National Aeronautics and Space Administration

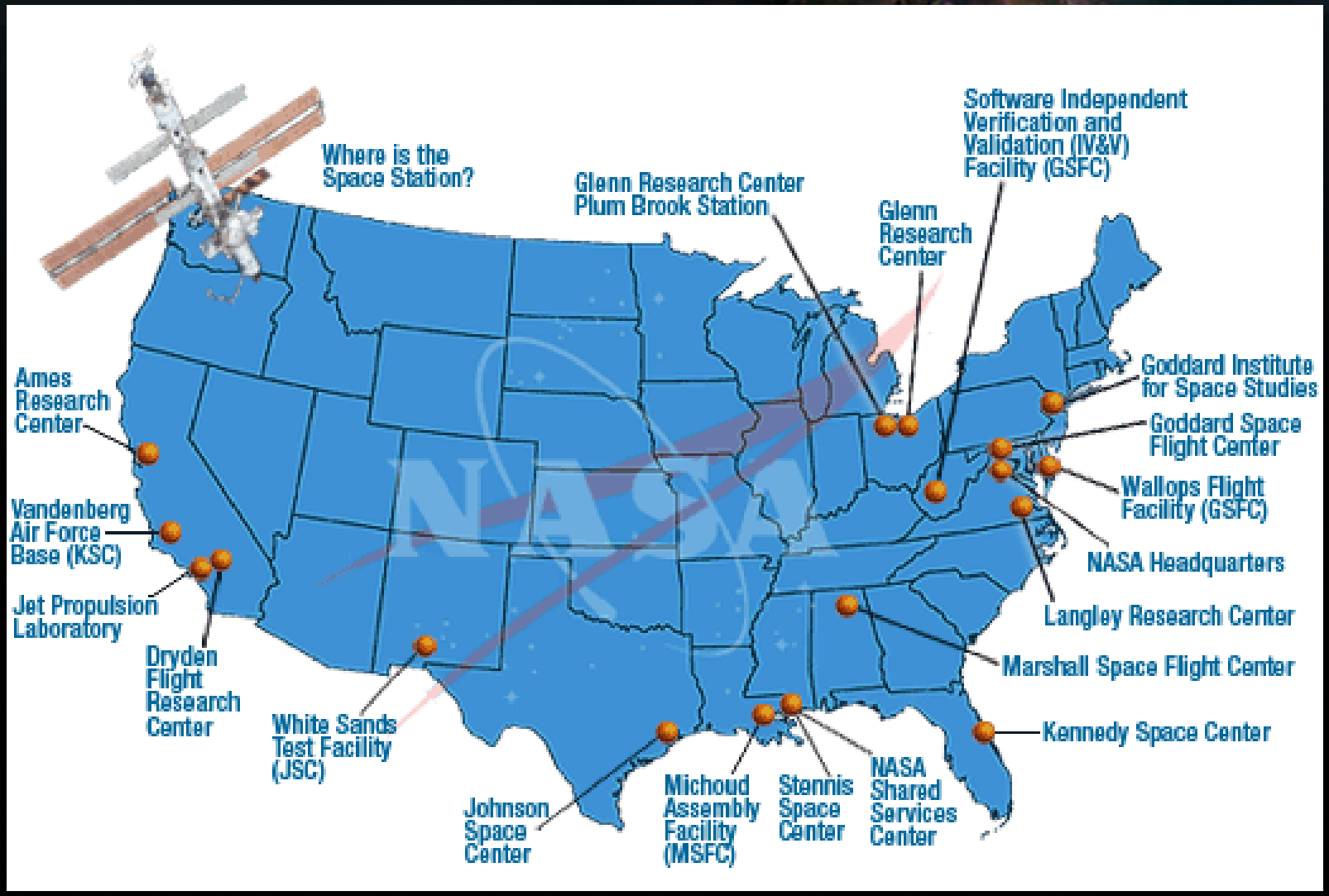
# NASA Fuel Cell Related Research in Ohio

Presented by: Ian Jakupca

Ohio Fuel Cell Symposium and Workshop

30 March 2017

# NASA Centers



# Fostering Capabilities & Industries


***Mission-Enabling Technologies***

**Technology Investments**

**New Industries**

**Technology Spinoffs**

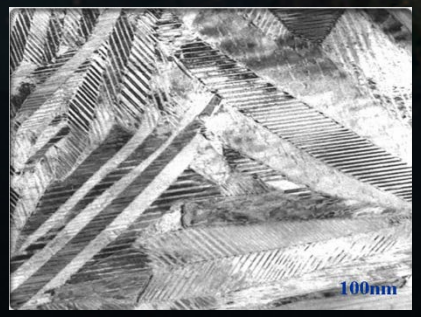
**Sustained Investment**

Searchable Database at: https://technology.grc.nasa.gov/patents

# NASA Activities In Ohio

## Aviation

- Avionics
- Emissions
- Propulsion

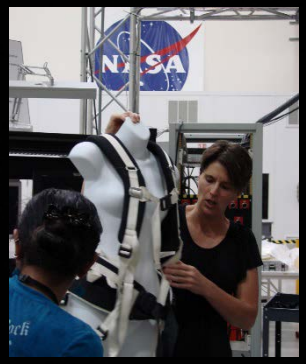



## Materials

- Ballistic Tolerance
- Surface Coatings
- New Materials

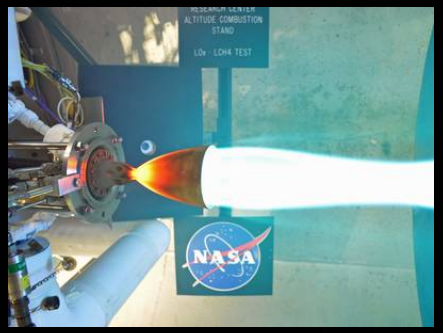
## Power

- Fuel Cells
- Batteries
- Solar Arrays
- Nuclear



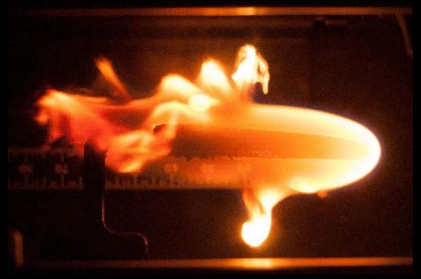
## Life Support

- Human Factors
- $O_2$ Recovery
- $CO_2$ Processing



## Propulsion

- Cryogenics
- LOX/$CH_4$
- LOX/LH

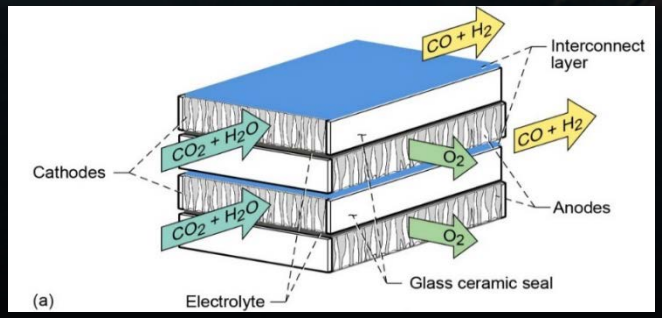


## Fuels

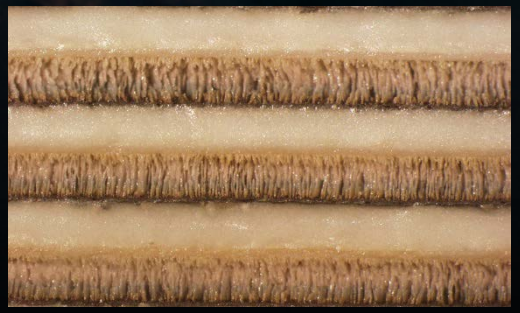
- $H_2$/He Separation
- Fuel Synthesis

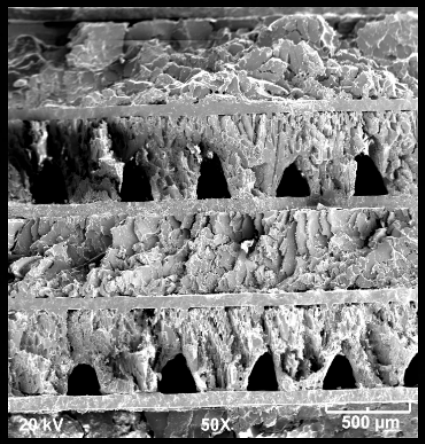
# NASA Activities In Ohio: Fuel Cell Power

Basic Research
- Electrodes
- Catalysts
- Electrolytes
- Electronics

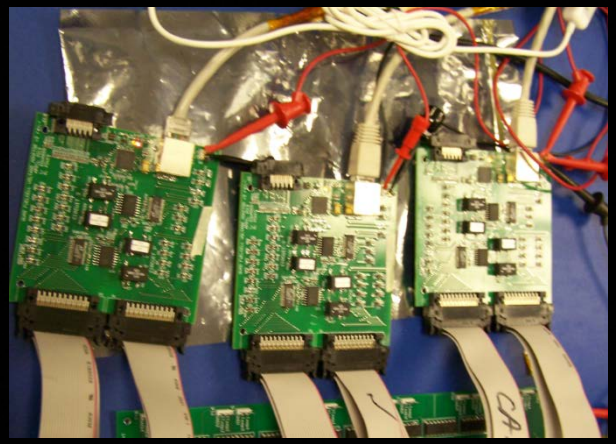


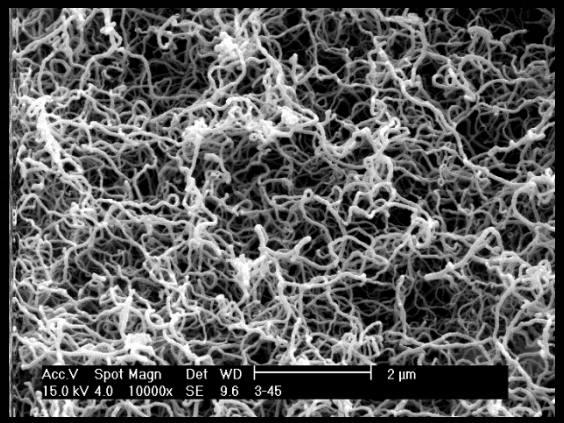
Stack Design


Seals



Electrodes


Electronics and Instrumentation

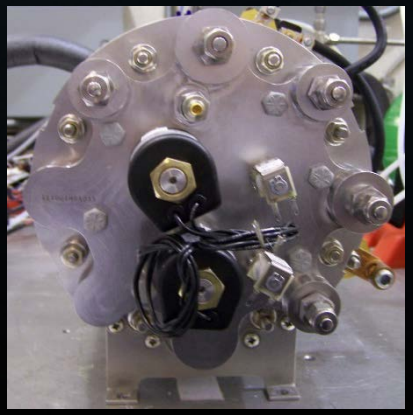


Microstructures

# NASA Activities In Ohio: Fuel Cell Power

Components
- Blowers
- Instrumentation
- Pumps
- Valves

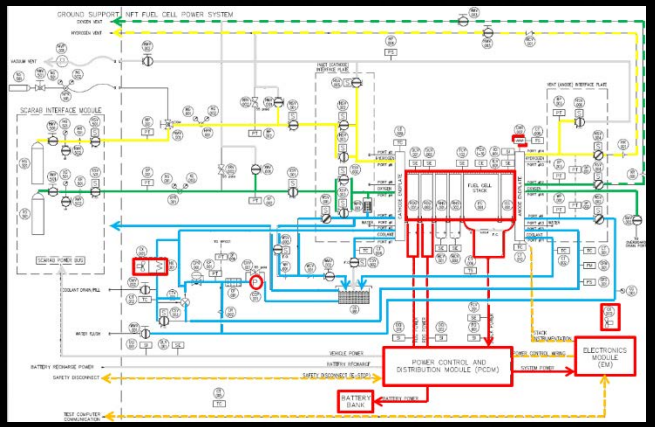
Vehicle Sub-systems
- Electronics
- Software
- Integration
- Operations



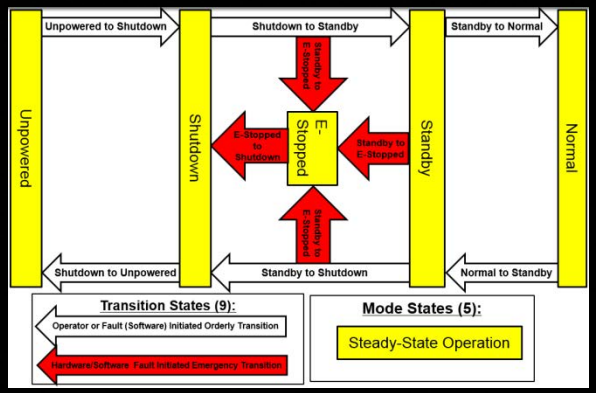
Additive Manufacturing

Operations

Packaged Electronics



Integrated Systems




Integrally Designed Safety

# NASA Activities In Ohio: Fuel Cell Power

Electric Aviation

Applications

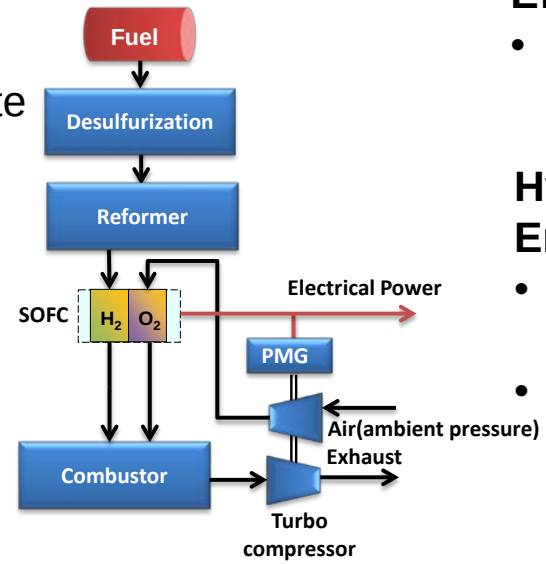
- Terrestrial
  - $H_2$/Air
  - Hydrocarbon/Air
- Aerospace
  - Air-independent ($H_2$/$O_2$)
  - Hydrocarbon/$O_2$

Space Vehicles

Autonomous Rovers

# NASA Activities in Ohio: Electric Aircraft

- Integration of key (yet proven) technologies to yield compelling performance to early adopters
  - "Useful" payload, speed, range for point-to-point transportation
  - Energy system that uses infrastructure-compatible reactants, allowing for immediate integration
  - High efficiency for compelling reduction in operating cost
- Early adopters as gateway to larger commercial market




**High-Performance Baseline**
- 160-190 knots cruise on 130-190kW
- 1100+ pounds for motor & energy system

**Efficient Powertrain**
- Turbine-like power-to-weight ratio at 90+% efficiency

**Hybrid Solid Oxide Fuel Cell Energy System**
- >60% fuel-to-electricity efficiency
- Designed for cruise power; overdrive with moderate efficiency hit at takeoff and climb power

Primary Objective: **Demonstrate a 50% reduction in fuel cost** for an appropriate light aircraft cruise profile (payload, range, speed, and altitude).



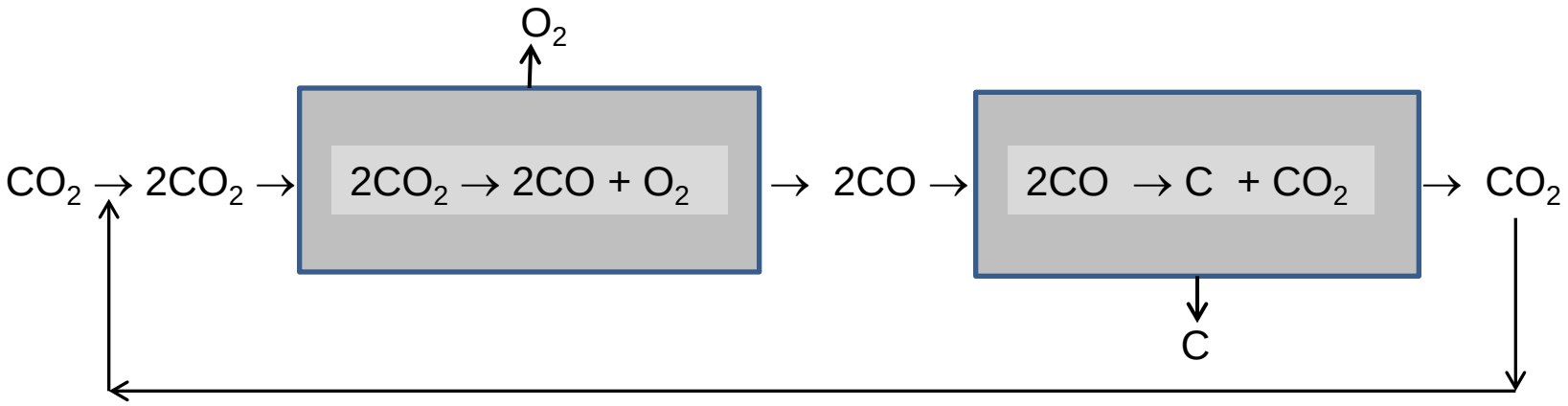
**POC**: Nickolas Borer, nicholas.k.borer@nasa.gov

# NASA Activities in Ohio: $O_2$ Recovery and $CO_2$ Processing

## Oxygen Recovery from Carbon Dioxide

Overall Oxygen Recovery Process

$$CO_2 \rightarrow C + O_2$$





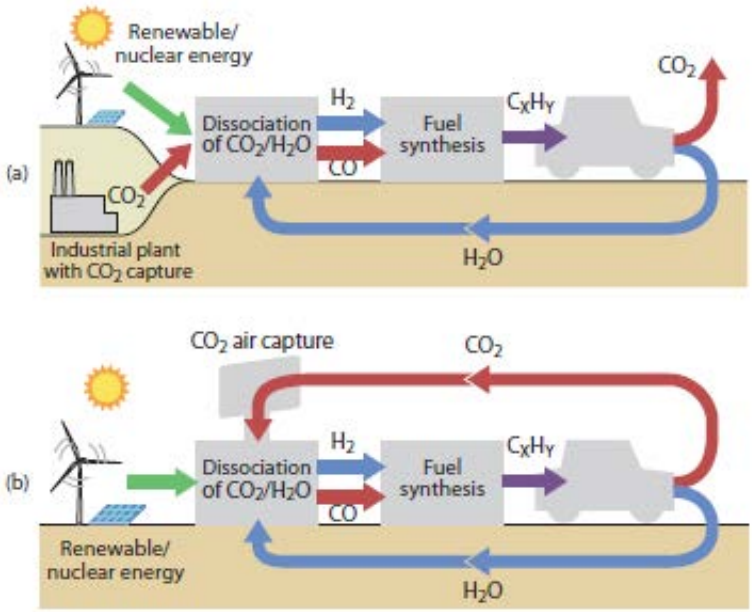

**POC**: Ken Burke kenneth.a.burke@nasa.gov

# NASA Activities in Ohio: Fuel Synthesis

## A *Green* Energy Application for SOE Co-Electrolysis:

### Manufacture of synthetic fuels from captured $CO_2$ and renewable energy

- Combined $CO_2$ and $H_2O$ electrolysis produces CO and $H_2$, a basic feedstock in the chemical industry (referred to as synthesis gas, or "syngas")
- Syngas can be utilized to produce a wide variety of liquid hydrocarbons via the Fischer-Tropsch (F-T) process.
  - F-T process is a mature technology presently used to manufacture synthetic lubricants, etc.
  - Sasol (South Africa) produces gasoline and diesel fuel on a large scale via F-T.
- Recent review paper trade study concluded that synthetic gasoline could be produced for costs as low as $2/gal.*
- Allows the "recycling" of atmospheric $CO_2$ while maintaining our present hydrocarbon fuel infrastructure.




Two possible $CO_2$-recycling scenarios:
(a) CO2 recycled from industrial plant emissions (potential to reduce $CO_2$ net emissions by 50%).
(b) Closed loop carbon recycling via $CO_2$ capture from Earth's atmosphere (near-zero net emissions).

* Study and above graphic from Graves et al., *Renewable and Sustainable Energy Reviews*, 15, (2011) 1-23.



**POC**: Dr. Robert Greene robert.d.green@nasa.gov

# NASA Activities in Ohio: $H_2$/He Processing

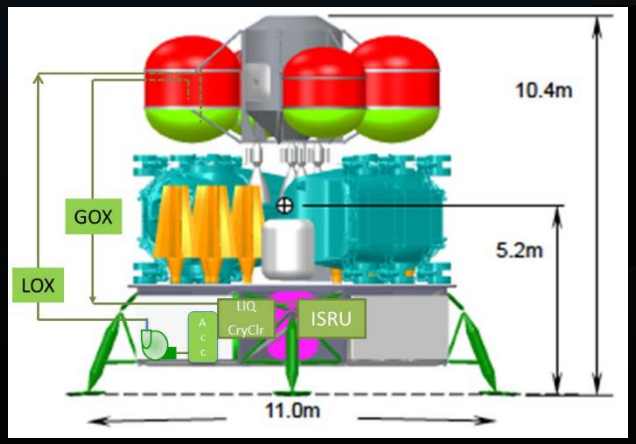
- Helium Supports various NASA Programs including:
  - Space Launch Systems (SLS)
  - Orion
  - NASA's Scientific Ballooning
- Helium supporting activities with Air Force and other customers under NASA reimbursable agreements, including:
  - ULA (Atlas V, Delta IV) – launch support and engine testing
  - SpaceX (Falcon 9) – launch support
- Helium used in both gaseous and liquid states for:
  - Purging hydrogen systems
  - Pressurization
  - Cooling
- NASA use peaked at ~130 million SCF for the Shuttle Program
- NASA usage estimated to remain between 70-90 million SCF annually

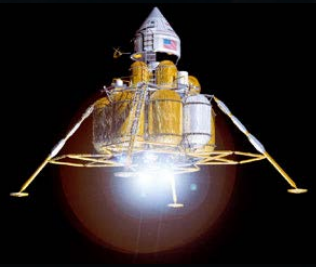
Source: Thomas M. Elam, KSC
Presentation: KSC-E-DAA-TN30802



**POC**: Ken Burke kenneth.a.burke@nasa.gov

# NASA Activities In Ohio: Fuel Cell Power in Space



Landers

Launch Vehicles

Lunar Outposts

Martian Outposts and Rovers

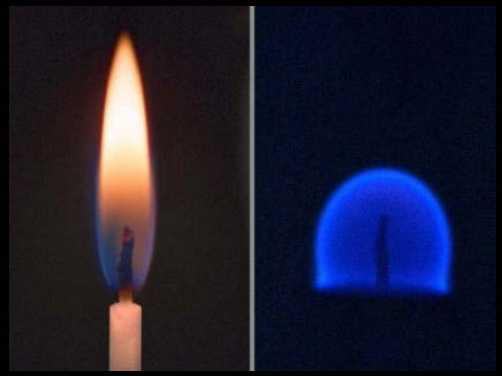
# NASA Activities In Ohio: Safety

**Basic Research**
- Catalysts
- Combustion
- Electrodes
- Electrolytes
- Electronics
- Hydrogen*
- Oxygen*

Hydrogen Safety

**Operations**
- Electrical Systems
- Fuel Transfers
- Hydrogen*
- Mobility Issues
- Oxygen*


Operations


Combustion

Oxygen Safety

# NASA Glenn Research Center Technical Points of Contact

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Electrolysis:

- PEM: William R. Bennett, william.r.bennett@nasa.gov
- Solid Oxide: Robert Greene, robert.d.green@nasa.gov

Fuel Cells:

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- Solid Oxide: Serene Farmer, serene.c.farmer@nasa.gov

Oxygen Recovery: Ken Burke, kenneth.a.burke@nasa.gov

Materials and Coatings: James J. Zakrajsek, james.j.zakrajsek@nasa.gov

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