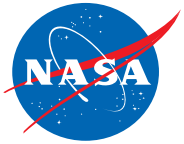

Installation of Ohio's First Electrolysis-Based Hydrogen Fueling Station

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Project Background

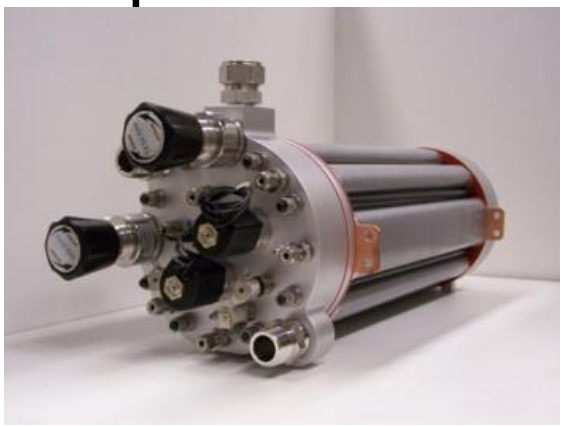
- Efforts began in January 2009 with grant awarded to Ohio Aerospace Institute by the Cleveland Foundation to design a hydrogen fueling station
- OAI purchased hydrogen fueling station equipment from Burlington, VT
  - Equipment was decommissioned and shipped to Cleveland for refurbishing and installation
- Efforts began in 2011 to plan for and install fueling station at Greater Cleveland RTA Hayden bus garage

Project Goals

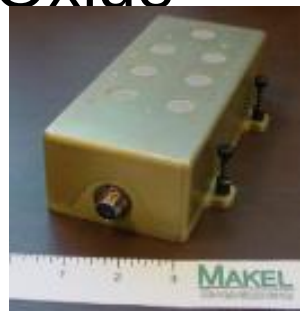
- Install an operational hydrogen fueling station that demonstrates electrolysis as a safe and reliable means of H_2 generation
- Demonstrate the terrestrial benefits of NASA-developed space technologies
- Demonstrate the commercial reality of using H_2 in a fuel cell-powered bus
- Support clean energy efforts

Integration of NASA Space Technology

- NASA has developed fuel cell technology for space applications since Gemini and Apollo
  - GRC currently focused on improving reliability and efficiency of fuel cells for space and terrestrial applications
  - GRC currently develops advanced Non-Flow-Through PEM fuel cells and Solid Oxide Fuel Cells



- Advanced hydrogen sensors developed & commercialized through SBIR and STTR programs with GRC, Makel Engineering and CWRU



Why Hydrogen and Fuel Cells?

- H_2 can be used as fuel to power fuel cell buses, passenger vehicles and stationary power systems
- H_2/O_2 or H_2/air fuel cells eliminate harmful emissions – they produce only water, electricity and heat
- Replacing diesel and gasoline-powered vehicles would reduce dependence on fossil fuels

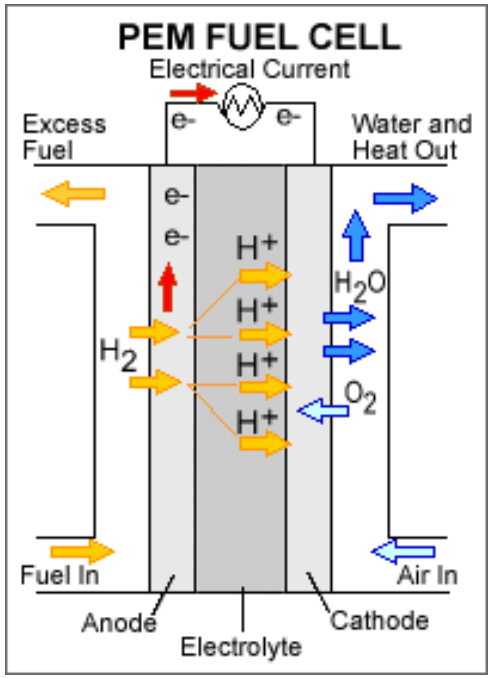
But how do we get the hydrogen we need?

Why Electrolysis?

- Electrolysis is a safe, clean method of producing H_2 directly from water without harmful emissions
- Allows for on-site H_2 generation, as opposed to delivered H_2, and eliminates the need to store large quantities of H_2
- Generates quality H_2 at purity levels acceptable for use in fuel cell-powered vehicles
- Compatible with renewable energy sources

How Does a Fuel Cell Work?

- A Proton Exchange Membrane (PEM) fuel cell converts the chemical energy of reacting hydrogen and oxygen gases to electrical energy, with only heat and water as byproducts
- A fuel cell will run continuously as long as fuel is available



Fueling Station Equipment

- Originally installed in 2006 in Burlington, VT by DOE and BP
- Principal Components
  - PEM Electrolyzer from NASA KSC
  - Compressor
  - Storage tank array
  - Hydrogen dispenser

PEM Electrolyzer from Proton On-Site

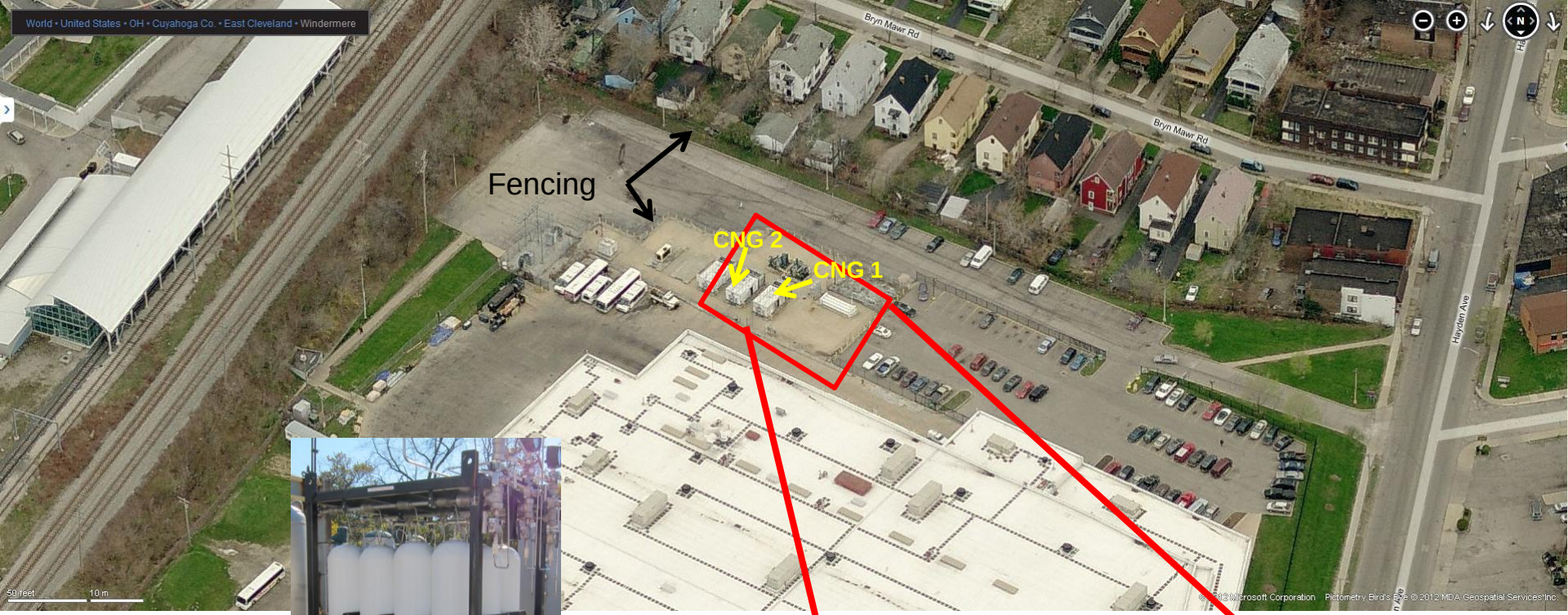
- KSC provided a newer electrolyzer from de-commissioned station in CA
- Electrolyzer uses city water and has internal de-ionization system to provide DI water to cell stacks
- Generates 0.99999 purity H_2
- Produces 12 kg/day (bus capacity 50kg)
  - Multiple units can be hooked up in parallel

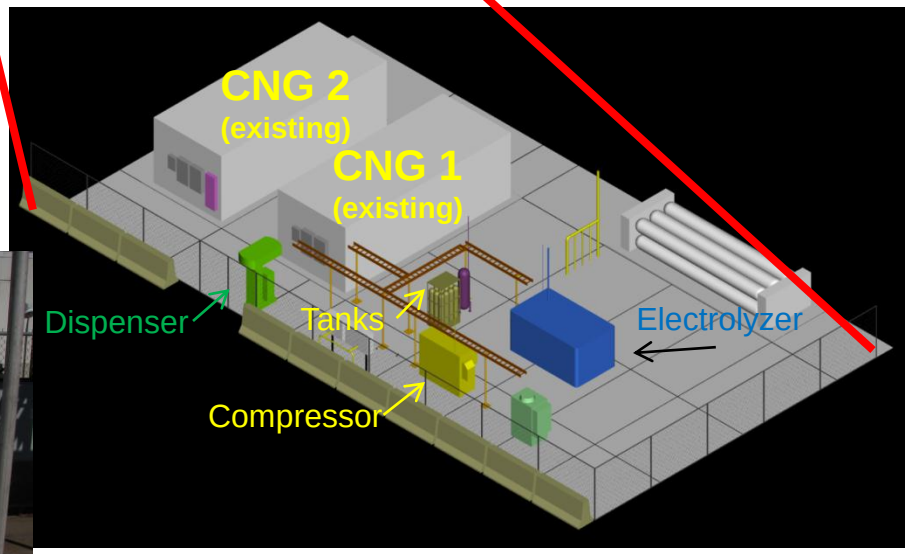
Storage & Dispensing

- Generated H_2 is compressed to 6500 psi
- H_2 stored in 12-60 kg capacity modular storage tank array
- Stand-alone dispenser unit requires PIN input and dispenses H_2 fuel directly into tank on fuel cell bus
- H_2 production and compression is automatic, driven by the storage tank pressure

Installation Site

- GCRTA's Hayden bus facility, E. Cleveland
  - Previously operated CNG buses
  - Infrastructure in place to house and maintain a fuel cell vehicle
- Located adjacent to Louis Stokes rapid station at Windermere, on the GCRTA's red line





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Hydrogen Dispenser

Storage Tank Array and Compressor

Hydrogen Fueling Station at GCRTA Hayden Bus Garage in East Cleveland, OH

Fuel Cell Bus Demonstration

- GCRTA leased a VanHool fuel cell bus from UTC Power (ClearEdge) through March 2013
  - Bus has demonstrated the safe, efficient use of hydrogen as a fuel; generate data to determine the benefits of replacing a diesel bus with a fuel cell bus utilizing electrolysis-generated H_2
- GCRTA ran the bus in revenue service roughly 60-80 miles/operating day, mostly on the #1 St. Clair route and other routes out of the Hayden garage
- GCRTA provided operational feedback to UTC/ClearEdge for Nutmeg Project under the FTA
- Bus was refueled as needed from H_2 station

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Photo by Michelle Murphy

National Aeronautics and Space Administration
Glenn Research Center at Lewis Field

- ✓H_2 powered PEM fuel cells eliminate harmful emissions
- ✓Only water and heat as byproducts
- ✓Virtually silent bus operation due to replacement of diesel engine with fuel cell
- ✓Reduction in moving parts means higher efficiency – less energy is lost as waste heat
- ✓Helps to reduce America's dependence on fossil fuels when H_2 fuel is generated via electrolysis combined with renewable energy sources


VANHOOL
2001
OD 860

Project Challenges

- Public feedback to the project was a mixture of positive/negative prior to installation
  - Public meetings were held to educate the public and discuss safety concerns
- Permitting process and pushback from city offices and officials
- Technical issues experienced with equipment and fuel cell bus; unfamiliarity with fuel cell bus operations and reliance on external support

Project Successes

- Fueling Station successfully installed and operational in October 2012
  - Demonstrated the safe, efficient production of hydrogen via electrolysis and its use in a fuel cell to power a bus
- GCRTA operated fuel cell bus for approx. 300 miles in training and revenue service
- Positive feedback from GCRTA bus operators and mechanics
- Positive rider feedback and media coverage

Future Possibilities

- Hydrogen production could be increased with the addition of a larger electrolyzer or a second unit and additional storage
- Additional H_2 could mean support for more fuel cell buses
- Station components and technologies can be upgraded to improve performance and increase output
- Amenable to renewable energy sources, producing a zero-emissions “well-to-wheels” fuel

Solar arrays at the NASA GRC

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Thank you for your attention

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