THE **MIDWEST HYDROGEN** CENTER OF EXCELLENCE

A Key Initiative of the Renewable Hydrogen Fuel Cell Collaborative

PANEL DISCUSSION: REAL LIFE EXPERIENCE

Jaimie Levin
Kirt Conrad
Mark Finnicum
Dr. Yann Guezennec
Debbie Swickard

RENEWABLE HYDROGEN FUEL CELL COLLABORATIVE

SARTA FUEL CELL BUS AND FUELING PROJECT

SARTA HYDROGEN FUEL CELL

SARTA Key Facts

- Transport 2.8 million passengers in 2014
- 210 employees
- $18 million budget
- Operates express routes to Akron and Cleveland (the longest route in Ohio)
- 30 routes and countywide paratransit
- Extensive use of technology

SARTA Vehicle Technology Types

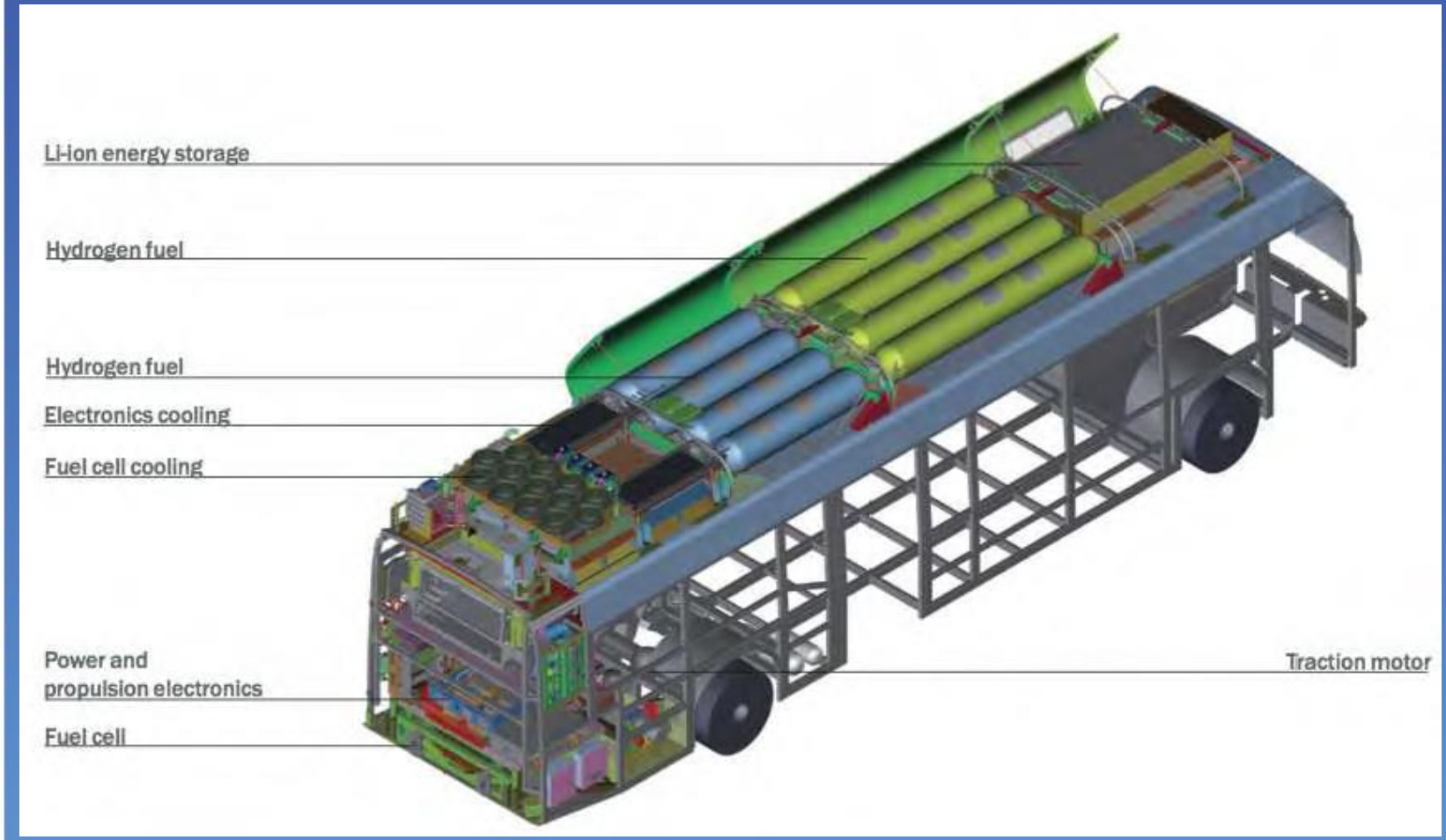
- 4 Hydrogen Fuel Cell Buses
- 11 CNG Paratransit Buses
- 11 CNG MV1
- 18 CNG Transit Buses
- 3 CNG Honda Civics
- 3 CNG Chrysler Town & County
- 4 Diesel Electric Hybrids
- 1 Diesel/CNG Duel Fuel
- 40 buses use B5 bio diesel

National Fuel Cell Bus Program

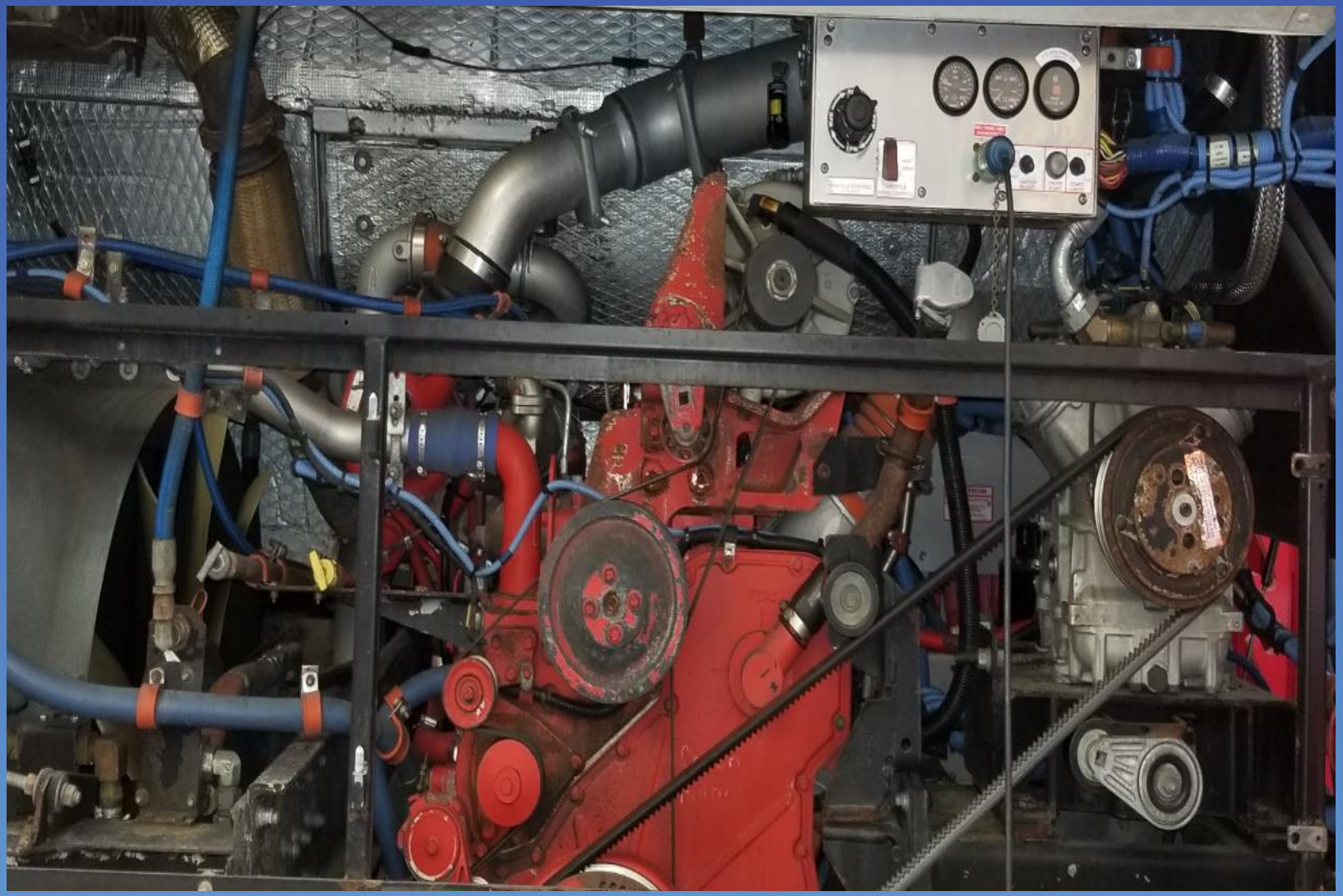
- Part of a $90 million Federal Transit Administration program
- Goal is to demonstrate fuel cell buses
- Set goals for performance and demonstration of vehicles
- Deployed vehicles in NY, CA, MA, and SC
- 2 fuel cell buses will be in Canton
- Total federal funding is $5.54 million

SARTA Fuel Cell Bus

Bus Schematic



Old Technology



Tomorrow's Technology Today

Inside Fuel Cell Bus

Compressors

Bus Specification

Item	Description
Bus chassis/model	ElDorado National 40' AXESS
Curb weight	34,800 lb (15,785 kg)
Seats/stands	37 plus driver/19 standees
Power plant	Ballard Power Systems FCvelocity® -HD6, 150 kW fuel cell
Hybrid system	BAE Systems Series HybriDrive® propulsion system
Electrical energy storage	200 kW, 11.2 kWhr nanophosphate Li-ion energy storage
Accessories	Electronic alternator, electrically driven cooling systems, HVAC, power steering, and air compressor
Fuel storage	Gaseous hydrogen: 50 kg at 350 bar
Range	260 miles (418 Km) under typical urban transit cycle and loads
Length, width, height	493.5 in (12.5 m) L; 102 in (2.6 m) W; 139 in (3.5 m) H

Compressor Pad

Hydrogen compressors

Hydrogen Storage

Station Controls

Project Goals for FTA/DOE

	Draft target			Draft target			
Bus Lifetime	12 years/500,000		Bus Avial	90%			
Powerplant Life	25,000 Hours, 6 years		Road Call frequency	Bus: 4,000/Powerplant 20,000			
				miles between roadcalls			
Fuel Economy	8 Miles per Gall diesel		Operaation time	20 hours per day/7 days per week			
Powerplant cost	$200,000		Range	300 miles			

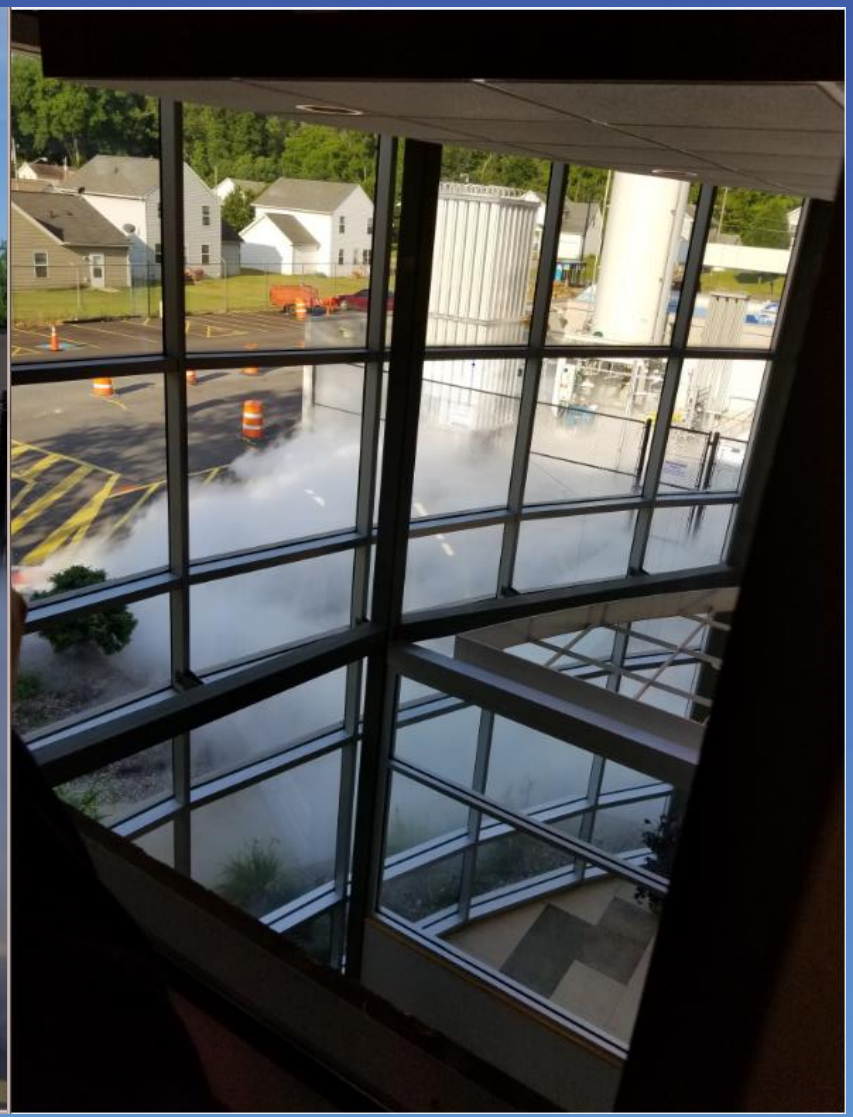
No Emissions Bus Program

- SARTA, CALSTART, OSU, Sandia National Laboratory, National Renewal Laboratory Honda, Ballard, BAE, El Dorado are partners to bring 8 Fuel Cell buses to Ohio
- Sunline Transit in Palm Springs, CA
- FTA and ODOT awarded over $20 million

Why Fuel Cells:

- Why did we get involved with fuel cells?
- What are our motivations? Expectations?
- Supply Chain
- Why should others support fuel cells?

Are There Any Dangers Amidst?



- The fact is – some of hydrogen's differences actually provide safety benefits as compared to gasoline, natural gas or other fuels.

Hydrogen Is lighter than air

When hydrogen is released in the air it dilutes quickly into a non-flammable concentration.

Hydrogen is odorless, colorless, and tasteless

Because it is not easily detected hydrogen sensors are used to detect leaks.

Combustion

Hydrogen can combust but it is its buoyancy, diffusivity, and small molecular size that make it difficult to contain and create a combustible situation.

Explosion

Only if the hydrogen has 10% pure oxygen or 41% air present will there be an explosion. Hydrogen compared to gasoline explodes at a much higher concentration than gasoline.

Asphyxiation

Hydrogen is less of an asphyxiate than gas because of its high buoyance.

THE **MIDWEST HYDROGEN** CENTER OF EXCELLENCE

A Key Initiative of the Renewable Hydrogen Fuel Cell Collaborative

DR. GUEZENNEC'S EXPERIENCE WITH FUEL CELL TECHNOLOGY

RENEWABLE HYDROGEN FUEL CELL COLLABORATIVE

Yann Guezennec (and many others) - Brief Summary of Experience with Fuel Cell Technology

- **15 year Experience in Educational Curriculum, Research and Demonstration in Automotive Fuel Cells** at Ohio State University Center for Automotive Research.

- **Research Activities:** Significant number of research contracts sponsored by industry (individual companies and CAR industrial consortium), the Ohio Third Frontier program, the US Army TACOM/TARDEC, and FTA (through CTE).

Yann Guezennec - Brief Summary of Experience with Fuel Cell Technology

- **Research activities** ranging from water transport inside PEM fuel cell stacks to fuel cell characterization, modeling, **fuel cell system modeling and control**, to **integration of fuel cells into hybridized FCVs** with optimal energy management.

- All these activities led to the establishment of the first **hydrogen refueling station** at OSU CAR (now closed), and a larger bus hydrogen refueling station with on-site electrolyzer (now open) on the OSU campus in **support of demonstration programs** involving a variety fuel cell vehicles: fuel cell golf cart, NEV, a passenger sedan to a full transit bus.

Yann Guezennec - Brief Summary of Experience with Fuel Cell Technology

- **Fuel Cell Education:**
  - Dedicated course offerings in several formats (short courses, graduate courses) since 2002 on the topic of **fuel cell systems for automotive applications** (*i.e.,* system focus, not electrochemistry or materials.
  - Graduate course offered regularly (every year) via and distance learning.
  - Fuel Cell Course integrated into **DOE Center of Excellence in Graduate Automotive Technical Education (GATE) program.**

  - Since 2002, short courses targeted primarily to General Motors Technical Education Programs delivered at many GM sites in US and Canada time frame, to several hundreds of engineers.
  - This short course has also been delivered live to Battelle Memorial Institute (Columbus), Hyundai (Korea) and the German automotive industry through the University of Stuttgart).
  - Since 2004, this short course is permanently offered in a self-paced format via distance leaning.

Yann Guezennec - Brief Summary of Experience with Fuel Cell Technology

- **Past demonstrations:**
  - **First FCV prototype**: Fuel cell hybrid golf cart, 2005, 1 kW PEM fuel cell, NiMH batteries.

  - **Ford Focus Fuel Cell Vehicle on loan from Ford Motor Company for several months, 2006.**

Yann Guezennec - Brief Summary of Experience with Fuel Cell Technology

- **Past demonstrations (cont.):**
  - **2nd FCV prototype:** Fuel cell hybrid Neighborhood Electric Vehicle (NEV), 2007/2008, 2x1.2kW PEM fuel cell systems, NiMH batteries.

  - **3rd fuel cell vehicle prototype: The ultimate FCV:**

    In partnership with Ballard, Ford Motor company and a host of other sponsors, OSU developed and raced the Buckeye Bullet 2: the **world's fastest fuel cell land vehicle at over 300 MPH !!!**

Yann Guezennec - Brief Summary of Experience with Fuel Cell Technology

- **Past demonstrations (cont.):**

U.S. Department of Transportation
Federal Transit Administration

  - **Participation in National Fuel Cell Program (NFCBP)**, 2012-2013, through Center for Transportation and Environment (CTE) as sub-contractor on on-going award to Design Line.
  - Program aborted in 2013 due to bankruptcy of Design Line…, but led to the installation of new hydrogen refueling station with on-site electrolyzer:

Opportunities and Challenges of Hydrogen as a Fuel for Transit Authorities

- **Pros:**
  - **Most efficient, ultra clean use, no greenhouse gases in vehicles.**
  - **Technology of fuel cell systems and ancillary systems has matured dramatically over past 10 years**: costly, but totally doable.
- **Cons:**
  - **The big elephant in the room: Hydrogen, yes, but where does it come from?**
  - **If buying industrial hydrogen, it is most likely produced from reforming hydrocarbons: pollution displaced elsewhere, not carbon neutral, very significant energy inefficiencies upstream**

    → Key to look at issues from a "*well-to-wh*eel" perspective…
  - **However great opportunities to couple with renewables and mitigate most problems, and also use hydrogen as intermediate energy storage… Must think BIG, bigger than your own backyard….**