Publishable summary

The SAGE ITD is made up of 6 Projects:

- SAGE1: Geared CROR technology acquisition,
- SAGE2: CROR demonstration on ground,
- SAGE3: 3-shaft Turbo-fan demonstration on ground,
- SAGE4: Geared Turbo-fan demonstration on ground,
- SAGE5: Turbo-shaft demonstration on ground,
- SAGE6: Lean Burn demonstration on ground.

Each Engine demonstration is similarly phased: (1) design (conceptual, preliminary, detailed), (2) manufacturing & assembly, (3) test.
SAGE1, 2, 3 & 4 conceptual design activities were carried out in 2008 & 2009 while SAGE5 started in 2009 by carrying out directly preliminary design activities. 2012 saw the introduction of SAGE 6 Lean Burn Demonstrator
Logically & consistently with the Projects time schedules, the Projects objectives for year 2013 were set as follows:

- For SAGE1: to continue to develop Geared Open Rotor Technology for a possible demonstrator engine outside the timeframe of CLEANSKY. This is based on the work performed under SAGE1 and SFWA,
- For SAGE2: to deliver and ground test a demonstrator and, on the basis of prediction and test data obtained from the engine, to assess the improvements in gaseous and noise emissions that may result from a production open rotor propulsion system,
- For SAGE3: to deliver and test a demonstrator engine and to assess the improvements in gaseous and noise emissions that may result from incorporating the technologies in a production engine,
- For SAGE4: to finalize Demonstrator conceptual design activities & to carry out Demonstrator preliminary design activities,
- For SAGE5: to deliver and test turboshaft engine and, on the basis of prediction and test data obtained from the engine, to assess the improvements in gaseous and noise emissions that may result from incorporating the technologies in a production engine.
- For SAGE6: to demonstrate the lean burn whole engine system to a TRL6 maturity level, suitable for incorporation into civil aerospace applications in the 30,000lb to 100,000+ thrust classes.

A separate work package, called SAGE0, is responsible for the management of the SAGE ITD. In addition to the planning & coordination activities, the organisation of the Annual and Intermediate SAGE Reviews in 2013 was set as a goal for SAGE0.

SAGE1 – Geared Open Rotor Technology Acquisition (led by Rolls-Royce)

There has been progress made during the first half of 2013 prior to the Go / No Go decision in SFWA ITD. Extensive work has been performed together with Airbus to prepare for the Z08 full aircraft model testing under SFWA in DNW in January this year. Rolls-Royce actively participated in the test with its own developed hardware, e.g. instrumented second generation CROR blades and discs. The Rolls Royce test with Airbus ran from 16.01.13 -.25.01.13. A high rate of about 74% of the defined priority 1 test points has been achieved. As not all priority 1 high power cases could be tested due to rig motor power limitations, some of the defined priority 2 points have been run. Overall 60 hours of WT-occupation were planned and 61hrs 49 min have been achieved. The rig test data appraisal under SAGE started already during the testing and will continue over the next months. Also the majority of the Z08 Minimum Body post processed test data from the test in May 2012 has now been received from SFWA, Airbus. As a start, Rolls-Royce and Airbus evaluated the test data quality and iterated the test data post processing until correct data sets could be generated for further evaluations. An initial loop analysis with some part of the test data has been performed, projected to flight conditions and discussed with Airbus in weekly meetings over the last five months. Final interim noise and performance results have been submitted to SFWA, Airbus, to inform the Airbus Go/NoGo decision in mid-July. Near-field noise evaluation methods and tools continue to be developed for rotor-alone tones and interaction tones. These tools are used to compare latest test data with the rig 145b2B (ARA 2011) data. Continuous validation with test data is on-going. In addition, these methods and tools are being applied to tunnel reverberation calculations to derive necessary data corrections. This also includes aero-methods and tools development and validation and associated CROR performance test data evaluations. The far-field methods are in appraisal against the most recent processed data from Z08 (both MB and full A/C). Transposition at low speed is involving many of the data corrections (in-flow and out-of-flow) and the projection to flight. The use of different microphone types on Z08 makes the evaluation, correction and projection process complex. At high speed, the work focuses on the effects of reverberation in the ARA wind tunnel which affects the measured noise levels. With respect to propeller system technology related work, Rolls-Royce has down selected baseline materials to be used for its material impact testing. This has been prepared and test pieces have been delivered. The tests are on-going and documentation of the results will follow. The current status of the Rolls-Royce CROR blade design loop stress analysis has been completed and reported. The Impact work (bird strike / ice ingestion) was performed and complete. The trailing blade integrity analysis has been started and is on-going whilst associated aeromechanical methods work is progressing.

Rolls-Royce is still actively involved in the EASA certification working group activities. General certification requirements have been identified and the definitions of potential means of compliance are under discussions. The next group meeting is planned for the end of June. The associated CROR Engine design and integration aspects continue to be iterated with the air-framer to establish a viable solution and to continuously update the understanding of the associated technology requirements. This also includes the continuing assessments of attributes of different engine configurations (pusher & puller) and installations. Iterative reviews continue with SFWA, and additional data pack updates have been provided to Airbus to feed into the SFWA, Airbus Go/NoGo decision in July.

In GKN, the focus was on delivering risk mitigation and technology maturation of material and manufacturing technologies. This progressed well delivering a report focusing on the need and requirements for inspection methods necessary to guarantee the quality of a safety critical component. A second report presented the TRL and maturation plan of 5 methods of non-destructive testing for Open Rotor rotating frame methods and procedures.

The second half of 2013 saw a refocus whilst awaiting the GO / No Go decision. However, during this period there has been a continuation of Z08 and Rig145 test date comparisons and although there is still years' worth of data to evaluate the initial comparison of calibrated and comparable Z08 and Rig145 test data shows very good agreement and provides an indication that there is a good potential to meet future noise requirements on future aircraft products with CROR. Progress reviews have been performed in the form of 'High Spot' and 'Project Status' meetings. Resource management, planning updates, planning for 2013 as well as regular internal and external reporting was performed. The overall RR open rotor technology development plans and strategies have been reviewed regularly and further consolidated. Regular project management committee (PMC) meetings with the JU have been prepared and supported. Also the half year and intermediate reviews on ITD level have been prepared and supported.

SAGE2 – Direct Drive Open Rotor Demonstrator (led by Snecma)

During 2013, Snecma continued the management and the technical activities for the SAGE2 project.

Preliminary design studies of the open rotor Integrated Powerplant Propulsion System (IPPS) have been finalized. They encompassed the composite propeller, pitch control, power gearbox, power turbine, fixed and rotating nacelle and structures, lubrication and cooling and control sub-systems and the integration of the sub-systems into the IPPS. The Preliminary Design Review has been performed for all main modules in Q4 2013 and will be closed in Q1 2014. This enables to start the detailed design activities which will be completed by the end of 2014 with the last Critical Design Review planed by December 2014.

First Long Lead Time Items (LLTI) forgings have been ordered.

For the propeller module, the aero-acoustic tests were successfully performed in July 2013 in ONERA facilities enabling the completion of aerodynamic and acoustic design tools calibration and validating the key parameters of the propulsor.

Alenia Aermacchi continued in 2013 the management and technical activities regarding the CROR integration into conceptual Regional Aircraft configurations. CROR integration analysis have been performed, considering different solutions of engine/aircraft interface (including engine noise reduction preliminary analysis).

For Avio, about the Power Turbine, the Concept Design follow-up review was passed successfully on September 2013. The Preliminary Design Review was held on December 2013 and a complementary PDR is planned in Q1 2014. For the Power Gear Box (PGB), the Concept Design follow-up review was passed successfully and the PDR has also been passed allowing the launch of the activities to reach the next program gate.

During the year 2013, GKN progressed on the preliminary design of the Forward and Aft Rotating Frames leading to a successful Preliminary Design Review in November 2013 and allowing the detailed design phase to start in 2013. The rough interfaces for the rotating frames were frozen to enable orders of long lead time material. The first forging orders were placed in quarter 4 2013. The manufacturing process list was developed along the functional design.

For Hispano a mock-up of rotating transformer has been developed for SAGE 2 derisk test. This mock-up has been delivered on September 2013 enabling the derisk test compaign to start end of 2013.

For the nacelle development lead by Aircelle, the preliminary design, modal analysis and fatigue analysis have been completed. The Rotating nacelle and fixed nacelle PDR were passed. In parallel of the design activities, Aircelle had to develop its manufacturing capabilities and a new manufacturing process : the first manufacturing trials showed very good compliance with the requirements. For the rotating cowls and nozzle, 2 CfPs have been launched and the CfP partners proved their capability on designing and manufacturing the requested parts.

For 2013 Airbus activities have been mainly focused on the FTD CROR demo engine specification elaboration and associated iterations with Snecma, the Demo engine noise emergence and transposition studies, the overall aircraft design loads and the specific studies for demo engine pylon physical interfaces and relocated oil module.

These activities allowed to support successfully the mid year FTD / CROR concept review for the propulsion system integration part. Overall feasibility of the FTD CROR concept was then demonstrated.

Clean Sky Open Rotor activities in SAGE and SFWA are coordinated through a common Snecma/Airbus roadmap

Furthermore, activities related to the assembly of the engine for the Ground Test Demonstrator have progressed : the engine assembly synoptic has been established and the schedule for the assembly and instrumentation of the whole Ground Test has been detailed. The Preliminary Design Review has been successfully passed on November 2013.

The concept of the test bench for the Ground Test Demonstration was frozen and the preliminary design has been achieved.

Call for Proposals have progressed to support the Ground Test Demo start in 2015 with 6 new projects awarded in 2013 for a total value of around 5,4M€ increasing the overall SAGE2 budget for Call for Proposals up to 32,2€ (19,5M€ of European funding). This enabled several new partners to reach the SAGE2 community. Additional four new CfP proposals have been published in December 2013.

SAGE3 – Large 3-shaft Demonstrator (led by Rolls-Royce)

Project SAGE3 has progressed very close to plan throughout 2013, achieving all of its major milestones and deliverables, suffering only minor slips in the delivery of the engine and major rig test programmes.

2013 was a crucial year for project SAGE3, with a series of demonstrations being delivered including the first full engine test. To minimise risk to individual technologies, SAGE3 is demonstrating technologies through a series of rig and engine tests designed to ensure that issues with no one technology will jeopardise demonstration of any other. All technologies were progressed in 2013 and most achieved significant milestones in their progress and validation. A large group of people have contributed to these successes and the following paragraphs are testament to their dedication and hard work; congratulations are due to everyone working on SAGE3 in 2013.

January 2013 saw the completion of the first SAGE3 engine test, when a Rolls-Royce Trent 1000 with the fancase dressed with the Advanced Dressings technology was run on the outdoor testbed in Stennis, US. This technology is a radical departure from traditional electrical harness and pipework installations, delivering weight savings, reliability and engine build benefits. The technology was applied to the fancase of the demonstration engine, which was passed to test in November 2012 and the initial engine testing was launched in late 2012. The engine achieved nearly 100 hours of testing of the Advanced Dressings, including extended periods of running with seeded out of balance on the engine low pressure system. The test was a considerable success, demonstrating the functionality of the Advanced Dressings and showing continued structural integrity and low levels of vibration response in the composite components, even under simulated mount failure conditions. Post-test analysis of recorded engine data confirmed the functional success of the testing. The engine was controlled through the Advanced Dressings for the majority of the testing and it proved impossible to distinguish between signals carried by the Advanced Dressings and equivalent signals carried by conventional harnesses. The vibration data recorded during the test has been compared with the pre-test predictions and a high level of correlation found between the predictions and the measured data. Prediction of modal frequencies has been particularly successful but even the more difficult prediction of response amplitudes under forced vibration conditions has achieved good correlation. Rig testing of Advanced Dressings to complement the engine testing has been completed for EMC (electro-magnetic compatibility) and integrity following fire. The combination of engine and rig test results has allowed TRL6 to be claimed for the Advanced Dressings technology. The technology will, nevertheless, be further developed in future engine builds under SAGE3 that will explore the optimisation of the technology, challenging the boundaries of the technology application.

The focus of engine testing has moved from the Advanced Dressings technology to composite fan demonstration. There will be three engine builds to demonstrate this technology, starting with a demonstration of the composite fan blades and ORCA composite annulus fillers in a ground test. This will be followed by flight demonstration of the same configuration and further ground testing of a full composite system including the containment case. A Test Readiness Review has been held for the first ground test, which found the project to be on course to deliver the test in December 2013. However, even with significant effort being directed to the delivery of components for this engine build the composite fan blades delivery was delayed, which in turn delayed the instrumentation and calibration, build and engine testing into early 2014.

Flight clearance of experimental engines is a challenging topic and a strategy to achieve clearance for flight demonstration of the composite fan blades and annulus fillers has been issued. Flight clearance documentation has been worked in draft form throughout 2013 and will be completed in 2014.

The Low Pressure Turbine demonstration strategy uses a mix of rig and engine testing to deliver validation of a range of technologies in the LP Turbine. Component level design review of the demonstration Low Pressure Turbine module showed the system to be gaining maturity and many long lead time items have been delivered. The donor LP Turbine module that will form the basis for the demonstration and provide the unmodified baseline Trent 1000 components for the build has been delivered to build, stripped and inspected prior to rebuild with the new technology parts; it was found to be in good condition. A CDR for the LP turbine build was held in July 2013, when functional engine integration assessments to support the engine build and testing were reviewed. The engine was found to be capable for supporting the proposed testing, both physically and functionally. Machining of parts for the module has been launched and the work package is on schedule to deliver the LP Turbine demonstration in 2014.

Call for Proposal topics continue to be supported by the project with a further six topics being awarded in 2013 with total value of 6.7M€. Call for Proposal topics continue to be supported by the project with a further six topics being awarded in 2013 with total value of 3.1M€. The consortium would like to welcome TWI Limited, Fundación IMDEA Materiales, CEIT, University of Birmingham and Manufacturing Technology Centre Ltd. LBG to the SAGE3 project and wish them well in the progress and delivery of their topics.

<u>SAGE4 – Geared Turbofan Demonstrator (led by MTU)</u>

SAGE 4 has successfully completed detail design efforts. After successfully passing preliminary design review DR4 in July 2013 and a successfully passed critical design review DR5 in November 2013, the SAGE4 demonstrator has cleared all hurdles for a general production release.

Technology development is on-going and has been closely tied to demo schedule to allow insertion into the demonstrator at appropriate risk levels. To properly validate the individual technologies, an instrumentation verification matrix and an instrumentation layout as well as test cycles have been pre-defined and approved in a test concept review in April 2013. Also a SAGE4 demonstrator engine health and monitoring concept is established.

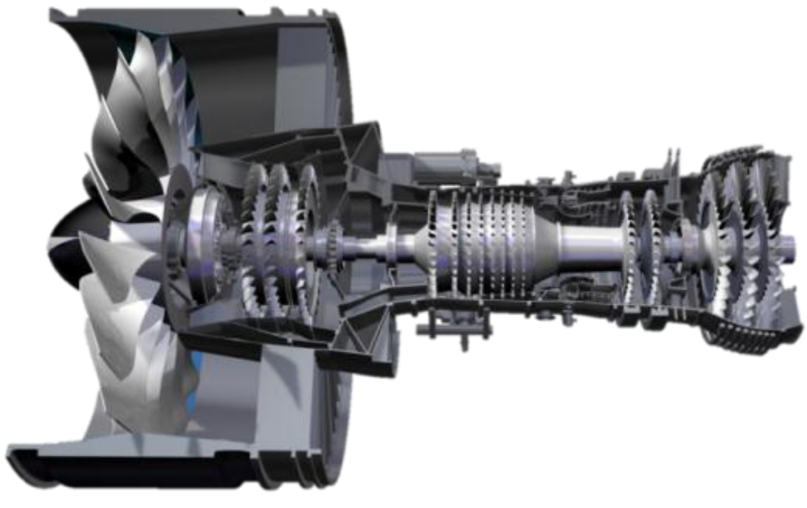
A major change of the demonstrator technology portfolio resulted from the decision to perform the validation of the new fan drive gear system on a gear test bed and not to integrate it into the SAGE 4 demonstrator. The advantages of testing the gear system under adverse operational conditions outweighs the disadvantage of a missing system integration into the donor engine.

Long lead time items like airfoil castings have been commissioned at a quite early stage of the detail design phase. Meanwhile all suppliers of raw parts and all manufacturers of finished parts have been selected and close monitoring of demo H/W has been established to ensure parts and components availability for module and engine assembly.

Efforts on supporting TE have continued and improved/new engine data and models have been submitted to GRA in order to study and establish rear mount and under-wing A/C models for GRA-130 Pax Regional A/C. Besides actively working 13 CfP projects, 4 additional CfP topics have been contracted in 2013. One more topic has been prepared for publication in Dec 2013 and is expected to start development work in mid-2014. In total SAGE 4 has been able to contributed more CfP topics than requested to satisfy the 25% CfP share set up of Clean Sky.

Defined risks levels decreased favourably and no high risk element is currently under special attendance. Necessary resources to accomplish the tasks have been available at a whole and helped to execute the program according to plan which is reflected in achieving all 2013 milestones and deliverables and an almost 100% budget consumption.

All in all, the SAGE 4 project in 2013 again successfully proceeded on its way to realise the defined project targets within the Clean Sky timeframe.



SAGE 5 – Turboshaft engine Demonstrator (led by Turbomeca)

The SAGE5 project shall provide TURBOMECA with the necessary technologies for the development of a new engine family equipping helicopter classes with a take-off weight from 3 tons (single-engine) to 6 tons (twin-engine).

The project aim is to deliver TRL6 for the sub-systems studied and design in SAGE 5 through appropriate testing delivering engine conditions representative of potential future engine applications. The representative environment for many technologies will be provided by components and engine test. The technologies to be demonstrated will deliver improved specific fuel consumptions, noise and emissions in-line with the goals of the Clean Sky programme.
Several innovative technologies will be incorporated in the compressor, the turbines, the combustion chamber, and the air intake exhaust parts.

The top level SAGE5 project objectives are:

- To demonstrate technologies that will decrease the fuel consumption of turboshaft engines through components efficiency increase, dimension and weight reduction

- To provide engines and rigs for technology validation and integrate the technologies to be demonstrated, developing and producing components as necessary.

- To develop enabling manufacturing technologies and materials/coating where these are necessary to deliver the engine technologies for demonstration.

- To deliver and test turboshaft engine and, on the basis of prediction and test data obtained from the engine, to assess the improvements in gaseous and noise emissions that may result from incorporating the technologies in a production engine.

The SAGE5 project will focus on demonstrating the following technologies:

- Technologies for high efficiency compressor stage : the component study will focus on improving compressor efficiency in order to be a contributor for fuel consumption decrease

- Technologies for high efficiency cooled HP turbine : the study main target is to be able to design small size, high efficiency cooled HP turbine in order to improve performance and reduce dimension for turboshaft engine and prepare a power growth capability

- Technologies for reliable and compact combustion chamber through development of size and weight decrease by studying a small volume combustion chamber, reliability improvement and life limit increase. This work will be combined with optimisation of the combustion process and fuel injection system.

- Technologies for high efficiency LP Turbine. The study will focus on efficiency improvement in order to contribute in fuel consumption decrease.

- Materials and coating development and manufacturing techniques to enable the static part to cope with higher temperature capability.

- Technologies for low noise device through development of a quiet exhaust that will enabling a reduction in noise and propose the best weight to noise compromise. This work will be undertaken through Call for Proposal.

- Technology for inter shaft architecture: this technology will enable a reduction in fuel consumption by reducing weight, reducing structure in the gas path and enables compatibility with high operating temperature.

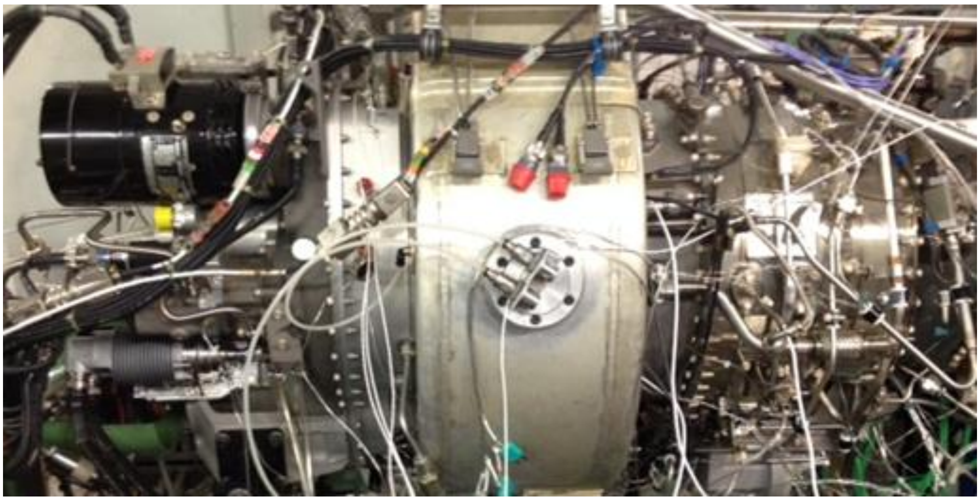
- Technologies for Low Nox Combustion chamber by studying a low Nox combustion chamber and integrate it on turboshaft engine, study the associated injectors and fuel system. This technology will allow decreasing Nox emission. This work is built on previous European programme and on National funding programmes.

- Technologies for control system through development of equipment aiming to reduce cost, weight/size or to enable operation at higher temperature level. This work is built through Call for Proposal.

Built 1 Engine assembly has been completed in January 2013. The first engine rotation is occurred in February 2013 and was officially celebrated in presence of Commissioner for Transport in April 2013. During year 2013 several engine test have been performed in order to solve some technical issues, to open the operating envelope and perform some performance test.

Manufacturing of build 2 parts have stated and have continued during the year. The specific instrumented parts have been also been manufactured.

Several Call for proposal concerning the control system have been completed with the delivery of prototypes. These prototypes have been tested on partial rig test.



SAGE 6 – Lean Burn (led by Rolls-Royce)

The Programme has seen a significant progress accompanied by a remarkable resource ramp-up. This underlines the importance of the herein developed technology for the company and associated beneficiaries. The overall Programme achievements are as follows:

- Concept Review (stage 1 exit review) with RR internal audit team held in May 2013 (M6.1.2)
- Critical Capability Acquisition Review on system level held in November 2013, by this TRL4 is formally achieved
- Preliminary Design Review (stage 2 exit review) with RR internal audit team held in November 2013 (M6.1.3)
- Successful integration of the Core Engine Test strand (WP 6.9): The programme leadership revealed in 2012 that the demonstration of the Lean Burn Capability on the Core Engine (WP6.9 refers) is an essential element in the Technology Readiness Road Map. Therefore, WP 6.9 (Core Engine Test) was embedded into the SAGE6 Programme in 2013. In particular the Full Annular Rig Test, which was conducted late 2013, contributed to the programme.
- For the demonstration phase all necessary activities have been launched such as establishment of the engine test programme, definition of experiments, engagement (placement of build and test activity demands) with RR test and build execution organisation

The Combustion module (WP6.2) design has progressed significantly such that the baseline designs of the combustor, injector and casings are in final detail definition. All have been reviewed and released for manufacture. The fuel manifold design review for manufacture release, due to the complexities of the interface with the existing engine external pipework package was delayed to late January 2014 to resolve the complex interfaces. The combustor forgings have been completed and being delivered to allow start of machining. The casing forgings are in process and the injectors have started manufacture. The Perspex rig unit at Loughborough University (M6.2.5) was completed and initial testing used to confirm module pressure drop and flow splits. The full annular high pressure combustion test unit for ALECSYS has progressed well and passed PDR and CDRs. The assembly readiness review (M6.2.4) was delayed to February 2014 to allow definition of the engine components to be used in the rig to be completed as the rig unit was significantly ahead of the rest of the programme. Manufacture of the test unit is on schedule for completion in early quarter 2 2014.

The Turbomachinery Integration Work Package (WP6.3) in 2013 basically comprises of the integration of the turbine behind a Lean Burn System. The Turbines support basically consisted of a preliminary submission of Performance and Capacity bids in Q2/2013. The final bids, however, could not be submitted until Q1/2014. Also part of this task was the successful support of the activities related to the delivery of the Swirl Probe for tests downstream of a Lean Burn Combustor. The probes were delivered on time for the test (with SAGE support) and the successful test produced very useful data for the understanding of Combustor – Turbine Interaction for a Lean Burn System (SILOET support).

Regarding WP 6.4 (Controls System, AEC): The aims of the fuel staging hydro-mechanical work package, during 2013, have been associated with the design and definition of a fuel system architecture, with specific focus on the definition of the hydro-mechanical staging unit (HSU). The hydro-mechanical staging unit (HSU) is a new fuel system assembly, whose primary function is to split the engine fuel flow between pilot and mains burners.

For the demonstrator engine (ALECSys) the HSU will be a new unit, that is integrated with an existing fuel system. However, for a production solution, the HSU may be integrated with other fuel system components.

The work package has also concentrated on other, new, fuel system components.

AEC has developed and matured the design of the new units and components required for the lean burn fuel system.

Work has also advanced on control system hardware and software development. CDRs for modified EEC and minor loop software control are scheduled for February 2014 (M6.4.2).

The Lean Burn rig capability acquisition demonstration (LeVeR, M6.4.1) has been delayed due to greater complexity of the design than originally assessed and will complete in 2014 enabling considerable interaction between the rig and associated this work package and the LeVeR rig capability acquisition programme.

The Installations work package (WP6.5) finished the period having achieved a concept design for all units, unit placements (M6.5.2) and matching fluid and electrical systems. Excellent progress was made in detailing up the requirements for the component definition phase, for both the specific systems required for the modified fuel system and collateral effects, specifically on the air system.

Throughout 2013, the Functional Integration (WP 6.6) focused within the SAGE programme on two topics, the thermal modelling of the staged fuel system and the noise modelling.

Intensive thermal modelling work has been completed in 2013 to define the maximum fuel temperatures within the staged fuel system across the flight envelope to support the design of the fuel system units and fuel manifolds.

To quantify the potential increase in noise levels caused by the lean burn combustor exit conditions, experiments are scheduled on the Oxford generic turbine rig facility. Despite failing to deliver the milestone (M6.6.1) due to the unavailability of the facility due to other emerging priorities, significant progress has been made in 2013 including the definition of the rig test matrix, the CFD based design and manufacture of the test section and the definition of the required instrumentation. The to be validated CFD simulations of the rig configuration have been completed. The rig measurements will be complemented by in-engine measurements on the next run of the EFE engine (WP6.9). To characterise the engine combustor exit conditions, CFD calculations are scheduled to deliver detailed exit boundary conditions.

The Engine Test Work Package (WP 6.7) has resumed in 2013 with a bigger team at RRUK. In addition to the herein described task T6.7.1 the following activities have been performed:

- Boroscope Inspection of 1st returned donor engine
- Discussion have been held with the relevant stakeholders on how to rework the existing intermediate case and HPC diffuser in order to gain instrumentation capabilities on these parts and a clear way forward has been identified.
- Work has been carried out to define the instrumentation requirements. Instrumentation design was launched at RRUK.

Regarding Work Package 6.9 (Core Engine Test): The assembly of EFE build 4 (Combustion functional & core water test) continues in Bristol. Module 5 assembly was completed end 2013 and the Module 4 assembly was completed in early January 2014 (M6.9.4). In parallel considerable effort has been expended by the Performance, Combustion & AEC teams to analyse, define and deliver the necessary control system functionality to support the planned Combustion testing. In particular, there has been a great deal of focus on preparing the control system to cope with the challenge of the core water test on a Lean Burn Control system, and to provision for flexibility to make adjustments to the control system during the testing. The engine control system is due for delivery to Bristol to support test preparation in mid-February. The engine will imminently be turned horizontally to permit work to continue with the leadout of applied instrumentation around the core engine. A level of externals hardware will also be fitted with the engine in the build shop but the bulk will be fitted once the engine has passed to the test bed early in February. Instrumentation and engine services connections will need to be made with the test bed, and the engine control system then commissioned. The first run of the engine to idle is planned by the end of March 2014.