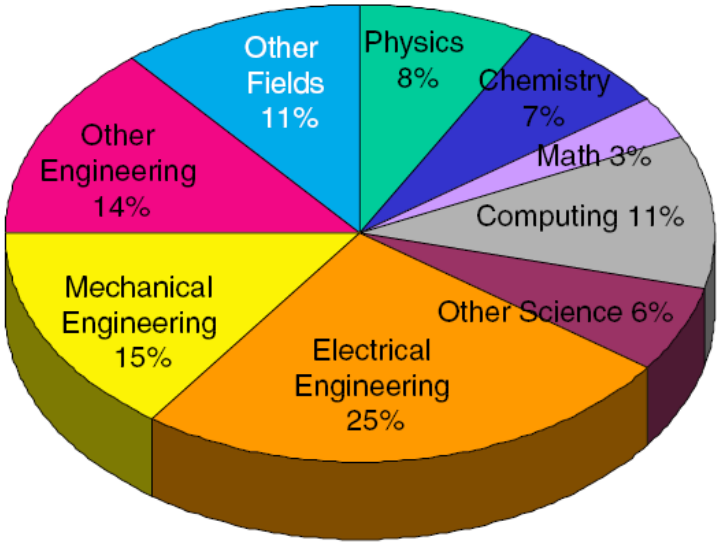
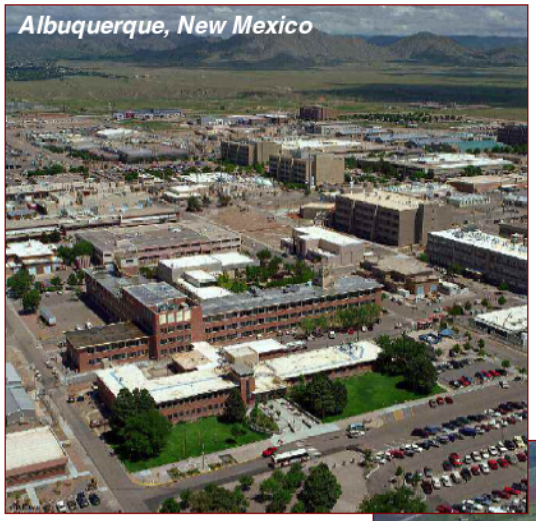
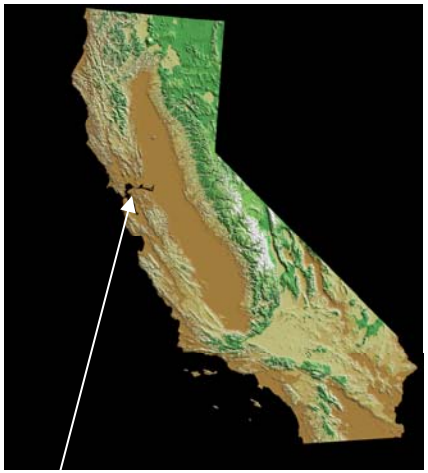






- ~ 8,300 employees
- ~ 1,500 PhDs; ~2800 MS/MA
- ~ 700 on-site contractors

Annual Budget ~ $2.2 Billion

($1.3 Billion DOE, $0.9 Billion work for others)

Website: www.sandia.gov

Why Hydrogen?

Concern #1: Our current oil-derived transportation fuels will become increasingly scarce

Hubbert's 1962 Prediction

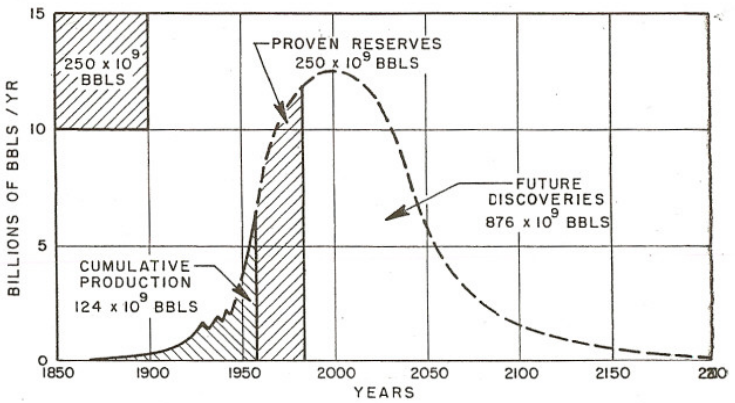
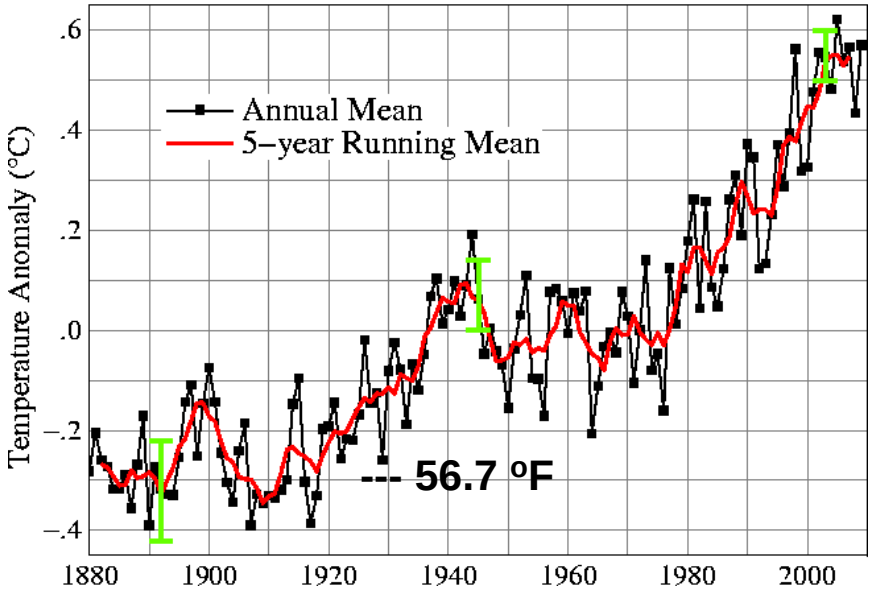


Figure 41. Ultimate World Production of Crude Oil

Concern #2: Our current oil-based transportation fuels will be threatened by world politics

Concern #3: Our transportation fuels (cars, aircraft) will become increasingly unusable due to global warming…

Global Land–Ocean Temperature Index



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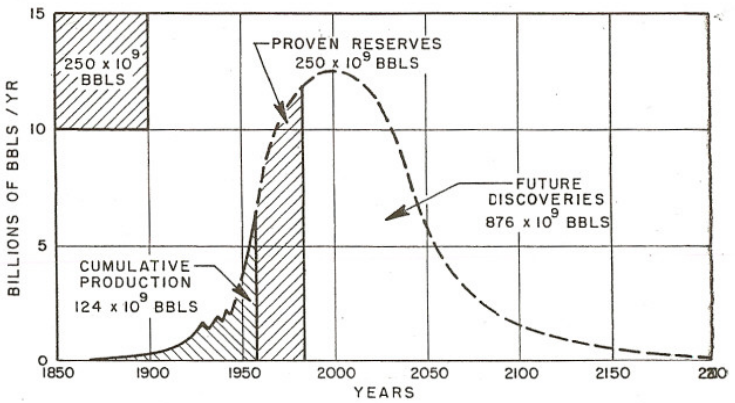

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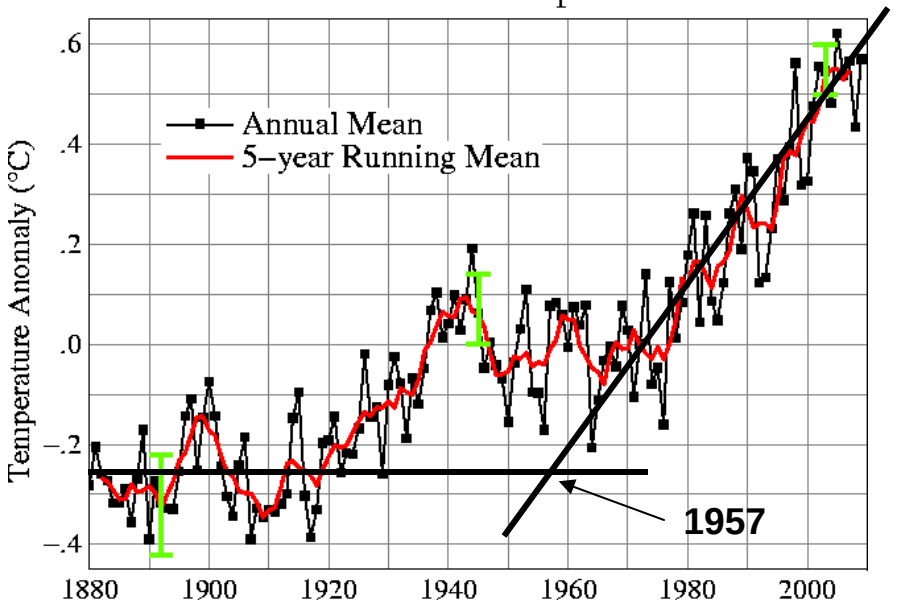


Global Warming is an Old Problem

-- from "Energy Resources", a Report to the Committee on Natural Resources of the US National Academy of Sciences, 1962, page 96

-- M. King Hubbert

"There is evidence that the greatly increasing use of the fossil fuels, whose material contents after combustion are principally H_2O and CO_2, is seriously contaminating the earth's atmosphere with CO_2. Analyses indicate that the CO_2 content of the atmosphere since 1900 has increased 10 percent. Since CO_2 absorbs long-wavelength radiation, it is possible that this is already producing a secular climatic change in the direction of higher average temperatures. This could have profound effects both on the weather and on the ecological balances."

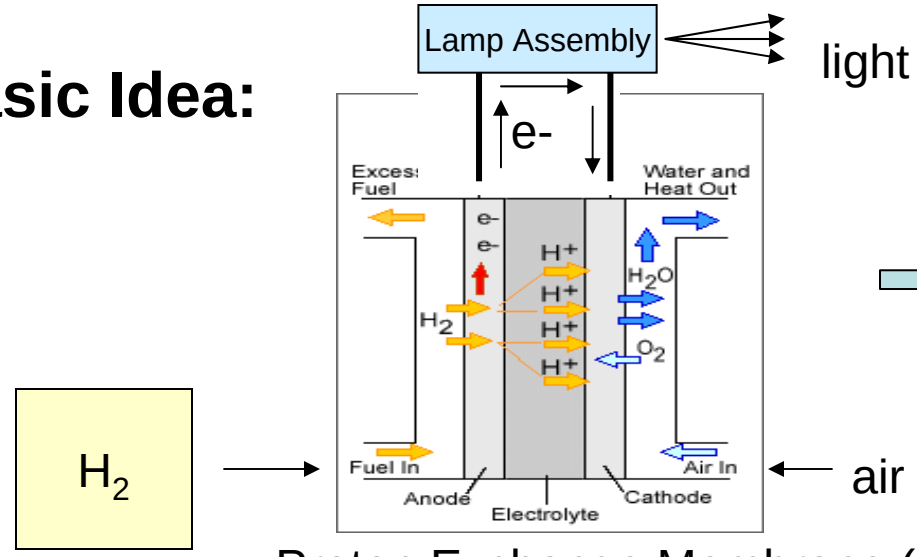
Origin: Boeing Interested in Bringing Fuel Cell Technology to Ground Support Equipment (GSE)

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**

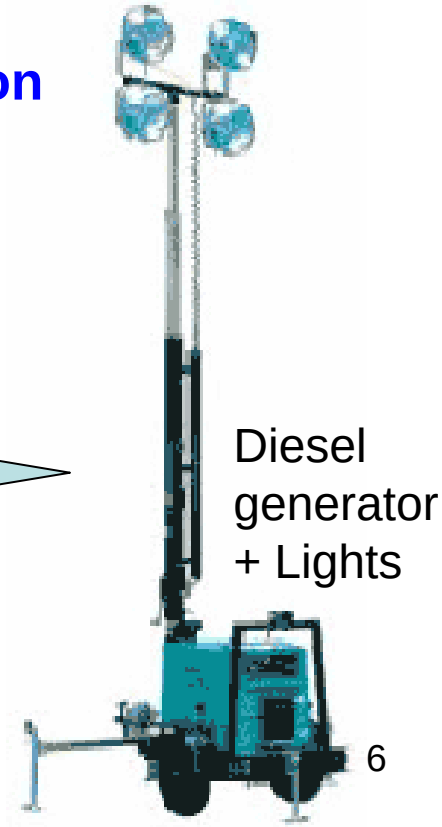
Initial discussions settle on a H_2 fuel cell demonstration for mobile 5 kW aircraft maintenance lighting:

Basic Idea:



Proton Exchange Membrane (PEM) Fuel Cell

replaces….



Diesel generator + Lights

Why We Want to Do This

Goal: To bring clean energy technology (lighting, H_2 fuel cells) to the construction marketplace, stimulate demand and the H_2 infrastructure, proliferate the technology. -- Transform the Marketplace

Great Performance Benefits:

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

Provides 73% reduction in CO_2 (equivalent) emissions if NG-derived high-pressure hydrogen 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, indoor use **-- commercially attractive**

Broader Technology Implications:

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

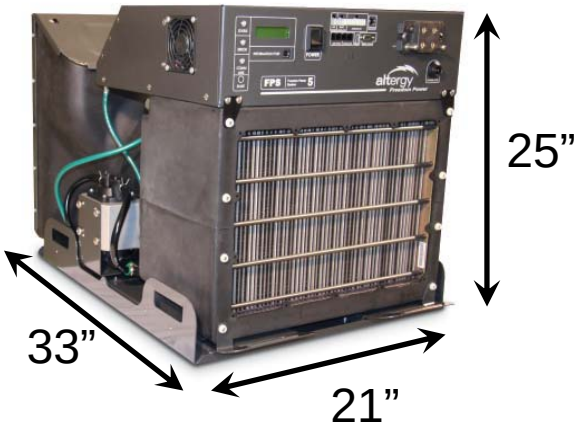
Fuel Cell Mobile Light Development Team

New Technology Experts + Manufacturing Partners + End Users

Combines New Power and Lighting Technology

PEM Fuel Cell

Altergy FPS-5 (5kW)

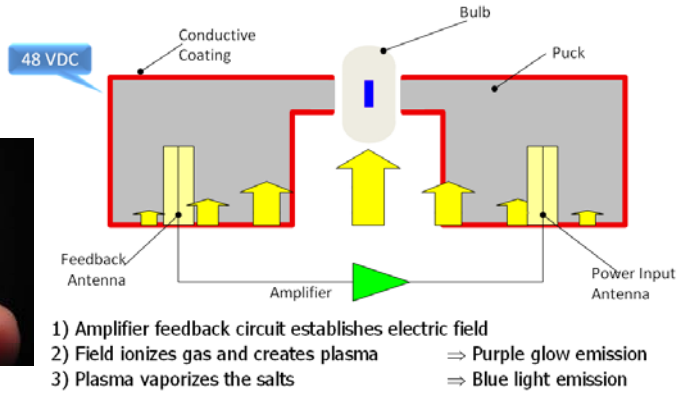


$H_2 + ½O_2 \rightarrow H_2O$

- High power density with low weight and volume
- Fast start, excellent durability
- Uses pure H_2 from storage system
- Oxygen obtained from ambient air
- 43% efficiency (diesel lighting ~ 27% efficient)
- No CO_2, NO_x or particulates emitted
- No moving parts, very quiet operation

Plasma Lighting

plasma light bulb



- High efficiency – 120 lumens/watt
- 50,000 hour lifetime
- Color Rendering up to 96 CRI
- Instant On, Dimmable to 20%
- Rapid Re-strike
- Compact source (1/4”x1/4”)
- No Audible Noise or Flicker
- Programmable
- Indoor and Outdoor Use

We Built an "Alpha" H_2/Fuel Cell Mobile Light

Alpha system built by Multiquip, Altergy Systems, Luxim, Stray Light

-- funded by Multiquip, Luxim, Stray Light Altergy Systems and Boeing

Employs two 5000 psi tanks of H_2 (4kg)

Altergy 5kW PEM fuel cell

8 Luxim Plasma Lights (2.5 kW total)

Multiquip Trailer

~ 20 hour duration at 2.5 kW with 4kg H_2

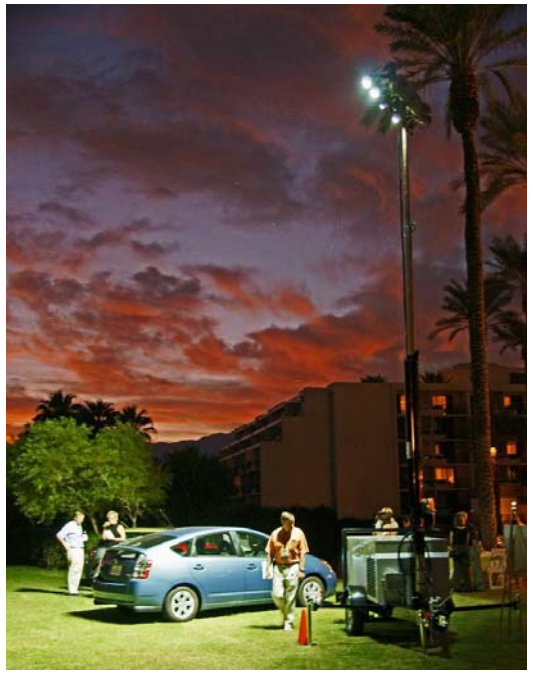
Alpha Unit Demonstrations:

- 2009 AASHTO Meeting ✓
- 2010 Academy Awards Show ✓
- 2010 National Assoc. of Broadcasters Mtg. ✓
- Caltrans District 3 Road Maintenance Work

Quiet Operation, Large Illuminated Area

Former Caltrans Director Randy Iwasaki (C)

Alpha System shown in technology show at 2009 AASHTO meeting



AASHTO = American Association
Of State Highway Transportation Officials

The Alpha System Was Demonstrated at Paramount Pictures on 1/14/2010

(Mark Bauserman and Russ Saunders discuss the system)

The project team was invited to deploy Fuel Cell Mobile Lighting at the Academy Awards event in Hollywood on March 7, 2010.

Getting Approval from LAFD for Oscars Use

We obtained approval from the LA Fire Department (LAFD) and from LA Building and Safety. This was accomplished by presenting H_2 and fuel cell information by viewgraph, and demonstrating the mobile light at Paramount on 2/9/2010

The Fuel Cell Mobile Light Deployed at the Academy Awards Show on 3/7/2010

- Used to light construction and takedown of the “Red Carpet”
- Used to light an entrance to the Red Carpet area, and provide power for a security portal (magnetometer).

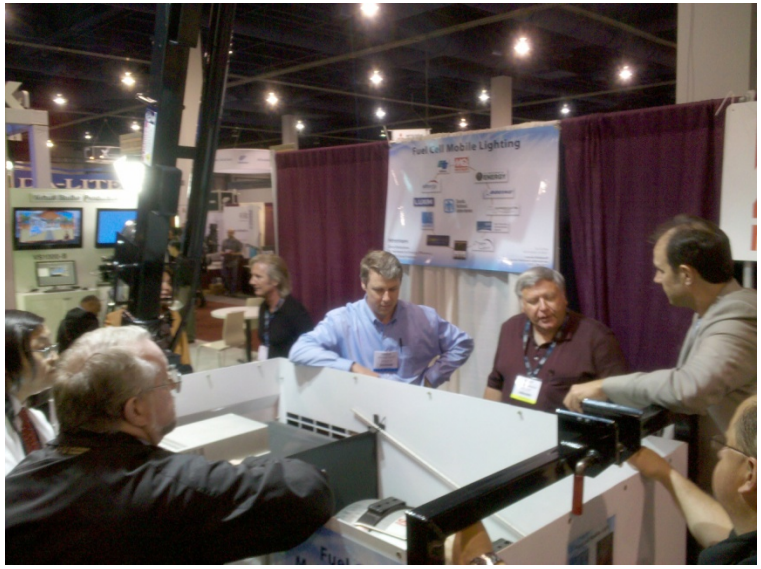
Overall, the workers loved the quality of the lighting, ease of use, how quiet the system was, and that it was non-polluting.

Final Stages of Red Carpet Preparations

Photos Courtesy of A.M.P.A.S.®

The Fuel Cell Mobile Light was “in the mix” during the final Red Carpet preparations. The unit was used by Academy personnel on their own, without supervision, and as they wished.

The Fuel Cell Mobile Light Can Be Used Indoors



Chris Robinson (C) from Disneyland inspects the Alpha Unit

--Fully approved by the Las Vegas Convention Center Fire Marshal for indoor operation at the 2010 National Association of Broadcasters (NAB) Meeting

Commercial FC Mobile Light Capabilities

- 40 hour duration (lighting)
- Indoor or outdoor use
- Area of illumination: 50 yds x 75 yds
  (at 3.5 foot candles)
- 3 kW of AC power available
- Easily moved
- Quiet: targeting 25 dB at 23 feet
- 30 foot tower height
- 5,000 psi hydrogen tanks (4)

Current Funding and Plans

DOE (EERE) and Boeing have funded the project to allow 6 Fuel Cell Mobile Lights to be built and tested:

Caltrans (So. Cal.), exposure to cold and road maintenance work

SFO (Hybrid Unit), performance of Hybrid system

Boeing (Washington State), exposure to sleet, ice, rain and fog

Kennedy Space Center (Florida), exposure to heat, humidity, salt air

Entertainment Unit (LA), performance for noise reduction, refueling

ConnDOT (Connecticut), subzero cold weather testing (TBD)

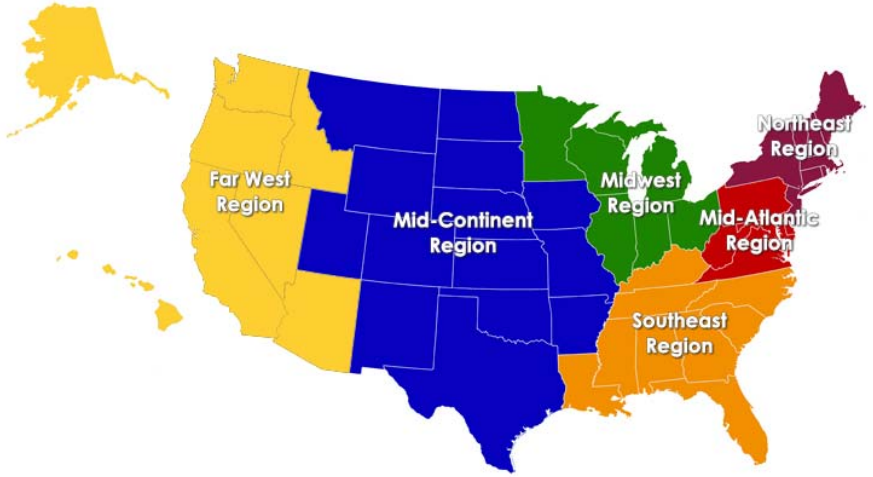
Our end goal is to get the necessary testing in to allow Multiquip to offer a commercial Fuel Cell Mobile Light by the end of the 2010

Fuel Cell Mobile Light at the NASA Kennedy Space Center (KSC)

Al Sorkin, NASA Kennedy Space Center point of contact

NASA KSC is a member of our development team:

- Evaluating and testing a unit, beginning in December 2010
- Reviewing the design
- Optimizing fueling procedures
- Identifying multiple uses in NASA operations



The Fuel Cell Mobile Light Project has recently been awarded a Federal Laboratory Consortium (FLC) Mid-Continent Technology Transfer Award for "Notable Technology Development".

-- award announced August 4, 2010

Summary

The team is a resource, for introducing clean technology products into the construction realm where there is a “technical pull” (“the thing works better”). We began with Fuel Cell Mobile Lighting. We are interested in other possible products, for example a mobile portable power system (15 – 20 kW)

We continue to push, seeking funding to bring fuel cell and associated energy efficient technology (e.g. lighting) into the mobile powered equipment marketplace. Finally…..

Acknowledgements– Fuel Cell Mobile Light

Boeing: Joe Breit, George Roe, Ty Larsen

DOE (EERE): Pete Devlin, Nancy Garland, John Christensen, Greg Moreland

Sandia-CA: Jay Keller, Terry Johnson, Marcina Moreno

Other Fuel Cell Mobile Light Project Partners:

NASA: Al Sorkin, Chuck Griffin, Rusty McLaughlin, Melissa Clevenger
California FC Partnership: Bill Elrick, Nico Bouwkamp, Jen Hamilton, Jordan McRobie
Altergy Systems: Mickey Oros, Chris Radley, Paul Schuttinger, Terry Carlone
Multiquip Inc.: Torsten Erbel, Steve Wingert, Jonathan Cuppett
Caltrans: Randy Iwasaki, Steve Prey, Randy Woolley
Ovonic Hydrogen Systems: Mike Zelinsky, Ben Chao
San Francisco International Airport: Roger Hoosen, Derek Fliess
Golden State Energy: Tom Damberger
Stray Light Optical Technologies: Gerald Rea
Luxim: Geoff Brown
Lumenworks: Thomas Skradski
Saunders Electric Inc.: Russ Saunders and Candace Saunders