NEXCERIS
where energy meets environment

SOFC/Turbine Hybrid Power System

Nexceris (Lewis Center, OH)
Czero (Fort Collins, CO)
Brayton Energy (Hampton, NH)

Project Vision

Nexceris and its team will design, build and demonstrate an ultra-high efficiency hybrid power system based on Nexceris' pressure tolerant and high efficiency solid oxide fuel cell stack and a gas turbine.

Nexceris Team

- **Scott Swartz (PI)**
- Gene Arkenberg
- Tom Harvey
- Chad Sellers
- Dave Kopechek

Czero Team

- Guy Babbitt
- Nick Echter
- Michael Sprengel

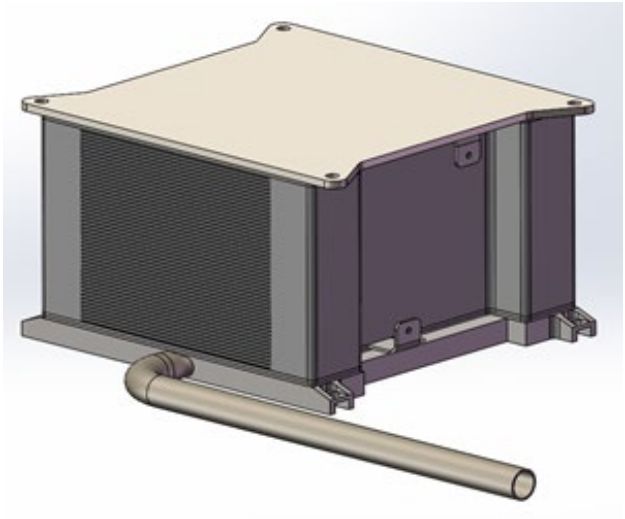
Brayton Team

- Jim Kesseli
- Tom Wolf

ARPA-E Project (Phase II)

Project Vision

Nexceris' team will design, build and demonstrate an ultra-high efficiency power system by hybridizing Nexceris' pressure tolerant and high efficiency fuel cell stack with a gas turbine.



Project Activities

- ❑ **Nexceris:** SOFC stack production scale-up. Stack supply for system builds.
- ❑ **Nexceris:** Pressurized testing of stacks (in collaboration with Washington State University, Czero and NETL).
- ❑ **Czero:** Hybrid system design/modeling and controls development.
- ❑ **Brayton Energy:** Turbine, combustor and heat exchanger technology.
- ❑ **Czero:** BOP procurement and system builds. Hybrid system validation and demonstration testing.

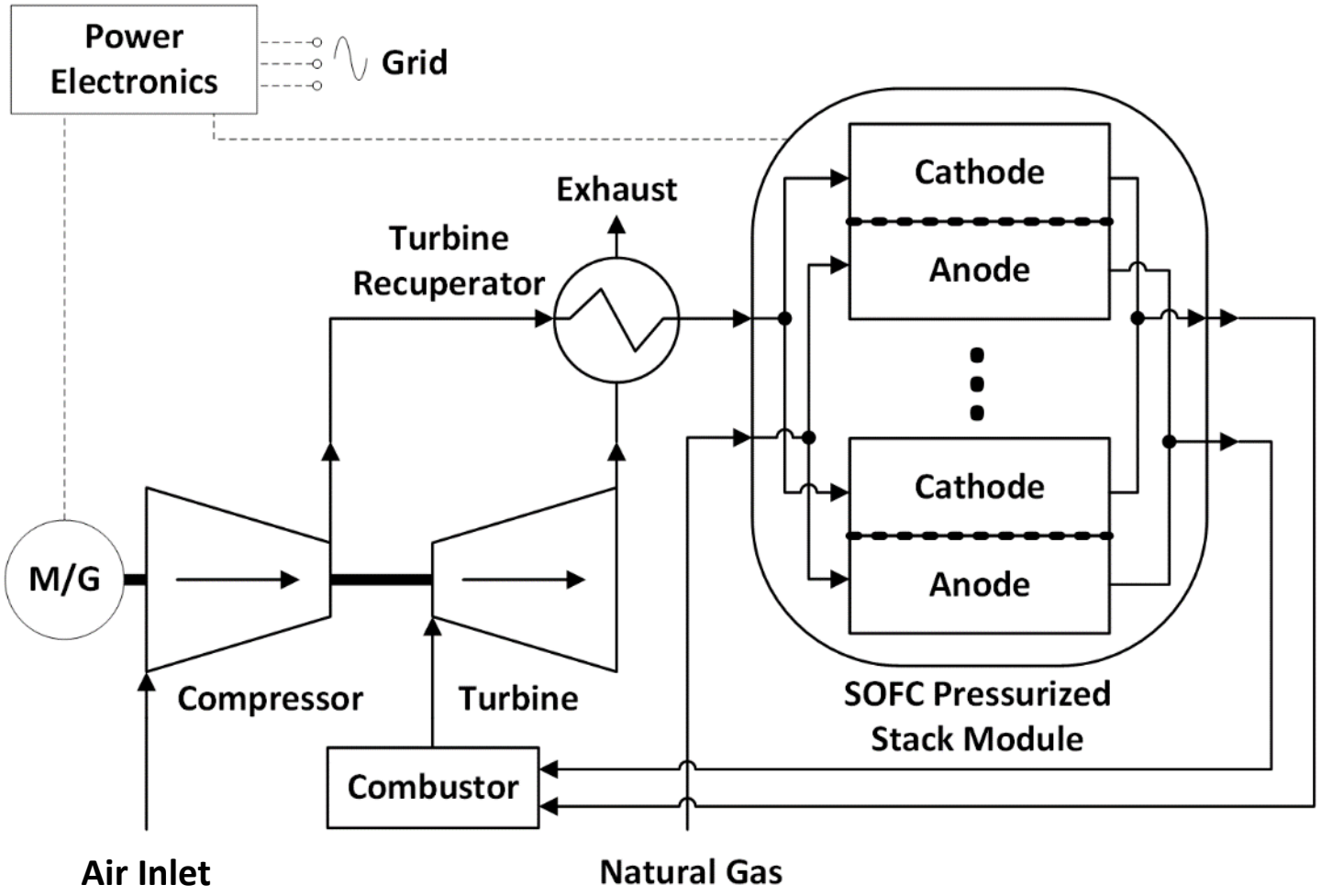
Hybrid System Design

Objective

Achieve ultra high fuel to electrical conversion efficiency by integrating a solid oxide fuel cell with a gas turbine.

System Design Targets

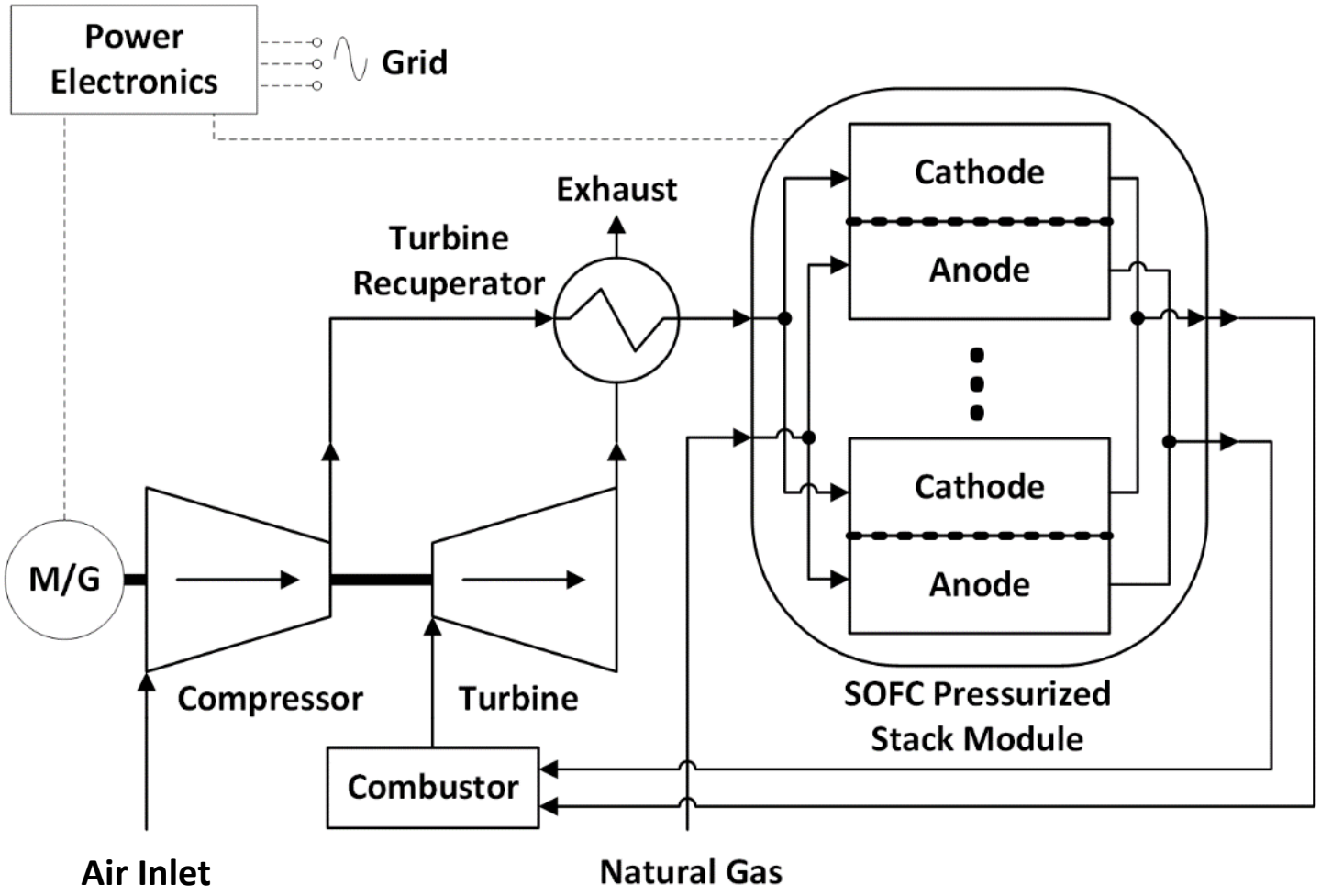
- ❑ 50 kW (net) power
- ❑ Natural gas fuel
- ❑ 70 percent net LHV efficiency
- ❑ Operation pressure of 2-3 atm
- ❑ Installed cost of $1,800 per kW



Hybrid System Design

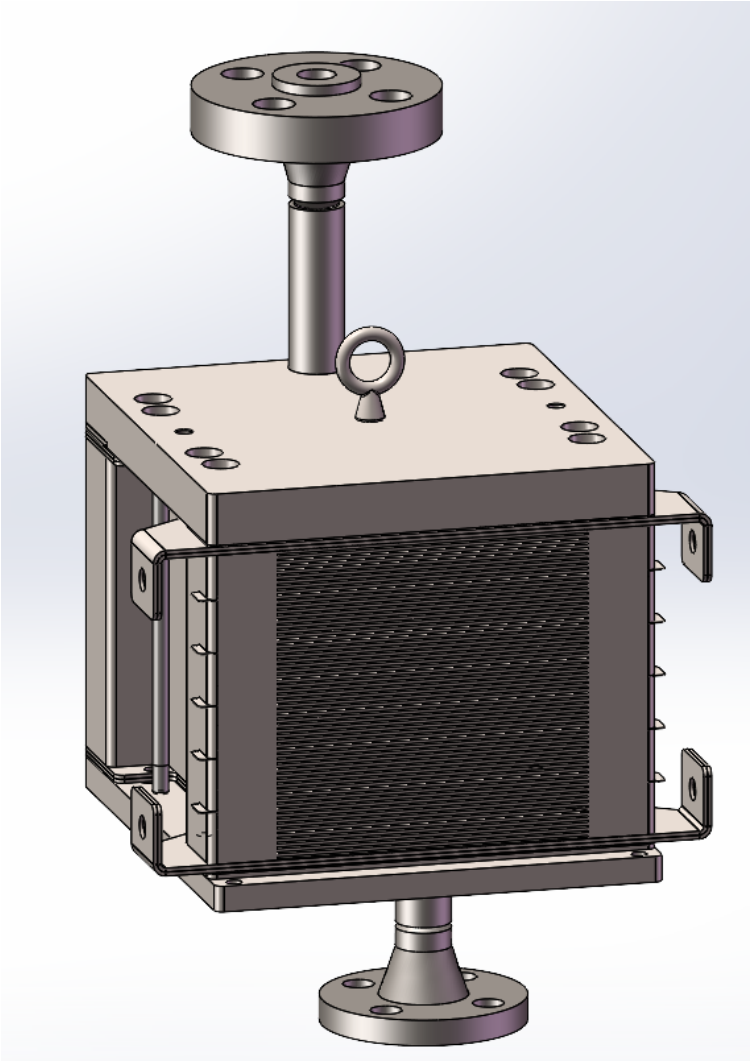
Design Considerations

- Power split between SOFC and Gas Turbine.
- Stack thermal management.
- Internal versus external reforming.
- Recycling strategies (anode exhaust back to stack or to reformer).
- Integration of multiple stacks into system – one large pressure vessel or multiple smaller ones?
- Start-up requirements.
- Control strategy.



SOFC Stack Development Work at Nexceris

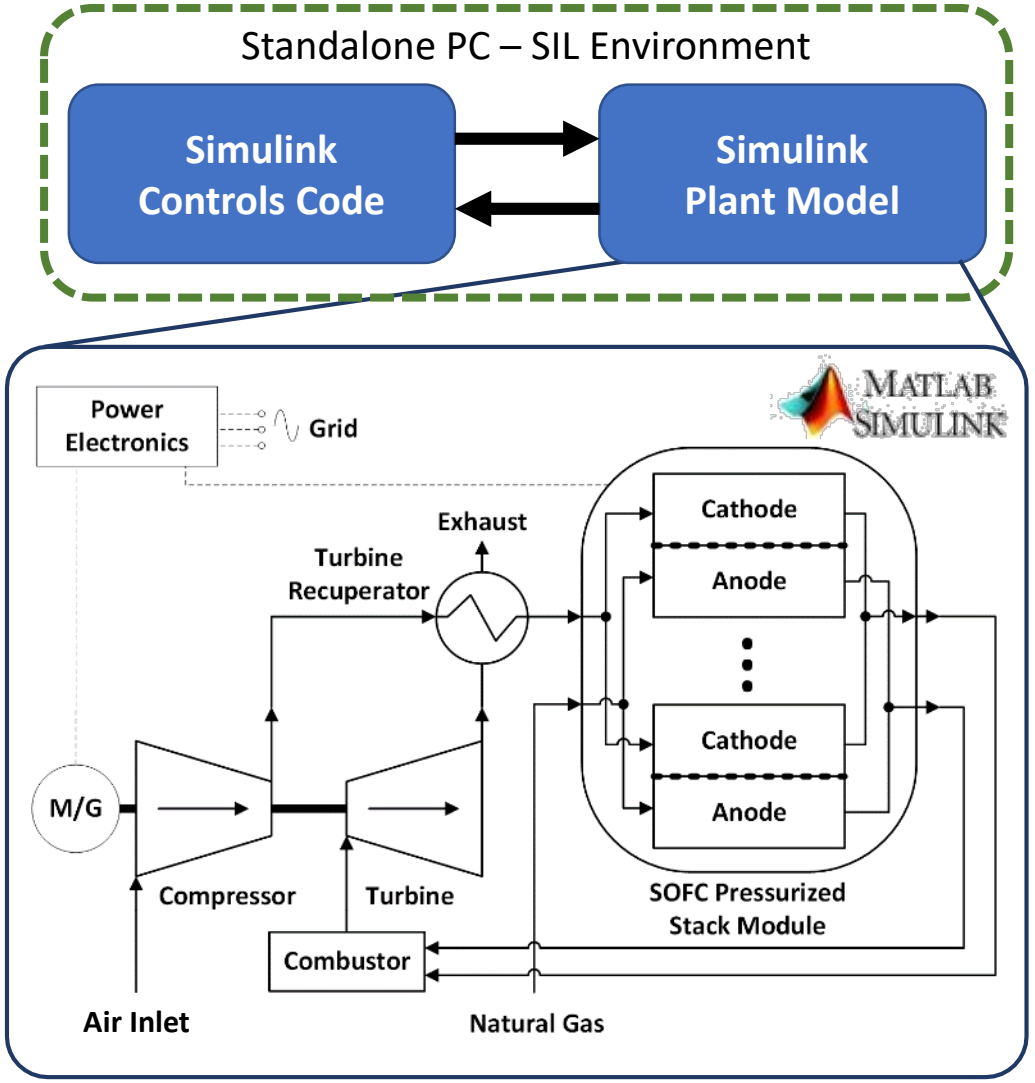
- Developed and validated model for reducing thermal gradients by spatially controlling the internal reforming reaction.
- Developed and implemented improved sealing materials and approaches to enable pressurized stack operation.
- Established large-area stack design for integration into prototype system.
- Validated stack designs by achieving targeted performance in sub-scale stacks.
- Pressurized testing of SOFC stacks is ongoing.
- Currently, manufacturing cells and preparing for stack production for system demonstrations planned for Q1 of 2023.



System Design and Control

Overview

- Dynamic system (plant) model of complete SOFC/GT system has been developed and subsystems validated.
- Plant model is supporting system architectural design and component sizing enabling an optimization of system performance/efficiency while accelerating development timeline and reducing technical risk.
- Plant model being used to develop/validate control strategies and code via MIL/SIL techniques as part of a model-based control strategy.



Market Applications

Transportation

- ❑ Maritime - Ships and Port Installations
- ❑ Freight and Passenger Rail
- ❑ Trucking

Stationary Microgrids and Distributed Generation

- ❑ Critical Power for Healthcare Facilities
- ❑ Remote EV Charging Stations
- ❑ Data Center Power

Market	Size (2020)	CAGR
Maritime - Vessels	$206B (Global)	1.10%
Freight and Passenger Rail	$1.8B (US)	10.3%
Heavy Trucks (Class 7 & 8)	$37.8B (US)	4.5%
Microgrids	$2.1B (US)	4.3%

Transportation – Key Benefits

- ❑ Emissions Reduction
- ❑ Energy Efficiency

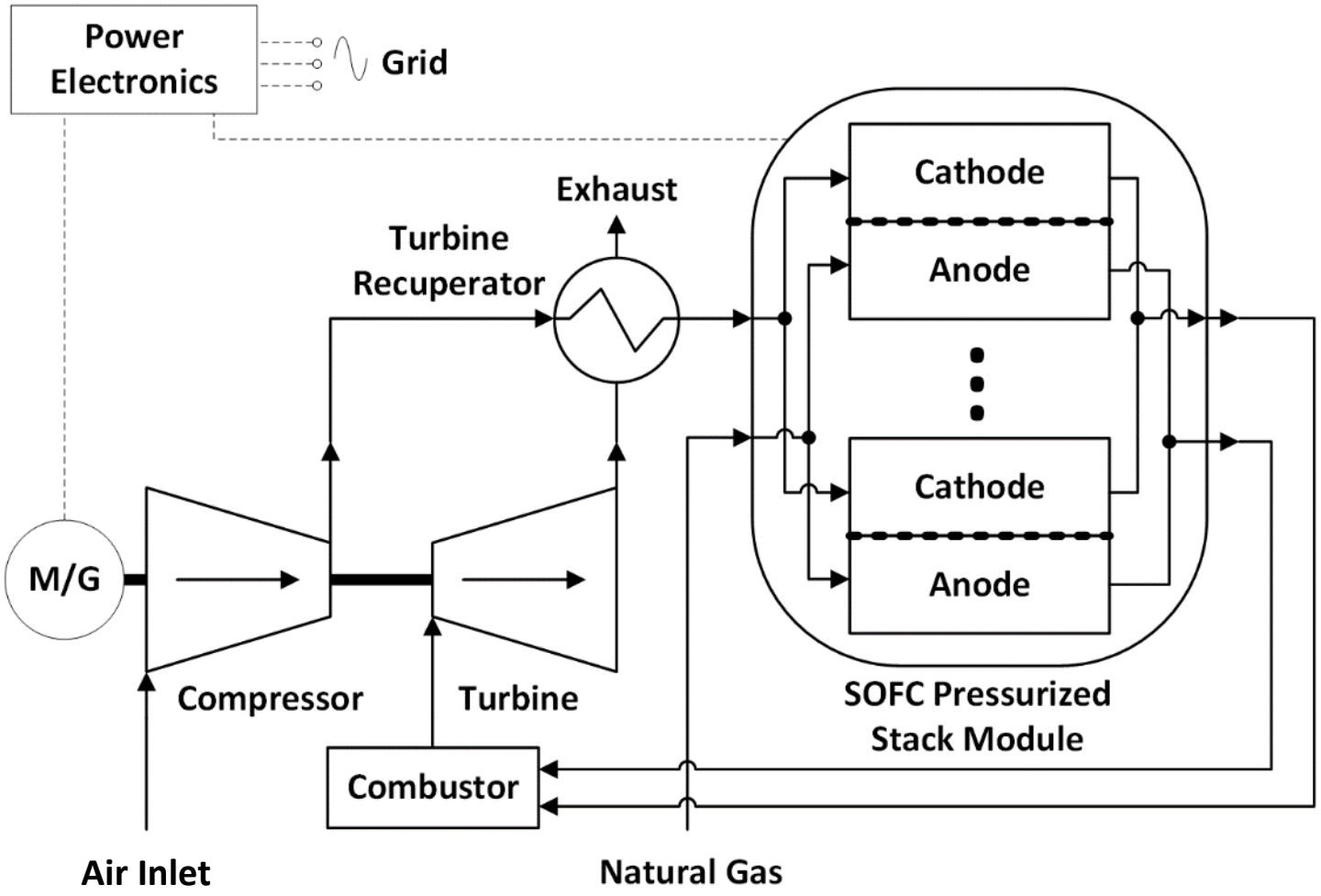
Stationary Microgrids – Key Benefits

- ❑ Resilience
- ❑ Sustainability
- ❑ Energy Independence

Future Project Activities

Status and Future Work

- System design has been completed.
- Pressure vessel and major system components have been ordered.
- Reformer has been designed and currently is being built.
- Turbo-machinery components being designed and built.
- Stack production and system build is planned for Q4-2022.
- Initial system testing planned for Q1-2023.



Acknowledgments

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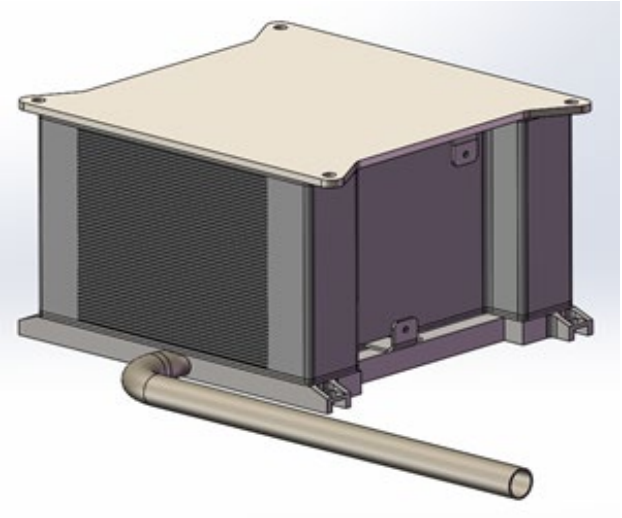

Special thanks to Czero and Brayton, and to my team at Nexceris!

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About Nexceris

- Founded in 1994, privately held
- Based in Lewis Center, Ohio
- People-first culture
- **Products:** Sensors, next generation batteries, and solid oxide fuel cells

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