CLEAN SKY - *Green Rotorcraft ITD (GRC)*

Periodic Report P7

(January 1st to December 31st, 2014)

Publishable summary

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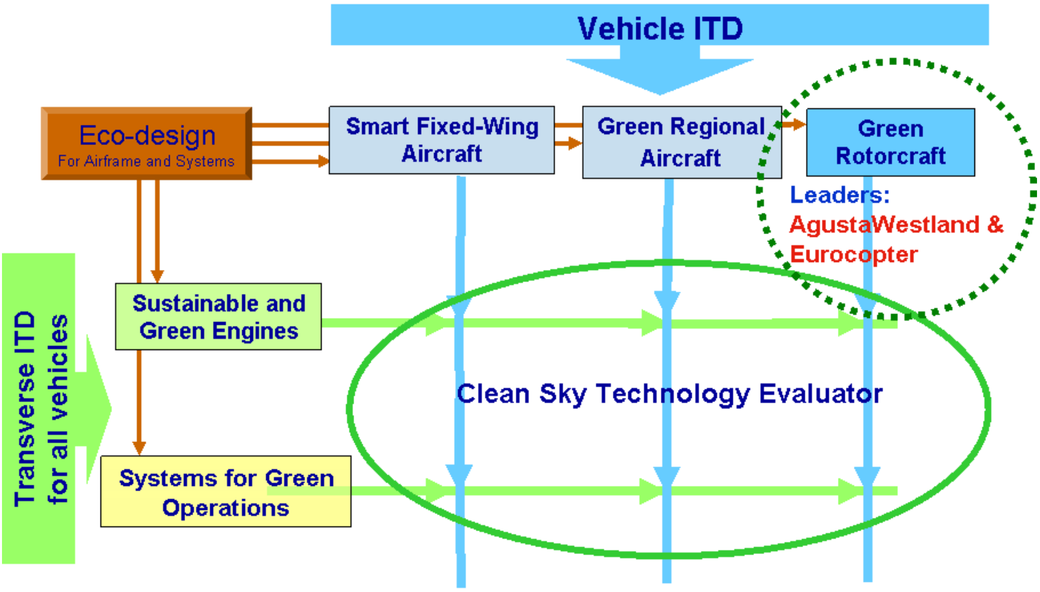
Publishable Summary

Context

The Green Rotorcraft Integrated Technology Demonstrator (GRC ITD) addresses environmental issues in relation to rotorcraft vehicle usage, as part of a wider Air Transport System considered in the Clean Sky Joint Technology Initiative (CS JTI).

Clean Sky aims to create a radically innovative Air Transport System based on the integration of advanced technologies and full scale demonstrators, with the target of reducing the environmental impact of air transport through reduction of noise and gaseous emissions, and improvement of the fuel economy of aircraft. The activity covers all main flying segments of the Air Transport System and the associated underlying technologies identified in the Strategic Research Agenda for Aeronautics developed by ACARE.

Clean Sky is built upon 6 different technical areas called Integrated Technology Demonstrators (ITDs), where preliminary studies and down-selection of work will be performed, followed by large scale demonstrations on ground or in-flight, in order to bring innovative technologies to a maturity level where they can be applicable to new generation “green aircraft”.



The Green Rotorcraft ITD gathers and structures all activities specifically concerned with the integration of technologies and demonstration on rotorcraft platforms (helicopters, tilt-rotor) which cannot be performed in platform-generic ITDs. There are however technical links with activities conducted within the EcoDesign ITD, the Sustainable Green Engines ITD, the Systems for Green Operations ITD and with the Technology Evaluator.

Objectives

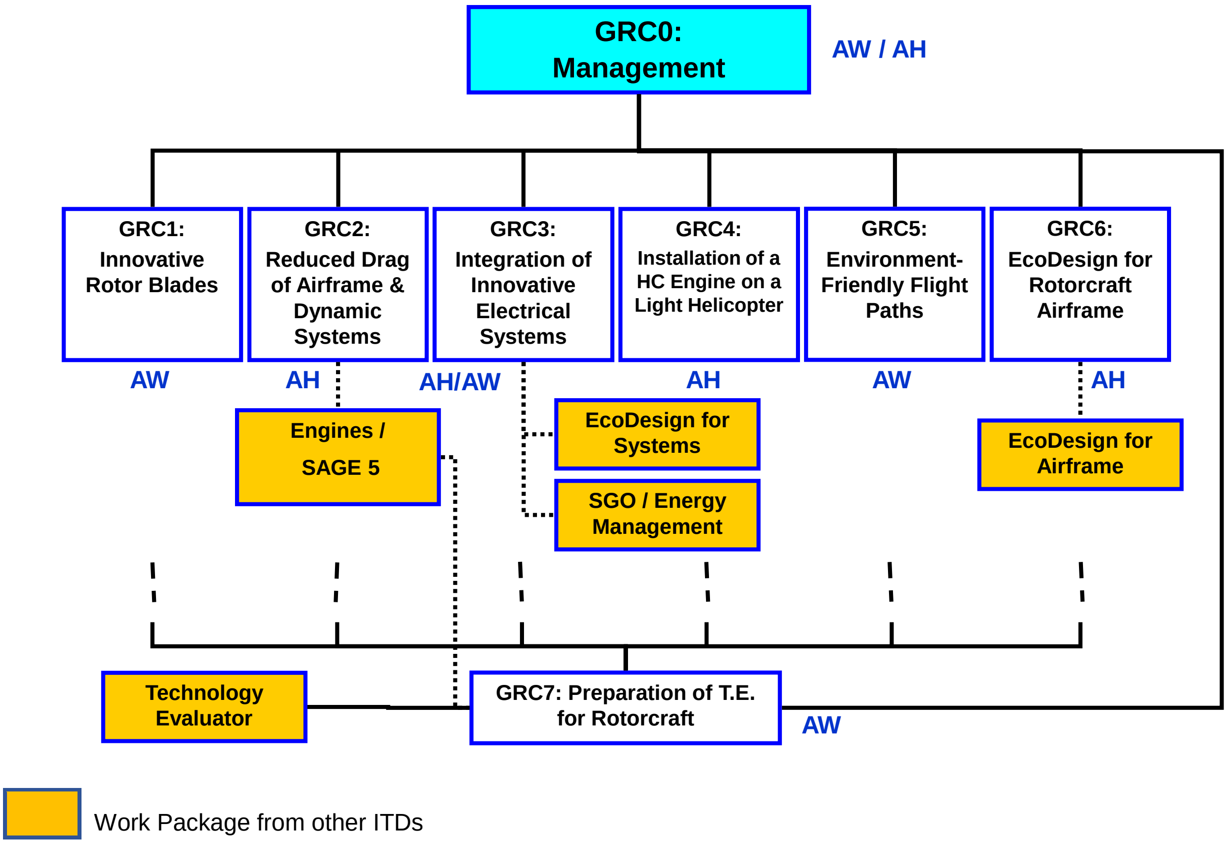
The Green Rotorcraft ITD addresses the challenge of minimising the impact of the sharply increasing rotorcraft traffic expected in the future - including the introduction of tilt-rotors - through a more efficient usage of energy and through a drastic reduction of greenhouse gas emissions and noise footprints throughout the whole mission spectrum.

With the goal to contribute to the overall objective of coming back within 20 years to the present global level of environmental impact while sustaining the expected growth of rotorcraft services, the Clean Sky initiative aims to reduce by half before year 2020, the specific impact of rotorcraft operations on the environment. In detail, taking into account year 2000 as baseline, the objectives of the GRC ITD and concurrent activities in other Clean Sky ITDs are to reduce CO_2 emissions by 26-40% and NO_x emissions by 53-65%, according to vehicle and technologies used, and to reduce average noise level by 10 dB.

Organisation

In order to contribute to the achievement of these global objectives, the project will develop a new high compression power plant, innovative rotor blades and new aircraft configurations. The project is organised along six technological streams dedicated to key topics and one stream dedicated to technology evaluation:

- Innovative rotor blades (GRC1)
- Reduced drag of airframe and dynamic systems (GRC2)
- Integration of innovative electrical systems (GRC3)
- Installation of a high compression engine on a light helicopter (GRC4)
- Environment friendly flight paths (GRC5)
- Eco-design demonstrator (rotorcraft) (GRC6)
- Technology evaluator for rotorcraft (GRC7)



The project includes also a management subproject (GRC0). It is scheduled to run over an eight year period starting on July 1st, 2008; it is jointly coordinated by AgustaWestland (AW) and Airbus Helicopters (AH).

Overview of work performed and results achieved

Main milestones achieved in 2014

- For innovative blades (GRC1): 2D test; Model rotor blade Critical Design Review (CDR) and Design of major components for full scale rotor with Active Gurney flaps (Preliminary DR); Test Matrix for Active Twist Blade.
- For airframe drag reduction (GRC2): Wind tunnel tests about passive shape optimisation and active means on the fuselage completed (TRL4); Optimised hub fairings: aerodynamic design freeze achieved Technology Readiness Level 3 (TRL3) and wind tunnel tests partly achieved (TRL4); Comprehensive analysis completed for air intakes and exhaust nozzles integration (TRL3); Wind tunnel tests for the light helicopter intake at full scale completed.
- For integration of innovative electrical systems activities (GRC3): Analysis reports on covered technologies across differing helicopter types were delivered; Data from the Partner projects were assessed regarding system mass and future electrical power requirements and supplied to GRC7 for platform evaluation; Deliverables included summary data for the tween engine helicopter (THE) configurations.
- For the High Compression Engine (HCE)-powered helicopter (GRC4): Iron Bird tests were completed by mid-February. Ground tests were postponed to the first quarter of 2015 because of engine testing delay.
- For environment-friendly flight paths (GRC5): AW139 numerical acoustic database updated and validated against flight data (TRL 3); Eco-flight IFR (Instrument Flight Rule) procedures for Toulouse-Blagnac airport (TRL 5); Validation and Verification of Eco-Flight Planner on prototype software (TRL 4); Flight Management System (FMS) simulation correctly coupled with flight simulator AWARE; VFR (Visual Flight Rule) noise abatement flight procedures evaluated in simulator using the head down display (TRL5); In-flight pollutant assessment on the SW4 completed.
- For eco-design for rotorcraft airframe (GRC6): Because of delays in the manufacturing of demonstrators, most of the planned deliverables and milestones will be achieved during the first two months of 2015. A report on tail cone panel manufacturing process was delivered.
- Concerning the GRC contribution to TE (Technology Evaluator) (GRC7): Fifth annual release of rotorcraft software and data package for the SELU1 (Single Engine Light Update 1) and HCE was delivered to the TE on time; Slightly behind schedule for the December 2014 deadline, TEHU1 (Twin Engine Heavy) will be delivered to the TE in the first quarter of 2015 with no negative impact to their assessment schedule.

The following extract from the Reviewers' Report issued after the Interim Review of 21st November 2014 gives some idea of the GRC ITD status.

"All technical presentations reflect a significant progress sustained by the clear willing to achieve TRL 6 in most of work packages. This ambition is illustrated by the confirmation of flight evaluation of 3 demonstrators (possibly 4 under option):

- Active Gurney Flap

- Aerodynamic drag reduction devices on EC 135

- High Compression Engine

- Passive Optimised Blade (optional)

and the validation on ground in a dedicated test rig of the "Electrical tail rotor drive".

These visible contributions to concrete GRC ITD outcomes will become from now the "flagships" of Clean Sky Programme and will deserve high priority in work plan carrying out.

A positive result is also secured by the excellent coordination between GRC5 and GRC7 about the cumulated effect of noise emission targets (GRC1) and noise footprint reduction obtained from optimised trajectories. The probability to fulfil the ambitious noise reduction of the Clean Sky programme seems now very high."

Activities performed in 2014 are summarised here after for each subproject of the GRC ITD.

GRC1: Innovative rotor blades

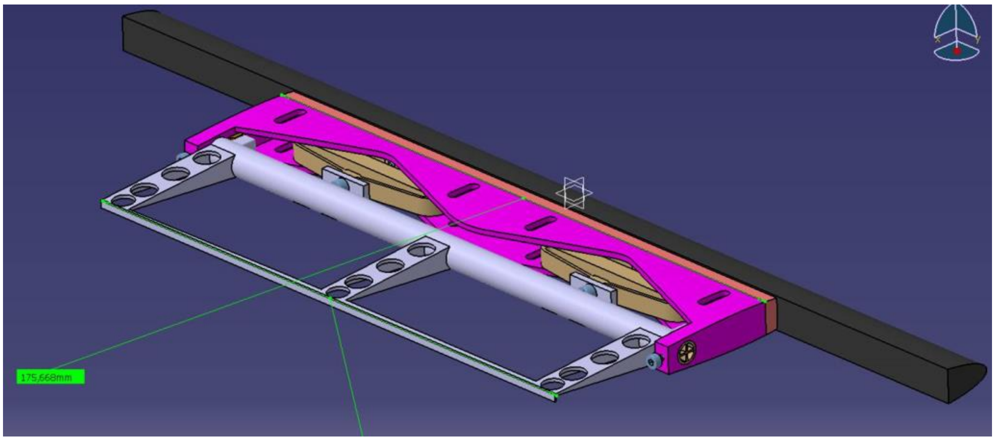
Helicopter rotor blade technology has been progressively 'fine-tuned' to extract the maximum efficiency from the rotor system. Increasingly sophisticated and more powerful computational tools are used for each development of a modern rotor system in order to gain increasingly smaller rewards. Inevitably, all helicopter rotor blade designs are a compromise, contending with the conflicting requirements of hover performance versus the needs of fast forward flight. For the latter, they contend with the difference of needs between the forward moving helicopter's lift generating advancing blade and the onset of stall on the retreating side of the rotor disc.

For this reason, helicopter manufacturers have turned their attention to the potential benefits of 'Innovative Rotors' being either a) 'Active' rotor systems, incorporating deployable (movable) components or surfaces within the blade and which are capable of allowing the blade to adapt to its ever changing environment and demands, or b) the design of conventional passive rotor technology that is optimised, using latest design capabilities, to better meet all operational conditions.

GRC1 is thus split between Active and Passive Optimised blade developments as outlined below.

Blade Technology	End Objective	TRL Objective
Active Twist (AT)	Acoustic Signature benefits	TRL 4 Laboratory demonstration
Passive optimised (PO) Blade	Overall blade optimisation	TRL5 Ground 'whirl tower' (Objective for TRL6 Flight demonstration assuming funding)
Active Gurney Flap (AGF)	Rotor performance (reduced engine emissions) for loaded rotor	TRL6 Flight Demonstration

In the P7 period (2014) of the CleanSky project, GRC1 reports that major component testing has either been completed to schedule or is about to commence. Five out of seven due deliverables were completed. Milestones were however less successful, primarily as a result of technical challenges across all three technology programmes (AT, PO and AGF tasks). Milestones expected in late 2014 will now be achieved in early 2015. The situation reflects the advanced nature of the research, and technical complexity of the tasks being undertaken.



Details of the model rotor AGF mechanism (AST design)

The 'Call for Proposal' activities across the AGF programme remained on schedule despite challenges. The development of 'methods/tools' supporting new GRC1 technologies were conducted as scheduled in 2014. Assessment of the performance and acoustic benefits of GRC1 technologies, along with mass and electrical power penalties, were refined and supplied to GRC7 as planned.

GRC2: Drag reduction of airframe and non-lifting rotating systems

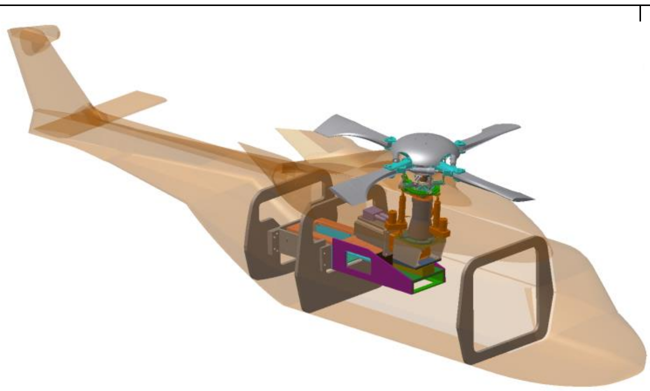
The GRC2 subproject deals with the aerodynamic optimisation of rotor hub and fuselage, and with the improvement of engine installation. The reduction of pressure drag generated by the fuselage and rotor head goes towards a reduction of the rotorcraft required power, whereas an improvement of the engine installation aims at increasing the available power of the installed engine.

Several helicopter weight classes, from light to heavy, different rotor-head architectures, from fully articulated to bearing less, are addressed. Moreover, active and passive methodologies are used to reduce the fuselage drag.

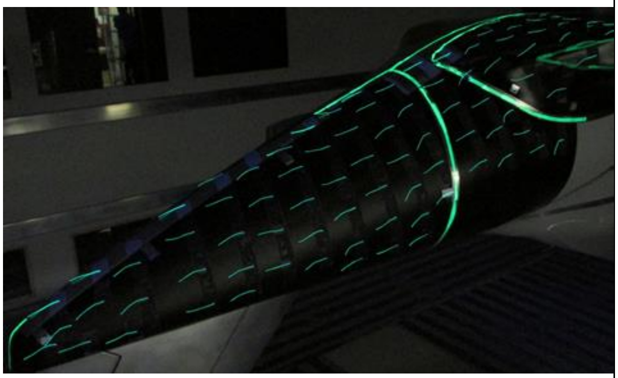
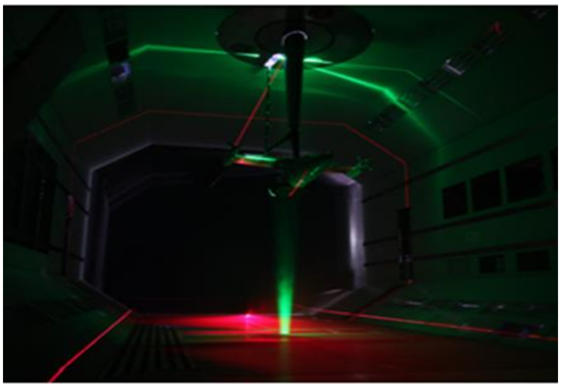
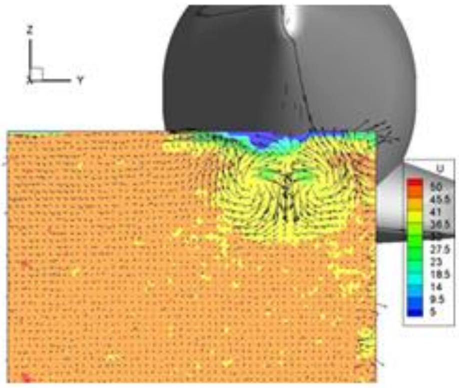
After having conducted a technology review in the field of rotorcraft drag reduction, a number of Technology Products (TP) have been identified by the GRC2 members. A pre-design activity was initiated for each TP with the objective of selecting the most promising ones. These TPs have been subjected to an aerodynamic and structural detailed design normally leading to a Critical Design Review (CDR). Manufacturing of down-scale or full-scale components of the selected technology product is being carried out, depending whether the benefit assessment shall be conducted in wind tunnel, thus reaching TRL 4, or in flight, leading to TRL6.

Most of the numerical activities to optimise the hub of the selected helicopter weight classes have been concluded reaching TRL3, whereas a few are still in progress. The third wind tunnel campaign to measure the EC135 optimized configuration, accounting for optimised aft body, landing skids and rotor head fairings, has been concluded by the Aerodynamic faculty of the Technical University of Munich in the context of the Partner project ADHERO, which was officially closed in the third quarter of 2014. Moreover the aerodynamic and structural design of a new full scale hub cap for light and heavy helicopter progressed during 2014.

Concerning the reduction of airframe drag, especially for blunt aft bodies and for the tail, wind tunnel testing of the improved aerodynamic design of the common helicopter (figure below – left) and tilt-rotor platforms (figure below – right) have been conducted, incorporating passive flow control systems (Vortex Generators).

	
ROD common helicopter platform (GOAHEAD) wind tunnel model construction (1:3.881 scale)	**DREAM-Tilt**: common tilt-rotor platform (ERICA) non-power wind tunnel model (scale 1:8)

In detail, a remotely controlled horizontal stabiliser for the helicopter common platform was manufactured in order to be tested in wind tunnel of Politecnico di Milano within the ROD Partner project, which started in 2013. Additionally, the geometry of a heavy helicopter with rear ramp configuration has been optimized reaching TRL3. Concerning the common tilt-rotor platform, the wind tunnel test campaign on the optimized configuration was completed within the Partner project DREAM-Tilt at the Swiss wind tunnel facility of RUAG. Such tests included the drag build-up for each component, the study of the boundary layer transition on the nose using IR thermography, mini-tufts visualizations and, thanks to the cooperation with CIRA, the PIV study of the wake behind the sponsons.

	
Optimized geometry	Mini-tufts visualization
	
PIV test execution	PIV reconstructed flow field

DREAM-Tilt: wind tunnel tests on the non-powered model of the common tilt rotor platform (ERICA)

Concerning engine installation tasks, a new side intake for the EC135 demonstrator designed and tested at full scale in wind tunnel at TUM-AER in the context of the ATHENAI Partner project. Manufacturing of prototype components started in 2014 and will be finalised in the first half of 2015.

A performance optimised engine installation of the ERICA tilt-rotor is also available. Detail design and manufacturing of wind tunnel components started. The new air inlet, exhaust and bypass of the ERICA nacelle will be tested in the wind tunnel at Politecnico di Milano in the context of the Partner project TETRA, which started early 2014.

GRC3: Integration of innovative electrical systems for rotorcraft

System power management strategies have been refined and principles aligned with the evolving technology developments in Partner projects and leading power supply technologies. High level architecture analysis and updated requirements and solution documents were issued.

Optimised electrical architectures were further refined using behavioural electrical network software models provided by the SGO ITD, leading to the production of a deliverable comparing simulation and test bench test results.

The **technologies for improved electrical system efficiency** were further developed, with all major projects progressing with Partners projects. Starter Generator manufacturing equipment was launched. Electrical and thermal simulation of power electronics architecture has been performed and acceptance tests will be performed at the beginning of 2015. The Power Converter and Energy Storage Partner projects successfully held a CDR ahead of schedule, concluded manufacture of prototypes and the initiation of component testing.

The **Energy Distribution & Consumer Systems** analysed outputs ensuring compatibility with evolving technologies of Partner projects. Thermal Energy Recovery: two demonstrators were manufactured and the Final Project Review held in January 2014, the project has been assessed using a TRL Review and concluded with a Final Report.

Energy Recovery Management: manufacturing equipment was launched and acceptance test was performed in the second week of December 2014. The implementation of ModBus as incorporated in the Boost converter was successfully tested in Copper Bird.

Electromechanical Actuator (EMA) technologies progressed through stages of design, build or test.

EMA for Flight Control System progressed through the demonstrator manufacture. EMA for Landing Gear has been assessed using a TRL Review and concluded with a Final Report.

EMA for Rotor Brake provided a test plan, and progressed to initial system evaluation. A Partner project extension was agreed to enable the conclusion of the partners' full system evaluation and analysis.

Electrical tail rotor drive development evaluated both conventional and fenestron tail rotors, providing innovative concepts allowing suppression of usual hydraulic systems. The conventional open rotor task included the definition, manufacture and delivery of a first prototype suitable for initial evaluation. The new demonstration phase of the open rotor task progressed through specification definition, supplier review and initiated a procurement phase. It is noted that schedule risks exist in that procurement process that may influence final demonstration timescales. The fenestron system provided a Preliminary Concept, with the activity stopped during the period after identification of a No-go issue.

The **Energy Supply System for the Piezo Actuation technologies** are incorporated into helicopter dynamic rotor systems. The CDR for PPSMPAB was cancelled, replaced by continuous technical meetings held to validate each step of the development in view of manufacturing tasks. The manufacturing of the Piezo Power System finished and has been assessed using a TRL Review and concluded with a Final Report.

Some technology evaluation is planned for evaluation on the Electrical Test Bench/Copper Bird. The harmonization of technology continued with test plans issued in this period. This included preparatory work for the integrated ground test demonstration with the scheming and design of equipment specific adaptation kits. A final and updated version of the Helicopter Electro-Mechanical Actuation System (HEMAS) test plan and HEMAS Adaptation Kit (HAK) interface document was issued and delivered to the EcoDesign ITD. HAK CDR was held in February 2014. HAK assembly finished and HAK's installation and integration test are conducted successfully.

No significant deviations regarding the Technical Annex plan were necessary.

GRC4: Installation of a high compression engine on a light helicopter

In period 7, three main objectives were set for GRC4:

- The first objective was to finish the tests on the engine bench. The tests started in March 2013, less than one and a half year after the design start of this new engine. The ultimate test is to run an endurance cycle required for the engine flightworthiness. Due to some issues during the testing, the duration of these tests has been extended until the second quarter of 2015.
- The second objectives was to complete tests on Iron Bird (started in November 2013).

Iron Bird test facilities

The tests were positively achieved at mid-February 2014, confirming the technical choices related to the following challenges:

- Damp reciprocating engine torque oscillations and vibration,
- Cool engine during Hover,
- Master clutching sequence,
- Control rotor speed (low engine inertia vs high rotor inertia).

- The third objective was to start ground tests on the Demonstrator Helicopter. Due to the engine testing issues, the ground tests start has been postponed to the first quarter of 2015.

During Period 7, the Flight Tests have been incorporated in the framework of GRC. They will follow the Ground tests, if these are successful. The Flight tests will validate the installation of the HCE up to Technology Readiness Level 6 (TRL 6).

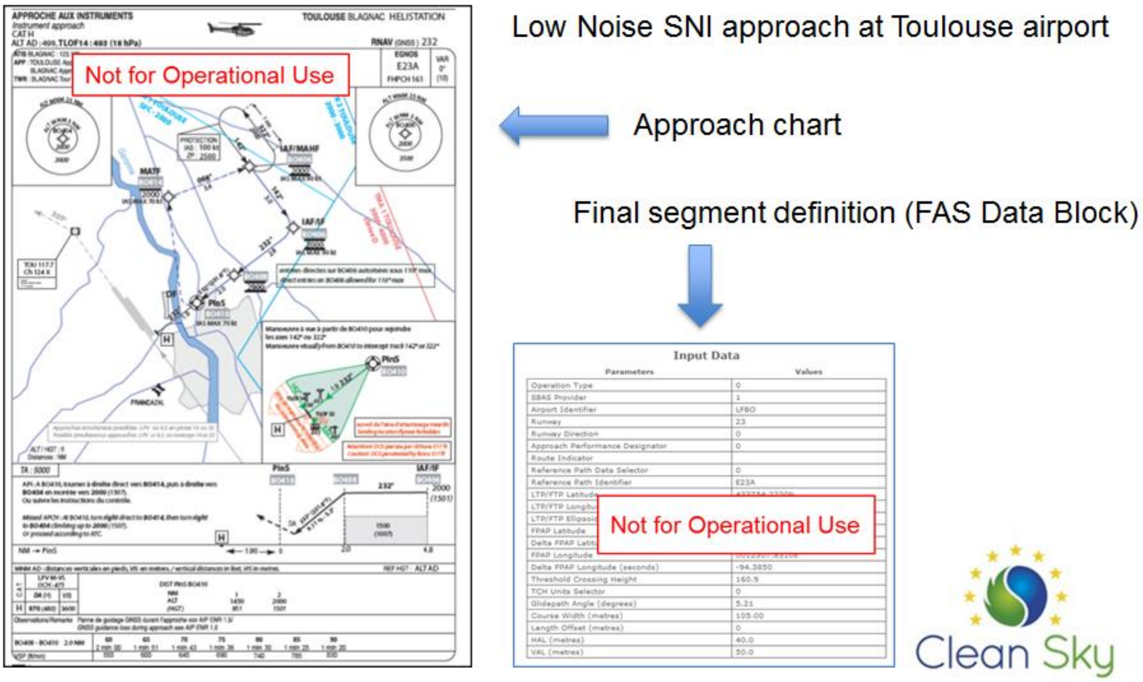
Rear tailfin of EC120 HCE Demonstrator

GRC5: Environmentally friendly flight paths

GRC5 is the CleanSky Green Rotorcraft subproject aiming at reducing noise and pollutant emissions for existing vehicle configurations, by innovating the flight procedures and mission profiles, and the pilot navigation and guidance systems necessary to implement them.

In 2014, subproject GRC5 steadily progressed through on-ground and in-flight demonstrations towards its final objectives of several low-noise and low-pollutant technologies with Technology Readiness up to level 6 (the highest expected in CleanSky). Technical difficulties encountered have been faced by putting in place dedicated recovery plans, with specific decision points in 2015 and back-up plans to secure the final demonstrations.

In the eco-Flight Procedures technology stream, innovative noise-abatement procedures for helicopters were designed and charted, and are ready for demonstration in 2015. The progress has been extremely strong for Instrument Flight Rule (IFR) procedures, with IFR low-noise trajectories for tilt-rotors also progressing (simulator software development, test scenario definition) towards the final demonstration by piloted simulation in 2015.



Detail of the approach plate (chart) designed for helicopter noise-abatement IFR procedures.

In the eco-Flight Guidance stream, most of the pilot indicators and guidance display systems were reviewed with high attention paid to their acceptability by the final users and operators. The concept of the so-called Blade-Vortex Interaction indicator was streamlined using short-term available functionalities in serial helicopters, and studying general but flexible recommendations to be implemented in the rotorcraft flight manual. The VFR (Visual Flight Rule) guidance based on the tunnel-in-the-sky technology was extended and ported to the helmet-mounted-display, which is now ready for piloted simulations and flight tests. Similarly the simulator software developments, necessary to assess the Low-Noise Algorithm for mission planning in VFR, are close to completion, with preliminary integration tests cleared in 2014.

Eco-Flight Guidance pilot in the loop simulations

For the eco-Technologies stream, which gathers other supporting innovations, the Pollutant Emissions Assessment task accomplished the validation of numerical estimates (made with state-of-the-art CFD models of the combustion chamber) versus the in-flight measurements of pollutants performed in GRC5 in 2013 (never reported before for helicopters in the literature). These data allowed the derivation of the so-called emission indexes for the considered engine and the accurate prediction of the produced CO2, NOx, CO and SO2 for several typical missions.

GRC6: Eco-design demonstrators for rotorcraft

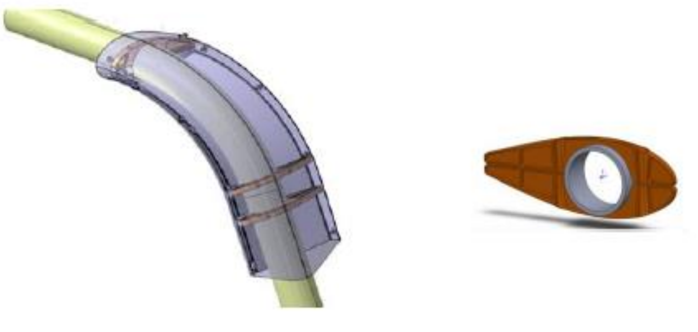
All GRC6 activities basically aim at a feasibility demonstration of technologies which were developed within the EcoDesign ITD. Because the EcoDesign demonstrations are not sufficient to claim a general applicability for rotary wing aircraft, GRC6 selected components and sub-assembly typical for helicopters. Based on these demonstrators, the technologies and materials were selected, adapted and developed further to enable positive results according to the Clean Sky goals.

GRC6 is addressing several demonstrators focused on thermoplastic composites and metallic assemblies.

The aim is to investigate the impact of thermoplastic CF on the weight of primary and secondary helicopter structures and trials with modern surface treatment technologies.

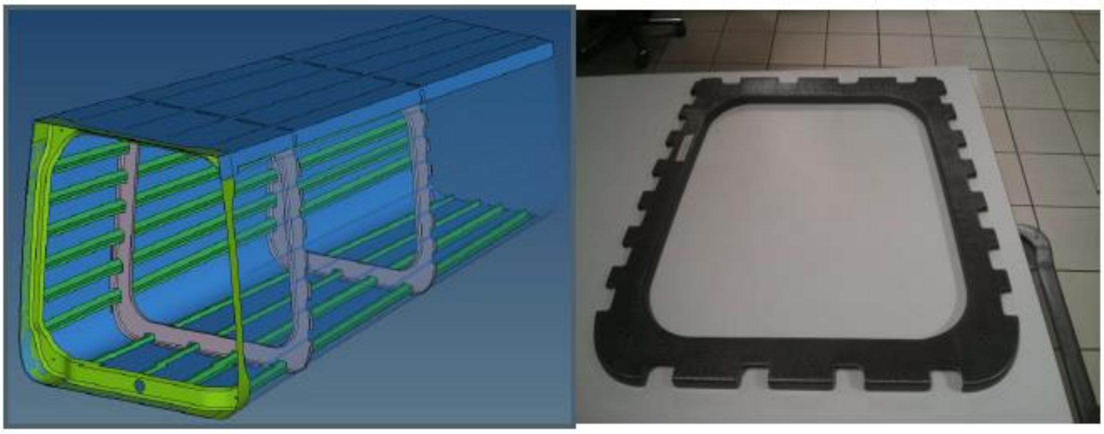
In 2014 all demonstrators were focused on manufacturing and assembly. All applied technologies are basically new and for this reason the maturity and especially the successful applicability for helicopter components was uncertain. Continuous manufacturing trials, on-going adaption of parameters and design iterations represented for this reason the biggest effort in 2014 (and also 2013). Several unexpected challenges were observed regarding manufacturability in general as well as manufacturing process.

In work package 6.1 the thermoplastic composite cross tube fairing, represents a demonstrator for several thermoplastic composite technologies, among them are fibre placement, stamp forming, welding and compression moulding of chopped fibres. The design has been completed and several iterations for process optimization have been undertaken until the end of 2014. This phase was completed and proceeded in the past months to tooling design and tooling manufacturing



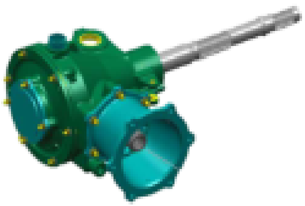
Left: Crosstube fairing and sub-components; Right: Thermoplastic composite rib assembly

In work package 6.2 thermoplastic tail cone is addressed. Most of the effort was invested into the coordination of tooling manufacturing. Additionally, the manufacturing of first skin panels for the tail cone demonstrator showed some difficulties in setting up the manufacturing process. At the end of year 2014, the first frames were produced and. The problem-solving activities have caused some delay but the root causes seem to be solved.



Left: sketch ; Right: Thermoplastic composite rib assembly

Work packages 6.3 and 6.4 are focused on transmission metallic parts. The manufacturing phase was completed and most of the surface treatments performed by suppliers with experience on the specific processes. After the treatment all parts will be sent back for final assembly and further tests (e.g. corrosion and environmental testing).



GRC7: Technology evaluator for rotorcraft

GRC7 had three external deliverables and one milestone relating to the delivery of the Phoenix platform V5.1 for the Technology Evaluator (TE)'s Fifth Assessments.

The data and software packages deliverables for the Single Engine Light update (SELU1) integrated with the TM developed engine model and High Compression Engine (HCE) generic rotorcraft were delivered to the TE as planned. The update of Twin Engine Heavy (TEHU1) deliverable missed the end of year deadline by a fraction and is subject to delivery to the TE at the beginning of 2015.

Following its delayed delivery to the first quarter, GRC7 with great support from GRC5 for the first time integrated the benefits of the low noise trajectories within the (TEM) platform. The HELENA process (development of noise hemispheres) was not without difficulty and only recently resolved for inclusion in the interim update with the TEHU1 model.

As a consequence this prolonged issue has had an impact on subsequent SELU1/HCE noise aspects. To minimise the effect, the SELU1/HCE platforms were delivered on time to the TE with the capability to model the CO_2 & NOx emissions. Relevant HELENA updates will follow in the first quarter of 2015.

Progress was made with the development of (TELU2) due for delivery in 2015.