

a) SAGE - Sustainable and Green Engines

The SAGE1 (Geared Open Rotor Demonstrator) project will continue to progress on development of key technologies required for technology demonstration, such as CROR aero and noise methods and prediction tool sets. High Speed CROR next generation blade tests will be carried out under SAGE1 complemented by Low Speed testing under the SFWA ITD, to establish a validated basis for later confirmation of technology feasibility, able to achieve defined CO<sub>2</sub> and Noise reduction goals. Effort on design, development and manufacturing of complex lightweight rotating structures will continue in 2011, mainly related to manufacturing processes. Enabling technology definition such as a new booster required for the demonstrator engine will be further progressed.

In addition, work will be performed in the fields of aircraft safety and certification feasibility, aerodynamics, acoustics and physical design, to establish understanding of technology implications on potential future product design and feasibility. Co-operation with the SFWA ITD regarding the feasibility and integration of the demonstrator with a flying test bed will continue. The feasibility and first top level concept of new associated new technology demonstrator engine control and its integration with an existing flight test aircraft will be evaluated.

To mitigate the risk that the mid-2012 review will not support the demonstration feasibility, preparatory work on an alternative demonstrator will be developed in parallel with continuing open rotor work. The alternative technology will be a lean burn combustion system with potential to significantly contribute to reduction of NO<sub>x</sub> emissions. The intended total scope of the project would be to demonstrate the functionality and operability of the new technology as an integrated system and to raise the lean burn system to TRL6. This highly complex and integrated system includes combustor, fuel distribution and control system, engine control system and engine heat management system.

The SAGE2 (Geared Open Rotor Demonstrator) project will be in the feasibility phase through 2011, the 2010 activities having been dedicated to comparison between Direct Drive Open Rotor and Geared Open Rotor configurations. The fuel consumption benefit of the geared configuration has been established leading to re-direct the SAGE 2 activities on this configuration. Preliminary design phase will commence in the second half of 2012.

The major areas of Demonstrator design focus will be the Propellers, the Pitch Control System, the front and rear rotating structures, the Nacelle rotating parts, the Power Gear-Box, the Lubrication & Cooling System & Equipment & the Control, Protection & Monitoring System & Equipment. Feasibility Phase Design Review is scheduled for end 2011.

The SAGE3 (Large 3-shaft Demonstrator) project will be in the preliminary design phase throughout 2011, having completed outline concept definition during 2010. Specific technologies for the first build of the engine demonstrator and for the intercase will transition from preliminary design to detail design during 2011, while technologies to be demonstrated on later builds will continue to develop from concepts into preliminary designs.

Partners for the intake liner, composite pipes and high temperature printed circuit board technologies will be selected through Call for Proposal and the designs and manufacturing plans progressed through 2011. This work will include impact analysis iterations between the Partners and Members to achieve an integrated design and material selection that is optimised

in conjunction with the manufacturing system. The technologies to be integrated into the engine demonstrator require detail analysis and modelling work to fully understand the potential impact of inserting these technologies into an architecture not originally designed for the new hardware. This work is planned to be conducted during 2011. In parallel, the SAGE3 project will be developing the demonstrator vehicle, test programme and facilities. Reviews for first build of the engine demonstrator are planned for September 2011 and preliminary design reviews will be held for technologies, including the low pressure turbine, to be demonstrated on later builds. Rig testing of the intercase features will commence during 2011.

In SAGE4, on Full Geared Turbofan demonstrator level concept optimisation results will freeze the demonstrator concept and lead in 2012 into pre- and detail design activities with the relevant milestones. This work will be accompanied by the same level of activity on a module level for the High Pressure Compressor, High Speed LPT, Fan Drive Gear System, Mid Turbine Frame and Turbine Exhaust Case. Detail design for other engine modules (engine modifications) are planned at the same time. Test stand preparation and adaptation work will ensure to support demonstrator testing later in the program. Components and modules development will be facilitated by rig testing in 2012 in order to minimise the risk at full demo testing.

In SAGE5, the pre-detailed design will be completed with the issuance of all technical specifications for turboshaft engine parts. The demonstrator will go on with detailed design study in order to hold the Critical Design review mid 2011. This work will be accompanied by the raw parts supply and the preparation of industrialisation of engine parts. In addition, the demonstrator engine test plan will be finalised, the test bench specific parts will be studied (such as electrical harnesses, engine to bench interfaces, etc.) Moreover, to prepare the engine test campaign, the demonstrator engine instrumentation detailed study will start. In parallel with the engine components, the rig test module will be manufactured and assembled in order to start test by last quarter of 2011 in order to minimise the risk at full demo testing.