DOE/Boeing Sponsored Projects in Aviation Fuel Cell Technology at Sandia

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Livermore CA 94551

DOE-DOD Workshop on Uses of Fuel Cells in Aviation

September 30, 2010

Sandia National Laboratories

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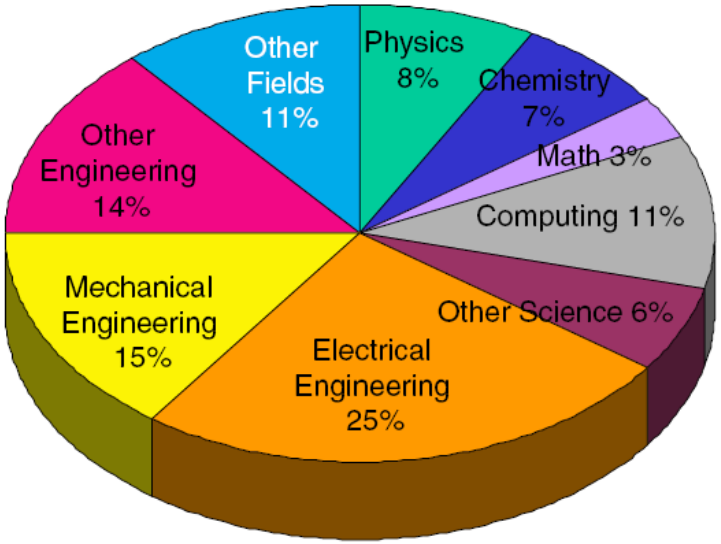
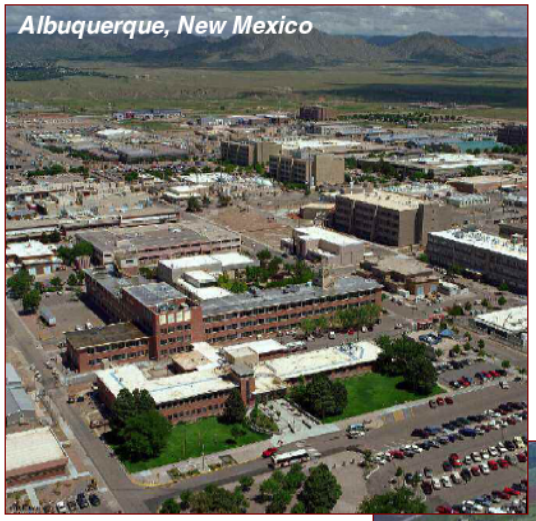
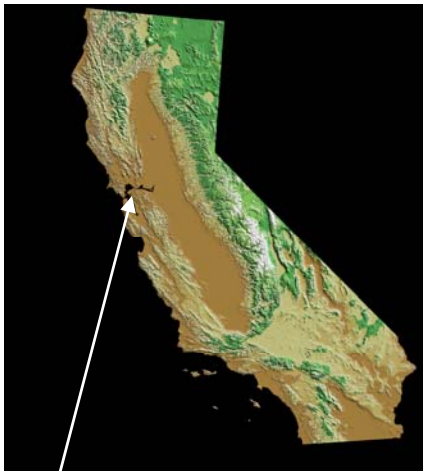






- ~ 8,300 employees
- ~ 1,500 PhDs; ~2800 MS/MA
- ~ 700 on-site contractors

Annual Budget ~ $2.2 Billion

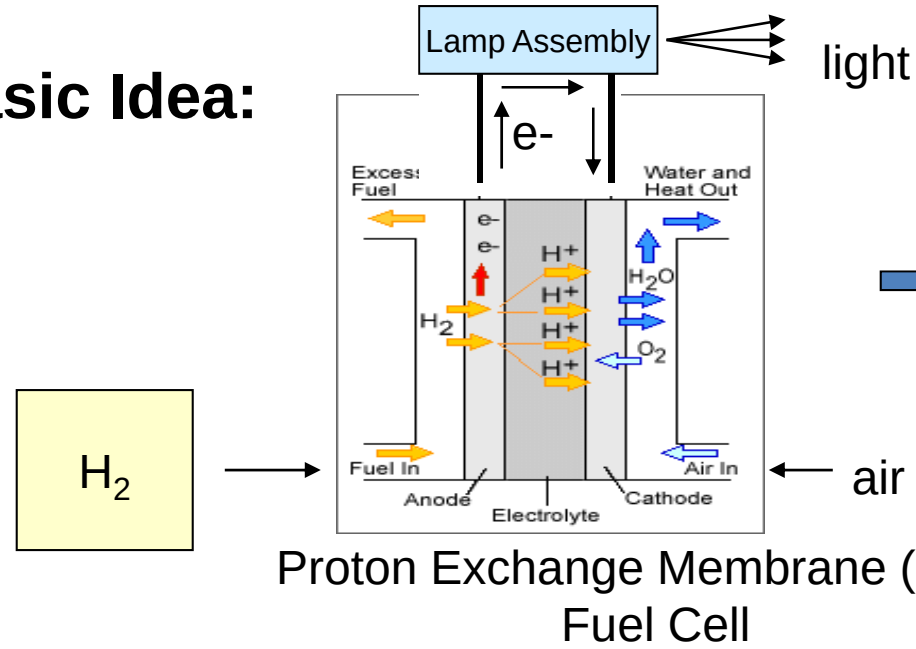
($1.3 Billion DOE, $0.9 Billion work for others)

Website: www.sandia.gov

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

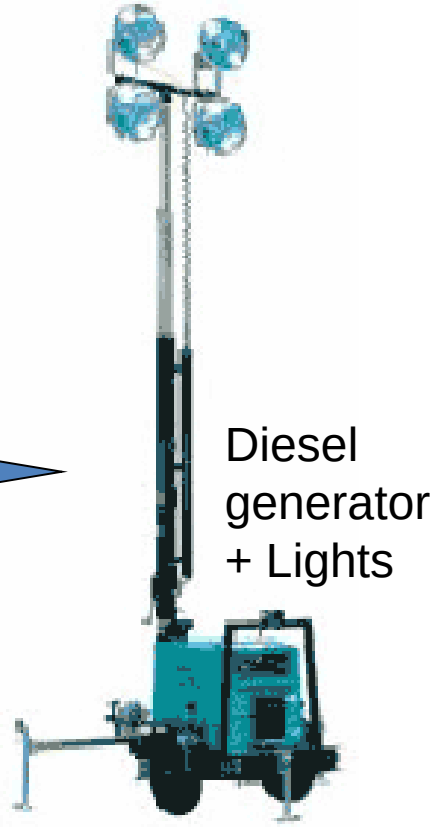
Initial discussions settle on a H_2 fuel cell demonstration for mobile 5 kW aircraft maintenance lighting:

Basic Idea:



Proton Exchange Membrane (PEM) Fuel Cell

replaces….



Diesel generator + Lights

Benefits: Quiet, no emission of particulates, NO_x, CO_2

Better energy efficiency

Lots of uses (airports, road work, film industry)

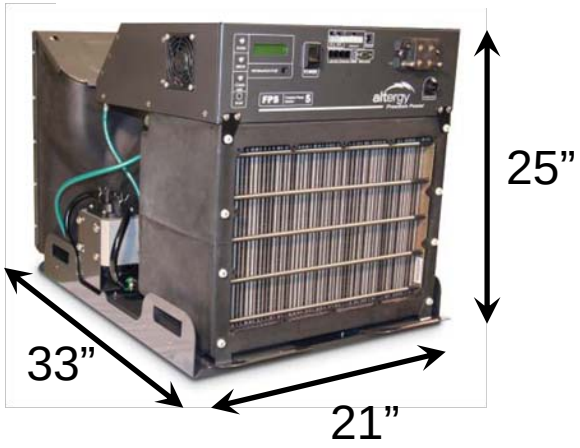
Fuel Cell Mobile Light Development Team

New Technology Experts + Manufacturing Partners + End Users

New Power and Lighting Technology

PEM Fuel Cell

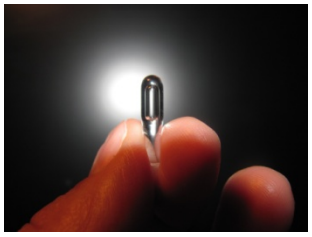
Altergy FPS-5 (5kW)



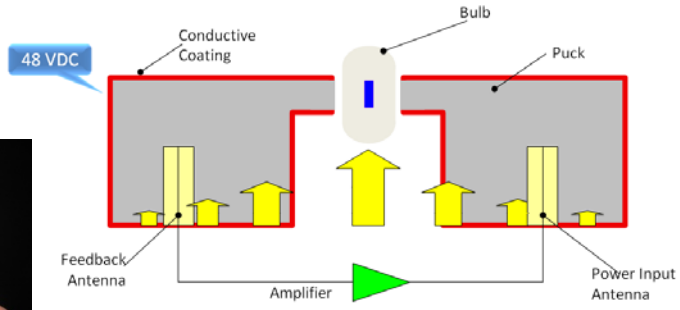
- High power density with low weight and volume
- Fast start, excellent durability
- Uses pure H_2 from storage system
- Oxygen obtained from ambient air
- 43% efficiency (diesel lighting ~ 27% efficient)
- No CO_2, NO_x or particulates emitted
- No moving parts, very quiet operation

$H_2 + ½O_2 \rightarrow H_2O$

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

Fuel Cell Mobile Light Capabilities

Fuel Cell Mobile Light used at the 2010 Academy Awards

- 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: 43 dB noise level at 23 feet
  (--- and can be reduced)
- 30 foot tower height

Current Funding and Plans

The DOE/Boeing will fund the build and field-test of 6 units for the purpose of duration and environmental testing:

Caltrans (Sacramento), exposure to snow, cold (upgrade of Alpha System)

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

Paramount Pictures (LA), performance for noise reduction

Disneyworld (TBD), exposure to gummy bears and cotton candy

We have an offer from the State of Connecticut Dept. of Transportation to cold test one of these units in the winter

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

Low-Temperature Fuel Cell Systems for Commercial Airplane Auxiliary Power

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Lennie Klebanoff
Dita Curgus
Abbas Akhil

Sandia National Laboratories

September 30, 2010

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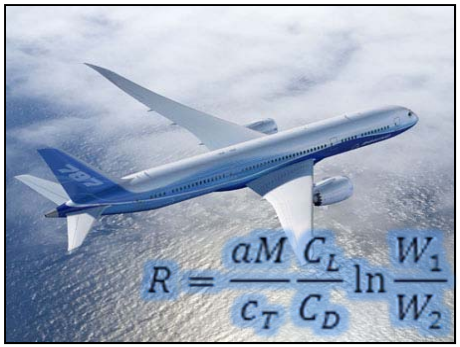
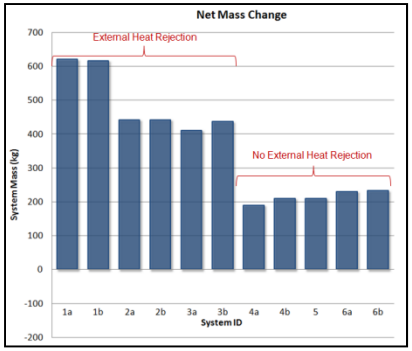
Here we briefly describe our ongoing study of fuel cell systems on-board a commercial airplane.

Scope



Method



Preliminary Findings

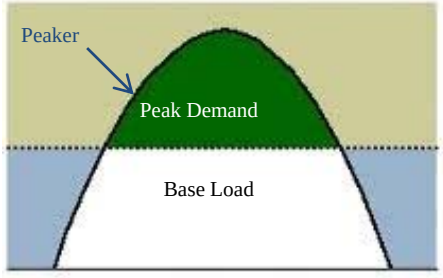
Sandia's current project is focused on PEM fuel cells applied to specific on-board electrical power needs.

Proton Exchange Membrane (PEM) Fuel Cell

Galley

In-flight Entertainment (IFE)

Peaker Power

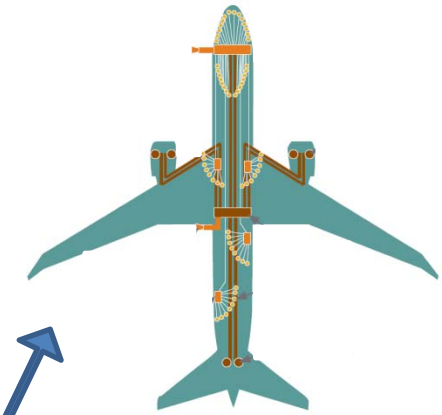


(Preliminary results are based on IFE study)

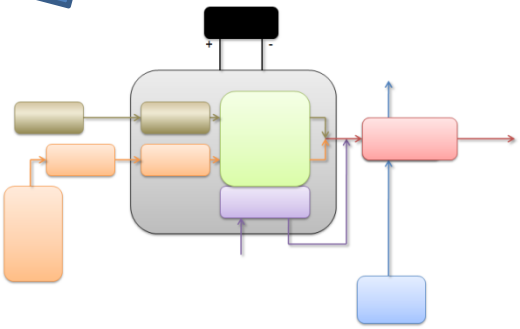
We want to understand how having a fuel cell on an airplane would affect overall performance.

Hardware Requirements and Sizing

Electrical Architecture Design



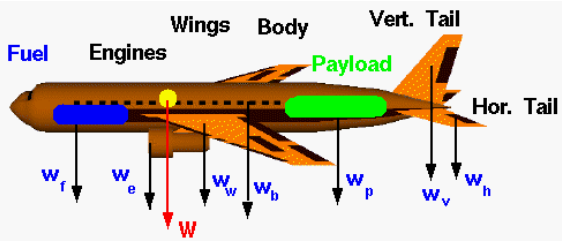
Thermodynamic Systems Analysis



Airplane Performance

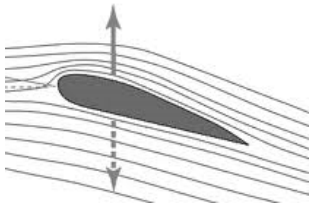
The fuel required to accomplish a mission is used to quantify the performance.

Empty Mass



Drag

Lift



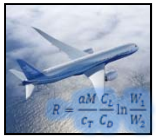
Range

Velocity

TSFC*

Required Fuel

*TSFC: Thrust-Specific Fuel Consumption



Our analysis shows the differences between the base airplane and the airplane with the fuel cell.

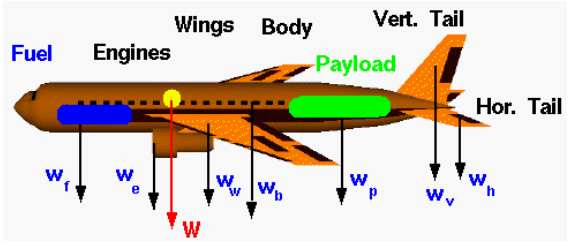
Base Airplane*

Compare

Airplane with fuel cell

Find

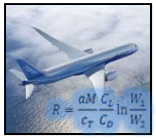
Change in Empty Mass



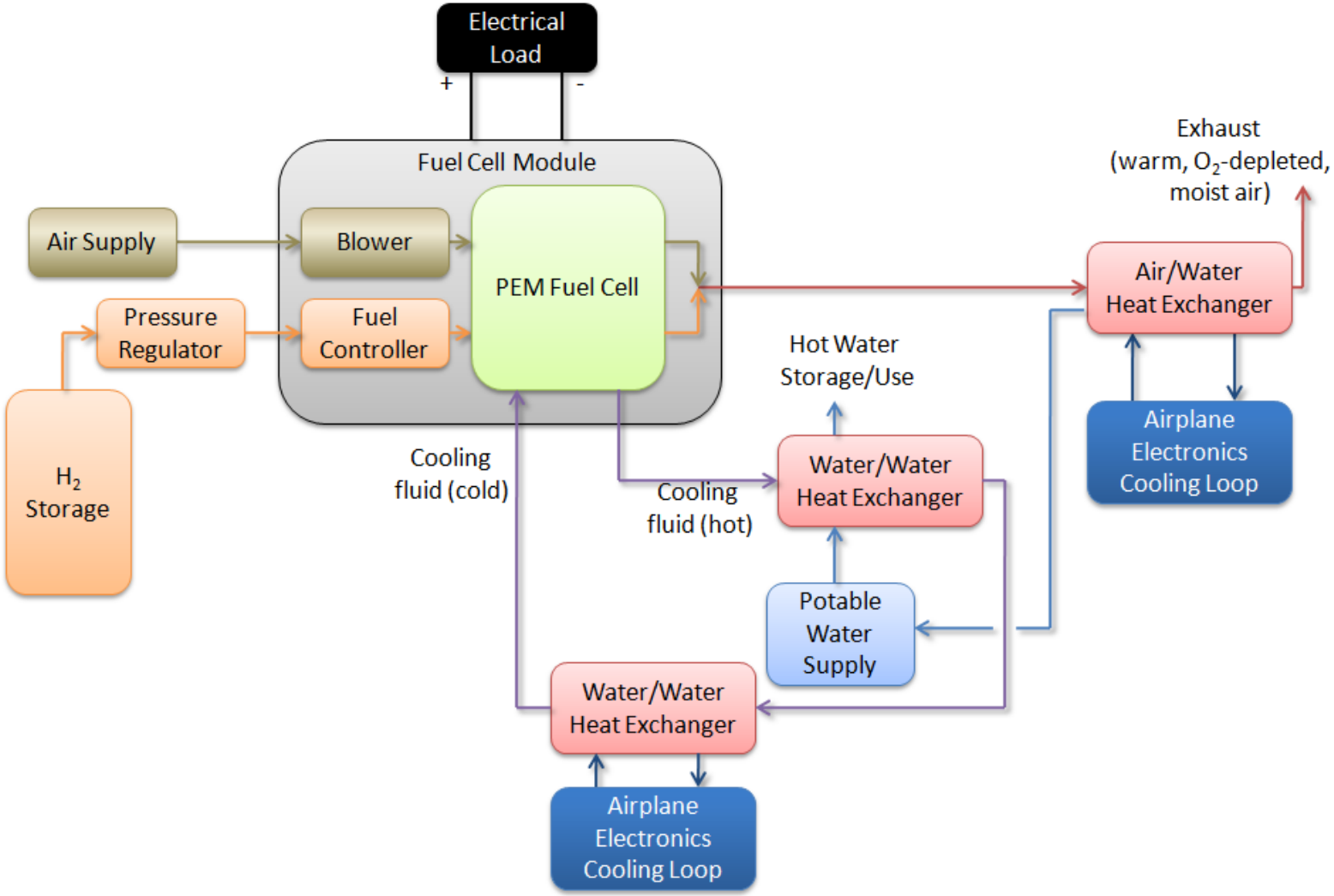
Change in Drag

Change in Required Fuel

*Base Airplane and Mission: 787-8 derivative, 5 hr flight, 20 kW IFE load

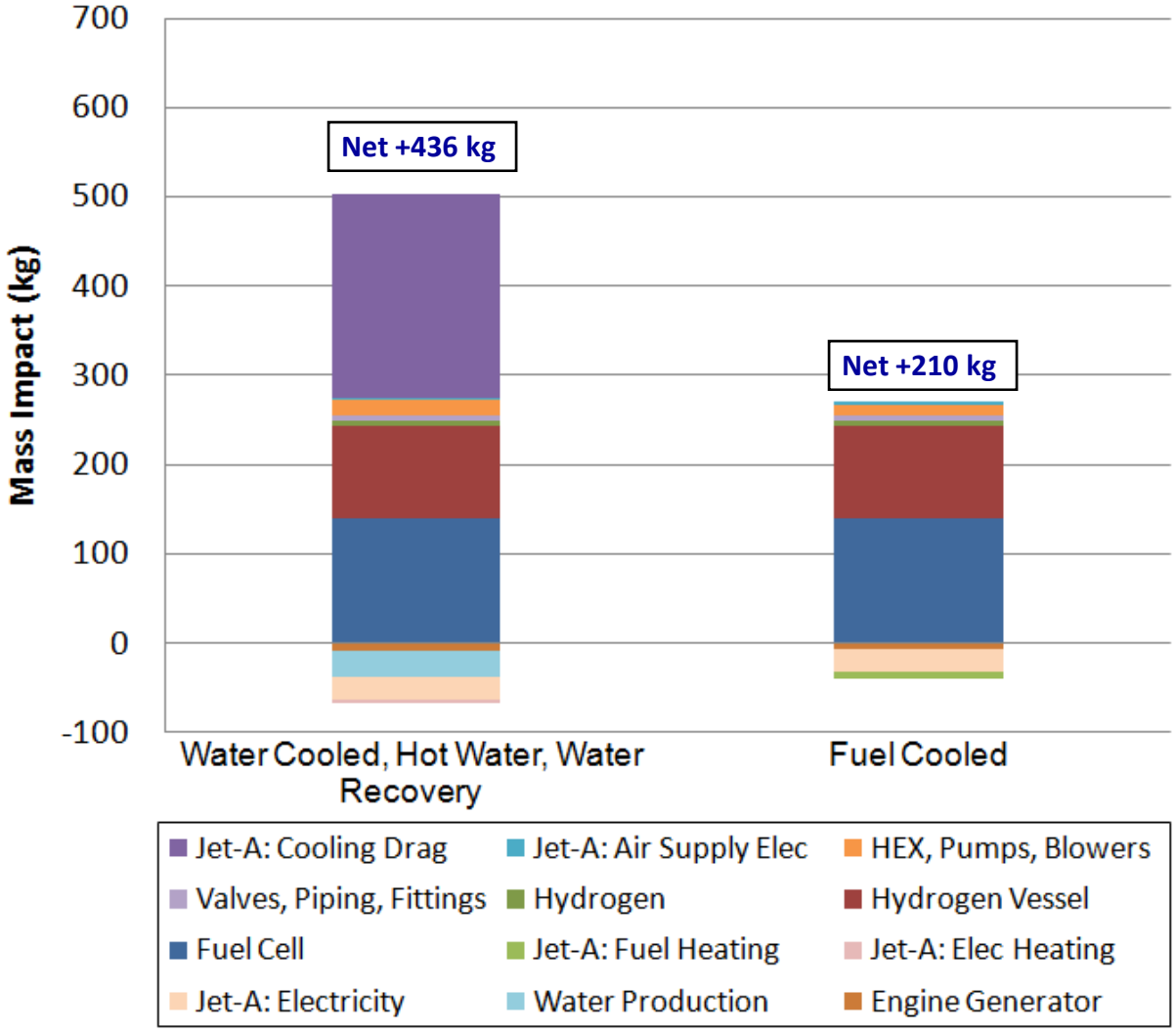


There are many ways of designing a system, depending on what you do with the waste heat.

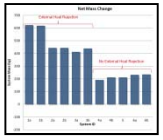


"Water cooled, Fuel Cooled, Water recovery"

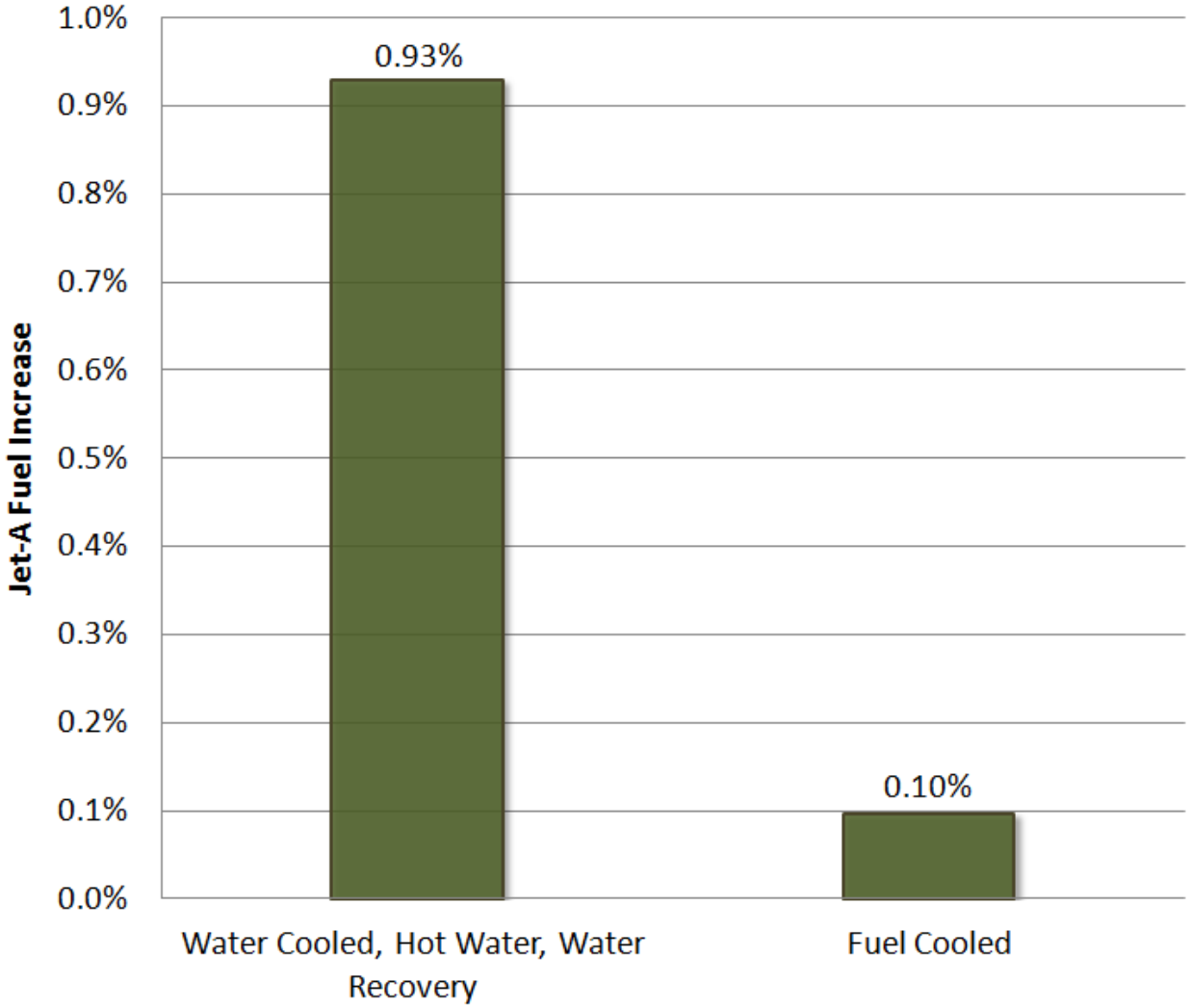
A system that requires ram air cooling has a large mass penalty due to increased drag.



Data for: 5 hr flight, 20 kW (net) PEM for IFE, H_2 in 5,000 psi composite tanks

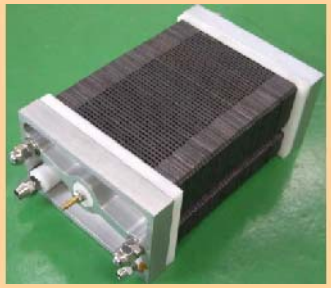


The bottom-line impact can be expressed as additional fuel required to complete the mission.



Early results suggest PEM fuel cells can be used on airplanes with manageable performance impact if heat is rejected properly.

Fuel cell generates heat



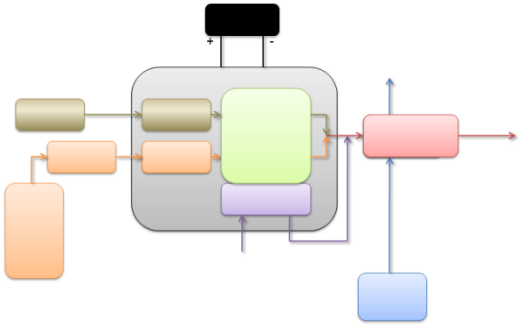
On-board uses may not fully absorb waste heat

Cooling system has large drag penalty

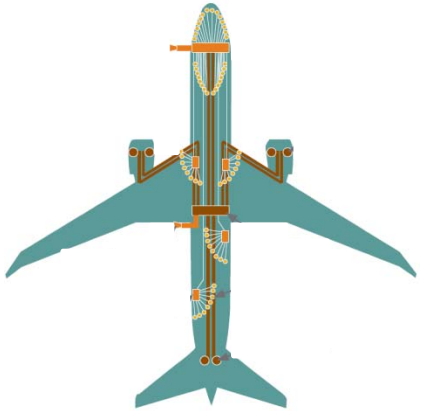
Reject through fuel system

For PEMs on aircraft, we are continuing to perform:

Thermodynamic analysis
(investigate configurations)

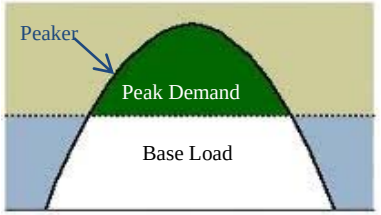


Integrated electrical design
(with dynamic modeling of the micro grid)



Hardware assessment
(performance, weight, and volume)

Galley and peaker application



Acknowledgements

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Caltrans: Steve Prey, Randy Woolley

SFO: Roger Hoosen, Derek Fliess

Golden State Energy: Tom Damberger

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