

Delivering on ambitious objectives



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Axel Krein

Executive Director, Clean Sky 2 Joint Undertaking



In my first message to our Skyline readers, I would like to tell you how pleased I am to be joining Clean Sky right now.

It is very gratifying to see that halfway through the Clean Sky 2 programme, we are delivering on our ambitious objectives. The numbers speak for themselves: after preliminary results from the assessment of the 9th Call for Proposals, I am glad to report 1477 participations representing 334 bigger industrial organisations, 420 small and medium enterprises, 373 research centres, and 350 universities. This results in some 700 unique entities from 28 different countries participating as Partners in Clean Sky 2.

Research and innovation in aeronautics are crucial for Europe, and European Public-Private Partnerships are proven catalysts for delivering innovative technological results. The success of the original Clean Sky and its successor, Clean Sky 2, lies in the collaboration of engineers and scientists from all across Europe. In this regard, I would also like to mention the excellent cooperation of representatives from the European institutions, members of the Governing Board, the EU Member States Representative Group and the Scientific Committee, all of whom provide input and guidance to facilitate our plans and actions.

A priority in the coming months will be to support the development of a new research programme for aviation within

Horizon Europe. This will involve European institutions, all Clean Sky stakeholders and other highly-skilled European partners. The task is clear: continue to meet the demand for air transport, which is expected to grow at a pace of ~4% per annum worldwide, while at the same time limiting aviation's impact on climate change.

The next Clean Sky Programme will have a strong focus on developing, maturing and finally demonstrating technologies with a significant decarbonisation impact on air vehicle operations. It is worth mentioning that new aircraft, incorporating Clean Sky technologies, would have to start entering into service from 2030 to 2035 in order to make a meaningful contribution to the Paris Agreement for combating climate change.

In this Skyline issue, you will find a number of examples of how Clean Sky is currently delivering on our ambitious objectives of reducing CO₂ emissions and noise levels in aircraft. The following projects, and many more, will be presented by the project coordinators at our high-level, two-day Clean Sky conference in Brussels on April 9th & 10th:

- Lighter and more efficient regional aircraft are targeted by the Composite Fuselage project, which is developing technologies to reduce weight and cost in the manufacturing process, as well as developing fuselage health monitoring concepts.

- The Hybrid Laminar Flow Control concept demonstrates how controlling the airflow around an aircraft can result in a reduction of fuel burn and emissions by up to 10%.

- The DiDi-FaCT project is testing power diode dies, a crucial part of the future electrification of aviation.

- The EFFICIENT project is pioneering European research into innovative, environmentally-friendly methods of fire protection in aviation.

- Humans and robots team up for the CRO-INSPECT project, resulting in more efficient inspections.

- In the CA³TCH project, a Digital Wind Tunnel carries out innovative flight simulations to bring pre-flight aerodynamic and aeroacoustic analyses to the next level.

You will also have an opportunity to be part of the Clean Sky community by joining us in May at AERODays 2019 in Bucharest, and at our stand at the Paris Airshow in June this year.

Thank you to Jean-Eric Paquet, the Director General for Research and Innovation at the European Commission, for his supportive contribution to this Skyline issue.

I wish you all an interesting read and hope to see you at our Clean Sky event in Brussels on April 9th and 10th.

VIEW FROM THE EUROPEAN COMMISSION

Jean-Eric Paquet

Director General, Directorate-General for Research and Innovation, European Commission



This is my second opportunity to address the Clean Sky community since my appointment a year ago as Director-General for Research and Innovation in the European Commission. I would like to take this opportunity to thank Mr Tiit Jürimäe for managing the Clean Sky 2 Joint Undertaking as Interim Executive Director and to welcome the new Executive Director, Mr Axel Krein. I wish him and the Clean Sky 2 JU team continued success.

It's an exciting time for aviation. All indicators point towards significant and sustained growth in the sector, and the future of European aeronautics looks particularly bright. I am convinced that the research and innovation efforts of the more than 700 Clean Sky 2 participants from 28 European countries – including universities, SMEs, research centres and industrial leaders – working together around highly ambitious goals will play a substantial role in maintaining this success in future.

However, we should not let this blind us to a stark reality: the ecological footprint of aviation is growing, and this is incompatible with increasing demands for environmentally friendly transport.

European citizens expect reductions in emissions that cause global warming, as

well as noise around airports. We should not be planning to achieve these goals at some date far into the future, like 2050, but as soon as possible. It is with this in mind that the potential continuation of the Clean Sky public-private partnership (PPP) under Horizon Europe is currently being considered.

The Clean Sky research and innovation (R&I) PPP has been funded since 2008 as a policy instrument to support work to address global challenges related to aviation, involving the EU, its Member States and the whole aeronautics community. We were pleased to see such a high number of participants to date. It is a concrete measure to address aviation challenges by translating broad priorities into roadmaps and activities, bringing together a community of innovators to work towards a common long-term goal.

The final evaluation of Clean Sky 1, and the mid-term evaluation of Clean Sky 2, have confirmed the success of both research programmes. The results – and flying demonstrators – of the Clean Sky 1 programme are tangible evidence of this success.

Horizon Europe promotes a more strategic, ambitious and impact-oriented approach to partnerships, ensuring an effective contribution to the Union's policies and

priorities, including R&I missions. It is time to work on a bold, yet realistic, aviation R&I programme for the future, targeting sustainability goals with a clear roadmap of deliverables that will underline confidence in the ability of aviation to prosper while becoming sustainable.

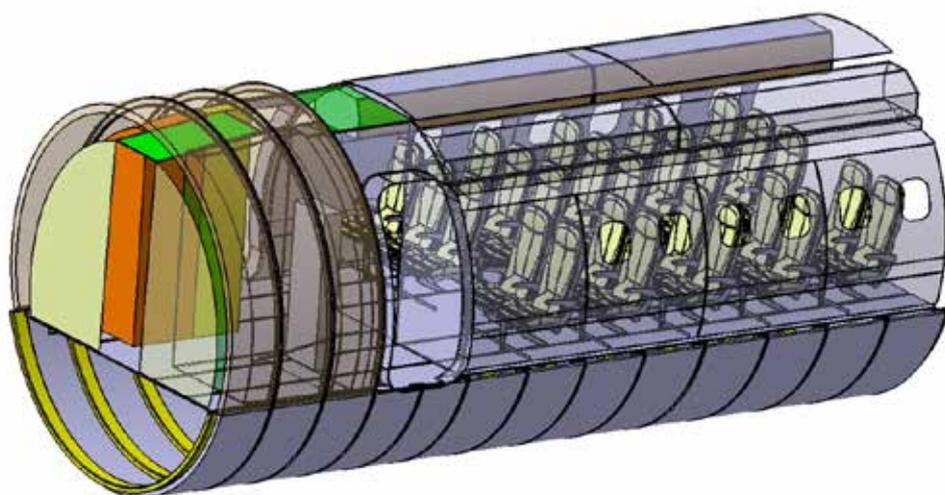
It will undoubtedly be necessary to encourage new actors to enter the stage alongside traditional ones, and to search for synergies with other programmes and sectors, including from all Member States, civil society actors, foundations and third countries.

The European Commission is working together with the Member States, the European Parliament, and European industry to define the best possible future partnerships under Horizon Europe. In aviation, the ambition is high: respond to demanding sustainability goals while maintaining global leadership, ensuring safety, adapting to a rapidly changing mobility landscape (one that features drones and air taxis, for example) and accelerating research, innovation, and the deployment of new and cleaner technologies.

Based upon the experience with the first two generations of Clean Sky, I have no doubt that the European aviation community will excel at tackling these challenges.

Circular Economy: Composite Fuselage for regional aircraft takes shape

Weight and cost reduction in the manufacturing processes and health monitoring of an aircraft fuselage are key to the competitiveness of Europe's regional aircraft industry. Clean Sky's Composite Fuselage project is pushing forward the technological frontiers for European aviation.



Clean Sky's Composite Fuselage project, part of the Regional Aircraft Innovative Aircraft Demonstrator Platform (IADP), aims to develop technologies that are suitable for an advanced regional aircraft fuselage and to integrate and validate them up to full scale demonstrator level. The demonstrators (there are in fact two, one for the structure and one for the cabin interior), are being produced at Leonardo in the form of full-scale fuselage barrels which are representative of a forward fuselage section, just aft of the aircraft cockpit. The project focuses around innovative low cost and low weight composites, advanced manufacturing and assembling processes, and structural monitoring.

"Aircraft affordability is a critical parameter for regional airlines, and in the Composite Fuselage project, technology-wise, we are using a new approach, focusing on the materials and how to integrate all the fuselage's design elements together with the new doors, new windows, frames and a new floor grid" says Ruud Den Boer, Project Officer at Clean Sky, adding that "production automation is also a very important parameter to support that, manifesting itself in such processes as automatic fibre placement and component integration".

Maintainability is an important factor too, so integrated health monitoring – similar to

what is available in road vehicles – is also a consideration within this project: "We are using very small sensors which are integrated into the composite material which can monitor and measure the health of the fuselage, which will help predict when maintenance is required. Embedded sensors in the fuselage will also detect if there is an impact such as a bird-strike or interaction with debris on landings. All of this will lead to the reduction of maintenance costs when eventually used in a production aircraft. But for now it is a technology development to assess if we can really produce this technology economically" says Den Boer.

The project's measurable results are already evident: In the first quarter of 2018 the Preliminary Design Review of a fuselage structural demonstrator was successfully completed, leading to the completion of the preliminary design phase. The project is now in the detailed design phase which will end in 2019 with the freezing of the fuselage component models in readiness for manufacturing to commence.

"Two full-scale fuselage demonstrators will be tested: the first one, the Structural Demonstrator, will be subjected to fatigue and static tests; the second one, the Passengers-Cabin Demonstrator, will assess vibro-acoustic, comfort, thermal tests and

systems integration" says Vittorio Ascione, who is responsible for Engineering/Structures Analysis and Methods at Leonardo.

"At the moment, tests on specimens, elements and sub-components have already been carried out, based on the application of the building block approach. And further results will be available through the full scale demonstrations even if results coming from tests already performed on innovative composite specimens are being used for the design phases".

As for the social and environmental benefits, Ascione says that "structural weight and cost reduction goals in the Structural Demonstrator will contribute to reducing CO₂ emissions, thanks to lighter structures and more automated and eco-compatible manufacturing and assembly processes. Increased comfort and wellbeing in the passenger cabin demonstrator will contribute to improving the passenger in-flight experience in advanced regional aircraft".

By the end of the project the structural behavior and the performances in terms of internal noise reduction, passenger comfort and wellbeing are scheduled to be evaluated through full scale tests which will be executed at Leonardo Aircraft Division and also at the Fraunhofer Institute.

ZOOM IN CLEAN SKY 2 RESULTS

Go with the flow: Clean Sky's Hybrid Laminar Flow Control Demo

Controlling the flow of air around an aircraft by making that flow laminar can reduce fuel-burn and cut emissions up to 10%. Clean Sky's Hybrid Laminar Flow Control (HLFC) demonstrator is putting the theory to the test.



Laminar flow is the Holy Grail for aerodynamicists, and in fluid dynamics laminar flow occurs when a fluid flows in parallel layers, with no disruption between the layers. Hybrid Laminar Flow Control, the subject of the HLFC Demonstrator project within Clean Sky 2's Large Passenger Aircraft (LPA) Innovative Aircraft Demonstration Platforms (IADP), is a means to ensure that the air flows around certain parts of the aircraft in parallel layers using a hybrid structure which can be mounted on the leading edge of the tail and of the wing, and by so doing, significant fuel savings and environmental benefits are possible.

"Imagine if you light up a candle. The bottom part of the flame is quite stable, but the top of the flame moves erratically" explains Xavier Hue - Clean Sky 2 Technical Leader at Airbus. "Think of laminarity as that lower, more stable part of the flame and contrast that with the top part of the flame which is "turbulent", moving everywhere. If we transpose this comparison onto an aircraft the air around the wing behaves like the flame. There we want to reduce the turbulent part of the flow that is generating drag, which means more fuel consumption. What we're aiming for is to have

the air flow around the airfoil (it can be a wing and/or a vertical/horizontal tailplane) more like the stable, lower part of the flame. So what we're trying to achieve with our HLFC system is to make sure we maintain the laminarity on the airfoil of the wing and/or the vertical/horizontal tail plane for as long as possible, so that the air is flowing in parallel layers".

"Drag reduction by using laminar flow technology offers a potential double-digit decrease of specific fuel burn for large and faster long range aircraft. Suction will be applied at the leading edge of airframe components such as on the wing, tails or nacelles. The complexity, weight, industrial viability, and operability of the required systems are key to materialise the aerodynamic benefits" says Hue.

The work package of the project will include two major ground-based demonstrators and one flight-test demonstration, which are complemented by research and wind-tunnel tests:

Demo 1 will focus on the development of HLFC horizontal tailplane and large-scale ground based testing to achieve a fully functional HLFC

on a leading edge segment at TRL6. Demo 2 will include the design, build and test of a large-scale ground based demonstrator of HLFC technology applied on a wing at TRL4. A flight test demo to acquire data in specific flight conditions and representative of airlines operations will be carried out with an Airbus A320 reusing HLFC test fin developed in a former EU project.

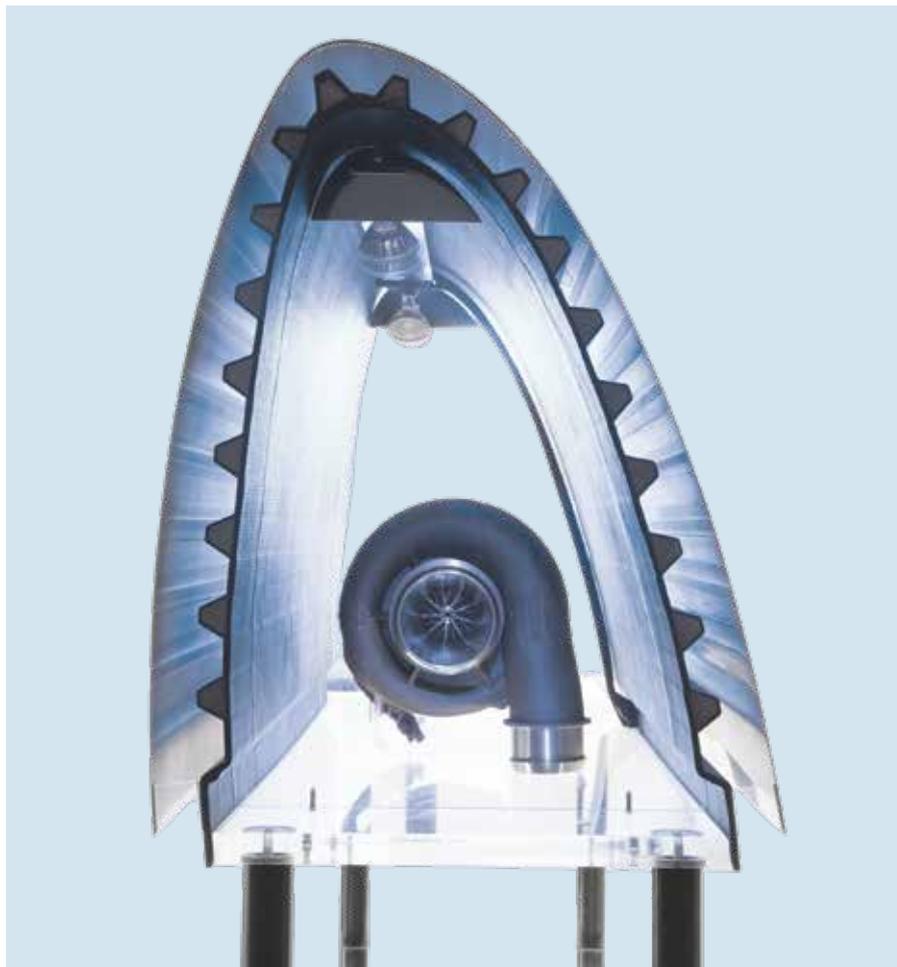
Sebastien Dubois, LPA Project Officer at Clean Sky reports that the project is now progressing towards developing a device which will be implemented to reinstate the laminarity of the air flow around the aircraft in order to avoid air turbulence: "Every time we go to reinstate such laminarity – either natural laminarity which means without any active devices, or using passive devices which is more linked to the shape of the product where we implement some active or passive devices to force the air-flow to become laminar – this will limit turbulence, contributing to fuel savings and reduction in CO₂ emissions" explains Dubois. To put the importance of this project to European aviation into a global context, he notes that "by comparison, overseas, a [hybrid laminarity] solution is already implemented on Boeing's latest aircraft generation, the B787".

What Clean Sky is doing in this project is to concentrate its efforts on implementing a solution on the aircraft empennage, focusing either on the fin (the vertical tailplane) or on the horizontal tailplane. A previous work-package within another EU project called AFLoNext already carried out studies on a fin – the project was completed last year with a solution flight-tested on the DLR aircraft, showing a potential benefit of HLFC. Some of the findings of that project are complementary to Clean Sky 2's Hybrid Laminar Flow Control project's objectives, which aims at fuel reduction and CO₂ reduction of half of one percent.

Half a percent might not sound substantial, but the bigger objective of the project is to demonstrate the potential of the technology. This means carrying out the work associated with defining the device and the materials, performing the manufacturing of the demonstrators, and also conducting experiments, with the objective of collecting information around the constraints associated with the deployment and implementation of such a new device onto an aircraft.

"If we want to benefit from a positive exploitation route of such a solution we need to assess and process all the potential adverse elements such as constraints of cleaning, constraints of operation, potential failures that could occur in operation and so on. This could lead to the decision to implement – or even not to implement – such a solution. The idea is really to assess the potential performance in terms of benefits but also performance in terms of operations, to determine what is required to operate such a solution onto an aircraft, and this is what will take place in Clean Sky," says Dubois, who adds that "There are two aspects to all of this: the design, development and the maturation of the technologies, and the assessment of the in-flight performance and in operations, over a certain duration, to capture all the necessary elements".

Though the project's focal point is oriented around the aircraft tail, the ultimate goal is not to implement this on the empennage but on the wing, where most of the potential resides.



By the end of the project, the expectation is to accomplish HLFC demos on the tails & wing; manufacture of a segment of a Hybrid Laminar Flow Control Leading Edge (tested on a large scale ground test); development of a 'one shot' process integrated with the micro-perforated Titanium sheet (developed in Clean Sky 2's HYPERDRILL project); fulfillment of the aerodynamic, industrial and operability requirements; and a simplified HLFC concept for high production aircraft rate at acceptable cost.

"If you implement this everywhere on the wing and on the horizontal tailplane and the vertical tailplane you could gain up to 10% fuel efficiency" says Airbus's Hue, who

points out that, in terms of progress, "there is a test pyramid planned, for which there are some samples already tested. Their evaluation is currently ongoing. Small scale demonstrators are being manufactured to secure and confirm the choice of the design solution. Achievements so far in the project include the completion of Demo 1, where the aeronautical and manufacturing requirements were consolidated with the system definition of the active/passive device, plus various coupon tests were passed, bringing the technology readiness level of the project to TRL3. Going forward, work started on Demo 2 in April 2018, and looking further into the horizon, the flight test demo is scheduled for 2019/2020".

ZOOM IN CLEAN SKY 2 RESULTS

Taking the heat. DiDi-FaCT tests power diodes to the limit

The trend towards the electrification of aircraft means greater use of power electronics and the scaling up of electrical generators to cope with the growing power demands of aircraft systems previously served by mechanical and hydraulic means. Power diode dies are part of this evermore electric future for aviation, but they have to operate within the searing and stressful confines of aircraft engines – how long can they stand the heat? Clean Sky's recently completed DiDi-FaCT project set out to take power diodes to the limit.



Power diodes are mission-critical components within aircraft electrical generators that must withstand the extreme temperatures of a hot engine environment with high rotation-induced compression stress, thermally induced shear stress, and low or even sub-zero temperatures when the generator is not running. They must also withstand dramatic acceleration from standstill to thousands of RPMs. Yet these diodes must perform reliably for extended periods with low losses for as long as the generator is operational. New techniques for packaging diodes using bare silicon dies, and new semiconductor technologies including silicon carbide, are now finding their way into these harsh-environment applications and show promise in terms of size, weight saving, thermal and electrical performance. But for how long are these new diode dies operationally fit for purpose?

The main objective of DiDi-FaCT (Diode Die Fatigue Characterisation and Testing) project which finished in December 2018 was to advance the understanding of the reliability of diode die material (silicon and/or silicon carbide) by analysis and testing. The analysis part of the objective was to develop a model that can predict the life of the diode die material under different combinations of mechanical, thermal and electrical loads. This information is very valuable for users of power electronic dies in harsh environments such as

aircraft generators, as it allows the optimisation of the die package design with regard to long-term reliability, paving the way towards large weight and efficiency improvements in generators and other equipment.

Prior to this project, the long-term reliability of diodes used in this type of demanding aeroengine application had not been conclusively tested, which is why Clean Sky's DiDi-FaCT three-year project set out to explore the operational limits and potential longevity of (project topic manager) Thales' diodes, with the objective of delivering an optimised and validated aging model of the dies.

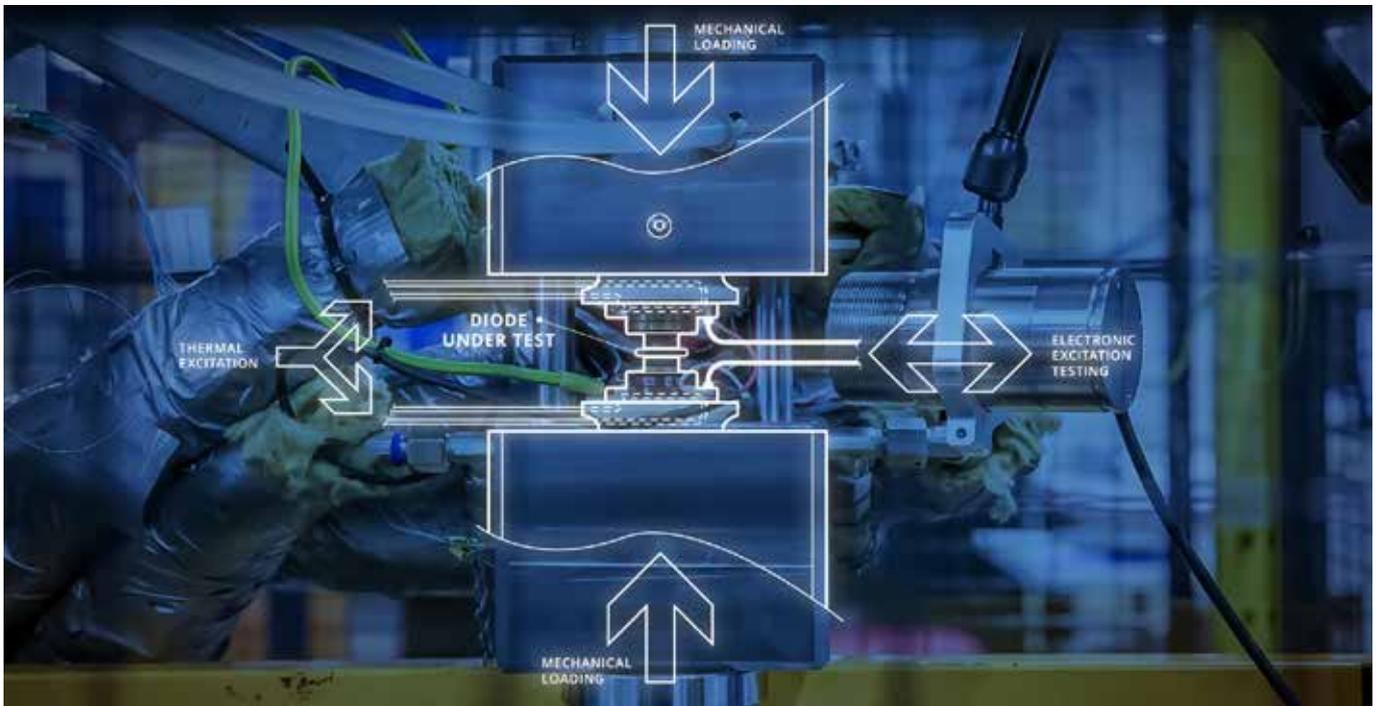
The results of the project deliver new knowledge of the long-term fatigue and wear parameters, providing vital assurance of the durability of diode dies. This will create an opportunity to use higher RPMs, increasing the generator's power density, and this means that the environmental footprint is reduced by fuel savings – in line with ACARE goals – by facilitating the design of lighter and more compact generators and starter/generators for use in Europe's next generation of efficient and eco-friendly aeroengines.

"With aircraft becoming more electrical, in other words with more electric loads, we

need more electric power in modern aircraft which normally means a larger and therefore heavier generator. Weight is always something that we want to minimize, so to reduce the weight of the generator you would have to use new technology which means rotating faster" explains Alte De Boer, R&D engineer at the Aerospace Electronics and Qualification department and project manager of DiDi-FaCT at NLR National Aerospace Laboratory in the Netherlands, the coordinator of the project.

"What happens in these generators is you need to do rectification from an AC current to a DC current and there is the need to do that on the rotor which is at the heart of the generator" says De Boer, "So it's usually quite hot there and also the rotor turns, which means that there is a centrifugal force. The working principles of the generator are such that if you want to turn the same machine faster you get more power out of it, and so your power density improves and you get more power per weight. That's of course what we always want in the aerospace industry – to get the weight down or to get more performance with the same weight".

Knowing fatigue characteristics of diodes provides confidence that generators can be operated at higher speeds, so power density



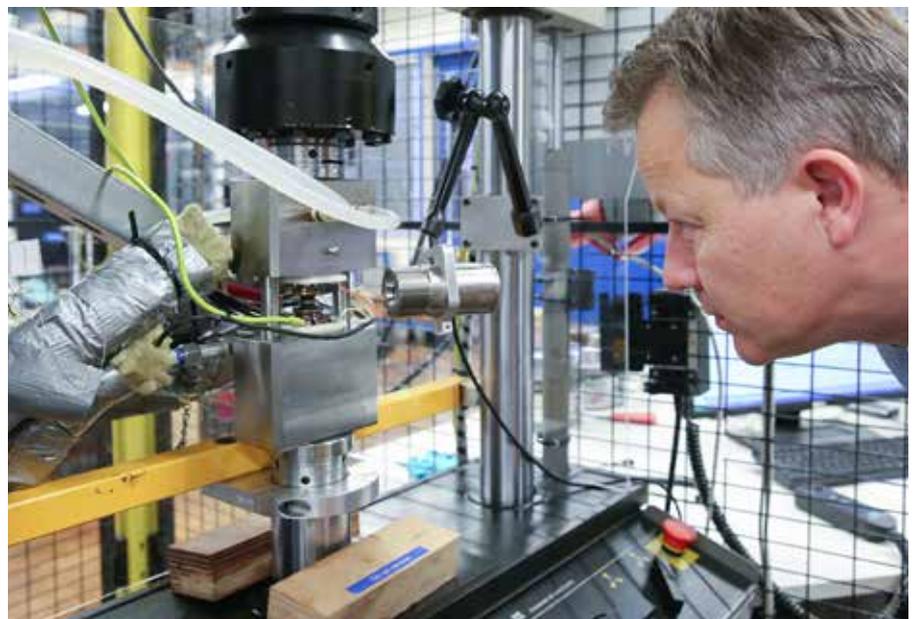
improves and weight can be reduced. And this means less fuel consumed, so less CO₂ and NO_x are emitted, contributing to reducing aviation's environmental impact.

The assumption at the beginning of the project was, says De Boer, that "by starting an engine up – spinning it up and spinning it down – that there would be some kind of fatigue effect on the diode die, like you have with metals. And if so, there would be a life limitation due to the high mechanical cyclic loading".

The testing process at NLR involved simulating the life cycle on the diode die through a process of mechanical pressure and temperature fluctuation over 100,000 cycles, the equivalent of starting and stopping a plane five times a day for more than 50 years, by means of a dedicated test bench.

"To investigate the fatigue behaviour we had to design, build and develop a very specific test bench that could do that. It had to do the mechanical cycling but it also had to have the temperature control because we wanted to test the diodes at various temperatures" says De Boer.

"The outcome of the project was that the fatiguing effect is different from the classic



fatigue that we're used to" concludes De Boer. "Normally we do fatigue testing of mechanical structures, even up to full size wings or other aerodynamics structures and also small components, and within NLR there's a lot of knowledge on the fatigue characteristics. The fatigue behaviour that we now saw with those

diodes is different and we have characterized how it is different – it is not classical fatigue. And the other important result is that within the pressure range, or the force range that the project's topic manager was interested in, we saw no indications that there were fatigue problems, so that is good news".

ZOOM IN CLEAN SKY 2 RESULTS

Hot topic: Clean Sky's 'Environmentally friendly fire protection' system

For the past four decades, the cargo holds of airplanes have been protected with fire-suppression and extinguishing systems that use Halon 1301. It's an effective agent and poses no risk to passengers. However there are two threats on the horizon that must be urgently addressed – and Clean Sky is turning these threats into a unique opportunity for European aviation, thanks to the EFFICIENT (Environmentally Friendly Fire suppression for Cargo using Innovative greEN Technology) project.



“Halon 1301 is a very effective agent. You don't need much of it to achieve your fire protection goals, therefore it doesn't add much weight to the aircraft. It's safe for use in the concentrations we need, so there's no danger to people. So from fuel consumption, safety, and from an economics perspective Halon is perfect and that's why it's been used over the last 40 years on board commercial aircraft to protect the lower deck cargo hold from fire” says Rainer Beuermann, Fire Protection CoC Cabin & Cargo, Airbus Operations GmbH.

But despite the suitability of Halon 1301 for fire suppression in aviation, Beuermann also points out that there's an environmental downside: “Halon depletes the ozone layer, and this regulation needs to be seen in the context of our product evolution policy, so if Airbus decides in the future that we need to come up with a new aircraft programme because of competitor pressure, then this new aircraft would have to be equipped with a Halon free system”.

Efforts to protect the ozone layer were adopted in 2008 under the Montreal Protocol, and ongoing

initiatives by the EU to mitigate the ubiquity of Halon include the Commission's launch, last year, of an evaluation of the Regulation (EC) No 1005/2009 (the Ozone Regulation). It's a serious issue that will affect Europe's air transport, though the regulation only applies to new type certificates, not to current production or derivative aeroplanes.

There's another looming issue in the background – an obsolescence risk. A sub group within the UN environmental programme has assessed the availability of Halon on a worldwide basis, and has determined that global stocks of Halon are diminishing and could run out by the end of the decade. Therefore, in addition to the environment there's a business risk to aviation operations.

“Clean Sky's EFFICIENT project, promoted by Airbus, seeks to design, develop, manufacture and test an environmentally friendly and economically viable Halon-free cargo hold fire suppression system which will reduce environmental impact by reducing weight and lowering aircraft CO₂ and NOx footprint” says Paolo Trinchieri, Project Officer at Clean Sky. “The project is a collaboration led by

Cranfield University with SP Technical Research Institute of Sweden AB, London South Bank University, all striving to come up with an entirely new Halon-free solution which provides at least an equivalent level of safety compared to Halon 1301”.

If Clean Sky develops a replacement for Halon, in addition to the environmental benefits there will be a unique business opportunity for European aeronautical companies and for the associated supply chain. After all, an alternative for Halon will be needed worldwide, not just for European aviation.

But an artificially created substitute with similar chemical characteristics to Halon 1301 would take more than 10 years to develop, would be prohibitively expensive and, being a niche product would be too commercially risky to develop. There are Halon 1301 alternatives that are suitable for land applications but these are not compliant with the stringent fire suppression requirements in aviation. The EFFICIENT team has been examining the possibilities from a variety of angles:

“The first question when we started this project was:



Are there any potential alternative agents? But there weren't any on our radar" says Airbus's Beuermann. "The SP Technical Research Institute of Sweden did some market research regarding alternative agents and developments on the market, looking at what is available and what might be available in due course. Based on this research they down-selected potential agents and came up with a final recommendation for further investigation, taking into account the stringent safety and performance requirements to be met by the agent. The current work now focuses on the use of inert gases as halon replacement agents based on the outcome of the agent-down selection".

Zodiac Aerotechnics is working on an On-Board Inert Gas Generating System that shall provide Nitrogen in such a quantity and quality allowing the safe suppressing of a cargo hold fire under all operational conditions. The manufacturing of the demonstrator unit is progressing and completion of the demonstrator is expected by mid 2019.

"But the replacement of halon with an inert gas does not enable the design of some kind of simple drop-in-replacement solution" says Beuermann. "New system philosophies and combined multi-functional systems architectures need to be considered for the next generation of halon-free cargo hold fire suppression systems".

A partner in the EFFICIENT consortium, The London South Bank University, has already carried out some large-scale fire suppression tests, because the first consideration that will drive the design of the system architecture is how much agent is needed in order to achieve the fire suppression goals and what concentration is required. The University also did some lab scale fire suppression tests in order to specify the required extinguishing concentration, as well as some lab scale explosion tests to determine how much concentration is needed to contain a propane enriched atmosphere, related to the very specific fire test scenarios inside the cargo hold.

Now that the required concentration is known, it is possible to use this preliminary data to design the architecture which is the backbone of the system, and it becomes possible to explore which technical options exist to either generate the agent on-board or to store it in high pressure cylinders.

"There are two ways to demonstrate this" explains Beuermann. "First you have to perform full scale fire suppression tests and then the second stream is we need to show that the agent distribution inside the cargo hold meets the specified design concentration. To suppress fire in the cargo hold you need to flood the entire cargo with the required design concentration and you need to maintain these same concentrations, bearing in mind that the cargo hold is not 100% airtight – we call it cargo hold leakage. As we lose some of the cargo hold atmosphere you have to compensate for any leakages. That means that under all operational conditions the system is able to build up and maintain the specified design concentration".

The pressure inside a cargo hold is significantly affected as an aircraft changes altitude during climb and descent phases of the flight, which in turn changes the agent distribution pattern. An important aspect of the project has been how to simulate realistic flight conditions, temperature and pressure changes – without the expense of using a real aircraft in flight, which would have been prohibitively expensive. Representative demonstrators are essential to reach the project's objective of reaching Technology Readiness Level (TRL) 6.

"One way we can work to achieve this is by using Computational Fluid Dynamics (CFD) to predict agent distribution inside the cargo hold" says Beuermann. "CFD results are of a very high quality but it takes a long time to get those results. Fraunhofer is working on a new simulation tool that allows faster assessment regarding novel or

redesigned fire suppression architecture. It runs on a standard laptop to provide fast first design tests for a first risk assessment. This tool builds on the results obtained from the Clean Sky 1 project and this could help us regarding the development of new Halon-free systems".

The findings of these CFD tests are complementary to a series of representative ground-based tests which include a full scale fire suppression test campaign scheduled for the end of March 2019 at Cranfield University. Additionally, the first agent discharge and agent distribution tests under representative flight conditions are planned for Q4 of 2019 at the Fraunhofer Flight test facility in Holzkirchen, Germany.

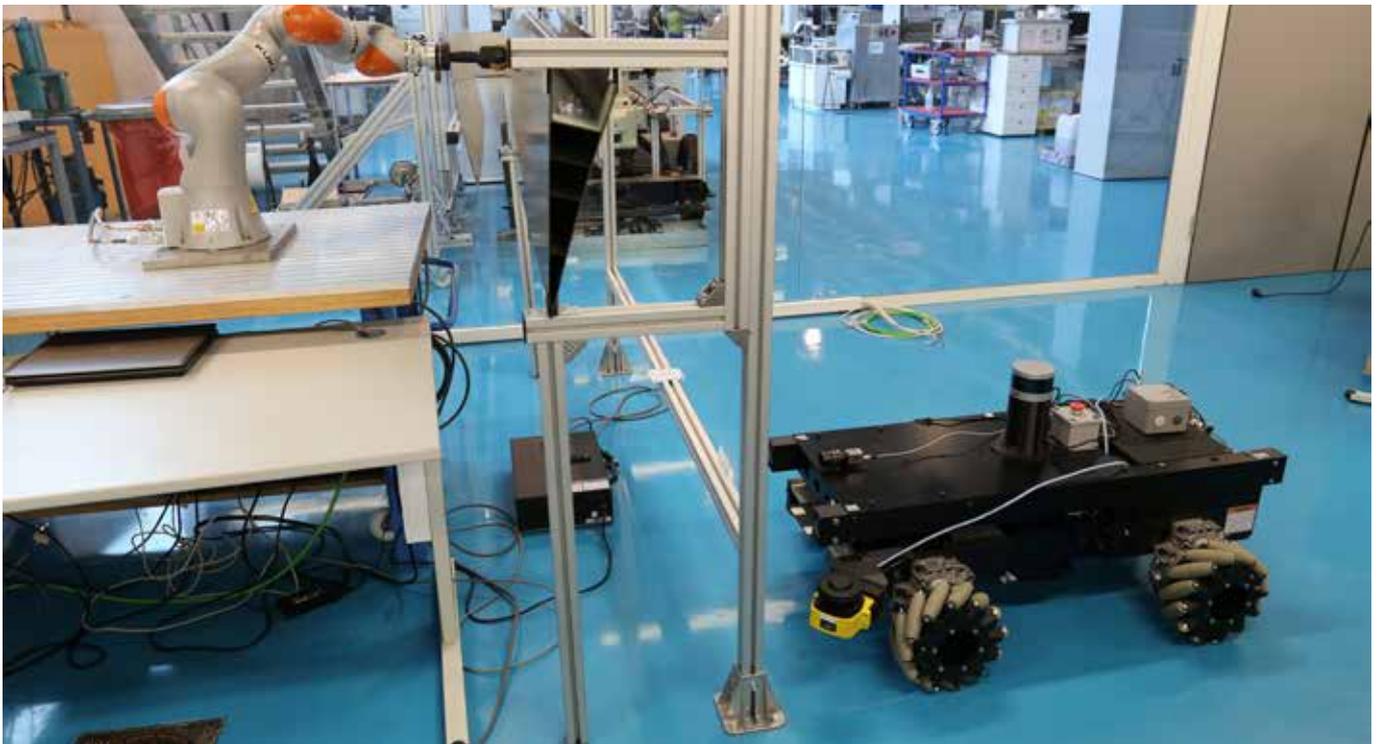
Fraunhofer's facility consists of a huge tubular pressure vessel containing part of the forward fuselage of an Airbus A310 complete with lower cargo hold, where it is possible to cool down the entire facility and change the pressure to create realistic in-flight conditions. The facility can even simulate descent profiles to represent changes in flight altitude to determine agent distribution contours over time. The results and information obtained from this testing are crucial in order to assess whether the fire protection objectives have been met or not.

"This is one of the beauties of Clean Sky 2, as we were not aware that this kind of flight test facility even existed in Germany, at least not here in Bremen" says Beuermann. "Clean Sky 2 has established the link to the flight test facility at Fraunhofer and has closed the gap in our validation and verification process because the conditions you have in a real flight are very difficult to simulate on the ground. By collaborating through Clean Sky we are learning where we can find new capabilities and skills within Europe that strengthen and reinforce the European research and technology network".

ZOOM IN CLEAN SKY 2 RESULTS

Humans and robots team up for Clean Sky's CRO-INSPECT

Increased use of composite materials in aircraft construction reduces weight and cuts fuel burn. That's beneficial for the environment, but the structural complexity of composites necessitates new inspection regimes to verify quality during manufacture as well as for early detection of product degradation throughout the service lifespan. These inspections use ultrasonic techniques such as 'guided waves', but are labour-intensive. Clean Sky's CRO-INSPECT project is developing a collaborative hybrid work cell whereby human diligence is complemented by robotic efficiency, paving the way for competitive industry processes in European aeronautics.



The trend towards automation in industrial processes is irrefutable, driven by cost savings, quality assurance and business efficiencies. But robotic processes have their limitations, especially when it comes to inspecting aeronautical components manufactured in composite materials. The complex structure of composites – combined with the intricate geometry of many aircraft components – means that human judgment is key to ascertaining the integrity of a part as it undergoes ultrasonic inspection, whether it's during the production process or later,

through its operational life. And by the standards of today's industry processes, such inspection processes are very labour-intensive.

What if the laborious human role could be complemented with, and accelerated by, the efficiency of robotics? That's the premise behind Clean Sky's 36-month CRO-INSPECT project, which kicked off in December 2016. It's already making significant strides towards proving its viability as a powerful concept for aeronautical inspections for the future – one that leverages the productivity of European

aerospace skills, bringing competitive advantage to Europe's aviation sector.

"The objective of CRO-INSPECT is to have a collaborative robotic solution because the inspection of aircraft components is, in some areas, almost impossible to automate – the idea is to have a more optimised and higher quality level of inspection" says Loreto Susperregi, Researcher at the Spanish research alliance IK4-Tekniker, the Primary Coordinator for the Clean Sky CRO-INSPECT project. Also supporting the project are inspections

solution provider Tecnatom, as well as Lortek, which is responsible for the ultrasonic 'guided waves' technology which is used for the detection of defects in composites.

Tekniker is using a specific aileron designed by SAAB for the mock-up and for the validation of the solution, but once the process is fully fledged it will be applicable to numerous other aircraft components.

"Today in the aircraft sector where they're manufacturing big parts inspection is very expensive because you have to mount a big infrastructure, so our approach is to use a small mobile manipulator that moves around the part and performs the inspection. If we are able to demonstrate that we can carry out inspections using this kind of solution it will be a more economical and more flexible solution" says Susperregi. "There are some areas of aileron inspection that cannot be automated with robotics, so the aim is to employ a collaborative robot which uses a mobile manipulator, a type of robotic arm. The idea is to provide more flexibility for inspections solutions, enabling inspection of different ailerons while human operators are safely working around the robot" says Susperregi.

To ensure safety the system is equipped with several sensors in order to detect the proximity of humans and will stop or reduce the speed accordingly, depending on the distance, because apart from providing the functionality – in this case, the inspection of the aileron – the system uses an ultrasonic tool. So the technologies in development at CRO-INSPECT focus both on the control of the platform that automatically performs the inspection operation, as well as on the safety behaviours that are required in order to avoid any risk to the people working around the robot.

Key to the viability of the project is the human element, both from the point of view of manoeuvrability and fine motor skills as well as from the perspective of analytical skills, says Susperregi: "The aircraft industry is



quite manual compared to other Industries, and for good reason. Human dexterity is very difficult to achieve with robots today. For operations that require human dexterity you need the integration of the human in the loop, and from an analytics point of view, human supervision is critically important in the inspections processes. As a general principle, if we're talking about repetitive activities without too much added value then probably a robotic solution will replace humans, but if we're talking about activities that require reasoning, common sense, and supervision – then I hardly see the replacement of the human by any robotic solutions".

In terms of progress, the CRO-INSPECT team say that they are working towards producing "functional prototypes where we can validate the technological approach that we have decided upon. We need to determine whether the configuration of the mobile platform with the robotic arm is flexible enough to provide a solution for the intended inspection activities. We will be finishing in August 2019 and the road map is to produce several prototypes at TRL6/7. In fact, we are building the mock-up of the solution here at Tekniker, and now we are mainly involved in the integration

of the mobile platform with the arm" adds Susperregi.

In the context of Clean Sky's drive to foster the technologies that will bring competitive advantage to European aviation and benefit its citizens, CRO-INSPECT is a key initiative in that bigger picture of nurturing efficiencies as well as industrial leadership in Europe's mobility ecosystems:

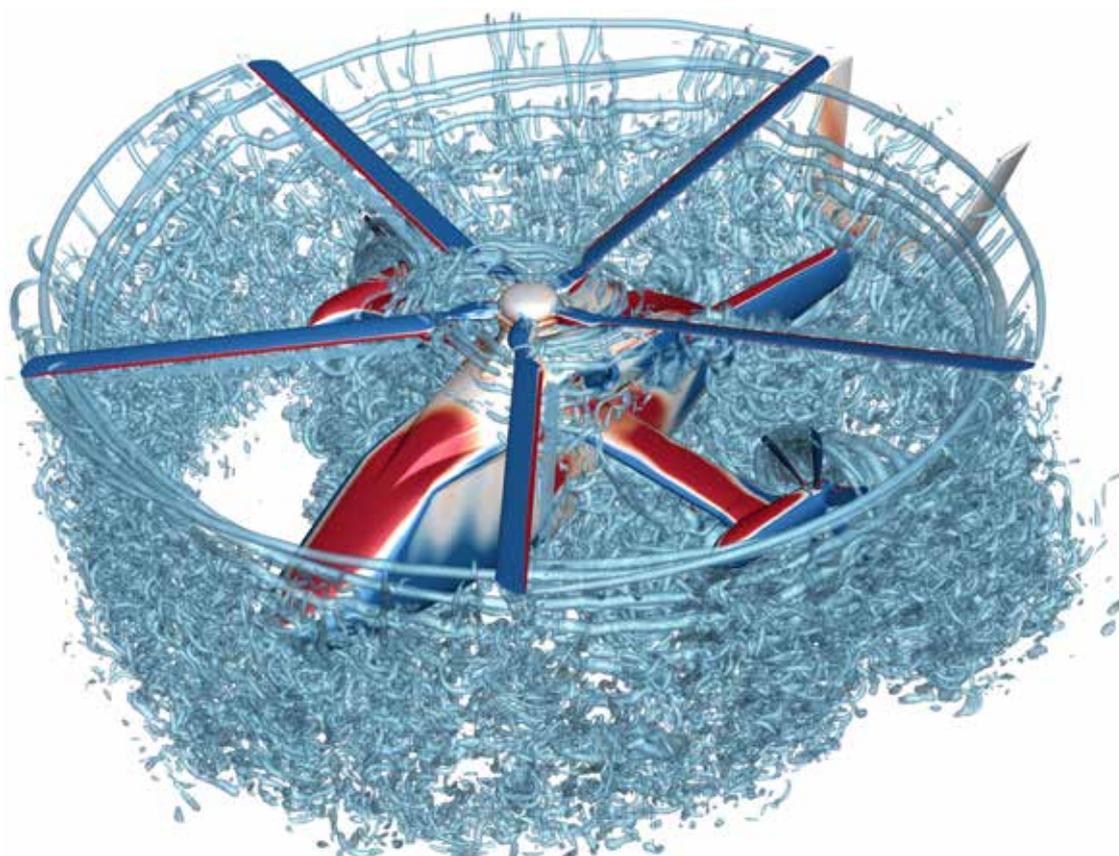
"CRO-INSPECT will contribute to a process optimization in terms of manufacturing timing; cost-efficient process (-7% of the inspection costs) and to an increased quality of the inspection. From an economic impact point of view, this means reducing the overall manufacturing costs, thus making European aeronautics more competitive", says Elena Pedone, Clean Sky's Project Administrator for CRO-INSPECT. "In addition, this technology could be spilled over to other economic sectors that use also composite materials, such as Wind Energy, and/or Ship-building, making the European Industry globally more competitive.

"Finally from the environmental point of view this means a reduction of the CO₂ and NOx emissions resulted from the manufacturing process, thus contributing to the ACARE goals."

ZOOM IN CLEAN SKY 2 RESULTS

Here's the CA³TCH... Reducing risk with Clean Sky's Digital Wind Tunnel

Innovative flight simulations using a 'digital wind tunnel' developed under Clean Sky's CA³TCH project bring pre-flight aerodynamic and aeroacoustic analyses to the next level.



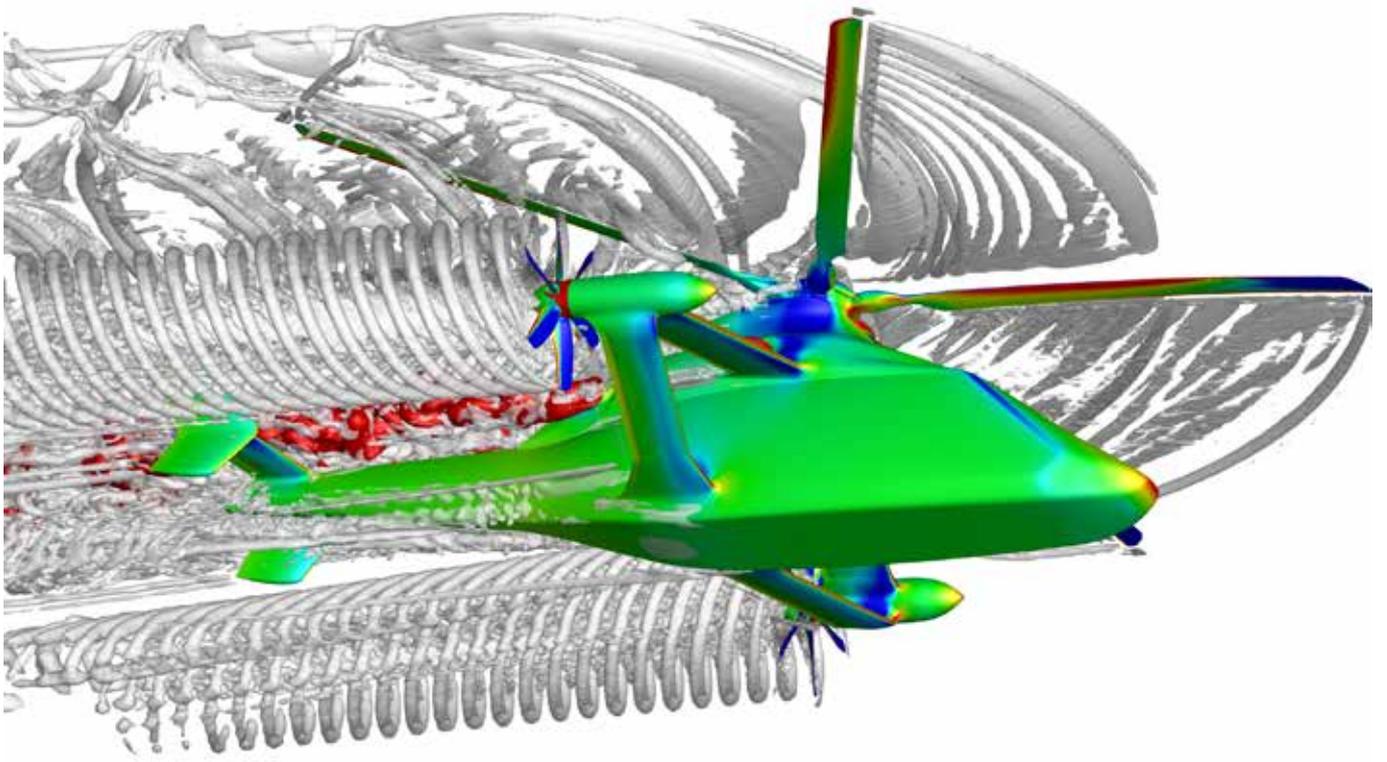
Now into the final year of its 48-month timeline, Clean Sky's CA³TCH (Comprehensive Aerodynamic - Aeroacoustic Analysis of a Trimmed Compound Helicopter) project is strengthening the competitive position of the EU aeronautics industry and underpinning European international aviation. Its primary aim is to establish the simulation technology required to support the aerodynamic design and development of Airbus's RACER (Rapid And Cost-Efficient Rotorcraft) demonstrator, all the way from rough estimates to detailed design and analysis at different flight states, through to the point of first flight. It's a comprehensive research study taking account of the full

external aerodynamic behaviour of the compound rotorcraft, whereby aerodynamics and aeroacoustics are being investigated through full-featured structural simulation and flight mechanics, using a 'Digital Wind Tunnel'.

"The goal of CA³TCH is to reduce risks before the first flight by elaborate flow simulations. This encompasses flight stability in adverse conditions, power and control limits in different flight regimes and, not least, noise emissions" says Dr. Manuel Keßler, Head of Helicopters and Aeroacoustics at the Institut für Aerodynamik und Gasdynamik (IAG) at Universität Stuttgart. "Our unique advanced simulation framework at IAG is able to

provide accurate and dependable answers to such questions by means of heavy use of supercomputing power".

This means, in practical terms, the University's 'virtual simulations' will provide insights to support the development process related to aerodynamic and aeroacoustic optimisation, flight mechanics properties and even handling qualities to a certain extent – all before the actual physical prototype leaves the ground. As the project approaches its final months CA³TCH will offer a potential 'halo effect' as publication and dissemination efforts in the pipeline spread this enhanced capability to related areas of European industry, from fixed wings to wind turbines.



The focus of CA³TCH started with detailed investigations of the flight mechanic stability and aerodynamic interference of the compound helicopter's rotor and wing under numerous flight conditions. Anticipating the wide range of operations that the vehicle will be potentially capable of, analyses were made of transverse and reverse flights, download factors on the wings – especially in hover mode – and flight stability, with focus on autorotation and other critical flight states, such as slow lateral flight.

Additionally, study has been ongoing of the most efficient operations possible at high speeds as well as noise evaluations, where acoustic analysis of the rotorcraft focuses on interference phenomena between the main rotor and propellers and the interaction of the sound generated there with the airframe.

Highly accurate CFD simulation of the complete vehicle configuration with all its

components, including consideration of the flow-structure coupling on the elastic rotor blades, and trimmed in load-free stationary flight, is eliciting valuable information about the predicted behaviour of the RACER, long before any hardware is manufactured. Hence, safety-critical issues can be identified and managed at an early stage, significantly reducing the risk before the first flight, resulting in condensed development time and cost reduction.

"Several million CPU-hours (equivalent to some thousand years on a desktop computer) of computing time have been invested, and the results have helped Airbus Helicopters to gain a better insight into the phenomena occurring on this innovative configuration" says Keßler. "They have cross-checked their own findings based on other tools, and sometimes we observed surprising issues necessitating adaptations, in order to mitigate. Three PhD candidates at IAG work on this ambitious undertaking".

Following validation of the RACER demonstrator's aerodynamic configuration last year, key subsystems have now successfully passed their Preliminary Design Review, paving the way for manufacture of the first components, with final assembly of the prototype planned in Q4 2019.

"First flight of the RACER prototype is currently scheduled for 2020" says Keßler, and the flight test regime of the actual demonstrator will amount to about 200 flight hours. But none of this would be possible without the additional digital wind tunnel analyses of Clean Sky's CA³TCH. Keßler adds that "if successful, this may evolve into a future product of Airbus Helicopters, achieving unprecedented efficiency and flight speeds, for a rotorcraft, thus enabling mission capabilities that are currently unavailable".

ANNOUNCEMENTS

10th Call for Proposals coming soon!

Keep an eye on our website for news on the 10th Call for Proposals which is due to open in May 2019:

<http://cleansky.eu/calls>

Save the date: Aerospace Europe Conference 2020

To pave the way for a single European aerospace conference, 3AF and CEAS are joining forces to launch the very first edition of the Aerospace Europe Conference (AEC2020), with the support of Clean Sky, SESAR and ESA.

The event will take place on 25-28 February 2020, and will provide an exceptional opportunity to exchange knowledge and results of current studies and to discuss directions for future research in the fields of aeronautics and space. Read more:

<http://cleansky.eu/event/aerospace-europe-conference-eac2020>

Aerodays 2019 Bucharest

Mark your calendars for the first installment of TandemAEROdays19.20, which will take place on 27-30 May 2019 in Bucharest, Romania. AEROdays (European Aeronautics Days) is the leading event in aviation research and innovation, a solid platform to share and review the latest developments in aeronautics and air transport across the European Union.

Read more on our website: <http://cleansky.eu/event/aerodays-2019-bucharest>



Le Bourget 2019

From 17-23 June 2019, Clean Sky will again join forces with the European Commission at the Paris Air Show - Le Bourget to showcase the innovative results of the programme so far and discuss the future of aviation research in Europe. Keep up to date on our website:

<http://cleansky.eu/event/le-bourget-2019>



53rd INTERNATIONAL PARIS AIR SHOW LE BOURGET JUNE 17-23, 2019
53^e SALON INTERNATIONAL DE L'AÉRONAUTIQUE & DE L'ESPACE PARIS - LE BOURGET 17-23, JUIN 2019

Executive Director: Axel Krein
Editor: Maria-Fernanda Fau, Advocacy and Communications Manager

The Clean Sky 2 Joint Undertaking receives funding under the Horizon 2020 Programme for research and Innovation.

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Find us on:



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White Atrium, 4th floor, Av. de la Toison d'Or, 56-60
1060 Brussels