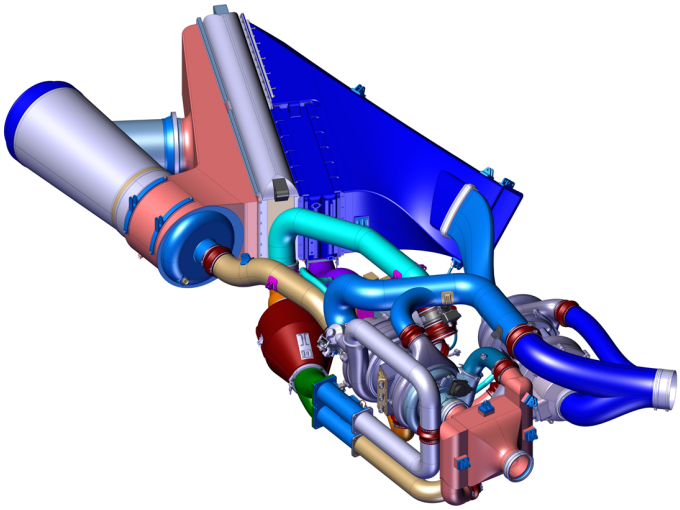
Horizon 2020
European Union Funding
for Research & Innovation

A breath of fresh air with Clean Sky's Environmental Control System

It's easy to take for granted that it's possible to breathe normally in an airliner cabin as it flies at cruising altitude, even when the air beyond the external skin of the aircraft is too cold and lacking in oxygen to sustain human life.



Electrical Environmental Control System ©Liebherr

To make the air suitable for passengers and crew during flight, aircraft are equipped with an Environmental Control System (ECS). Typically this involves ingesting air from outside the airplane which is bled off the engine (near the intake) which is then pressurised and heated to a comfortable temperature using an air cycle system. This breathable air is then routed into the aircraft cabin. The air in the cabin is blended with a fresh intake of air in a 50:50 mix which is recirculated every two to three minutes.

This method of supplying breathable air has served aviation reliably for over 60 years. And it's also the subject of curiosity in the mindset of the general public, as heightened concerns related to the pandemic oriented around the air we breathe in public spaces and on public transport. As Clean Sky project officer Paolo Trinchieri notes, 'the Environmental Control System is a key system in an aircraft, because it's linked to air quality and it's very relevant in this period of Covid.' The focus of this paper will not address specifically air quality in detail but the energy consumption of such environmental systems with the ultimate goal to contribute to emissions reduction.

One of the downsides of today's aircraft air conditioning systems is that bleeding air off the engines reduces their thrust output by between approximately 5-8%.

'For that reason, Liebherr Aerospace Toulouse and Airbus are working together on a Clean Sky 2 initiative to create a more energy-efficient Electrical Environmental Control System (EECS) that will be applicable to the next generation of more electric aircraft — a system that contributes to saving fuel burn, thereby cutting CO_2 and NOx emissions.'

A more energy-efficient system for supplying breathable air will contribute to Clean Sky's objectives for sustainable flight as well as the European Commission's EU Green Deal ambitions. The project runs until 2023, and is underpinned by the development of two key techno-bricks developed in Clean Sky 2: a turbomachinery-based 'Air Cycle System' (Clean Sky Demonstrator D11), and a 'Vapour Cycle System' (Clean Sky's D13 Demonstrator).

A smart two-step system

The air cycle system brings in a 'fresh flow' of ambient air from outside the aircraft (though not from the engine as in conventional aircraft environmental control systems) which is then pressurised and conditioned to a temperature appropriate for passenger and crew comfort in the cabin. This air cycle system is coupled with a vapour cycle system, powered by a centrifugal compressor, which provides additional cooling capacity for the thermal (temperature) control.

This combination is innovative in itself (today's cabin air conditioning systems do not have a vapour cycle system), but the innovation goes further, in that the overall system does not rely on air offtake from the engine.

'And the significance of this,' notes Trinchieri, 'is that the engines can be optimised for thrust — which is key during take-off and climb phases of flight — while the EECS saves weight and energy off-take through being more electrically, rather than pneumatically, oriented. It's a win-win approach that translates, ultimately, into fuel burn savings and a reduction in CO_2 and NOx emissions.'

'The idea behind our EECS is that instead of taking air from the engine, our system takes and uses the ambient air from outside the aircraft which we use for both pressurisation and air conditioning,' explains Kader Benmachou, Head of R&T programs and IP at Liebherr-Aerospace Toulouse.

Benmachou points out that one of the main motivations behind the project is that 'air conditioning systems are one of the main energy consumers in the aircraft, so we're introducing new innovative technologies mainly to reduce the energy offtake in order to keep it competitive.'

While the major stakeholders in the project are Liebherr and Airbus, Benmachou says that 'this demonstrator is more than an enabler to mature the technology — it's also the result of cooperation with several partners across Europe. Through Clean Sky 2 we selected 12 consortia from 5 European countries, including academics and SMEs, that support the demonstrator with various technologies and modelling capabilities to simulate the complex architectures integrated within the air cycle and vapour cycle systems.'

One size fits all

The EECS model is developed around a specification based on a single-aisle short-medium aircraft type. However, Benmachou points out that Liebherr is undertaking analyses to define the 'boundary conditions' — the limits of size of aircraft that this technology is applicable to. The methodology will enable the system to be tailored to different sizes of aircraft.

'We have to do some analyses in order to evaluate the quality of such technology for both smaller and larger platforms, though ultimately the choice will be in the hands of the airframer. From Liebherr's side, we want to be ready for whatever platform will be selected by the airframer.'

Opportunities for energy saving

What makes this project particularly relevant to the more electrical aircraft of the future is the fact that the system is electrically driven versus today's pneumatically based systems. This presents the opportunity for 'mutualisation,' whereby the same power electronics used to drive the EECS can also support other power electronics-driven functions, such as the start-up mode function for the main aircraft engines.

'If we reduce the number of power electronics in the aircraft we reduce the weight,' says Benmachou. 'And this opens the doors to having some mutualisation with the other loads. By using the same power electronics we can reduce the overall number of components and reduce weight in the aircraft, and this is what we call "multi-use capability".'

Status of the project

In 2020 the EECS passed its critical design review (CDR) with the airframer and the combined air cycle and vapour cycle system designs have been solidified. The results were positive and the manufacturing of the demonstrators is underway in preparation for the risk-driven development analyses, where models will be calibrated based on partial hardware component demonstration and previous data in order to reach appropriate representativeness.

'We do not need to develop the entire fuselage and so on as we are developing an air consuming pack whose size is comparable with a conventional pack. This is being tested at Liebherr's testing facilities where we have all the means to simulate the environmental constraints — what is being developed is a full scale demonstration at system level, not at aircraft level,' explains Benmachou.

'We have started the development of the major full scale rigs that will be tested in Liebherr's facilities from the second semester of 2021 until the end of 2022 in order to reach the TRL6 objectives in 2023,' he adds.

Though the original intention was to undertake a flight test campaign to test the EECS, this has been replaced with extensive ground tests at Liebherr's Toulouse facilities, using a system test bench, dedicated rotor and stator test benches, a vibration bench, a bearings test bench, a seals test bench, and a components test bench with ice particle ingestion.

The project has undergone analysis at system level of the benefits of an EECS compared to a conventional ECS with, reports Benmachou, 'some benefit which is between about 5-8% in terms of energy offtake — it's clearly an enabler for the more electrical generation of aircraft.'

However, he qualifies this by saying that 'what is relevant at the end of the day is the assessment that needs to be done at airframe level, because the decision to go for an electrical aircraft will be done by the airframer after considering the overall technologies integrated in the aircraft.'

The Clean Sky advantage

The development of the EECS is progressing, says Benmachou, 'thanks to the Clean Sky ecosystem, which has enabled the project to create a major high-level demonstrator with partners in order to go a step further and reach the objective in terms of impact analysis and demonstration of the feasibility of the technology.'

'Ultimately,' concludes Benmachou, 'the airframer will only select this technology if it's in the interest of the airlines — therefore competitiveness is an important detail, and Clean Sky has enabled us to make such a high level and representative demonstration.'

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