

Compact Additively Manufactured Innovative Electric Motor

Overview/Description

New manufacturing methods are needed to enable innovative electric motor designs that have much higher power densities and/or efficiencies compared to the current state-of-the-art. Additive manufacturing (AM) offers the potential to radically change motor designs so that they have compact designs, multi-material components, innovative cooling, and optimally designed and manufactured components.

Relevant Applications for the Motor Class



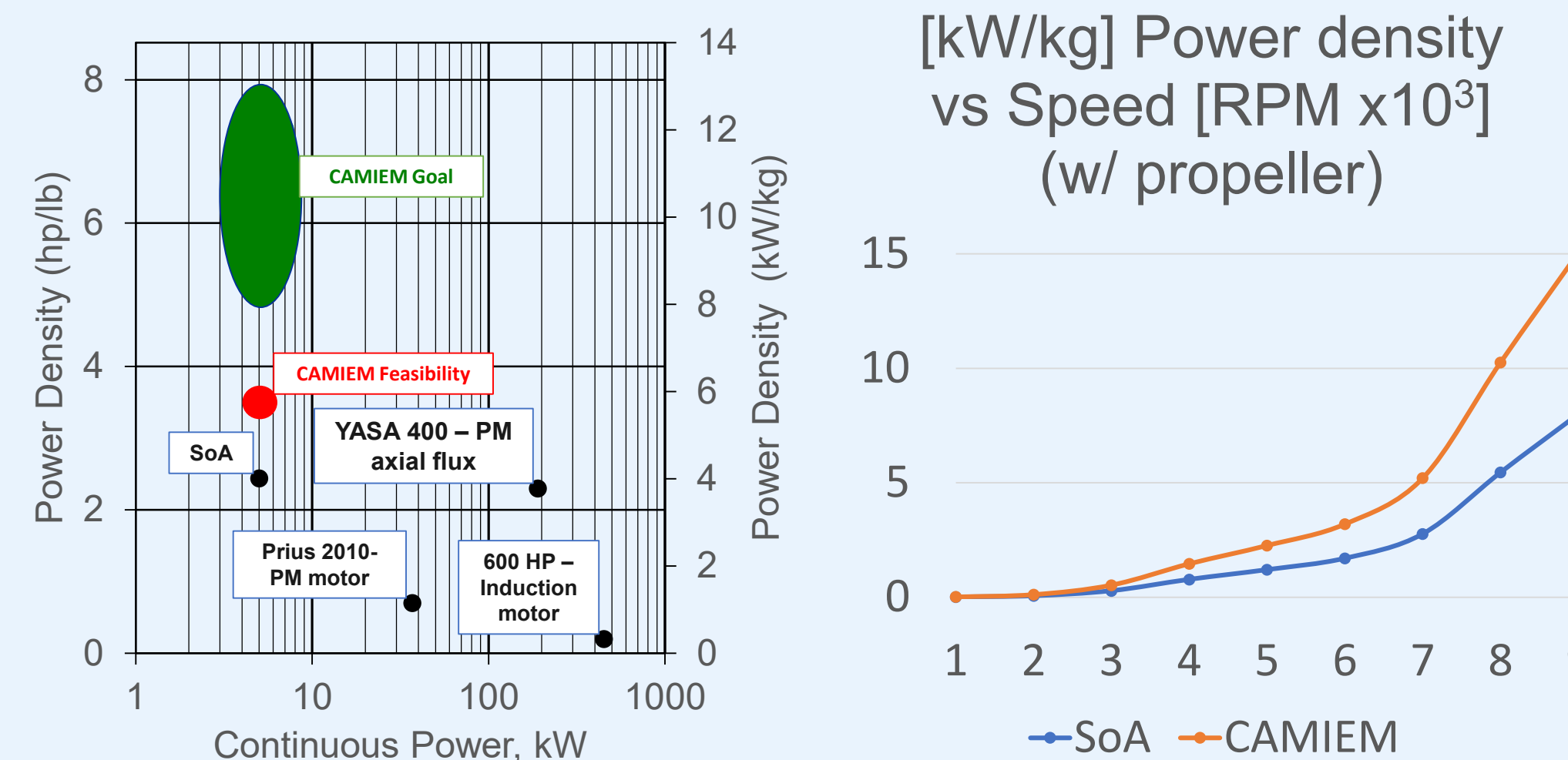
Urban Air Mobility



NASA 15 Passenger Tilt-wing

Feasibility Assessment

- For a 3x improvement in power density, system studies by Georgia Tech project a 28% reduction in gross vehicle weight and a 24% reduction in mission energy for the NASA 15 Passenger Tilt-Wing.
- Evaluate the feasibility to additively manufacture motor components towards achieving benefits of more compact, lightweight, efficient, and power dense motors.
- Assess new motor topologies and design concepts enabled by the additive manufacturing process against baseline motor to achieve higher power densities over the State of the Art (SoA).



Partners

- NASA GRC / Additive manufacturing of high performance stators. PI/POC: Michael Halbig
- NASA LaRC / Additive manufacturing of structural motor components. POCs: Dr. Samuel Hocker & Christopher Stelter
- NASA AFRC / Electric motor ground test. POC: Ethan Nieman
- LaunchPoint Technologies / Baseline electric motor; Innovative electric motor designs. POC: Mike Ricci
- University of Texas El Paso / Advanced manufacturing, winding & embedding of a litz wire stator. POC: Dr. David Espalin

Recent Results / Status

- Two baseline motors were re-configured using AM design structural components for CAMIEM-v1 and CAMIEM-v2.
- CAMIEM-v1 had a mass savings of 7% and was propeller tested at AFRC, demonstrating feasibility.
- Multi-physics models were used to evaluate the potential impact for additively enabled designs for stators and thermal management components.
- A fully integrated motor configuration with AM components is projected to increase power by 2x, power density by 1.8, and torque density by 2x.

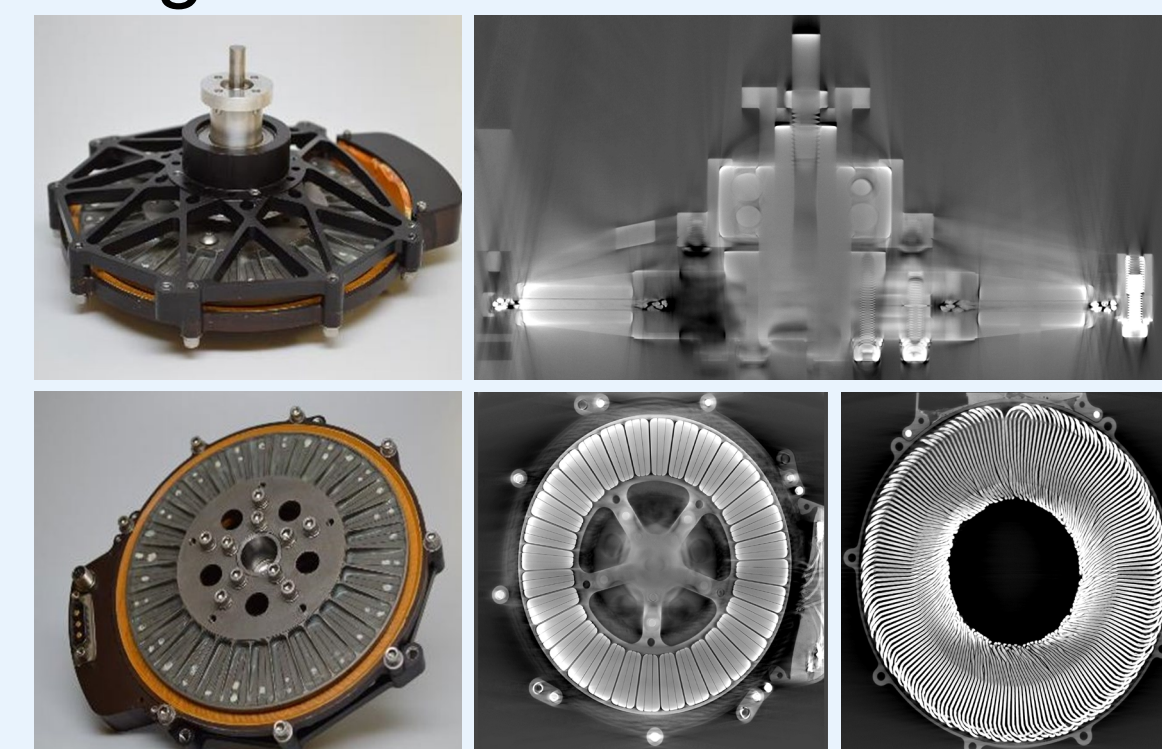
Next Steps

- Complete experimental validation of the CAMIEM-v2.
- R&D of relevant additively manufactured structural, thermal management, and stator components.
- R&D of materials tailored for additive manufacturing.

Publications

2019. Additive Manufacturing for Achieving Innovative Electric Motor Designs. Michael C. Halbig. Conference Presentation. 43rd International Conference on Advanced Ceramics & Composites. Daytona Beach, Florida. January 27-February 1, 2019
2019. Binder Jet Additive Manufacturing of Soft Magnetic Materials for Aircraft Electric Propulsion Systems. Daniel Oropeza, Steven M. Geng, Michael C. Halbig, A. John Hart, Mrityunjay Singh. Conference Presentation. 43rd International Conference on Advanced Ceramics & Composites. Daytona Beach, Florida. January 27-February 1, 2019
2019. Additive Manufacturing for Aerospace Applications. Michael C. Halbig and Mrityunjay Singh. Conference Presentation. 43rd International Conference on Advanced Ceramics & Composites. Daytona Beach, Florida. January 27-February 1, 2019
2019. Evaluation of Conductive Silver Coils in Additively Manufactured Axial Flux Electric Motors. Hunter Leonard, Anton Salem, Michael C. Halbig, Mrityunjay Singh. Conference Presentation. 43rd International Conference on Advanced Ceramics & Composites. Daytona Beach, Florida. January 27-February 1, 2019
2019. Direct Writing of Conductive Silver Pastes for Electric Motor Applications. Anton Salem, Hunter Leonard, Valerie Wiesner, Michael C. Halbig, Mrityunjay Singh. Conference Presentation. 43rd International Conference on Advanced Ceramics & Composites. Daytona Beach, Florida. January 27-February 1, 2019
2019. Electrical and Thermal Characterization of 3D Printed Thermoplastic Parts With Embedded Wires for High Current-Carrying Applications. KMM Billah, JL Coronel, MC Halbig, RB Wicker, D Espalin. Paper. IEEE Access 7, 18799-18810. 43496
2019. Additive Manufacturing Enabled Innovative Materials and Structures for Aerospace Applications. Michael C. Halbig and Mrityunjay Singh. Conference Presentation. 2nd Global Forum on Advanced Materials and Technologies for Sustainable Development (GFAMAT-2). Toronto, Canada. July 21-26, 2019
2019. Post-Processing AM-made Rotorplates for Axial Flux Permanent Magnet Motors: Successes and Challenges. Samuel Hocker and Christopher Stelter. Conference Presentation. "Materials Science & Technology". Portland, OR. 29-Oct. 3, 2019
2019. Additive Manufacturing of Multi-Material Systems for Aerospace Applications. Michael C. Halbig and Mrityunjay Singh. Conference Presentation. "Materials Science & Technology". Portland, OR. 29-Oct. 3, 2019

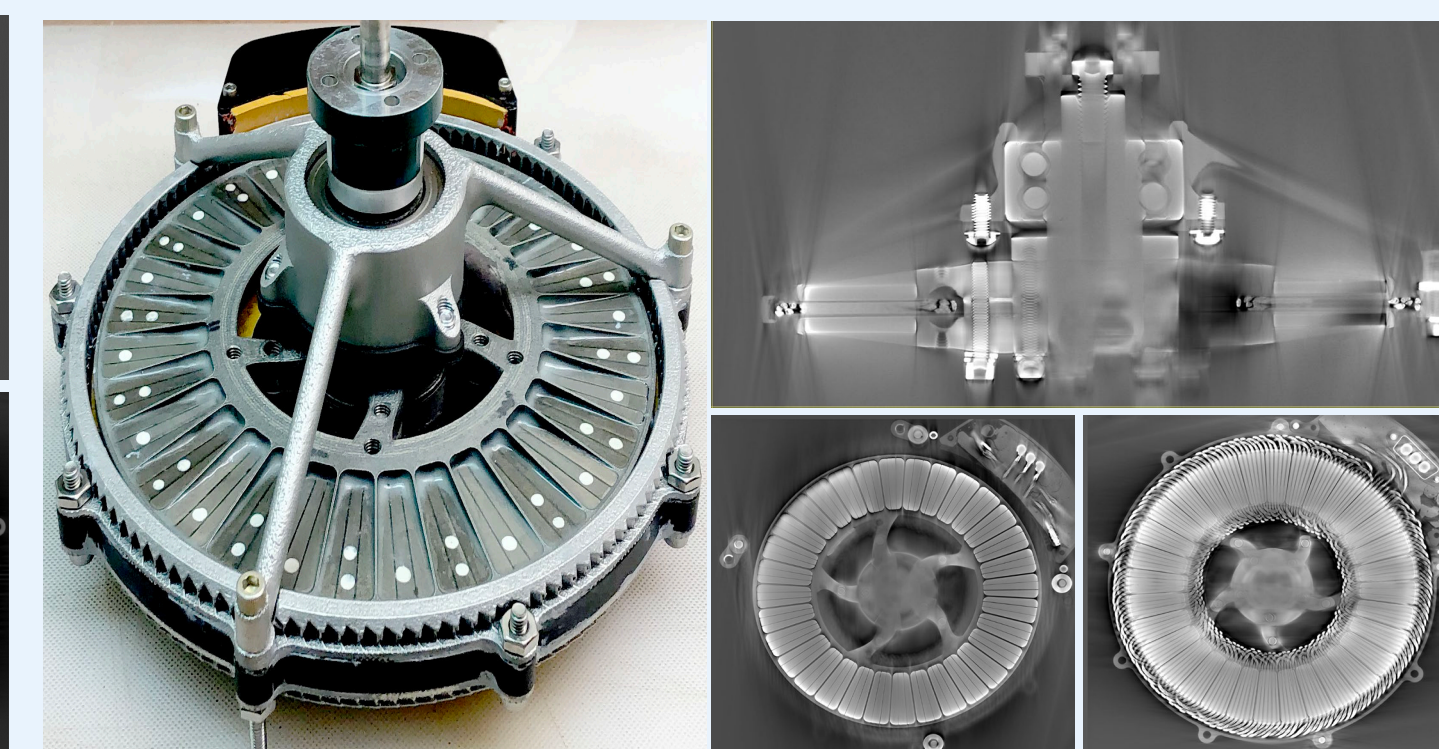
SoA Axial Flux Permanent Magnet Motor



Axial Flux with Halbach Arrays of Magnets

- Mass = 1968 g
- Motor Constant ~24 V/rpm

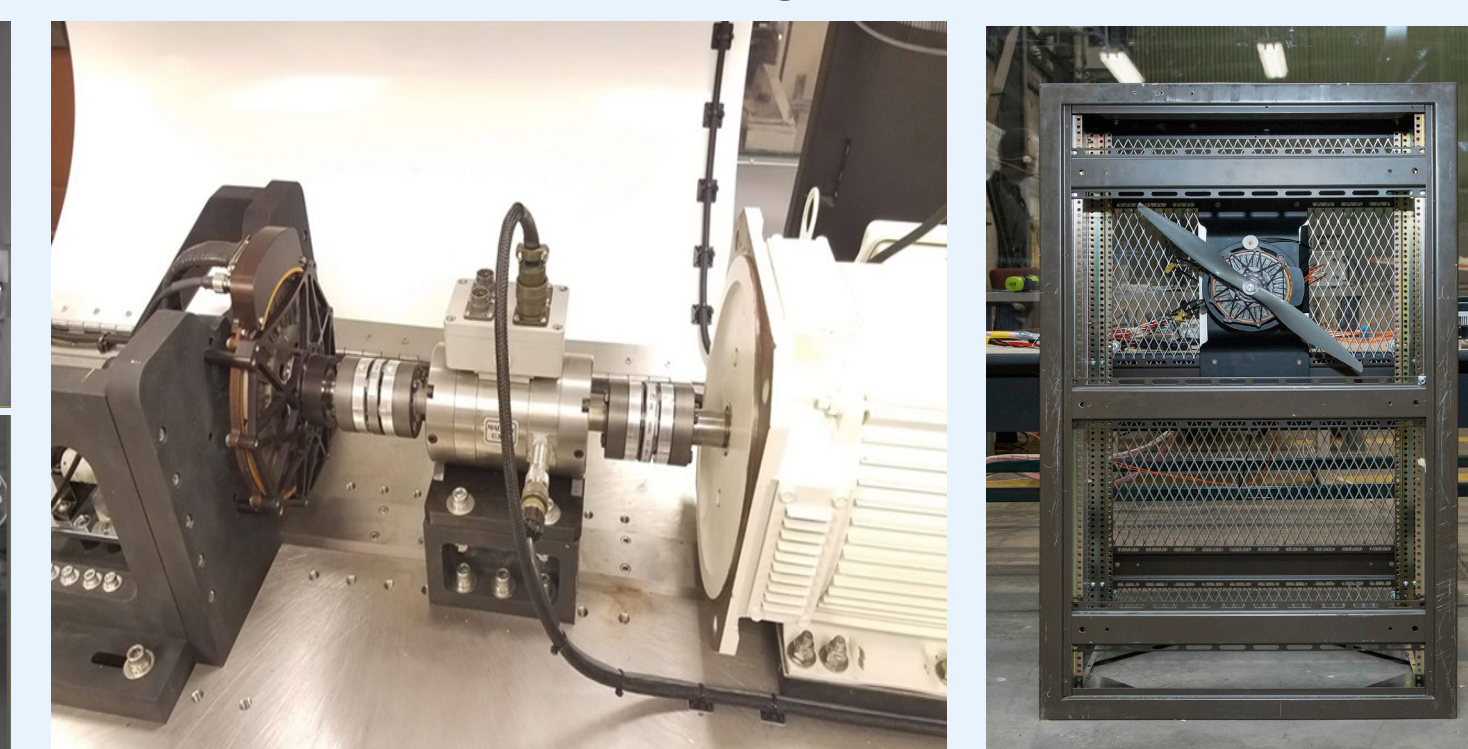
"CAMIEM-v2"



AM rotors, 3 leg housing, and finned stator cooling ring

- Mass = 1870 g (5% less mass)
- Motor Constant ~35 V/rpm

NASA Motor Testing Capabilities



Dynamometer

Propeller Test Stand

