Durable and Efficient Centrifugal Compressor-Based Filtered Air Management System and Optimized BOP for HD Fuel Cell Applications

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DE-EE0009619

DOE Hydrogen Program
2022 Annual Merit Review and Peer Evaluation Meeting

Project ID # FC351

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Project Goal

- Develop low cost, high reliability air management system components needed in order to minimize heavy duty (HD) fuel cell vehicle operator costs
  - Enable widespread adoption of HD fuel cell vehicles.

Overview

Time and Budget

- Project start date: 5/30/22 (projected)
- Project end date: 8/30/24
- Total project budget: $2,240,672
  - DOE share: $1,760,000
  - Cost share: $480,672
  - DOE funds spent: $0
  - Cost share funds spent: $0

Partners

- Project lead: MAHLE Powertrain
- Partner organizations: BMTS, MAHLE Filter Systems, Oak Ridge National Laboratory
- Industry advisers: GM Global Propulsion Systems, SoCalGas, Adaptive Energy

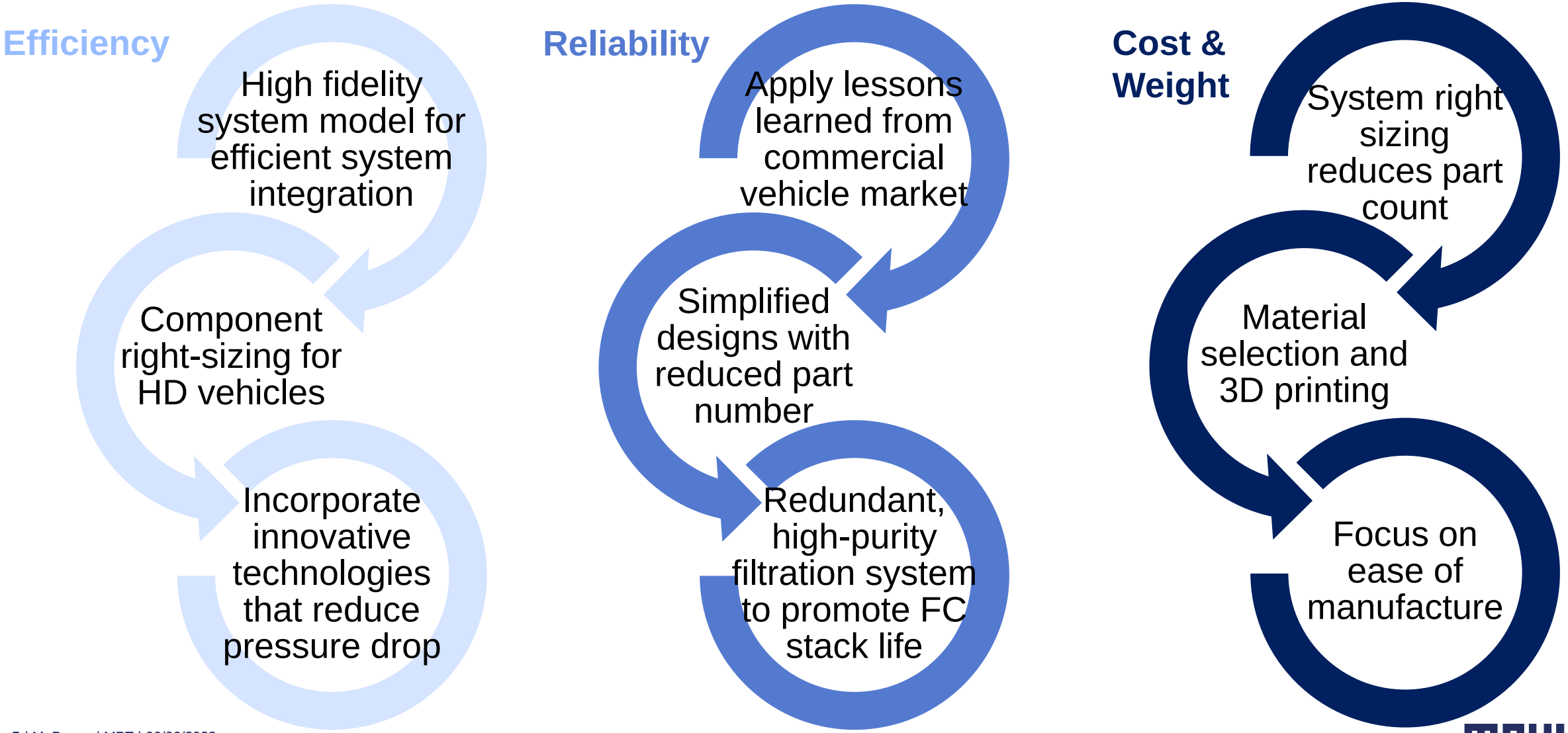
Relevance

- Aerodynamically optimized air compressor using innovative bearing technology and materially optimized expander → achieve HFTO target compressor and expander efficiencies and reliability for Heavy Duty FC Vehicle
  - Promote private sector update of HD FC vehicles
- Primary and secondary filter development targeting improved FC system durability and efficiency
- Component design focusing on ease of manufacturing and packaging space to reduce system cost and weight

Characteristic	Units	HFTO Target	Proposed Approach to Meet Target
Compressor Efficiency @ 100%; 50%; idle flow	%	75; 80; 62	Optimal aero design, higher compressor rotational speed with 3D bearing
Expander Efficiency @ 100%; 50%; idle flow	%	70; 80; 60	Material change, VTG
Durability; Reliability	Hours; MBRC	25,000; 50,000	Apply commercial vehicle lessons learned to turbocharger design, core unit (3D bearing) design with focus on durab
System Cost	$/kW	12	Centrifugal compression w/ 3D bearing - reduced part count, reduced manufacturing costs
System Weight; Volume	kg/kW; L/kW	0.5; 0.25	BMTS compact e-motor, higher compressor rotational speed with 3D bearing

Approach

Holistic HD FC air management system development



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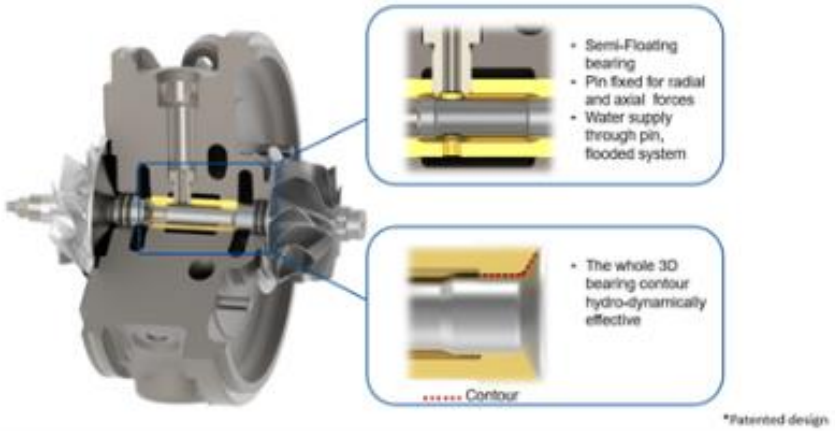
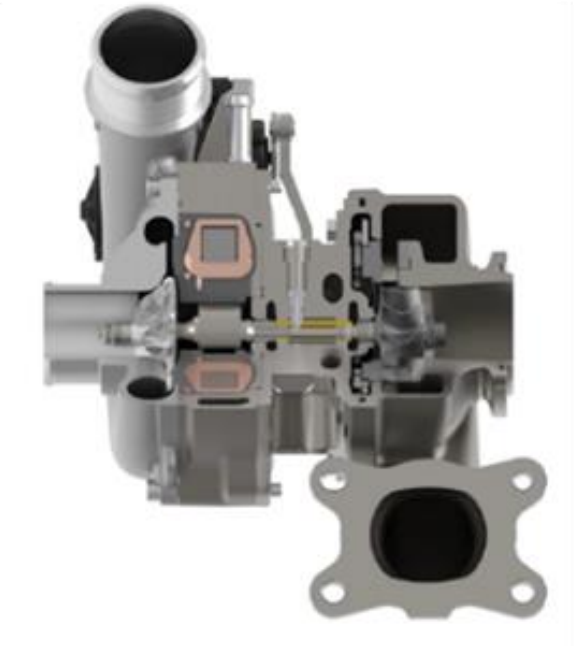
Approach

Air Compression

- Innovative water-lubricated 3D bearing used in single-stage centrifugal compressor
  - No oil lubrication to promote FC stack health
  - Bearing technology allows for tight clearances – improved efficiency and compressor speed capability
- Variable turbine geometry (VGT) with erosion resistant coating used for improved expander efficiency and durability
- Leverages current high-reliability design for automotive sector





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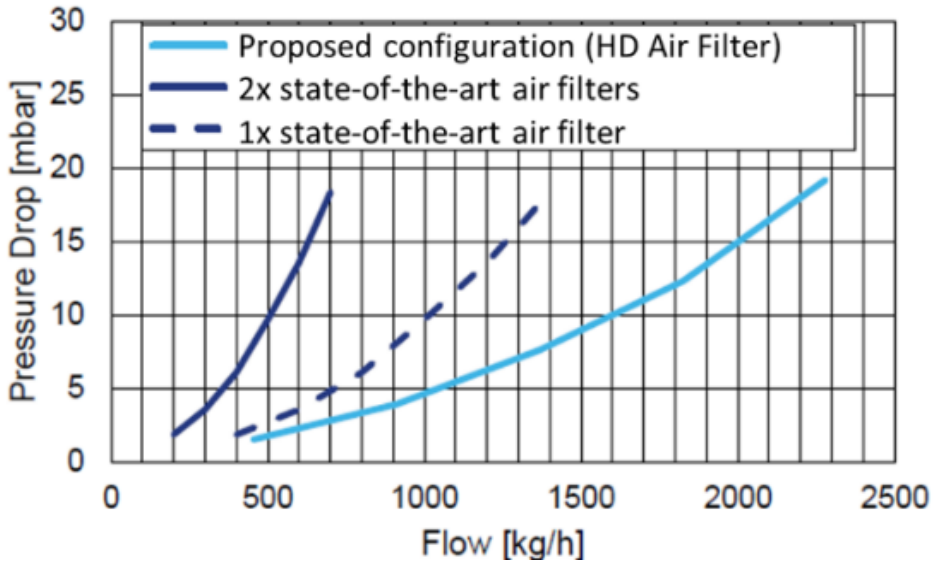
Approach

Air Filtration and Adsorption

- Size-optimized air filter with particle filtration (salt), adsorption (H2S, NOx, etc.) to stay below max allowable concentration for stack
- Innovative filter media
- Right-sizing air filter configuration produces lower pressure drop when compared to state-of-the-art



Air Filter Subsystem Configuration	2x state-of-the-art air filters	1x HD air filter (project scope)
Maximum allowed airflow	320 g/s (2x 160 g/s)	> 285 g/s
Expected pressure loss at 285 g/s	10 mbar	5 mbar

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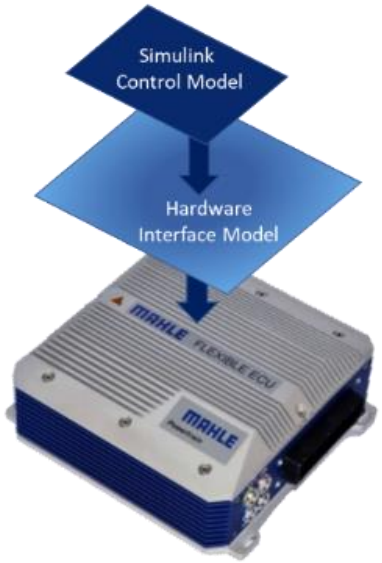
Approach

Low Temperature Catalysis of Intake Air

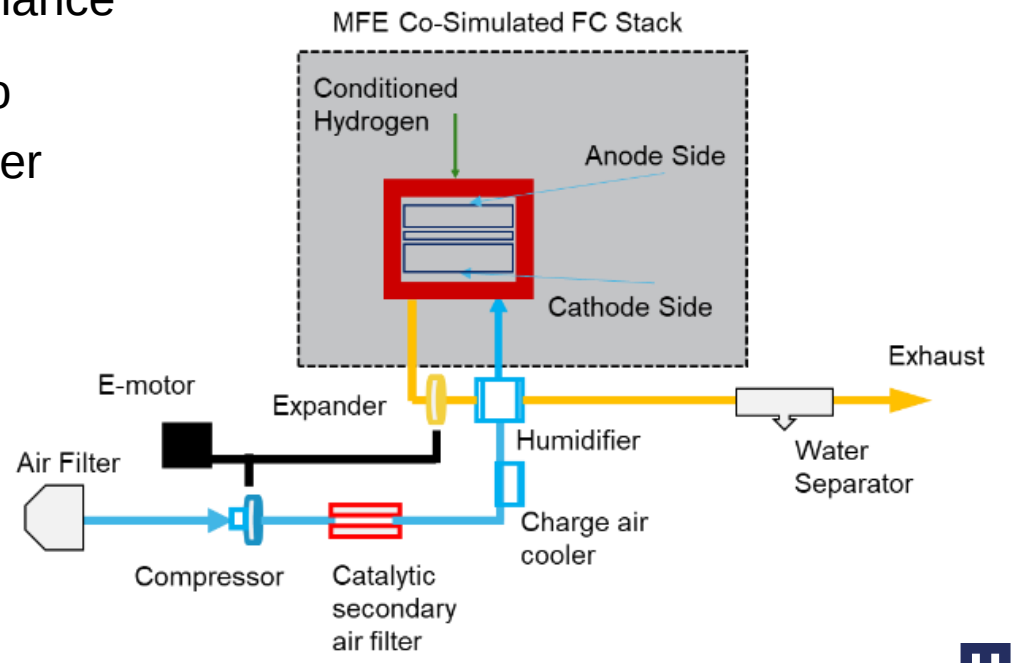
- Development of secondary catalytic air filter to remove >90% of potential cathode poisons
- Based on materials developed for low temperature catalysis (< 200°C)
- Redundant filtration approach for ultra-purity intake air to promote long stack life

Approach



Fuel Cell Control and System Modeling

- Quasi-empirical 1D fuel cell system model incorporating fuel cell stack and balance of plant (BOP)
  - Will be used for optimization of air management components through right-sizing and interface control to ensure system-level performance is consistent with component-level performance
- Controls development using prototyping FC control unit to address catalytic air filter regeneration (if necessary), water management, and air compression system functionality



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Technical Accomplishments and Progress

- This is a new project; as of this writing, the project has not yet begun.

Responses to Reviewer Comments

- This project was not reviewed last year.

Collaborations

Partner			Project Roles
MAHLE Powertrain	MAHLE Powertrain	Industry	*Project lead*; system modeling, control system development, system integration and testing
BMTS TECHNOLOGY	BMTS	Industry	Air compressor and expander design, development, and testing
MAHLE	MAHLE Filter Systems	Industry	Air filter development and testing
OAK RIDGE National Laboratory	ORNL	National Lab	Catalytic filter development and testing
GENERAL MOTORS GLOBAL PROPULSION SYSTEMS	GM Global Propulsion Systems	Industry	*Industry advisor*; HD fuel cell specifications and modeling inputs
SoCalGas	Southern California Gas Company	Industry	*Industry advisor*; Market usage consulting
adaptive energy	Adaptive Energy	Industry	*Industry advisor*; Packaging and weight-reduction inputs

Remaining Challenges and Barriers

- N/A; this project has not started as of this writing.

Proposed Future Work

Remainder of FY 2022

- Project kickoff
- System model construction
- Preliminary component specification
- Component specification refinement based on modeling results
- Interface control

FY 2023

- Component specification finalization
- Component design, procuremet, and initial testing
- System performance projection
- Controls system development

Any proposed future work is subject to change based on funding levels.

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Summary

- Development of low cost, high efficiency, high reliability air management system for HD fuel cell vehicles
- System efficiency improvement through modeling-based holistic design approach, intelligent controls, and proposed innovative air compression technology
- Redundant filtration system targeting high efficacy over a wide operating range to improve fuel cell stack durability
- System cost and weight reduction through component designs with a focus on ease of manufacture and reduced number of parts

Technical Backup and Additional Information

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Technology Transfer Activities

- Technology Transfer activities have not yet begun as this is a new project.

- Future plans: acquiring a fuel cell stack from a stack supplier as a platform for final subsystem demonstration
  - In discussion with several suppliers and potential sponsors