Clean Sky 2
JOINT UNDERTAKING

Innovation takes off

Skyline

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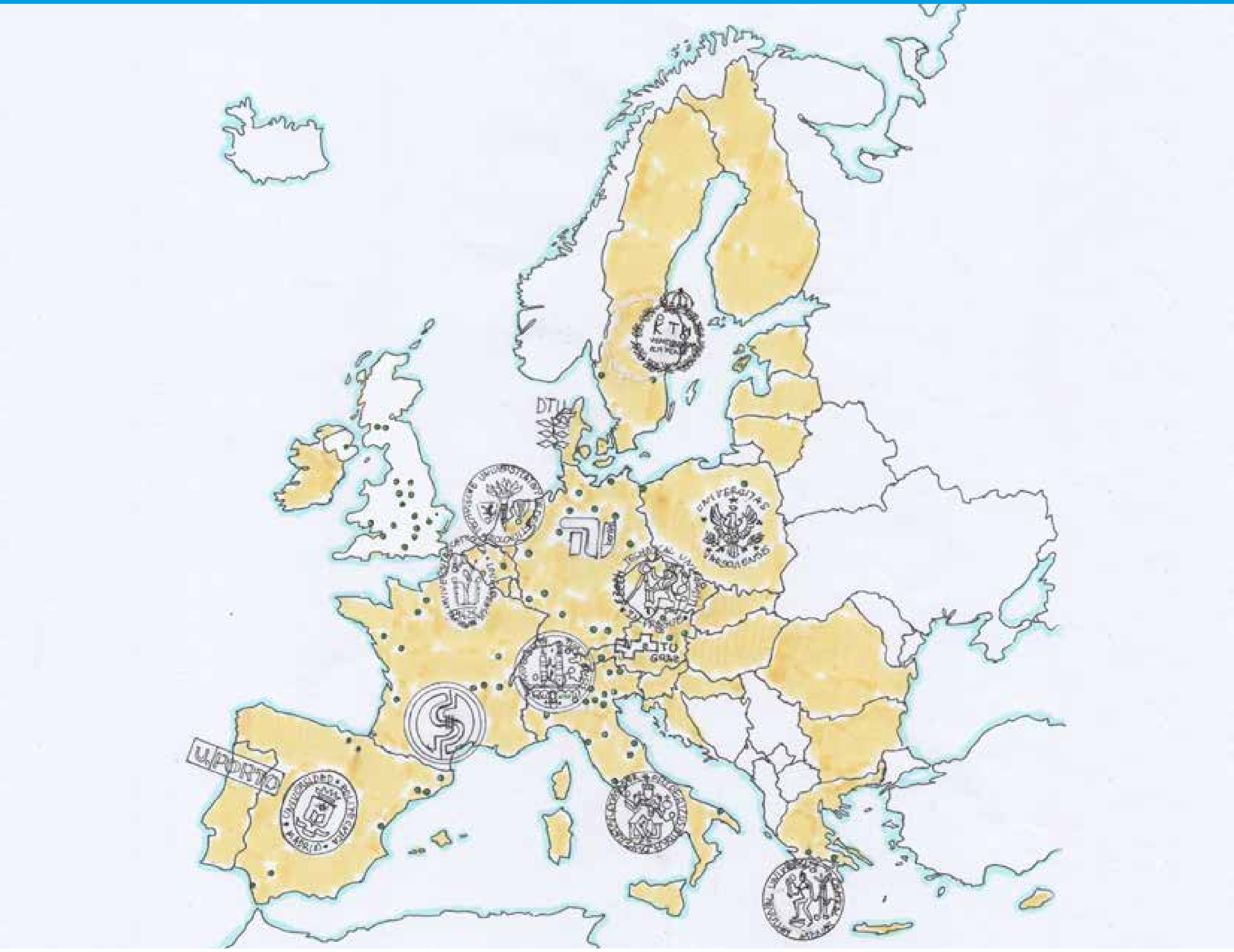
European universities: the next generation of innovators



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EDITORIAL

Axel Krein
Executive Director, Clean Sky 2 Joint Undertaking

Dear Clean Sky community,

We are only now beginning to return to normal in the wake of the COVID-19 lockdown and I hope that you, your families and your colleagues are safe and well.

The pandemic has hit the European aviation sector particularly hard. Almost 90% of Europe's flights were grounded during the lockdown, and the entire aviation sector will continue to face significant challenges in the months to come.

However, difficult times present us with new opportunities. Satellite images of pollution-free skies during the COVID-19 lockdown show us the benefits clean, emissions-free aviation could provide in the future, but obviously not at the cost of the mass economic disruption caused by the pandemic. This fuels our determination to make climate-neutral aviation a reality, in alignment with the European Commission and in support of the European Green Deal and the economic recovery ahead.

At Clean Sky, we took swift action to mitigate any direct COVID-19 related disturbance to our activities. The deadline for Call 11 was deferred, the release of pre-financing and payment for projects was accelerated where possible, timelines for those projects that are experiencing COVID-19-related difficulties were amended and we have defined new ways of working to enable business continuity.

Nevertheless, the disruption experienced by our stakeholders has also had an effect on the Clean Sky projects and we are currently investigating in detail the impact of COVID-19 on the implementation of our entire work programme. We are currently forecasting a delay of approximately four months in the implementation of the programme but together with all our project participants, we are doing our utmost to minimise the delays as much as possible. On the positive side, it is worth noting that Clean Sky's 11th Call, launched in mid-January, attracted the largest number of applications we have ever received, with a 36% increase in proposals.

I would also like to take this opportunity to highlight the ongoing public consultation with regards to the so-called Strategic Research & Innovation Agenda (SRIA) for the proposed new European Partnership for Clean Aviation under Horizon Europe. The entire aviation stakeholder community, as well as private European citizens, are encouraged to participate. This partnership, proposed by the European Commission, aims to build on the successful collaboration between the European public and private sectors already established in Clean Sky programmes to deliver aviation's contribution to Europe's ambitious climate goals.

Don't miss out on your chance to share your views on the proposed Clean Aviation Partnership by downloading its Draft Strategic Research & Innovation Agenda and providing your input via the online survey on www.clean-aviation.eu.

Turning now to the theme of this Skyline issue, the next generation of young innovators. Our university partners are a constant source of bright ideas and inspiration along the road to clean aviation. Under the umbrella of Horizon 2020, we are developing hard-hitting, ambitious technologies that channel the knowledge of universities and researchers to deliver our environmental objectives whilst maintaining the highest safety standards.

Our Clean Sky Academy in particular focuses on strengthening links with academia and actively engaging university students in the Clean Sky programme – you can read all about it on page 4 in an article written by our Chief Scientific Officer, Dr. Jean-François Brouckaert.

This edition of Skyline will highlight a selection of the universities that are involved in Clean Sky projects. You will hear from Prof. Andreas Strohmayer of the European Aeronautics Science Network, and from Prof. Pat Wheeler and Prof. Serhiy Bozhko of the University of Nottingham on the importance of collaboration between universities, research centres, SMEs and industry to achieve zero emissions.

We have an insightful article from the European Association of Aerospace Students (EUROAVIA), outlining their hopes and predictions for the future of clean aviation, and last but not least, we will explore a selection of projects powered by Clean Sky that are led by universities – ACHIEVE, TICOAJO, FloCoTec, DevTMF, PROPTER, and ICOPE.

I would like to thank all our contributors for providing us with these engaging insights from the world of universities.

Don't forget that you can stay informed about all of Clean Sky's news and activities on our website and via our social media channels.

With my best regards

Axel Krein

CLEAN SKY ACADEMY

Dr. Jean-François Brouckaert

Chief Scientific Officer, Clean Sky; Secretary of the Clean Sky Academy Working Group

What is the mission of Clean Sky Academy?

The Clean Sky Academy Working Group was established back in 2015. The objective was to better involve students in the programme through strengthening the link with academia and research centres. The group was composed of a number of independent experts with academic backgrounds. In early 2017, we decided to formalise this working group at institutional level by inviting the major European associations active in the academic and research community – PEGASUS, EASN, EREA, CEAS and EUROAVIA – to officially appoint one representative to the group.

The group is now composed of representatives of these bodies, complemented by some independent high-level experts non-affiliated to the above and also from academia and research bodies, selected via an open call for expression of interest. In terms of membership through these associations, we can now reach out to more than 40000 email addresses all over Europe.

What are the main objectives of the working group?

By regulation, Clean Sky is already supported by two advisory bodies: the States Representatives Group (SRG) and the Scientific Committee, which have advisory roles in terms of the JU's Work Plan, its strategic orientation and its scientific priorities.

The Clean Sky Academy Working Group was created to reinforce the links with academia and academic research activities and stakeholders, to strengthen their involvement in the Clean Sky 2 Programme and formalise interfaces with their various representative bodies in order to reach out to their networks and to the academic community at large. The group provides advice to the JU in the form of reports, opinions and recommendations on:

- **Dissemination and communication initiatives,** by supporting the dissemination of relevant Clean Sky information to their respective networks and by arranging dedicated communication initiatives on Clean Sky during the conferences organised by Clean Sky Academy members.
- **Educational aspects,** by organising and promoting dedicated events concerning students (e.g. annual lectures at academic establishments by Clean Sky representatives) to attract students´ interest in the Clean Sky Programme. An ambitious objective is to understand how technology transfer can be improved, or knowledge transfer to universities, so that the latest innovations appear as quickly as possible in the students' curriculum and in academic lectures. This is a challenge that must be taken up with both professors and students, which is also closely linked to the dissemination of results of the Clean Sky research.
- **Promotional aspects,** in particular by supporting the Clean Sky PhD Awards initiative, contributing to the evaluation of the submitted applications. Clean Sky is currently running the 5th edition of the Best PhD Award in Applied Sciences and Engineering in Aeronautics. Last year's ceremony was held in May 2019 at Aerodays in Bucharest. With this award, Clean Sky wants to underline the fact that our programme provides many opportunities to the students to perform high level research, in particular through the opportunity to perform a PhD.
- **Research aspects,** by providing inputs on how to maximise the value of academic input in the research activities in Clean Sky 2, including possible additional research topics (Thematic topics) in relation to the Clean Sky 2 high-level objectives and possible support actions (e.g. linked to dissemination and exploitation, analysis of and support to involvement of universities/research organisations in Clean Sky) to maximise the impact of Clean Sky actions.

Clean Sky Best PhD Award ceremony at Aerodays 2019, L-R: Dr Roberto Merino-Martinez (1st prize), Prof. Andreas Strohmayer (EASN), Dr Joel Serra (2nd prize), Prof. Mario Guagliano (Politecnico di Milano), Dr Francesco Rea (3rd prize), Dr Jean-François Brouckaert (Clean Sky)

Clean Sky Academy and Horizon Europe?

Upstream research is an essential component of the roadmap towards a 'Climate-Neutral Aviation' by 2050 in line with the European Green Deal. Many disruptive ideas are in the pipeline, with innovations in new aircraft configurations, new propulsion systems based on hybrid-electric architectures or even breakthrough technologies such as liquid hydrogen as a sustainable fuel for aviation. Academia and research centres have always been at the forefront of these promising research areas and Horizon Europe will undoubtedly be an opportunity to strengthen even further their involvement in our collective challenge to achieve the highest short-term impact in terms of mitigating climate change.

A STRONG EUROPEAN COLLABORATION FOR CLEAN AVIATION

Prof. Dr. Andreas Strohmayer
University of Stuttgart; EASN Chairman

> "In order to timely implement radically new technologies, as required for the given challenge, a roadmap with a well-considered link between upstream research – to a significant extent performed by academia and research institutes – and demonstrations in a relevant environment and therefore close to industry and market will be of the essence."

The aerospace community today faces a major challenge with the ambitious goals set by the European Commission to have a climate-neutral aviation system by 2050, in line with the European Green Deal. But the aeronautics sector is prepared to accept this challenge and a key to success will lie in a strong collaboration of engineers, scientists and regulators.

EASN, the European Aeronautics Science Network, was established to advance the aeronautic sciences and technologies and to promote, encourage, coordinate and focus efforts between universities, research organisations, industry and SMEs which are active in Europe in the field of aeronautics and aerospace. With this mission EASN actively contributes in the preparatory work for a new European Partnership following Clean Sky 2. The main focus of this programme will be on the timely development and maturation of technological solutions that can address the decarbonisation challenge and on their integration in large scale demonstration platforms, preparing a market introduction early enough to achieve a significant impact before 2050. Traditionally aerospace has long development cycles which are not compatible with the task at hand, so the new Partnership has to ensure an efficient transition from academic research and innovation to commercialisation. In order to timely implement radically new technologies, as required for the given challenge, a roadmap with a well-considered link between upstream research - to a significant extent performed by academia and research institutes - and demonstrations in a relevant environment and therefore close to industry and market will be of the essence. Means for an accelerated maturation of innovative technologies from low technology readiness levels to industrial application also have to be put in place. As an active member of the Preparation Group of the new European Partnership between the Commission and the European Aeronautics Stakeholders, EASN can be a key contributor to this end. The same is true for the dissemination of the Clean Sky project results, where academia can provide a platform in a well-defined context of Open Science and Open Innovation.

A strong link between Clean Sky and EASN has also been established in a completely different field with the 'Clean Sky Academy', a working group set up to strengthen the cooperation and involvement of academia and research centres in the frame of the Clean Sky objectives. With our strong participation this Academy facilitated the introduction of Thematic Topics in the Clean Sky calls for proposals, as well as the creation of the Clean Sky PhD Award. The establishment of such links between academia and industry was initially somewhat difficult as we tend to have inherently different points of view of technology development and related risks and timelines, but through a permanent, open and fruitful dialogue, step by step, the situation today has appreciably improved. In the meantime, the huge benefit in the cooperation of all stakeholders in aeronautical research and development has been realised and reached the level of signing at the Paris Air Show 2019 a joint declaration for aviation research under Horizon Europe. A main objective of this new European Partnership is to have a continuous and close research collaboration between all stakeholders, jointly defining and prioritising research actions and demonstration projects with a significant impact in terms of climate neutrality and competitiveness. In a way with such development the initial mission of the Academy will have to be revised, as a strong link is now in place. In this situation the Clean Sky Academy could reorient its mission more towards the promotion of future talents for our sector who are prepared to take on the challenges ahead of us and to further develop an ambitious vision for an even cleaner aviation.

GRASPING THE UNKNOWN

EUROAVIA - European Association of Aerospace Students, AS Aachen

We are entering an aviation industry that is more complex than ever. Every 15 years, the number of aircraft and passengers doubles. While these are indeed good news for the stakeholders of the industry, this also implies additional fuel consumption, emissions, and noise. Only if we manage to assure sustainable growth, aviation can further improve our lives and connect more people.

However, this cannot be solved by just one technology. To name but a few, we will need not only electric and hybrid propulsion, but also biofuels or alternative fuels along with modern aerodynamic structures. Further, we must not forget the rapidly increasing potential of data collection and analysis from entire aircraft fleets. Merging these innovations means mastering unparalleled complexity on our way to a greener future.

There is no doubt that these ambitious goals require extensive measures by the aviation industry. In addition, we have to deal with the still unpredictable but surely enormous consequences of the current global crisis, where even the largest companies are struggling and the best graduates are facing unemployment. With airlines already projecting operation of smaller fleets due to significantly lower air travel after the crisis, the budgets for the conventional aircraft manufacturers are certain to be downsized. Nevertheless, there are already creative solutions to compensate for the layoffs and we, as a community, shall continue to focus on the mentioned goals. Concluding from discussions with experts and representatives of the industry, from our point of view, there are some concepts standing out. While it is predicted that zero-emission technologies will take some more time in development and implementation, they will certainly shape the future of aviation as a whole. We believe that key areas will be urban air mobility, electrification of short-haul flights, and autonomy. These avant-garde technologies will greatly improve the efficiency of aircraft operations and also the general safety of passengers and cargo. Yet how can we face what we collectively do not know?

The European community needs to join resources creating cooperation between industry and academia, involving the next generation of students. EUROAVIA is the European Association of Aerospace Students and represents the interests of over 2200 members from 42 different universities in 18 European countries. Its Affiliated Society (AS) Aachen is a founding member of the association and represents one of the leading engineering institutions in Europe. The RWTH Aachen University has proved itself among the largest innovators in modern flying vehicles ranging from the novel small rotorcrafts to QSTOL (Quiet Short Take-Off and Landing) aircraft. The faculties also strive towards constant innovations in remotely controlled aircraft and UAS (Unmanned Aerial Systems), while continuously working on improving the conventional flight technology.

AS Aachen is the voice of all the passionate students at the RWTH who want to contribute to reach the goals of modern air transport set by the European Commission. Most of our members are conventional engineers, but the future of aeronautics will not only be mechanical but also digital. For example, new aerodynamic structures like e.SAT's box wing configuration need faster and more complex simulations. Gathering and analysing an unprecedented amount of data will allow us to find new patterns and improvements, but this requires insights into novel fields. Most engineering students are not confronted with present-day advanced technologies in their studies such as Quantum Computing or Artificial Intelligence. It is therefore important to equip future professionals with these tools by including these topics in the curriculum, or establishing and participating in relevant multidisciplinary workshops. Grasping the unknown can be challenging, but the aerospace industry is a dream factory. By exploring new territories, we can realise these dreams and achieve the goals and challenges facing our industry.

DRIVING INNOVATION IN CLEAN SKY 2

Professor Pat Wheeler
Clean Sky Director, Institute for Aerospace Technology, University of Nottingham

Professor Serhiy Bozhko
Director, Institute for Aerospace Technology, University of Nottingham

The University of Nottingham has been a Member of the Clean Sky Joint Undertaking since 2008, where it was involved in setting the ambition for More Electric Aircraft within the Systems for Green Operations ITD as an Associate Partner.

In 2020, its Clean Sky research budget stands at €54.4m, with 4 core partnerships across 3 Integrated Technology Demonstrators (ITDs) and is working across all six System and Platform Demonstrators (SPDs).

The University, through its Institute for Aerospace Technology (IAT), has been successful in bidding for 29 projects so far in Clean Sky 2; employing over 100 researchers from across Europe and worldwide, as well as working across the entire aerospace supply chain with 7 large organisations, 23 small to medium sized enterprises, 12 universities and 5 research and technology organisations to deliver key aerospace components, technologies and scientific insights.

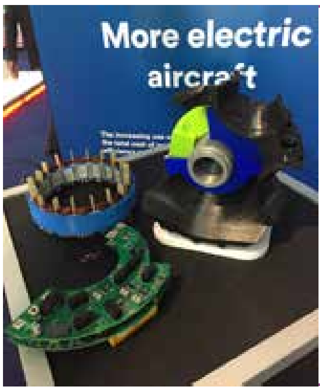
University of Nottingham projects are contributing to several major demonstrator platforms in Clean Sky 2 including:

- **Airbus Helicopters RACER** - ASTRAL and POCOL projects
- **Leonardo NextGen Civil Tiltrotor** – INSTEP project
- **Rolls-Royce UltraFan** - AOrbit, AERIS and DevTMF projects
- **Safran next generation turboprop** - ACHIEVE and PROTEUSS, QUICK and IGNITE projects
- **Airbus future fuselage** - MISSION and MARQUESS projects
- **Leonardo future turboprop** - ASPIRE, ESTEEM, ENIGMA and IDEN projects
- **EFan X** – PHiVe, H2LSPC and LIFT projects

Professor Pat Wheeler, IAT Clean Sky Director said; "Nottingham is extremely proud of its 12-year history with Clean Sky. We took the earliest opportunities to work together and drive innovation by building trust in our ability to deliver and work as a partner in the programme. We became the only university to be an Associate Partner in its own right in Clean Sky 1, with University Clean Sky team members sitting on the Governing Board of the Joint Undertaking, and we have been the only university in Europe to sit on this top-level committee.

As we have scaled up our work with Clean Sky, a key learning point has been to ensure project management personnel and processes are in place in addition to our aerospace engineers and experts. Two of our researchers won the Best Clean Sky PhD Award two years running – Dr Tao Yang in 2016 and Dr Fei Gao in 2017 – for their work contributing to aircraft electrification, a key theme as we now aim towards zero-carbon aviation. Clean Sky has enabled us to build technology demonstrators with industry partners: Safran hailed our green taxiing motor as a highlight of Clean Sky 1 at the end of CS1 Conference. Demonstrating how our technology can be implemented in future, cleaner aircraft are my personal highlights of working in Clean Sky. I look forward to taking more of our research and technology demonstration into the Clean Sky 2 and 3 technology demonstrators and driving the future of cleaner aviation."

Professor Serhiy Bozhko, IAT Director, added: "Clean Sky is a valuable framework enabling long-term collaborations for the benefit of future cleaner aviation. A key strength of Clean Sky is that the long-term programme allows Leaders to define a programme with a strong element of technology pull so there is a good chance of the outcomes being integrated into products. Research and innovation activities can happen to enable ambitious research to take place with the potential for higher gains at a level of risk that companies would not normally accept for their own R&D activities. I am ambitious for the IAT and we are committed to building research and industry partnerships across Europe: our aerospace researchers and experts are working hard to ensure our projects contribute to the CS2 technology demonstrators and a cleaner future for aviation." For more details:
www.nottingham.ac.uk/aerospace



ACHIEVE: Advanced mechatronics devices for a novel turboprop electric motor-generator and health monitoring system

The aim of the ACHIEVE project is to develop an innovative mechatronic system which is multi-functional, more efficient, reliable, compact and lighter and hence contributing towards higher performance and more efficient and greener turboprops. This project brings together a team of power electronics and electrical machine manufacturers to deliver a novel advanced mechatronic device which is due to be integrated and tested on the Safran-led Tech-TP demonstrator. The developed mechatronic device is essentially a 40kW electrical motor/generator system that will provide the aircraft with electrical taxiing capability through powering a set of propellers and electrical power generation capability whilst in flight. The ACHIEVE stakeholders are the University of Nottingham (UK), Power System Technology (France), NEMA (UK), and Safran (France).

NOVEL COMPRESSOR TECHNOLOGIES FOR FUTURE HIGH-EFFICIENCY COMPRESSORS

Christian Köhler M.Sc., Dr.-Ing. Christian Helcig, Christian Schäffer M.Sc., Prof. Dr.-Ing. Volker Gümmer
Technical University of Munich

*FloCoTec research team:
Prof. Dr.-Ing. Volker Gümmer (Head of LTF),
Dr.-Ing. Christian Helcig (chief engineer of LTF),
Christian Köhler M.Sc. (research associate for numerical work scope in FloCoTec), Christian Schäffer M.Sc. (research associate for experimental work scope in FloCoTec)*

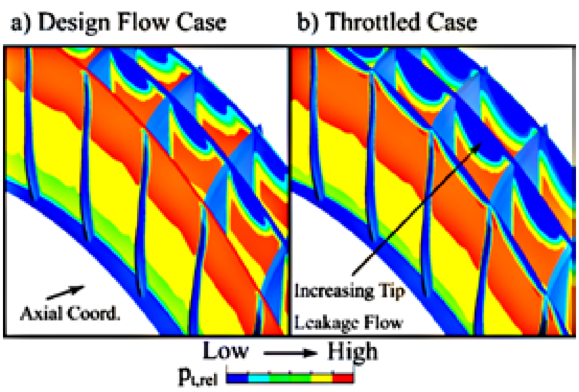
The continuous growth of the air transport sector provides both benefits and challenges for the aviation industry. As current trends show a steady rise in the number of annual passengers, the impact of aviation on the environment increases, which requires novel aero engine concepts and technologies to reduce pollutants as well as noise emissions. One way to mitigate the environmental impact of an aero-engine is to increase its thermal efficiency by implementing higher core engine pressure ratio cycles. However, a larger core engine pressure ratio inevitably leads to a reduction of the core engine size and cross-sectional area, thus causing detrimental aerodynamic effects due to large relative rotor tip and stator seal clearances. These effects penalise the compressor's operational behaviour and performance (see picture). To tackle these aerodynamic challenges, the Technical University of Munich (TUM) is investigating innovative flow treatment (FT) technologies including an advanced 3D blade design for high-pressure compressor (HPC) rear stages in the framework of the project FloCoTec (**Flo**w **Co**ntrol **Tec**hniques Enabling Increased Pressure Ratios in Aero Engine Core Compressors).

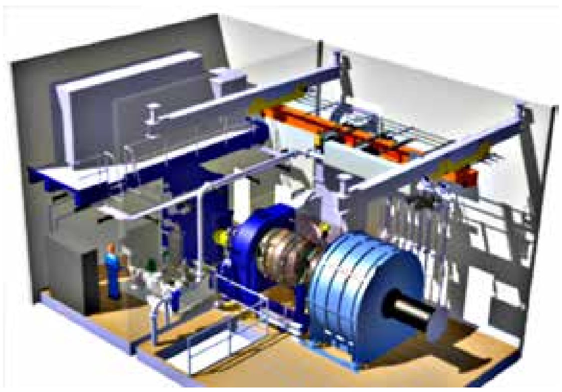
The novel FT approach provided by TUM consists of two parts. First, casing treatments (CT) will be applied within the HPC. These self-regulating FTs are commonly applied within academic test cases to extend the compressor's stall margin and to mitigate the detrimental effects caused by the tip leakage flow. Regarding CTs, TUM can look back on the work of numerous researchers who successfully designed and investigated the behaviour of these FTs. The focus here was mainly on the application of CTs within the transonic front stages of compressors, where strong interactions between occurring shocks and the rotor tip vortex limit the compressor's operational behaviour. Within FloCoTec, TUM will apply CTs to compact HPC rear stages in a subsonic flow regime. So far, the application of CTs within a subsonic environment is merely investigated and therefore is one ambitious approach beyond the current state-of-the-art.

Second, TUM will supplement CTs by implementing complementary FTs by the means of hub blowing FTs. This novel concept of combined FTs is chosen to leverage the full potential of CTs and to develop an HPC rear stage configuration, which provides superior capabilities regarding operability and performance.

The design of the combined FTs will be carried out by conducting high-fidelity numerical simulations. As the interaction between the FTs and the compressor blades requires extensive unsteady CFD simulations, TUM will utilise its resources by the means of high performance computing to gain an enhanced insight into the effect of the FTs. In addition to the numerical design activities within FloCoTec, TUM will experimentally investigate an advanced HPC rear-block blading on the university's unique high-speed research compressor test rig (HSRC). The HSRC provides the capabilities to test HPC rear stage concepts under engine representative operating conditions. Within the HSRC, TUM will apply small scale, high-frequency measurement techniques. This measurement setup will be used to determine the inherent unsteady loss mechanisms and entropy generation within the HPC. The ambitious approach of utilising high temporal and spatial resolution within TUM's compressor rig is beyond the current state-of-the-art. The generated results will complement available literature for the scientific and industrial compressor community.

Following our mission statement of taking responsibility for future generations, we at the TUM, together with our partners, develop technologies for novel eco-friendly and sustainable aero engines.





Left - Numerical stage calculation results showing an increase of tip leakage flow for throttled cases visible through the growth of low relative total pressure contours towards downstream rotor regions; Right – Digital model of TUM's unique high-speed research compressor (HSRC) test rig

THE CHALLENGE OF TITANIUM/COMPOSITE ADHESIVE JOINTS FOR THE AEROSPACE INDUSTRY: TICOAJO PROJECT

Dr. Theodoros Loutas

Assistant Professor in the Department of Mechanical Engineering and Aeronautics, University of Patras

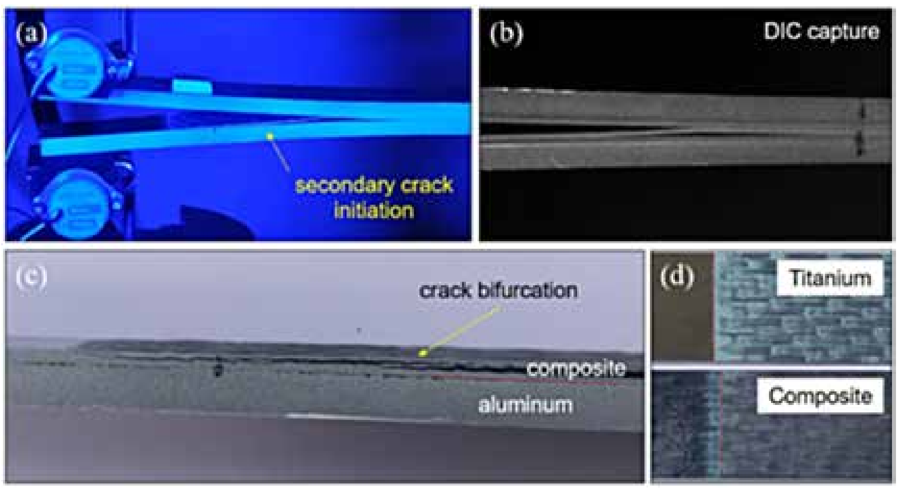
Future aircrafts will have to be more fuel-efficient in order to accomplish sustainable air transport growth. One of the key enablers to achieve this fuel efficiency is drag reduction by improved aerodynamic efficiency: more specifically, by laminar flow control. A promising structural solution is the combination of a micro-drilled outer titanium surface adhesively bonded with an inner composite (segmented) structure. The critical topic dealt with in the TICOAJO project is exactly the characterisation of the interfacial fracture toughness of the titanium-composite adhesive joint. The project was coordinated by the Netherlands Aerospace Centre (NLR) in a partnership with the University of Patras (UPAT) and Technical University of Delft (TUD).

The main technical objectives of the TICOAJO project, as defined in the proposal preparation stage and in line with the specifications set by the topic manager (Aernnova), are as follows:

- define cost-effective industrial manufacturing processes for titanium-composite joints
- characterise the interfacial fracture toughness under static, fatigue, and high-speed loading
- investigate environmental and temperature influence
- predict damage growth behavior at sub-component level
- experimentally verify the validity of numerical predictions by a representative test

The project was implemented in five main technical Work Packages. NLR undertook the manufacturing of coupons and panels and proposed four different union technologies to be experimentally assessed. They developed a test apparatus for moment-loading of the joints and performed a series of static tests in Mode I and II. TUD investigated the pre-treatment of the Titanium and the CFRP (carbon fibre reinforced polymer) adherents and proposed innovative routes achieving excellent bonding between adhesives and adherents. TUD also led the fatigue testing and panel testing activities as well as the testing in a controlled environment.

UPAT participated in the majority of Work Packages and has been heavily involved in most testing activities. More specifically we participated in quasi-static testing together with NLR (Figure 1) and in fatigue testing together with TUD, and we completely undertook the high-speed testing. TICOAJO project was an excellent opportunity for UPAT to work towards the Clean Sky high-level objectives and achieve several scientific objectives in collaboration with the partners. We extended the state-of-the-art data reduction framework through a new analytical approach that takes into account the effect of residual thermal stresses as well as the bending-extension coupling induced by the use of aluminum backing beams which prevent the Titanium from yielding. We showed that for the TICOAJO joint (and all bi-material joints in general) there is a non-negligible effect of the thermal stresses on the fracture toughness. We utilised the same framework for data reduction in fatigue testing. For the needs of the high-speed fracture toughness characterisation a novel setup was developed which utilised a modified Split-Hopkinson pressure bar configuration to load the joint under study in mode I and mode II. Interfacial fracture toughness in high-speed conditions were for the first time obtained for this joint utilising a new theoretical approach that accounts for the kinetic energy of the adherents as well as the vibration effects. High-speed video and Digital Image Correlation captured the high-speed phenomenon perfectly, giving us an insight of the fracture processes involved.



A highlight of static testing activities

The benefits for a university like UPAT of participating in such a research project cannot be stressed enough. Three young talented PhD students were closely involved in TICOAJO. We defined topics for their PhDs inspired by the scientific challenges that TICOAJO set. We worked closely with the topic manager to get a deeper knowledge of how industry deals with R&D. Our work attracted the interest of researchers and stakeholders in the field of dissimilar materials joining, putting new collaborations in place. A number of scientific publications in high-impact journals and major conferences were produced which highlight the novel character of the work implemented and the successful achievement of the technical objectives for the project.

DevTMF: raising the standards of European aviation

Improving the sustainability of European aviation correlates directly to the development of new materials – or improvement of existing ones – that are used in aeroengines. And to ensure safety, materials used within the hostile internal environment of an aircraft turbine engine – especially the rotating turbine discs – must withstand dramatic variations in temperature and mechanical stress. Clean Sky's DevTMF project is dedicated to developing methods and models so that the European aerospace industry can predict how materials in turbine discs perform in conditions where both stresses and temperatures vary with time.

Coordinated by Linköping University, with the participation of Swansea University and The University of Nottingham, Clean Sky's DevTMF (Development of Experimental Techniques and Predictive Tools to Characterise Thermo-Mechanical Fatigue Behaviour and Damage Mechanisms) project is on a mission to put European aeroengine manufacturing at the forefront by improving the industry's ability to predict the behaviour of materials under extreme and variable conditions. The project is a part of Work Package 5 of Clean Sky's Engines ITD – Very High Bypass Ratio engine demonstrator – focused around technologies including engine core optimisation and integration, compressor efficiency, and structural design for low pressure turbines.

There are three strands to the project: Improvement and development of advanced standard and non-standard cutting-edge Thermo-Mechanical Fatigue (TMF) experimental methods and harmonisation of the test methods to enable standardisation by performing studies into the phenomena for a range of representative parts; advanced metallurgical assessment of structural disc alloys, looking at multiple variables to determine active damage mechanisms that control the life under TMF operating conditions; and physically based coupled models, with experimental validation, capable of predicting TMF initiation and propagation lives of components subjected to complex engine cycles and which are suited to implementation in the computer programmes used to predict component lives. The project will take these technologies to TRL5.

"Low emissions, improved fuel efficiency and advanced temperature capability are pivotal to Rolls-Royce's Advance™ and UltraFan™ engine demonstrator programmes. To improve gas turbine efficiency necessitates weight reductions or increases in temperature. Either way, materials are key," says Svjetlana Stekovic, Senior Researcher and EU Senior Research Officer at Linköping University (LiU). "DevTMF will demonstrate the capability of increasing the operational window of the existing disc alloy and of using a new developed alloy in relevant engine components. In both cases, the capability of alloys and TMF technologies to cover existing and future requirements will be validated. Knowledge of TMF failure is critical in understanding component reliability because TMF cycles are caused by uneven temperature distribution across components. Therefore reliable TMF prediction depends on reproducing the right temperature cycles homogeneously across and along specimen gauge length, as well as establishing high quality material and mechanical TMF property data."

Work has been performed at LiU to characterise static and dynamic thermal gradients as well as use of different heating methods for validating TMF crack initiation and propagation test methods. Also, the effect of static and dynamic crack tip heating in induction field was studied to provide more in-depth analysis as high heating rates and good accessibility for crack monitoring techniques make induction heating the preferred heating method for TMF tests in this programme.

"DevTMF has made significant developments to the existing test methods to ensure robust TMF testing with repeatability and standardisation a top priority. With preferred test methods in place, the main programme of TMF testing is underway. A round robin test series (undertaking comparable tests but in different laboratories) has been conducted to generate a technical base towards a standard protocol," – and that's a key point, says Dr. Stekovic. "The EU has an active standardisation policy that promotes standards for better regulations to enhance European industry competitiveness and ensure interoperability of products and services, reducing costs, and improving safety. Standardisation bridges the gap between research and the market by enabling the fast and easy transfer of research results to the European market. One of the main activities in DevTMF is to produce a Code of Practice for the TMF experimental methods, which will be a base for future standardisation through the High Temperature Mechanical Testing Committee of the European Structural Integrity Society (ESIS) and International Organization for Standardization (ISO)."

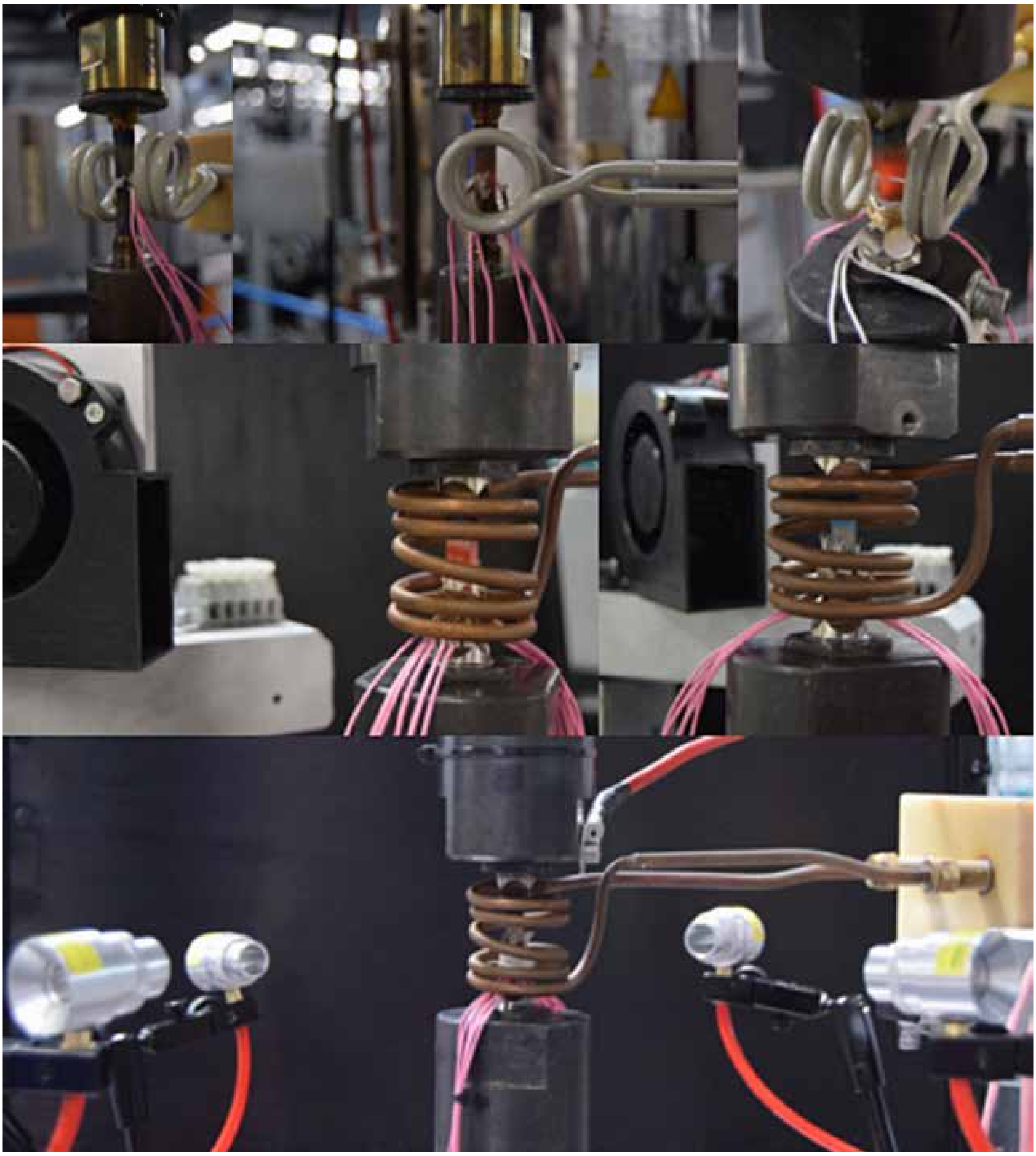
In pursuit of this standardisation drive, several foundational tasks have been carried out under the modelling efforts, which will facilitate advanced material modelling of the candidate turbine disc alloy for TMF crack initiation and crack propagation mechanisms, and material parameter identification and optimisation tasks have been conducted using isothermal test data.

"Initial results are promising and a great deal of work has also been conducted on comparing computational 'cycle jumping methods' which reduce computational time when the developed material models are applied to production components," says Dr. Stekovic.

By the end of the project the materials understanding and lifing models will help optimise the performance of existing individual aero engine components, enabling reduction of fuel consumption by allowing them to run at higher temperatures and pressures, thereby increasing engine efficiency and reducing CO_2 emissions without hardware modifications. Over a longer timescale the project will influence the development of new disc alloys and ultra-efficient future aero engine designs.

"By the end of the project, DevTMF will achieve a more accurate prediction of product life of gas turbine components under TMF conditions, potentially prolonging engine service life which will translate into quantifiable environmental and economic benefits for Europe's aeroengine industry," concludes

Dr. Stekovic. "A rough performance study indicates that if DevTMF delivers material and TMF lifing methodologies capable of allowing a turbine disc to operate at 750ºC instead at 700ºC under complex cycles whilst maintaining component integrity, it will result in fuel burn saving and CO_2 reduction of 1.7%. A 1% specific fuel consumption in these products is equivalent to 350kg less fuel used per engine per transatlantic flight, which reduces the cost of ownership by approximately €100,000 per engine per year."



PROPTER: tackling the complex aerodynamics of tomorrow's rotorcraft

It's hardly surprising that to create a new type of aircraft that flies as fast as an aeroplane but can also hover like a helicopter (and is in fact a blend of both types of vehicle) – presents a set of unique aerodynamic challenges. Clean Sky's PROPTER project addresses the complex aerodynamic interactions presented by Airbus Helicopter's RACER compound helicopter, which is equipped with an overhead rotor (like that of a conventional helicopter) but also has a wing and two propellers installed on the wingtips.

The RACER (Rapid And Cost-Effective Rotorcraft) demonstrator – one of two demonstrators in development for Clean Sky's Fast Rotorcraft Innovative Aircraft Demonstrator Platform (IADP) – will fly faster than a regular helicopter (with a high cruise speed of 220 knots), yet will retain the agility and hover capability of a conventional helicopter. This elicits uncommon aeronautical challenges for its designers, and these are being addressed by Clean Sky's PROPTER consortium – comprised of Netherlands Aerospace Centre (NLR) and Delft University of Technology – which is focused on the performance analysis and design of the propellers under the influence of the wing, overhead rotor and fuselage of the rotorcraft. The topic leader is Airbus Helicopters.

For European aviation such a rotorcraft makes intercity flights such as Paris-London or Paris-Brussels possible in less than an hour, with the added advantage of vertical take-off and landing for urban accessibility. And for medical emergency and evacuation flights it means getting further and faster to those in need, enlarging the mission footprint of that ever-critical 'Golden Hour'. But to deliver this versatile capability, a well-founded knowledge of the complex aerodynamics around the compound helicopter is a prerequisite.

"PROPTER generates such knowledge by means of large-scale high-fidelity computer simulations, the so-called Computational Fluid Dynamics (CFD), revealing the involved physics of the flow and produces high-confidence numerical figures," says Bambang Soemarwoto, Senior Scientist at NLR – Netherlands Aerospace Centre. "Additionally, the project addresses the design of the propellers to minimise power required, and therefore minimises fuel consumption, eventually contributing to reduction of CO_2 and NOx emissions."

PROPTER encompasses an analysis and design process with a wide range of physical complexity and method fidelity, from a rather simple configuration (an isolated propeller) – but with a challenging set of tasks: the propeller design has to cope with multiple flight cases. This means that there's a complex interactional flow between the propellers mounted on the wings, the main overhead rotor, and the airframe. And to scrutinise the aerodynamics of this complex set-up, PROPTER deploys the best of two worlds of CFD software: ENFLOW, a research code developed at NLR in various European and national research programmes, and ANSYS-FLUENT, a commercial code used at Airbus Helicopters. To cross-check these two sets of analyses, a code-to-code comparison, both for analysis results and design results, will give a sound understanding of the modelling and best practices applied, providing assurance of the fidelity of the numerical results and their integration in the industrial environment.

"The kind of computer simulations conducted during the course of the project is unique," adds Soemarwoto. "Important knowledge on the interactional aerodynamics has been generated for the three most important flight modes: cruise, hover and autorotation. Aerodynamic sensitivities due to variations within these flight modes have also been assessed, contributing to the design of the control law. And thanks to the high-fidelity computer simulations, an in-depth understanding of the interactional flow field around the compound helicopter configuration and its impacts to propeller aerodynamic characteristics will be obtained by the end of the project. In the design aspects of the propeller, the project results will show that, through an advanced aerodynamic design optimisation methodology, a significant power reduction is possible."

Airbus Helicopters has scheduled the first flight of the RACER demonstrator for the end of 2021, and in terms of dissemination and exploitation of the project, a webinar will be organised. Unique innovations have been generated during the course of the project, and in the context of aerodynamic analysis and design of propellers, some of the innovations are considered to have significant potential to deliver benefits to propeller manufacturers, and these will be shown in the webinar.

"We think that some of the results of our activities will be useful to European propeller manufacturers. I've identified that there are 25 propeller manufacturers in the EU and most of them are SMEs, so we're now in the process of inviting them to this webinar where we can show the things that we have used in the project and share what we have experienced," says Soemarwoto.

> "Unique innovations have been generated during the course of the project, and in the context of aerodynamic analysis and design of propellers, some of the innovations are considered to have significant potential to deliver benefits to propeller manufacturers"

Cool your jets! ICOPE tackles new challenges in thermal mana

The trend in aviation towards electrification presents new challenges, one of which is managing the unwanted byproduct of electrical systems: heat. An ineffective dissipation of heat could lead to a drop in the efficiency of specific airborne systems. Clean Sky's ICOPE (Innovative COoling system for embedded Power Electronics) project explores new approaches to onboard thermal management using novel air cooled heat sinks and advanced materials.

With hydraulics and pneumatics becoming progressively superseded by electrical systems as aviation evolves into a more ecological future, Clean Sky has been focusing on effective and sustainable solutions oriented around thermal management. This not only improves the science of onboard cooling for aircraft systems, but also paves the way for boosting the European aviation industry's knowledge and expertise in anticipation of the next generation of aircraft, when electricity will be used not just for the aircraft's systems but also for propulsive power. Moreover, Clean Sky is creating the prerequisite techno-bricks that will enable hybrid-electric (and eventually fully electric) aircraft to cope with the heat management challenges associated with onboard high voltage electricity generation, storage and safe relaying to electric fans that will ultimately replace today's turbine, turbofan and turboprop engines.

In recent years, the trending technologies used for cooling power electronics and other semiconductor devices have moved from air cooled solutions to liquid cooled (or two-phase flow solutions, using evaporation), as these are more effective in managing higher levels of heat transfer density, enabling electronic equipment to function within suitable operating temperatures.

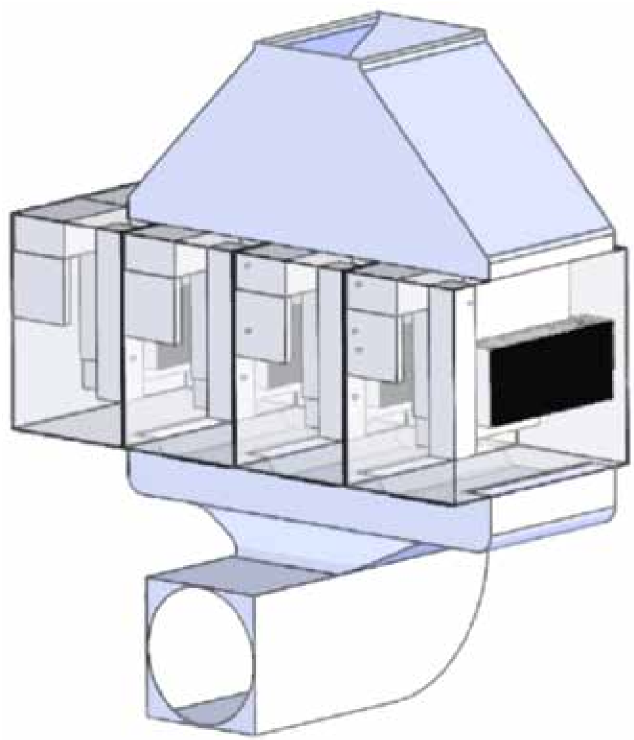
But with new types of power semiconductors becoming more commonplace in aircraft, that are made from heat-efficient materials, it now makes sense to re-evaluate the use of air cooled systems, as these weigh less and are generally more reliable and require less maintenance.

"Silicon carbide (SiC) and gallium nitride (GAN) can withstand much higher temperatures than usual materials, and also reduce the losses to evacuate," says Marc Pontrucher, research and technology development manager at Thales, referring to these new power semiconductors. "These open a window to revisit the option of air cooling, which has many advantages in terms of equipment simplicity, reliability, environmental impact and cost."

Mathieu Bouton, hardware specialities thermal and mechanical engineer at Thales, adds that, "there is a real advantage of using air cooling because the overall mass of heat sink and cooling system will decrease, it's an easier solution to be integrated into our products, and it's a more reliable option. Regarding the air cooling, the only point to increase efficiency is to use innovative materials for the heat sink in order to obtain the maximum area of exchange and the minimum thermal resistance."

Hence, Clean Sky's ICOPE project, which started in May 2017 and is near completion, focuses on developing new concepts for air cooled heat sinks using advanced thermal management materials including annealed pyrolytic graphite (APG) and metal matrix composites (MMC) such as aluminium graphite, which have been identified as potentially suitable candidate materials. The project also looks at integrating some newly developed heat sinks into a thermal management bay.

The ICOPE Consortium draws on the expertise of heat sink and APG design specialists Aavid-Thermal Division of Boyd Corporation; as well as the knowhow of Schunk Carbon Technology, experts in the field of MMC. This team is complemented by the analytical skills of the Heat and Mass Transfer Technological Center (CTTC) of Universitat Politècnica de Catalunya (UPC) who have specific competences in analysing air cooled heat exchangers and air flow in enclosures.



Power management bay cooling air duct assembly concept model gement

The project involves the development of two new types of heat sink: (A) which uses annealed pyrolytic graphite (APG) and has folded fins, while the second type (B) combines metal matrix composites (MMC) with APG. A final task focuses on the design, manufacture and testing of a power management system bay which incorporates four heat sinks to provide even and efficient air distribution with an adequate flow and velocity distribution.

"ICOPE is investigating the development of novel air cooled heat sinks to go beyond the limit in terms of electronics air cooling," explains Dr. Joaquim Rigola, who is a professor at UPC and coordinator of the ICOPE project.

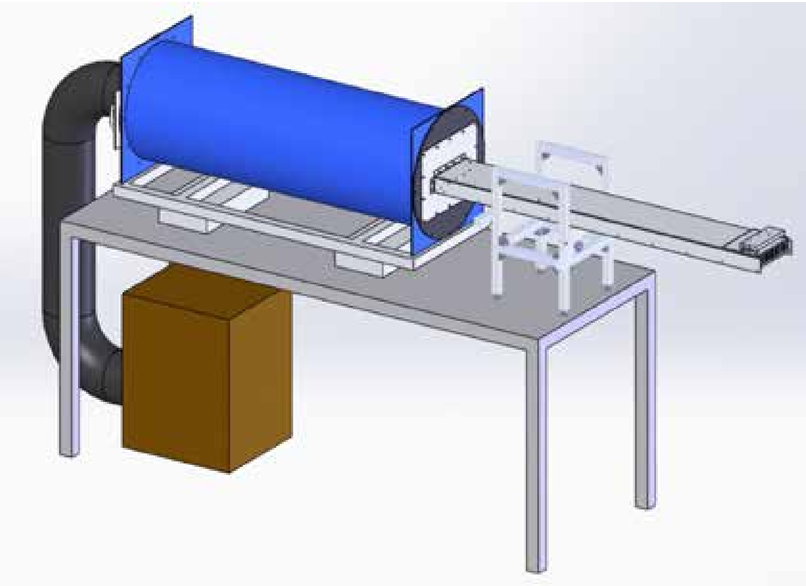
"The main innovative aspect is the implementation of advanced materials with outstanding thermal conductivities, which activate a higher primary surface of the heat sink, further beyond the surface of the heat sources (Stage A of the project prototypes). The project is also incorporating other materials that introduce an additional benefit in terms of expansion and contraction characteristics (Stage B of the project prototypes), aligning better with the behaviour of the semiconductors, then minimising the thermal stresses between them and increasing the reliability and safety of the units," indicates Dr. Carles Oliet, adjunct professor and researcher at UPC.

"The current status of the project is very advanced for Stage A prototypes," says Dr. Rigola. "They have been already manufactured and successfully tested, covering the requirements set by the Topic Manager in terms of maximum base temperature, maximum pressure drop and maximum weight. Regarding Stage B prototypes, they have already been designed, suggesting three different combination of materials. These alternatives are in different stages of development, one ready to be tested and the other two undergoing manufacture. Regarding the bay, the design is also closed and the manufacturing under progress. Summarising, the project evolves adequately with very interesting results and prototypes that cover the initial expectations."

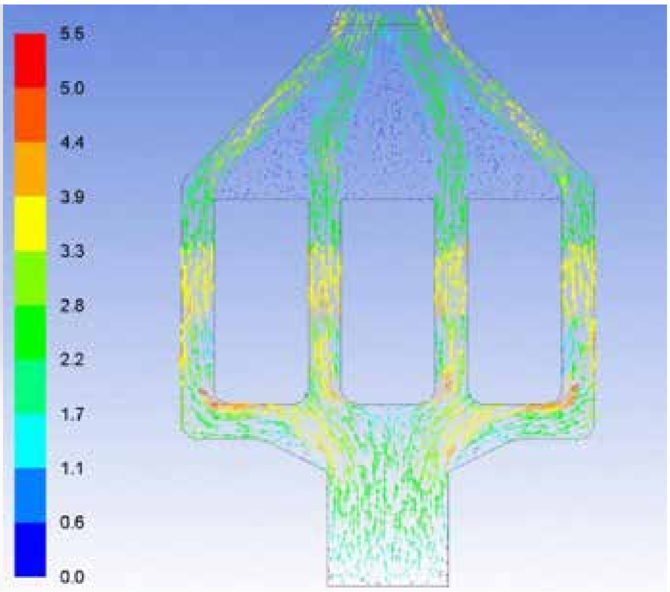
"The implementation of air cooling for the electronics is a simpler and more reliable option, that could avoid the use of additional circuits and components related to the liquid or two-phase cooling," says Dr. Oliet. "The potential reduction in overall cooling system weight also implies a very interesting output to increase the competitiveness of the industry."

Looking at the broader societal gains for Europe, Dr. Rigola says that the ICOPE project has benefits that are applicable in other sectors beyond aviation:

"Some outcomes of the new designs can also impact other energy generation and conversion industries, as the cooling of power electronics is in increasing demand in those sectors. For example, within the energy conversion in a wind turbine nacelle there are similar power management bays with several power conversion modules. Also within any variable-speed controlled motor in the cooling/refrigeration and heat pump industries there is a need to cool down the associated power electronics."



Heat sink test bench concept



Simulation velocity vectors for the duct distributing air to four heat sinks

DON'T MISS...

Have your say: public consultation launched on proposed Clean Aviation partnership

The public consultation on the draft Strategic Research and Innovation Agenda (SRIA) of the proposed Institutionalised Partnership for Clean Aviation under Horizon Europe was launched on 15 May. The entire aviation stakeholder community, as well as private European citizens, are encouraged to participate.
Take the survey at www.clean-aviation.eu

'Highlights 2019': En route to climate-neutral aviation

2019 was a significant year for Clean Sky. We are delighted to announce the launch of the Clean Sky Highlights 2019 report, available now for download. Halfway through the programme, it is gratifying to see that our vast ecosystem of researchers and engineers is delivering cutting-edge results for greener aviation in fields such as propulsion, systems, aero structures, aerodynamics, and overall aircraft configuration. To date, Clean Sky has successfully engaged more than 900 actors across the public and private sector, of which, approx. 340 are SMEs, 110 are research centres, 150 are universities and 300 represent industry. Thanks to the united forces of these participants, we are on track to deliver our ambitious objectives of reducing emissions and noise in aircraft, in alignment with the European Commission's Green Deal. The Highlights 2019 report is designed to give you a taste of Clean Sky's main achievements in 2019, as part of the EU Horizon 2020 programme. You'll find a sample of some of our innovative technical advances, visualisations of our ever-increasing participation figures, insights into our current synergies and a glimpse of the future for clean aviation. **Read the brochure: www.cleansky.eu/publications**

Twenty new Clean Sky 2 Results Stories are now online

A fresh batch of twenty new Clean Sky 2 Results Stories have been added to our website! As part of the EU's Horizon 2020 research and innovation programme, this collection of stories showcases a sample of Clean Sky 2 projects and illustrates the progress that we've made to date, highlighting the practical solutions and innovative technologies that we are pursuing to dramatically reduce the carbon footprint of aviation and achieve climate neutrality by 2050 in line with the European Green Deal.
Read more: **www.cleansky.eu/zoom-in-on-clean-sky-2-results**

Executive Director: Axel Krein
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