NASA SBIR 2021 Phase I Solicitation

A1.06 Vertical Lift Technology and Urban Air Mobility

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

Scope Title: Electric Vertical Takeoff and Landing (eVTOL) Electric Propulsion Safety and Reliability

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. The majority 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 takeoff 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, safety and reliability of the electric power system and electric powertrain for these UAM/eVTOL vehicles.

This solicitation is seeking advancements in technologies that will improve the safety and reliability of the electrical power system/powertrain of UAM vehicles. There are three areas of main interest for this solicitation focused on the safety and reliability of the electrical power/powertrain system: (1) prognostic and diagnostic technologies for electric motors, (2) fault protection of high-voltage power system, and (3) advancements in thermal management technologies for electric motor systems. Based on industrial motor research and field data, use of continuous monitoring of conditions, such as temperature and vibration, can reduce the failure rate of motors by about two-thirds [Ref. 1]. This conclusion is based on data from large motors, but the physics of aviation motor degradation may be similar and future service experience may produce a similar overall trend. Due to the power levels envisioned for UAM vehicles, most will require high voltage (>540 V) operation, with the corresponding high-voltage direct current (DC) protection devices to ensure safe systems [Ref. 2]. Advancements in thermal management technologies, noted below, are also of interest given that temperature influences the overall safety and reliability of the power/powertrain system.

The application of the requested technologies should be relevant to the NASA Revolutionary Vertical Lift Technology (RVLT) project's reference concept vehicles [Refs. 3-4], 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.

Through this solicitation, NASA is seeking advanced technologies supporting UAM electric/hybrid-electric propulsion in the areas of:
Prognostic/diagnostic technologies: Operational performance diagnostics and prognostics technologies for electric motors and motor controllers to improve life and reliability of the system and reduce unscheduled maintenance for improved affordability. Technologies of interest related to motors/motor controllers include novel sensor and/or sensing technologies, data analysis algorithms, and methods to classify, fuse, or otherwise combine multiple sources of information for diagnostics, prognostics, and remaining useful life assessments. Proposers should consider the anticipated vehicle usage that will require differing motor power requirements for different phases of likely UAM flight profiles and maneuvers (power transients). The proposers should quantify any additional mass and/or power required (for example, mass of any additional sensors and associated cabling). Solutions that add minimal or no extra mass are of higher value and interest. The topic scope for the operational performance diagnostics and prognostics technologies is limited to the powertrain, motor controllers, and associated supporting systems for lubrication and cooling. The scope does not include batteries, fuel cells, fuel burning engines, avionics, communications equipment, or airframe structures.

High-voltage protection devices: The high voltages expected in these systems will require properly rated protection devices. These do not currently exist for aeronautics-rated applications. While DC and alternating current (AC) architectures are both under consideration by designers, the focus here is on DC systems as these are the first being investigated by NASA. For this call, advanced technology high-voltage protection devices proposed should be applicable for systems with these characteristics: Voltage of 540 to 1,000 V, 100 to 200 A continuous operation with <5 msec clearing time. Other aspects of interest are current-limiting capability, high efficiency, and high reliability.

Thermal management technologies: Lightweight, durable, and efficient thermal management solutions for 100 kW continuous-class electric motors are sought. Preferable are solution technologies that could be scaled and applied to aviation motors in a continuous power range of 20 to 500 kW. The most prevalent motor topology proposed and studied for this application are the permanent magnet motor family. Both passive and active approaches for thermal management may be applicable. Examples of technologies sought include integrated channels in rotor components, integrated heat pipes, and solutions enabled by additive manufacturing. Intended outcomes are effective and invasive solutions for motor rotors and windings with minimal mass and efficiency penalty. Solutions that demonstrate an improvement in reliability of the cooling system will be given extra consideration. Proposals should address the continuous motor specific power enabled by the innovations and the associated mass and efficiency penalties.

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 that address safety and reliability supported by analytical studies including modeling and simulation. Phase I effort should establish Phase II goals and should quantify projections of improvements to safety, reliability, and unscheduled maintenance assuming success of Phase II goals.

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 aircraft 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.

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.

References: