

# FOIL BEARING SUPPORTED COMPRESSOR-EXPANDER

---

PRINCIPAL INVESTIGATOR: DR. GIRI AGRAWAL

PRESENTER: BILL BUCKLEY

R&D DYNAMICS CORPORATION

DOE PROJECT AWARD #DE-EE0009617

JUNE 7<sup>TH</sup>, 2023

DOE FUEL CELL R&D FOR HEAVY-DUTY APPLICATIONS

PROJECT ID: FC349

2023 ANNUAL MERIT REVIEW AND PEER EVALUATION MEETING

# Project Goals

---

Develop a fuel cell system Compressor-Expander for heavy-duty vehicle applications. It must meet the following requirements:

- Flow 143 to 285g/s of air at a compressor ratio up to 2.5 efficiently over a wide operating range.
- Be highly reliable and have a long service life.
- Be versatile to allow broad usage across many fuel cell platforms
- Be able to be mass-produced at lower cost.

# Overview

## Timeline and Budget

Project Start Date: May 1, 2022

Project End Date: November 1, 2024

Total Project Budget: \$2,000,000

- Total Federal Share: \$1,600,000
- Total Cost Share: \$400,000
- Total DOE Funds Spent\*: \$755,796
- Total Cost Share Funds Spent\*: \$188,949

\*As of 04/07/2023

## Barriers

- Meeting the efficiency for the Compressor expander at the required pressure ratio.

## Targets

- 75% compressor efficiency and 70% expander efficiency at 285g/s and a pressure ratio of 2.52.
- System cost less than \$3,000 at 100,000 units/year.
- Durability of 25,000 hours under various loads.

## Partners

- Industry Collaborator: Loop Energy
- University Collaborator: University of Texas – Dallas

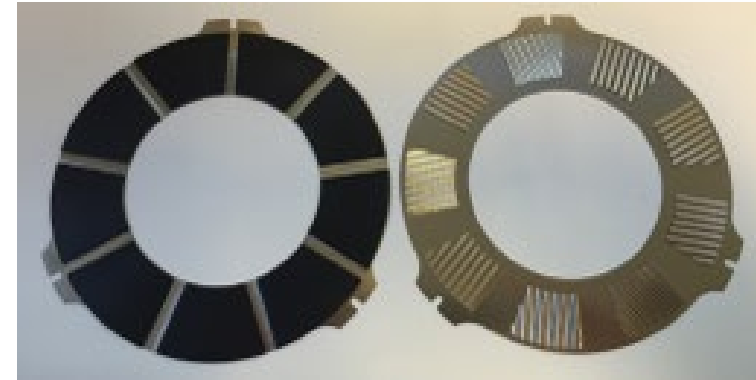
# Potential Impact

- The Compressor-Expander is the key component of the balance of plant in a hydrogen fuel cell.
- The foil bearing supported Compressor-Expander being developed under this project will allow automotive and heavy-duty truck fuel cell manufacturers to deliver small, efficient, and extremely reliable fuel cell air management systems to their customers at a reasonable price.
- Successful completion of this project will create significant additional manufacturing jobs at R&D Dynamics and their partners/subcontractors.

Technology	Advantages
Oil-free foil air/gas bearings	<i>No oil contamination</i> , increased reliability, high vibration & shock capacity, smaller size/weight, no scheduled maintenance, quieter operation, and high start-stop cycles
Centrifugal compressor and turbine	Higher efficiency and smaller size/weight
Surge bypass and variable turbine nozzles	High efficiency over wide operating range
Drive with silicon carbide (SiC) switches	Higher switching frequency, higher operating temperature, and smaller size

# Approach

- High speed centrifugal compressor/expander
- Supported on oil-free foil air/gas bearings
- Surge bypass and variable turbine nozzles
- Permanent magnet motor (DCPM)
- Motor drive with silicon carbide (SiC) switches
- Smaller size and weight



# Milestone Review

	SOPO Date of Completion	Milestone	Status	Comment
BP1	August 2022	Preliminary Design	100%	Completed!
	January 2023	Detailed Design & Analysis	100%	Completed!
	January 2023	CE & Drive Drawings	50%	In progress, preliminary drawings done as of 4/14/2023
	May 2023	Test Rig Design and Manufacturing	45%	Test rig design and power supply integration started
	May 2023	CE & Drive Manufacturing	20%	Parts quoting underway, stator stacks ordered
	November 2023	CE & Drive Assembly and Development Testing		
	November 2023	Budget Period 1 Go/No-Go Decision Point		
BP2	November 2024	Cost Estimate and Production Plan		
	November 2024	Durability Protocol Testing		

# Performance Targets

Characteristic	2030 Targets	Basis	Today's Values	Mitigation Strategy
Compressor Efficiency*	a=77%, b=69%, c=46%	Predicted Performance Map	a=73%, b=75%, c=68%	Test rotor, compare against prediction, and then iterate
Turbine Efficiency*	a=70%, b=80%, c=0%	Predicted Performance Map	a=72%, b=68%, c=0%	Test rotor, compare against prediction, and then iterate
Motor Efficiency*	a=95%, b=95%, c=80%	Power meter	a=97%, b=TBD, c=TBD	
Drive Efficiency*	a=97%, b=97%, c=80%	Power meter/thermal balance	a=98%**, b=TBD, c=TBD	
System Weight	<125kg	<0.50kg/kWe, 250kWe System	CE: 24.4kg	
System Volume	<62.5L	<0.25L/kWe, 250 kWe System	CE and Drive: 34.8L	
System Cost	<\$3,000	\$12/kWe, 250 kWe System, @ 100,000 units	TBD	Better idea of actual costs after quoting is completed
Performance	Pressure rise and flow at each Operating Point			

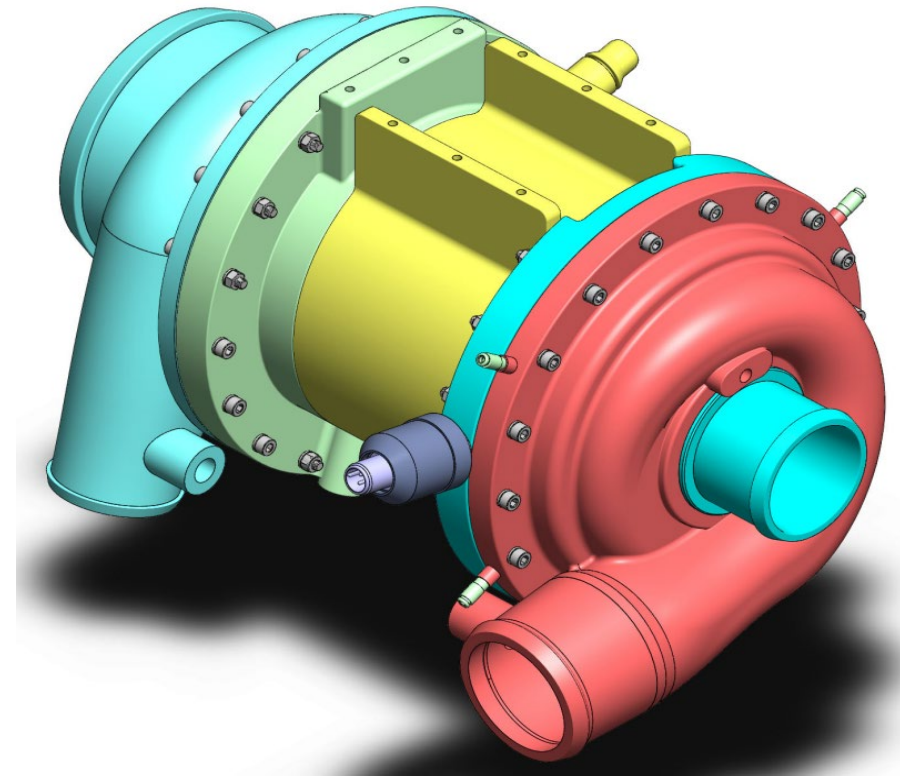
\*DE-FOA-0002446: 100% flow is a, 50% flow is b, Idle flow is c

\*\*neglecting conduction losses between the drive and motor

# Accomplishments & Progress

## Budget Period 1: 2022-2023

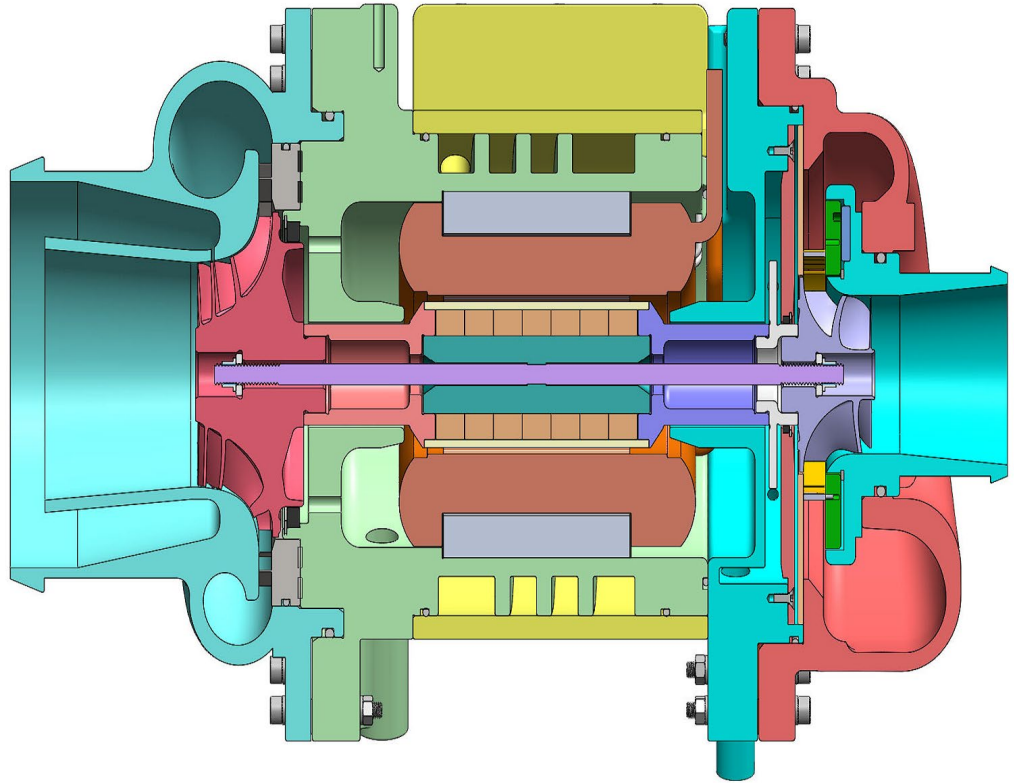
- Project awarded to RDD on May 1, 2022
- Developed product definition, created an initial layout in Solidworks, and completed preliminary design of CE
- Completed detailed calculations to validate the size and design of the compressor, turbine, motor, bearings, and housings
- Completed predicted aerodynamic performance of the CE



# Accomplishments & Progress

Budget Period 1: 2022-2023 (cont'd)

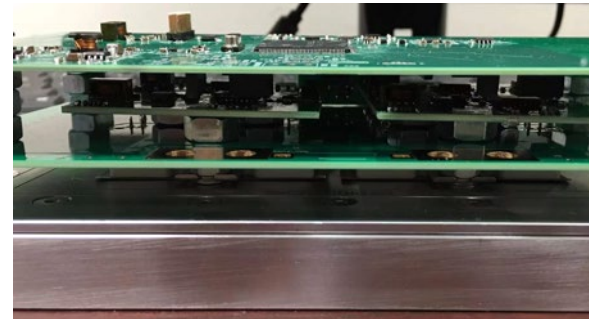
- Completed detailed analyses for:
  - Critical speed
  - Forced response
  - Thrust balance
  - Internal cooling flow
  - Motor design
  - Motor cooling
  - Fits & clearances
  - Transient response time
  - Impeller FEAs



# Accomplishments & Progress

## Budget Period 1: 2022-2023 (cont'd)

- Integrated results of analyses to complete the detailed design of the CE and Drive to support their fit, form, and function
- Completed preliminary design and fabrication of prototype Drive electronics including prototype software for development testing
- Drawings and documentation for CE and Drive manufacturing are underway
- Quoting for parts manufacturing is underway



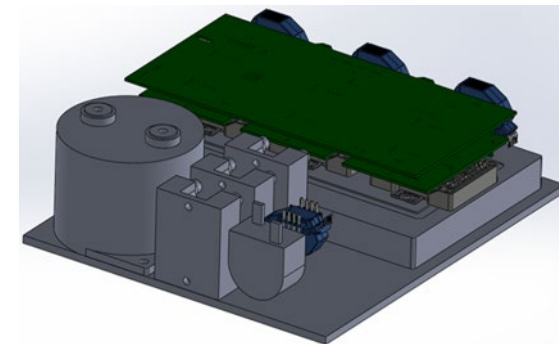
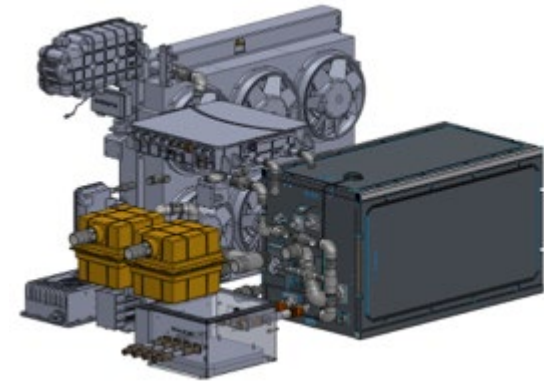
# Collaboration & Coordination

## Loop Energy

- Fuel cell development partner
- Specification development
- Performing system integration and field testing

## University of Texas – Dallas

- High frequency drive and control software design and development



# Proposed Future Work

---

## FY 2023

- Complete final drawings and documentation for Compressor-Expander (CE) and Drive manufacturing
- Fabricate hardware to assemble (3) three CE and Drive development units
- Design and manufacture components of the test rig for development testing
- Assemble (3) three CEs and Drives for development testing

## FY 2024

- Perform durability testing on the CEs and Drives

# Summary

---

- Project awarded May 1<sup>st</sup>, 2022
- Foil air/gas bearings offer increased reliability, high vibration & shock capacity with lower lifetime maintenance cost
- Centrifugal compressors and turbines provide the highest efficiency and smallest size/weight
- Higher switching frequencies and operating temperatures with SiC switches in the Drive provide greater efficiency and reliability
- Preliminary design of the CE and Drive completed
- Prototype Drive electronics and software produced for development testing
- Detailed design and analyses completed for CE and Drive
- Drawings and documentation for CE and Drive manufacturing are underway
- Component fabrication and machine assembly for in-depth testing is expected to be completed before the end of FY 2023