

# FAA Hydrogen Fuel cell research

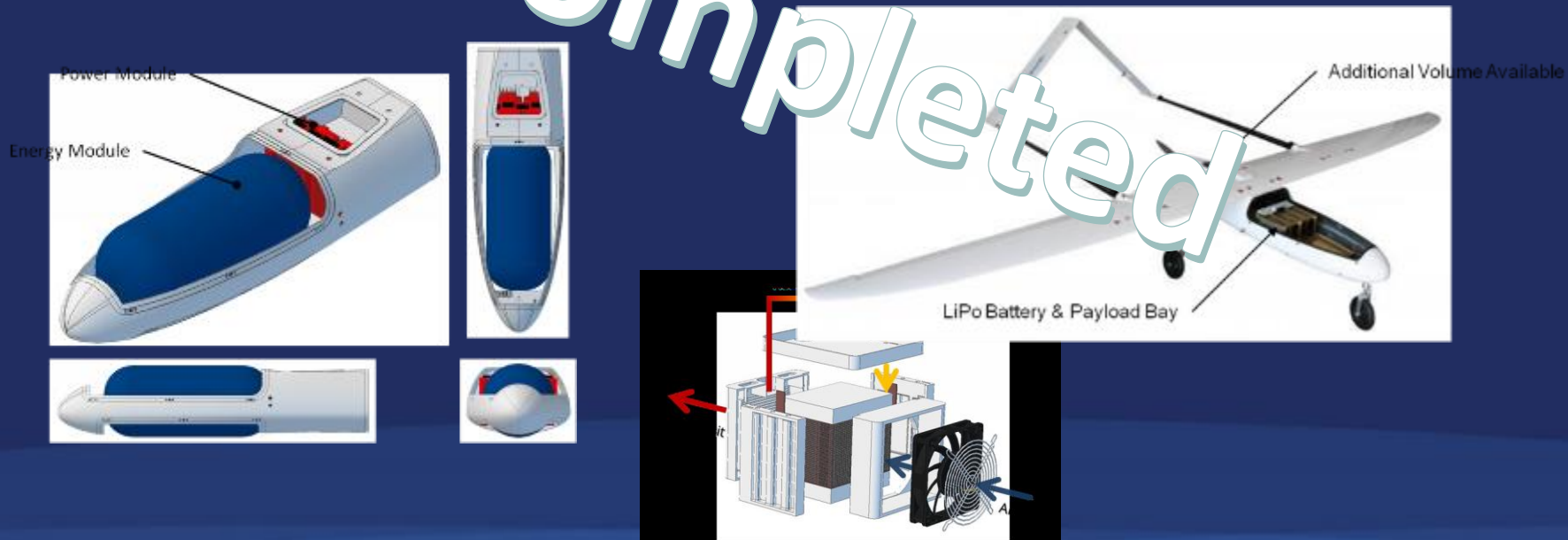
- M. Walz DOE



**FAA**



a fuel cell based power and energy system for high to low altitude unmanned aerial vehicles. This will be a lightweight and flexible fuel cell system with hydrogen and oxygen storage, providing long duration flight within and outside of demanding environments. Building on the work of the Energy Supply Device Aviation Rulemaking Committee (ESD ARC) Infinity is mapping the ARC recommendations for applicable parts of the regulations as they apply both to a generic fuel cell system and to the UAV fuel cell system currently under development

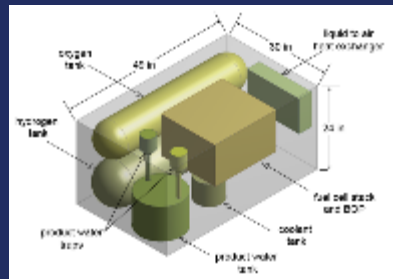


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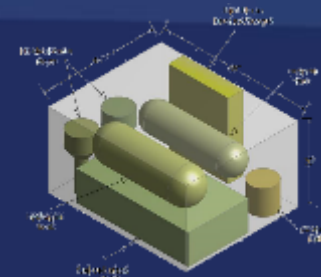


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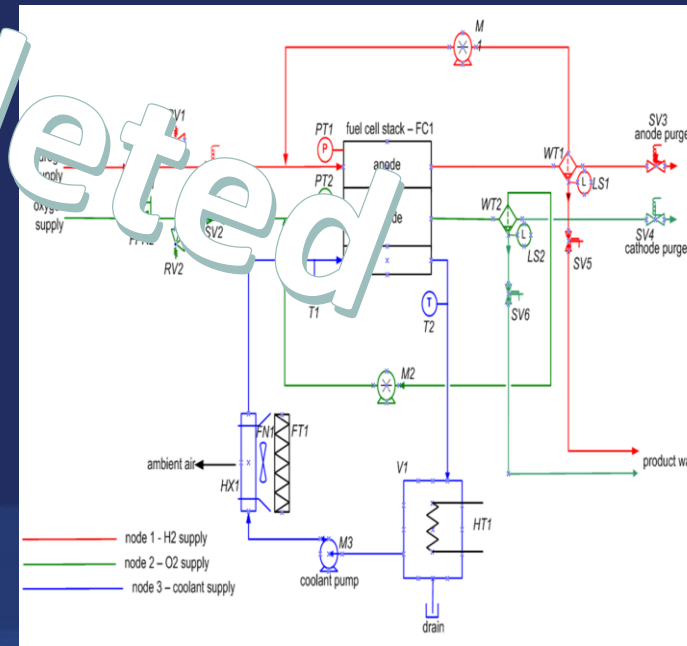
**Purpose-** The project is proposing to evaluate two types of systems. Our preliminary assessment is to do one inside the cabin and one outside. These are two environments with unique requirements. We also propose to look at one that is highly integrated into the aircraft and the other is very independent of the aircraft. For example, the emergency power would be outside the cabin, but highly integrated into aircraft system and critically important to safety. A galley cart would be minimally integrated into aircraft systems, but would be inside the cabin. TESI proposes to review application options with the FAA and OEMs and determine at the start of the program which application provides the most value to the FAA and to aviation OEMs.



**Medevac Power System – MPS**



**Emergency Power Systems – EPS**



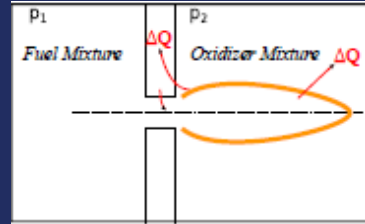
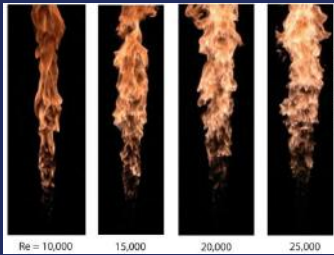
Completed



# FAA SOFC Project

**Purpose-** The SOFC power system architecture developed for the NASA electric-flight initiative to develop a safety management approach for the FAA. The SOFC power system will be assessed for possible safety hazards while identifying methods to contain potential failures or inhibit the propagation of failure effects. Testing will be performed on an SOFC stack that undergoes a controlled failure, to evaluate containment of the hazards identified during analysis. Based on the test data and analysis results, the FAA will provide the FAA with airplane interface definitions that will assist the design integration and monitoring of SOFC power systems. Recommendations will also be provided for certification of an SOFC power system for airborne applications in a manned aircraft.

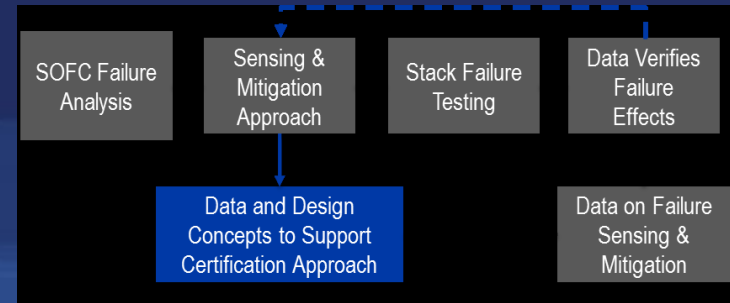
## Hot Fuel Gas Leakage:



- Flame length is mainly a function of
- Orifice diameter
  - Fuel mix
  - Flow speed or pressure drop not as important
  - Helps prediction of hazard effects



Completed



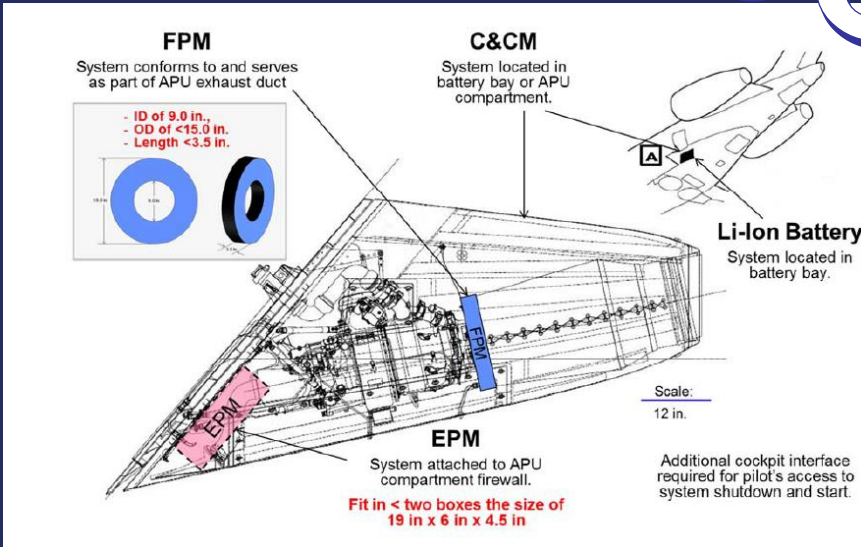
DOT/FAA/TC-19/17 "Evaluation for a Lightweight Fuel Cell Containment System for Aircraft Safety"



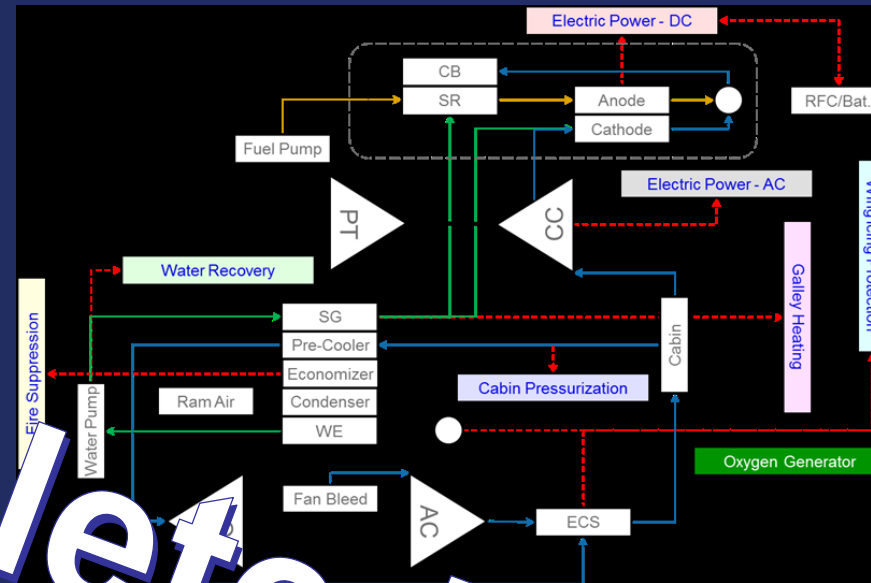


# FAA Fuel Cell Project

**Purpose-** The objective of this work will be to develop a Recommended Technical Standard Guidelines (RTSG) document. This RTSG is intended to serve as a basis for an industry standard, and eventually, support government issued certification requirements for fuel cell systems installed on aircraft. The initial step will be to create a set of requirements for this guideline. Honeywell envisions that this document will be based on a current federal standard, such as Technical Standard Order C77b which is used for the certification of Auxiliary Power Units on commercial air transport aircraft.



Completed



- Three implementation possibilities detailed in the Initial Detailed Research Plan
- PEMFC APU Using Stored Compressed H<sub>2</sub>.
- SOFC Using Reformed Jet Fuel.
- Self-Contained Regenerative Fuel Cell System

Primary Functions	Legacy System	Stored Pure H <sub>2</sub>		Regenerative		Reformation	
		Stored Oxidant	Air	Stored Oxidant	Air	HTPEM	SO
Emergency Power	RAT						
Ground Operation Power	APU						
Takeoff/Climb Power Augmentation	ME Generator						
Cruise Electric Power	ME Generator						
Flight Idle Electric Power	ME Generator						
None Stop Power Supply	ME, APU, GP						
Battery Tender (V.T), Silent Watch	None						
<b>Secondary Functions</b>							
Anti-freezing, Thermal Management	None						
Cargo Bay Fire Suppression	Halon						
Fuel Tank Inerting	ASM						
Water Recovery	Water						

Wide Body Intercontinental: Green  
Narrow Body Short - Mid Range: Blue  
High End Biz-jet: Purple  
Multiple Platform: Yellow  
Weak Proposition: White



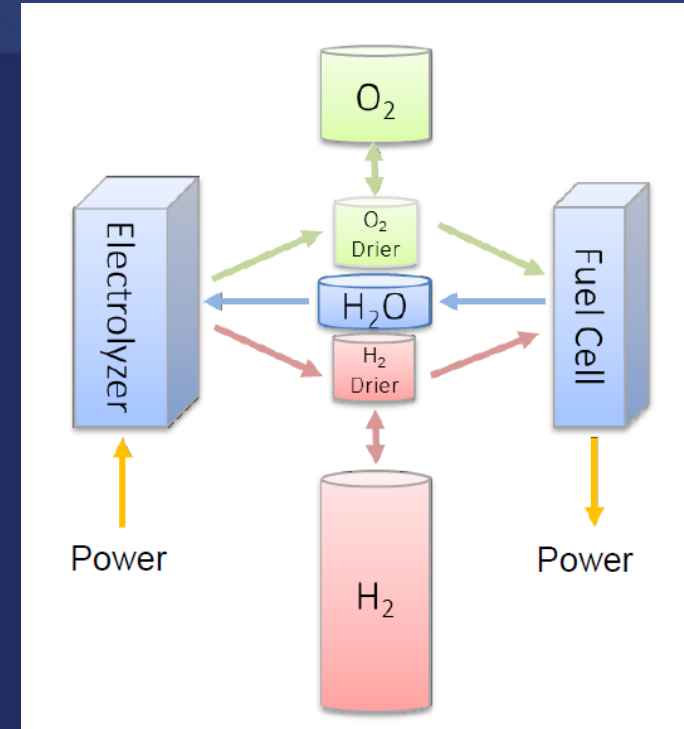
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DOT/FAA/TR-20/9 "Aircraft Fuel Cell and Safety Management System"

# Giner, Inc.

Will study Regenerative Fuel Cell (RFC) systems for aircraft applications by modeling a PEM RFC system, the size of a service cart, that would be used for on-board power for small electronic items.

During the charging mode, while the plane is grounded, water is electrolyzed into hydrogen and oxygen gases which are dried and stored in their respective tanks. During the discharge mode, the gases would be recombined in a fully automated and controlled manner in the fuel cell to generate power and water.



## Benefit to the FAA and the Aviation Community:

- 1) Develop a comprehensive model for sizing regenerative fuel cell (RFC) systems for aircraft applications
- 2) Determine the risks and necessary precautions associated with the RFC system
- 3) Generate assessment criteria for determining RFC system/aircraft compatibility for the establishment of aviation standards and specifications
- 4) Provide the FAA information and guidance regarding safe and proper operation of PEM electrochemical fuel cell systems used for supporting aircraft power needs.



# Infinity

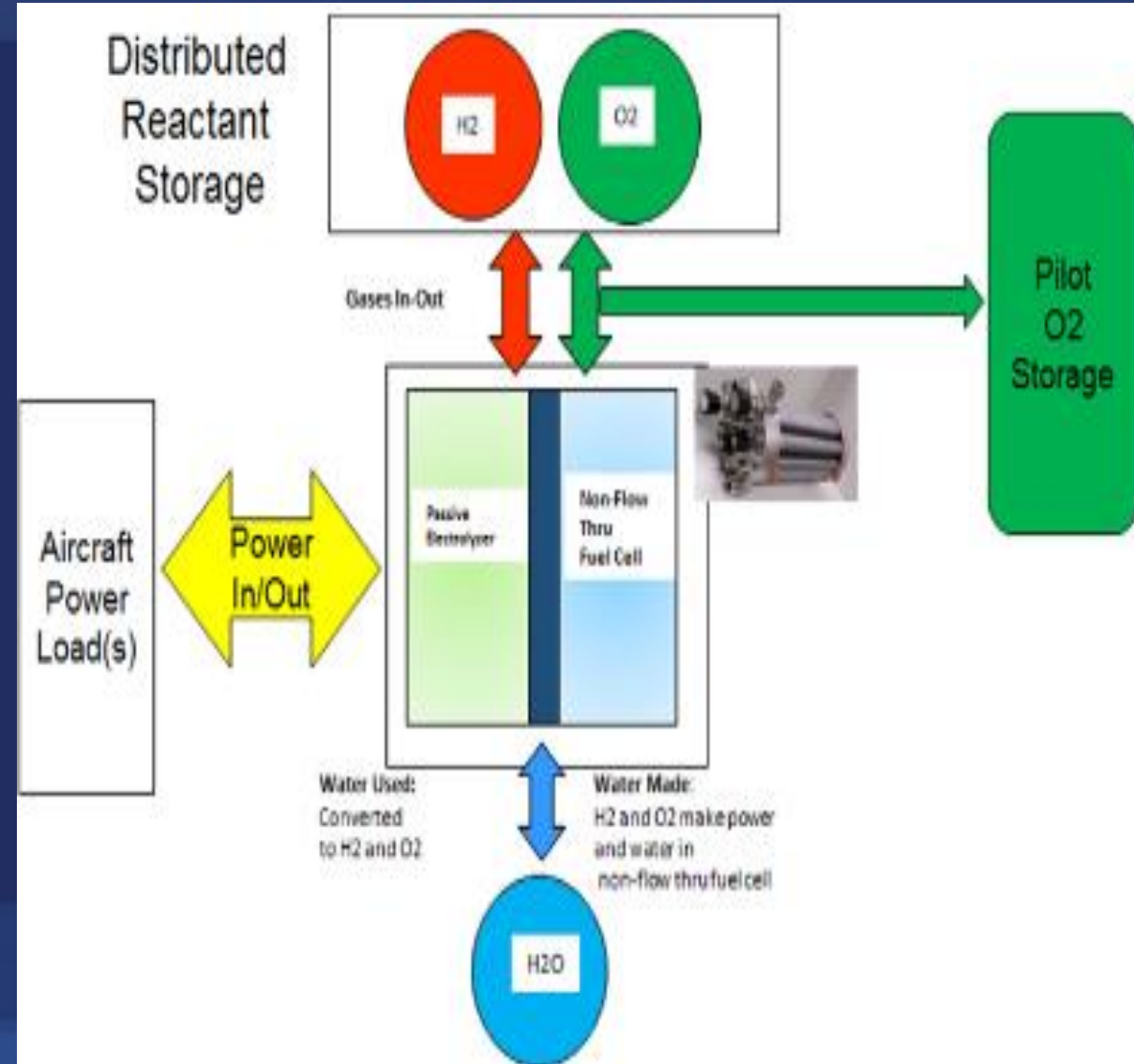
Will perform a design feasibility study of a Multi-Mode Regenerative Fuel Cell, MMRFC.

In power mode, the FC would provide emergency power fueled by hydrogen and either pure oxygen or air.

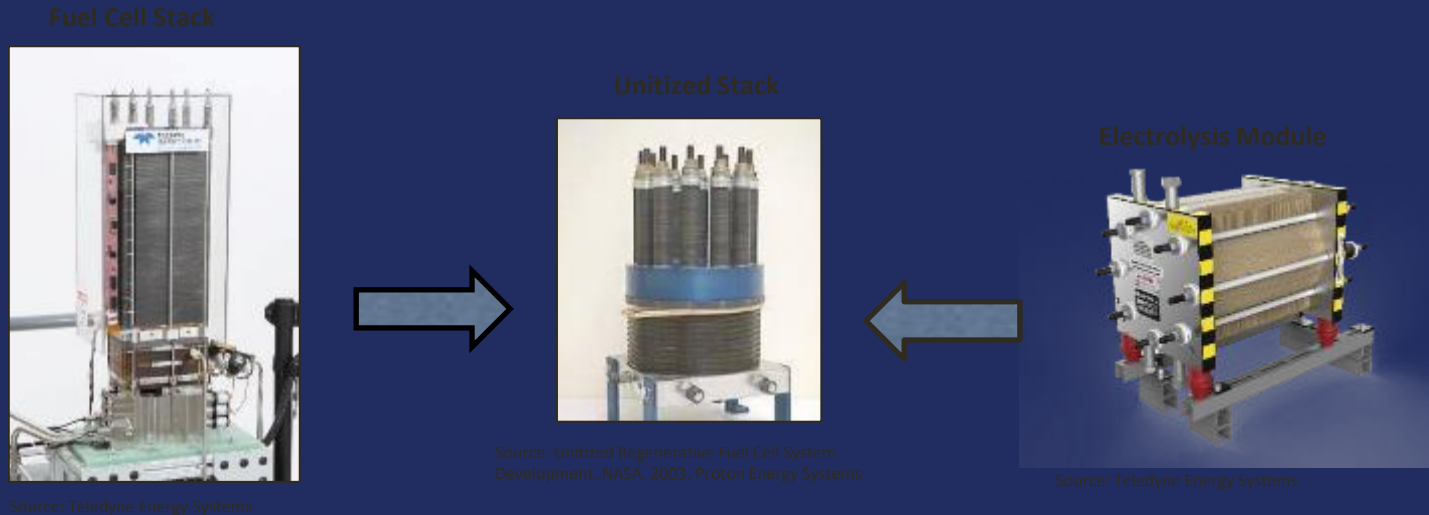
In regenerate mode, the FC would provide high-pressure oxygen to storage for both fuel cell reactant and to **eliminate servicing of emergency pilot oxygen.**

## Goals

- Determine characteristics of what constitutes a safe regenerative and/or reformer fuel cell system (installation, operation, monitoring, control and maintenance).
- Identify any maintenance action or reliability issues to be include in the Instructions for continued airworthiness
- Identify processes for safely managing, storing, fueling, and servicing hydrogen and other fuel sources
- Identify and assess risks associated with RFC systems and mitigating



# Teledyne Membrane Electrode Assembly for Reformate Tolerant PEMFC



TESI will generate and use that specification to procure and/or manufacture MEAs to be tested with a simulated jet-fuel reformat. Testing will be performed on single cells and short stacks with results compared to standard PEM technology supplied with pure hydrogen.

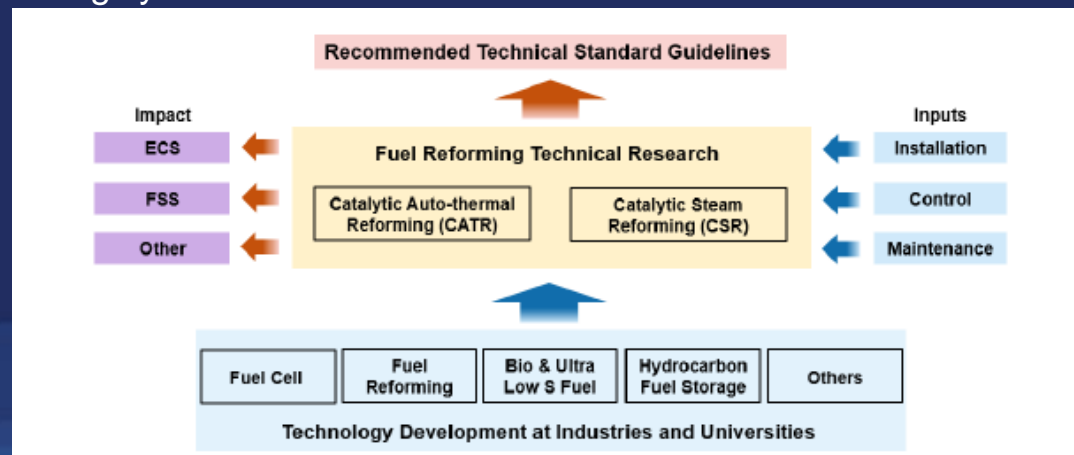
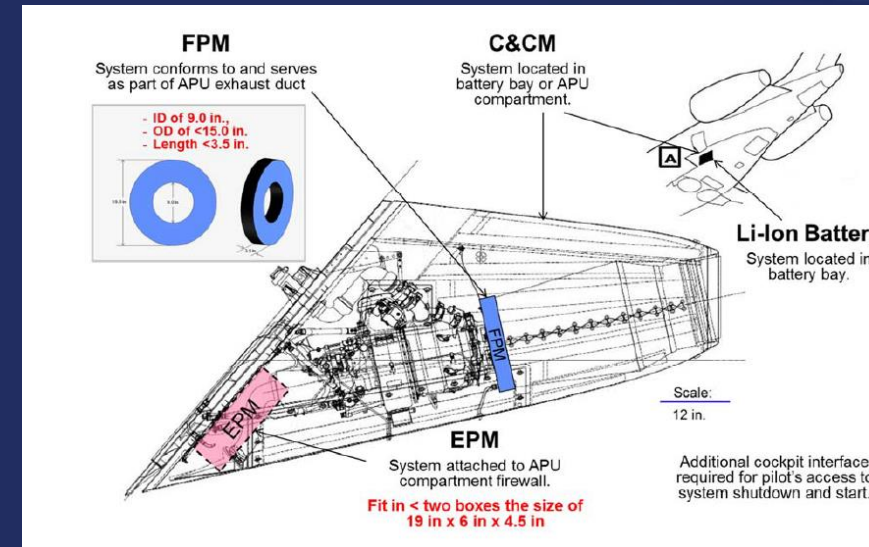
- PEM fuel cell stacks and electrolyzers (along with photovoltaics) are combined in a regenerative fuel cell system to allow for long aircraft flight duration
- PEM fuel cells and electrolyzers use the same chemistry and reactions in performing their functions
- It is possible to perform both functions with the same stack hardware, which in theory could reduce the overall mass of the regenerative fuel cell system.
- A single, unitized stack may have performance limitations due to the need for dual functionality



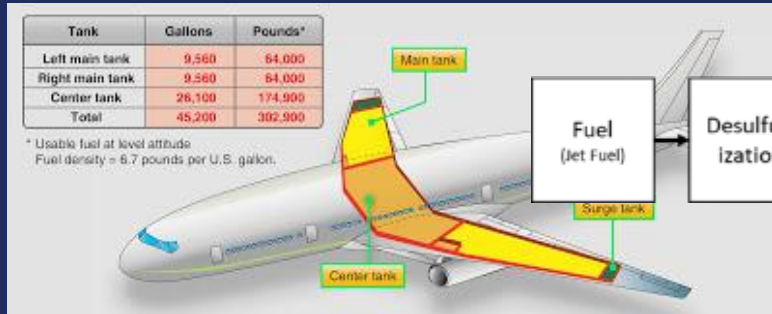
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**Purpose-** Aircraft Safety Management for Fuel Reforming Systems study is to assess the installation, operation, maintenance, reliability characteristics, and to establish certification guidelines for safe adaptation of fuel reforming systems that convert commercially available hydrocarbon fuels from onboard fuel storage systems, such as Jet A, to hydrogen-enriched gases for the operation of fuel cell power systems on aircrafts. The objective of this work is to develop a Recommended Technical Standard Guidelines (RTSG) document intended to serve as a basis for an industry standard, and eventually, support government issued certification requirements for fuel reforming systems installed on aircraft..



# Teledyne PEM Fuel Cell with Hydrogen from Jet-Fuel



Source: [Aeronautics Guide](#)

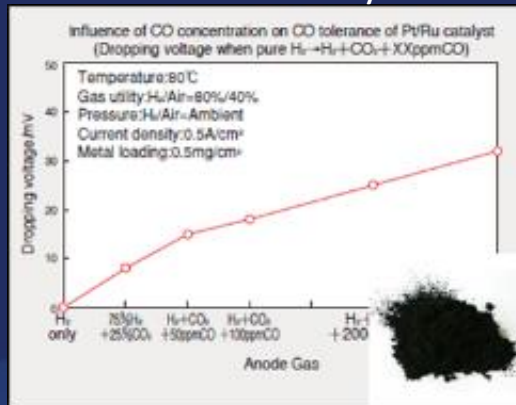


Fuel Cell Stack



Source: Teledyne Energy Systems

## Reformate Tolerant Catalysts



Source: [Tanaka Technologies](#)

## HT-PEM Stack



Source: [Advent Technologies, Inc.](#)

- PEM fuel cell stacks can use jet fuel as a hydrogen source, eliminating the need for high-pressure hydrogen storage tanks
- Turning jet fuel into usable hydrogen requires extensive fuel processing equipment
- Even with cleanup steps, hydrogen will contain some small concentration of CO, which dramatically reduces fuel cell efficiency
- Alternate catalysts or high temperature PEM (HT-PEM) fuel cells can mitigate the impact of CO on performance

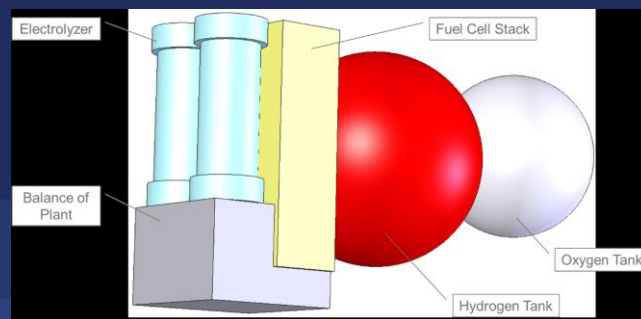
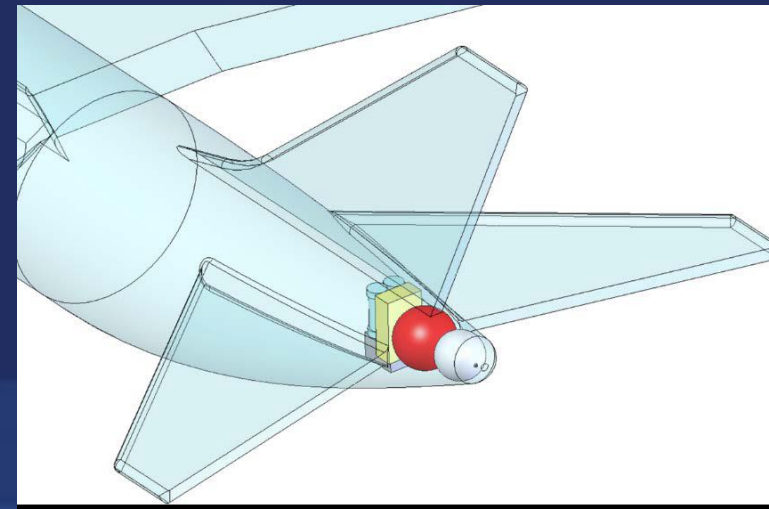
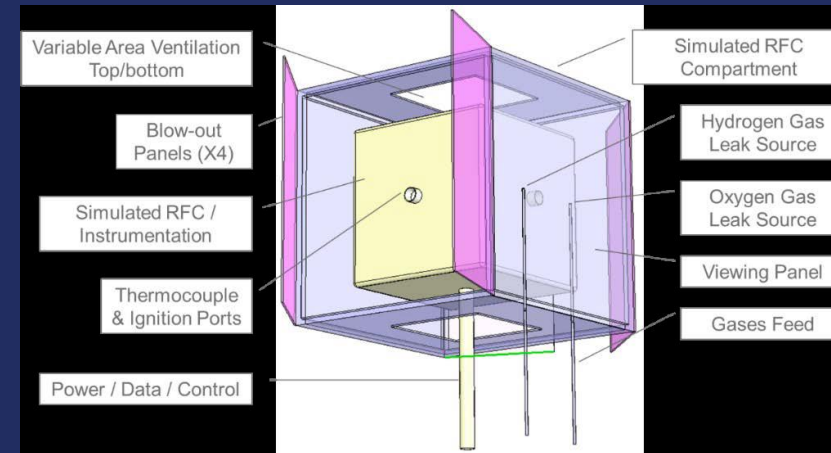


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**Purpose-** The purpose of this program is to study and develop regenerative fuel cell technology for safe, certifiable installations on aircraft. This research includes the following applications, but it is not limited to this list.

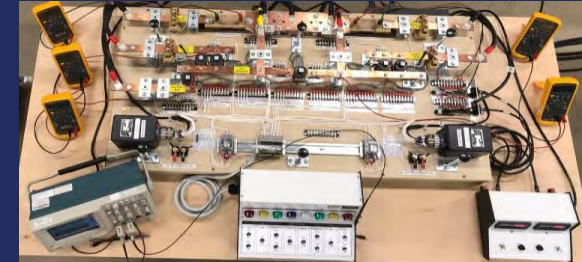
- Primary propulsion for light propeller airplanes
- Emergency Electrical Power Generation
- Backup power
- Use of aircraft fuel to generate reactants
- On board water generation
- Efficient combined use heat and electrical power

For any application of regenerative fuel cells, stack failure hazard should be defined and quantified for the application. Also, details of how the technology will interface with aircraft systems should be discussed. The goal of this research is to develop practical experiments and acquire data to support FAA and global partners for appropriate standards, regulations, and demonstration of safe compliance.



# Current test capabilities of motors less than 50 HP in the More Electric Aircraft Lab

- **Electrical power generation**
  - Rotating generators/starters up to 50HP
  - Hydrogen Fuel cell PEM and Solid Oxide
- **Electrical Power Distribution**
  - Solid state Primary and Secondary
    - Up to 1000VDC low current
    - Up 300VACrms
- **Electrical Motor testing**
  - Up to 50HP
- **Electrical Load protection**
- **Electrical Power Quality**
- **Energy Storage Batteries load testing and charging**
- **Electrical Load control**
  - PWM
  - Motor control
- **Regenerative voltage suppression**
- **Wireless control of avionics loads**
- **Avionics Load testing**
- **UAS and small aircraft primary propulsion**
- **EMI effects of electrical flight controls**



# FAA Early Engagement & Certification projects

- Alakai is a 6-rotor electric propulsion multicopter powered by multiple fuel cells.
- Zeroavia early engagement
- FAA Center Emerging Concepts and Innovation has established a Fuel Cell team and employed the expertise of the Tech Center to support the development of the new regulation & policy required to help ensure the safe entry and operation in the NAS



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