Summary description of the project context and the main objectives.

The more-electric aircraft will require higher performance and more compact electric actuators (motors) which will run hotter putting severe limitations on their operation. Today's objective of the aircraft industry is to push up the temperature limit.

The context of this project is *Propellers electrical de-icing system: reliability assessment of key technologies for high temperature electrical machines* .It is a part of the SAGE2 Demonstration Project aims at designing, manufacturing & testing a Counter-Rotating Open-Rotor Demonstrator. It involves most of the best European Engine & Engine Modules & Subsystems Manufacturers.
The SAGE2 Demonstrator incorporates two counter-rotating propellers, which should be deiced. An electrical deicing system is studied to supply and transfer the power necessary to the deicing. For this system several type of electrical machines are considered. High reliability of such machines in a harsh environment (high temperature) is a key target for the project.
The activities of this topic concern the assessment of reliability of materials and windings for high temperature electrical machines through tests campaigns.

The project objective is to evaluate the reliability of motor winding technologies able to work at high temperatures. To achieve this goal within the time define in the Clean Sky call sheet, it is necessary to rely on existing technologies, which offer opportunities for rapid implementations on conventional machines, while opening new opportunities towards higher temperatures with innovative technologies.

This project analyses existing insulation options and advances the state of the art of high temperature electrical motor windings. All this work is new because the objective is to push up the temperature limit. There are some initial studies on ceramic wire coatings which are very promising technologies.
However, the base material of the windings must be specified and the general mechanical characteristics of the insulated wires, required for various coil geometries, needs to be investigated.

Three sets of technologies have been studied:
- The technologies based on enameled wires associated to polymer impregnation varnishes.
- Technologies based on wires wrapped with glass fibber associated to impregnations made with epoxy resins.
- The insulation technologies based on ceramics, which offer potential prospects for very high temperatures.

The three sets of technologies have been tested for increasing temperatures on representative test vehicles (twisted pairs and motorette) involving measurement systems able to get the main parameters of the insulation system (DC and AC leakage currents, partial discharge inception voltage, breakdown voltage,…). The analysis of changes in recorded parameters during the test campaigns estimated the maximum permissible temperature in the heart of the winding for each technology. These data, combined with constraints of implementation of each technology defined recommendations for the design of electrical machines able to operate at high temperatures for each selected technology.

The part relating to the use of ceramic insulations opens the way to a major technological leap. With such materials, the maximum operating temperature of electrical machines are no longer imposed by the winding insulation system but by other parts (magnetic or mechanical), consequently new design methods will have to be developed. It is therefore important to put this new approach against the best we might obtain from other technologies by proposing solutions applicable in the short term.

This project reinforces European competitiveness in the field windings of electric motors. It also provide some information about the applicability of ceramic windings. Also, the project provide material and process data useful for motor health monitoring.

In the short term, this study will help the design electrical machinery of conventional construction, able of overcoming the current thermal limits. The recommendations for machine design give a range of technological solutions based on the desired maximum temperature. For a temperature range higher than another, some additional constraints appear. This study helps to make sound choices leading to the construction of a reliable machine in the context of severe application for example in the core of an open rotor where the temperature and mechanical stress are important. In the longer term, ceramics insulated windings will produce insulation systems able of withstanding temperatures until the Curie point of magnetic steel. When these coils will be developed, it will be possible to design radically different electrical machines able of operating in hot atmospheres. At room temperature, this solution will increase the temperature difference between hot spots and cold ones that can greatly increase the current densities, therefore the specific power. However this study had showed that this wires aren't yet optimized for winding. Magnet wire with ceramic insulation needs to be improved particularly on their breakdown voltage and reducing the radius of curvature too restrictive for winding applications