A1.06  Vertical Lift Technology for Urban Air Mobility -Electric Motor Fault Mitigation Technology

Lead Center: GRC
Participating Center(s): AFRC, ARC, LaRC

Scope Title
Electric Vertical Takeoff and Landing (eVTOL) Electric Motor Fault Mitigation Technologies

Scope Description
The expanding Urban Air Mobility (UAM) vehicle industry has generated a significant level of enthusiasm among aviation designers and manufacturers, resulting in numerous vehicle configurations. Most of the prototype UAM vehicles have more than 4 rotors or propellers, have electric propulsion, carry 2 to 6 passengers, fly more like a helicopter (vertical take-off and landing) than a fixed-wing aircraft and will fly relatively close to the ground and near buildings. There are many technical challenges facing industry’s development of safe, quiet, reliable, affordable, comfortable, and certifiable UAM vehicles and vehicle operations. One of those challenges is the subject of this SBIR subtopic, namely, safe, and reliable operation of electric motors (100- to 200-kW class) for eVTOL vehicles to accomplish UAM mission (numerous daily operations; hover-cruise-hover loading cycle) [Ref. 1].

[Megawatt electric propulsion systems for CTOL transport aircraft is addressed in the A1.04 Electrified Aircraft Propulsion subtopic.]

The application of the requested technologies should be relevant to the NASA Revolutionary Vertical Lift Technology (RVLT) Project’s reference concept vehicles [Refs. 2-3], which embody the key vehicle characteristics of the UAM vehicle configurations being designed throughout industry. Technologies proposed for this solicitation should be relevant to 100-kW-class motor-rotor powertrain elements with scalability in the 20- to 500-kW class. Due to the power levels envisioned for UAM vehicles, most will require high-voltage (>540 V) bus operation, with the corresponding high-voltage direct current (DC) protection devices to ensure safe systems [Ref. 4].

Through this solicitation, NASA is seeking advanced technologies supporting electric/hybrid-electric propulsion for the advance air mobility and specifically the UAM mission (concept of operations) in the areas of:

- Electric Machine/Motor Fault Detection and Fault Mitigation: This solicitation is seeking technology advancements that will address the fault detection and fault mitigation for electric machines used in eVTOL vehicle propulsion systems. There are several key faults that are typical for electric machines: electrical, mechanical, and magnetic. Through this Small Business Innovative Research (SBIR) solicitation, technologies are being sought that would preclude common electric machine faults and/or detect and mitigate the faults to ensure safe vehicle operations. Technologies targeting the mitigation of turn-to-turn and turn-to-ground stator short circuit faults in a permanent magnet aircraft generator and/or motor are of especially high interest. Technologies are sought that either allow a motor/generator to continue operating
in the event of a stator short circuit or enable quick shut down of the motor/generator before the fault enters a thermal runaway condition.

- **Electric Motor Performance Improvement Technology: Single Fluid Motor with High Power Density and High Reliability:** Novel and innovative efforts are sought to develop high-performance electric drive motors that utilize a fluid as both the motor coolant and bearing lubricant. Vertical lift propulsion using electric motors to drive rotors and/or propellers offer the potential for lightweight and high efficiency partly through the elimination of ancillary systems found on conventional aircraft. Amongst these systems are hydraulic fluids and lubricating oils. For example, a direct-drive electric motor or those that utilize noncontact magnetic gearing (i.e., flux modulation machines) [Refs. 5-9] could function without lubricating oil provided their bearings could operate solely using the water-based coolants used for motor thermal management. Conventional steel-based ball and roller bearings are susceptible to corrosion and wear when operated using water. NASA has developed newly emerging NiTi (nickel-titanium) alloy bearings [Refs. 10-11] that are impervious to corrosion and have been shown to operate reliably when immersed in water. While a single-fluid electric motor utilizing oil could be conceived, the high viscosity of oils and their low heat capacity tend to limit electric motor power density. It is further recognized that magnetic, electrical, and rotordynamic characteristics of such machines are critical to success and are influenced by material selections. The use of emerging bearing material technologies, such as NiTi and ceramics, for bearings to operate well using a single fluid (such as water, water-based with additives, or appropriate dielectric fluid) [Refs. 12-13] could provide needed tribological, thermal, and electrical performance while achieving power density and reliability comparable to existing conventional designs. However, proposers will need to consider and address several considerations including bearing wear, bearing fatigue, strategy for robustness to debris carried by the fluid stream (including debris arising from bearing fatigue or wear), and bearing stiffness as these will influence the rotor-shaft-bearing subsystem. This topic specifically seeks electric motors using liquid-lubricated bearings. Electric motor concepts using grease-lubricated bearings are not within the scope of this topic.

**Expected TRL or TRL Range at completion of the Project**

2 to 4

**Primary Technology Taxonomy**

**Level 1**

TX 01 Propulsion Systems

**Level 2**

TX 01.3 Aero Propulsion

**Desired Deliverables of Phase I and Phase II**

- Analysis
- Research
- Prototype

**Desired Deliverables Description**

Phase I of the SBIR should develop design concepts for specific technology advancements supported by analytical studies including modeling and simulation. Phase I effort should establish Phase II goals and should quantify projections of technology performance in the detection and mitigation of motor faults.

Phase II of the SBIR should further develop the designs and validate achievement of goals through additional analysis, modeling, and simulation and through system/component functionality experiments. Phase II incorporates experiments with aircraft relevant hardware available commercially or through partnership with an aircraft component supplier and modified with innovative technology from this SBIR effort.

**State of the Art and Critical Gaps**
There are over 200 UAM vehicle concepts in varying stages of development. The immediate focus of the vehicle developers is overcoming obstacles on the path to certification. The public has experience flying in large transport and regional fixed-wing aircraft and are calibrated to associated safety levels for commercial air transportation. Detailed certification requirements for UAM vehicles are still under development by the relevant certifying authorities. For UAM aircraft, research is needed that addresses safety and reliability expectations of the traveling public and certifying authorities for the UAM mission. The concepts of operations for the UAM mission consists of numerous flights per day with power system/powertrain loading associated with vertical flight (hover) and forward flight for each flight. This concept of operations establish unique safety and reliability challenges for the power system/powertrain. Technology advancements are required to achieve these challenges.

Relevance / Science Traceability

This subtopic is relevant to the Aeronautics Research Mission Directorate (ARMD) Revolutionary Vertical Lift Technology (RVLT) Project under the Advanced Air Vehicle Program. The goal of the RVLT Project is to develop and validate tools, technologies, and concepts to overcome key barriers for vertical lift vehicles. The project scope encompasses technologies that address noise, speed, mobility, payload, efficiency, environment, and safety for both conventional and nonconventional vertical lift configurations. This subtopic directly aligns with the mission goals and scope in addressing safety and reliability of nonconventional vertical lift configurations. RVLT along with other ARMD projects are pursuing technologies, tools, and research that will enable new aviation markets to address the operational and vehicle requirements for the advance air mobility missions and specifically the UAM (air taxi) mission for VTOL vehicles.

References
