



Space Technology Mission Directorate Game Changing Development Program

Ryan Gilligan, Ian Jakupca | Regenerative Fuel Cell (RFC) Project | Annual Program Review | September 10-12, 2024

Project Overview



Timer

Needs Addressed by Project

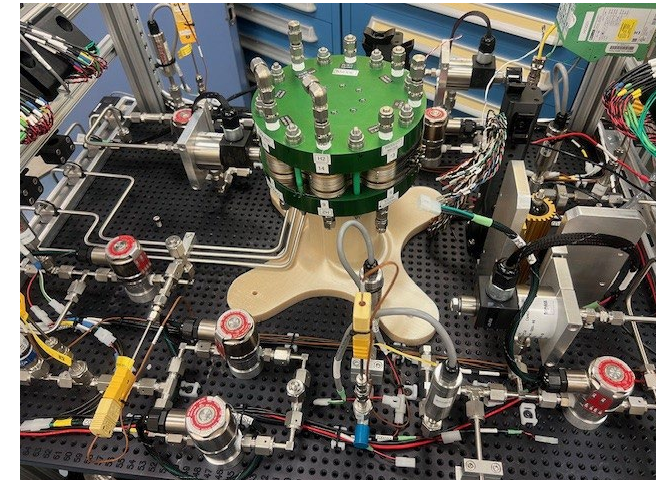
Stakeholder (i.e. HLS)	Energy Storage for Moon & Mars surface exploration, crewed landers, habitats and long-term lunar power infrastructure	Addressed Shortfall Areas: Advanced Power (505, 1595), Advanced Thermal (1618), ISRU (572, 1583)
Stakeholder	Demonstrate regenerative fuel cell (RFC) energy storage system technology for sustained and reliable electrical power for surface missions where PV/Battery or nuclear options are not feasible.	HLS (Lunar Surface)

Project Goals

Goal #1	Develop, build, and demonstrate a Breadboard Regenerative Fuel Cell (RFC) energy storage system for lunar surface applications that can provide 2 to 3.4 times the energy storage capability of state-of-the-art packaged lithium-ion battery systems.
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Project Objectives

Objective #1	Develop RFC Energy Storage System Requirements.
Objective #2	Develop a Breadboard RFC Energy Storage System design.
Objective #3	Build a Breadboard RFC Energy Storage System.
Objective #4	Demonstrate the Breadboard RFC Energy Storage System in a laboratory environment.

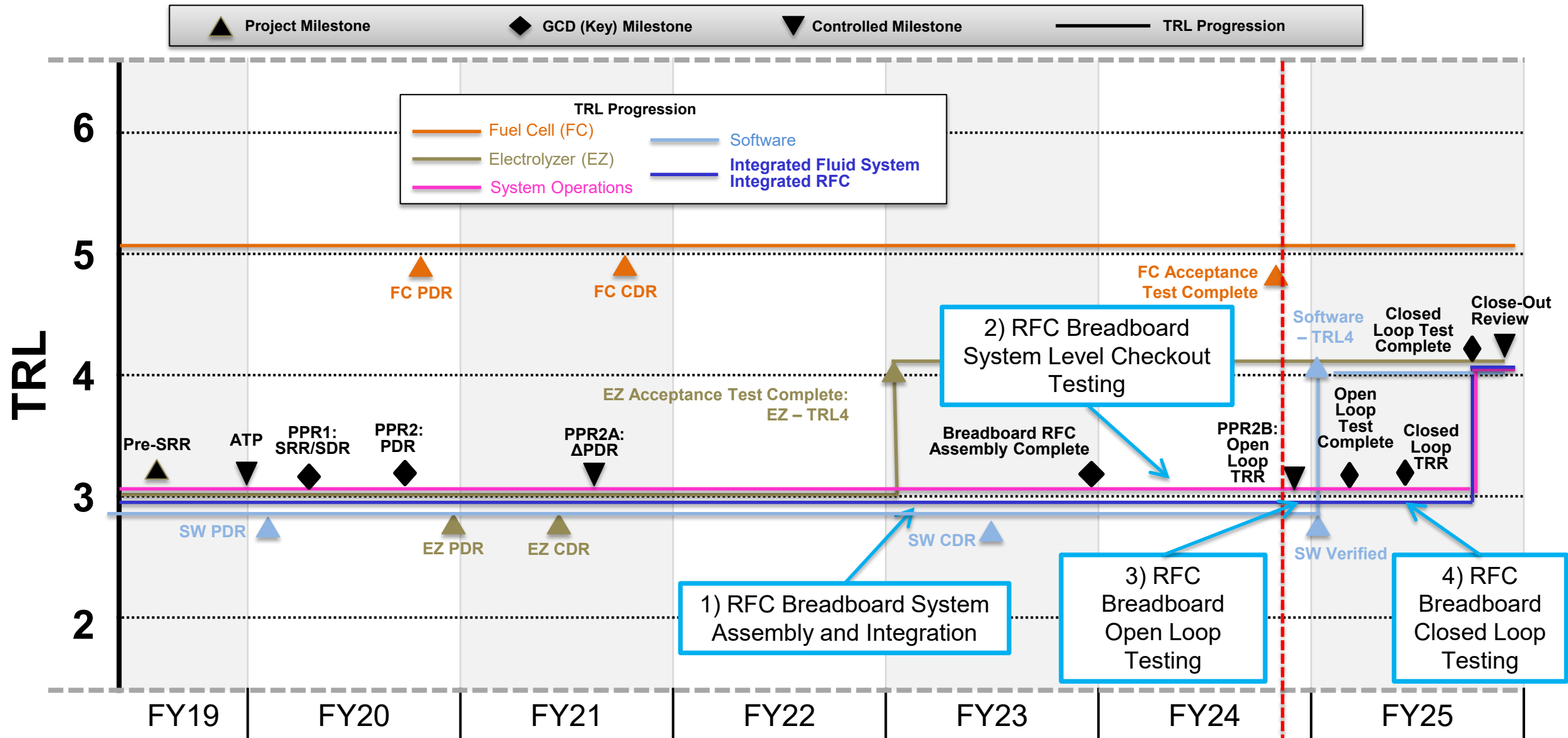


RFC breadboard fuel cell cart with backup 7-cell fuel cell stack

RFC Project Technology Maturity Schedule / Project Life Cycle Milestones



Timer



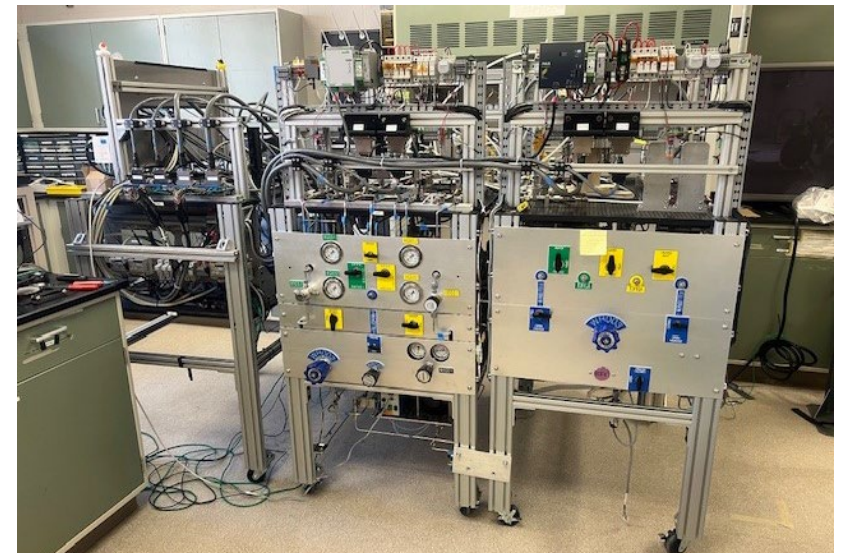
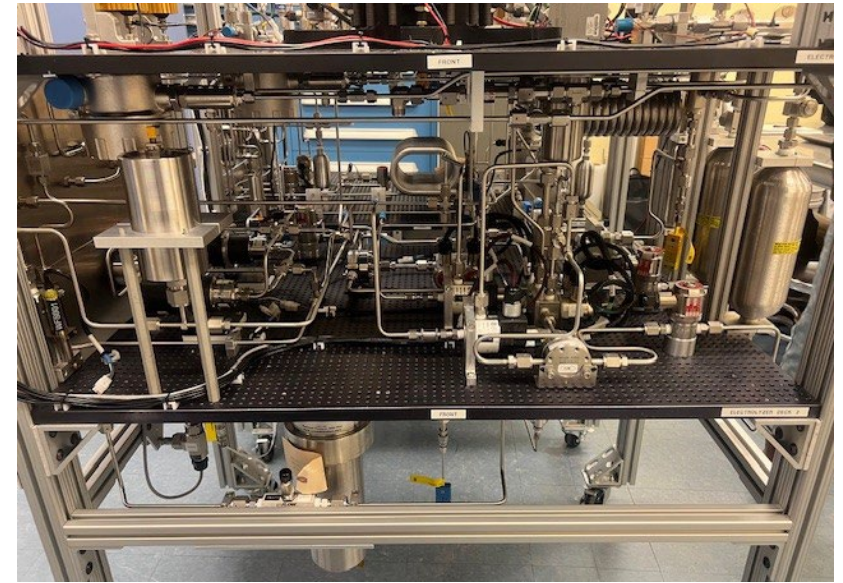
Regenerative Fuel Cell Project

Technical Progress and Results



Timer

- Completed precision cleaning for oxygen service of hundreds of components
- Completed system reassembly after precision cleaning for oxygen service
- Integrated RFC breadboard into GRC Space Power Research Laboratory
- Completed subsystem checkouts
 - Power/avionics subsystem, fluids subsystem, electrolyzer and fuel cell stack tests



Electrolyzer cart middle deck showing oxygen, hydrogen, and water subsystems (top). Avionics, FC, and EZ carts integrated into GRC Space Power Research lab (bottom).

Regenerative Fuel Cell Project

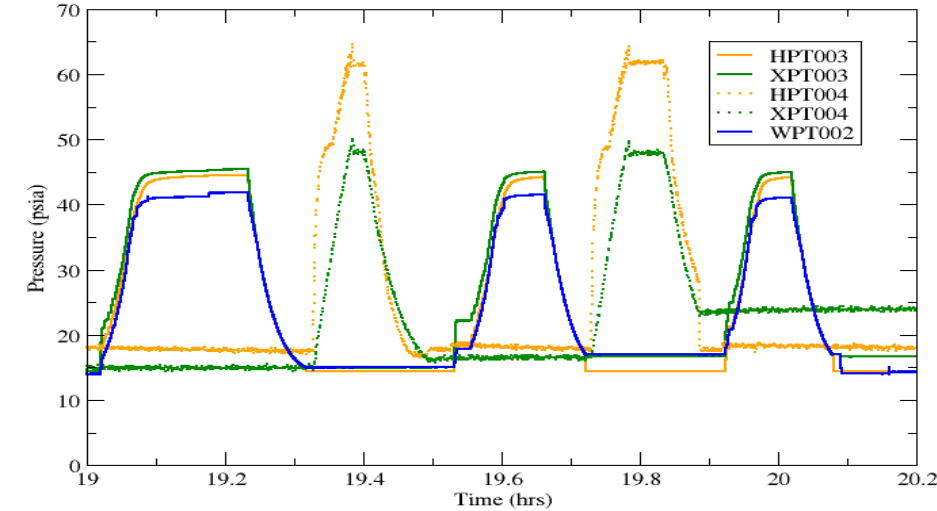
Technical Progress and Results Continued



Timer

- Started integrated system functional checkouts using nitrogen
 - Verified multiple software/hardware interactions
- Resolved multiple non-compliant hardware and software issues
 - Flow restrictors for more controlled fuel cell pressurization, relocation of bellows accumulator, swapped water pressure regulator, high pressure lift pump
- Engineering team often implemented hardware and plumbing changes to mitigate schedule issues resulting from mechanical technician shortages

FC <-> EZ Transitions



RFC breadboard hydrogen, oxygen, and water system pressures during mode transition checkout tests (top). RFC engineers troubleshoot an anomaly during checkout testing (bottom).

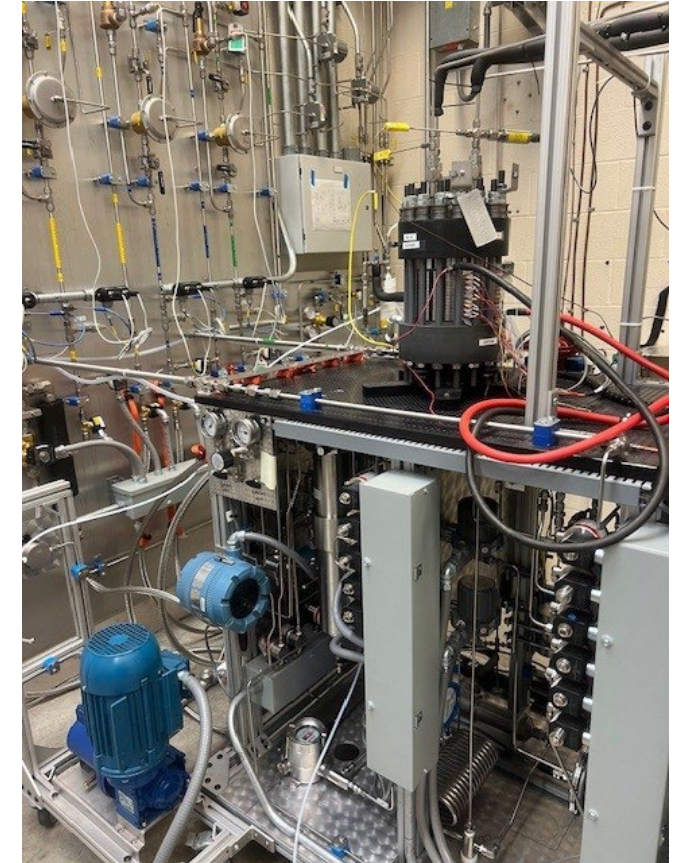
Regenerative Fuel Cell Project

Technical Progress and Results Continued



Timer

- Finished commissioning of Electrolyzer (EZ) Test Stand
- Completed EZ stack performance validation testing
 - EZ stack maintained for 2 years following non-operational maintenance procedures
 - Test validated maintenance procedure as no degradation in EZ performance observed in data



Giner high pressure liquid anode feed EZ stacks (left). RFC test engineer operates EZ test stand during EZ performance test (middle). Completed EZ test stand in GRCs Fuel Cell Test Facility (top).



Regenerative Fuel Cell Project

Technical Progress and Results Continued



Timer

- EZ testing revealed RFC breadboard design water management deficiencies:
 - Water level sensing in custom oxygen-water phase separator
 - Liquid water removal from EZ hydrogen outlet
- Implemented designs changes to address deficiencies
 - Checkout testing in progress
- Fuel cell Stack #1 delivered by Infinity Fuel Cell and Hydrogen



12-cell, 150 cm2 fuel cell stack delivered to GRC by Infinity Fuel Cell and Hydrogen (left).

Water-oxygen liquid-gas phase separator attached to load cell level sensing apparatus for checkout testing on RFC breadboard (right).



Regenerative Fuel Cell Project Transition/Infusion Status



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- Further component development needed to advance RFCs to TRL5
- Components requiring technology development to meet performance, environmental, or reliability requirements:
 - Deionized water lift pumps, electrolysis compatible biocides, electrolyte mechanical properties (FC & EZ), electrolyte performance stability (FC & EZ), safety sensors (H_2 in O_2), radiation tolerant avionics and power electronics, high flux thermal switch (kW-scale)
- Other NASA programs and external agencies independently addressing some technology development for their missions. Informal collaborations established where mutually beneficial.

Regenerative Fuel Cell Project Assessment Summary



Timer

Project Name	Performance				Comments
	C	S	T	P	
Annual					Technical – Testing of phase separators and liquid level sensing in progress Cost – Project within cost allocations for FY24 and FY25 Schedule – On-track for TRR end of September Programmatic – Resource conflicts with multiple projects challenged workforce progress

	Oct	Nov	Dec	Jan	Feb	MYR	Apr	May	Jun	Jul	Aug	APR
C												
S												
T												
P												

December through February – Oxygen cleaning and system reassembly exceeded estimates by 3 months
May – HLS Fuel Cell Test GTA utilizes key RFC resources (facilities and personnel)
June – Electrolyzer testing reveals unanticipated electrolyzer performance requiring changes to RFC balance of plant