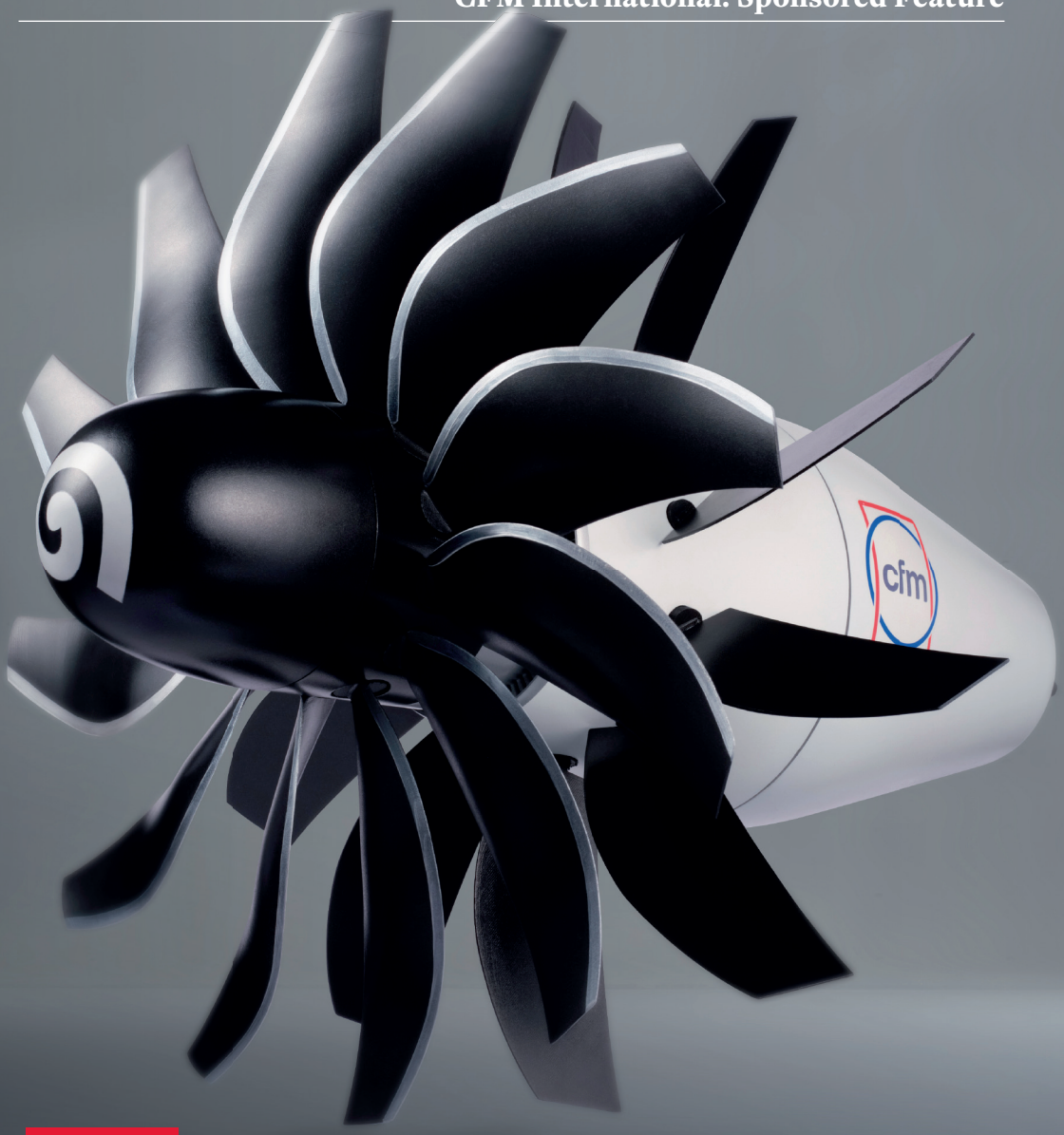


LEADERS AREN'T BORN. THEY'RE ENGINEERED.

RISE
A CFM PROGRAM

We are on the path to a more sustainable future.
A revolutionary goal like net zero by 2050 needs a revolutionary technology approach. We are open to the possibilities.

cfmaeroengines.com

RISE: A STEP CHANGE IN **AIRCRAFT PROPULSION**

CFM's Revolutionary Innovation for Sustainable Engines (RISE) program will fundamentally alter the aviation landscape

According to Arjan Hegeman, Future of Flight Technologies Leader, GE Aerospace—one of the two partners involved in CFM alongside Safran Aircraft Engines—the RISE program involves multiple elements that will redefine aircraft propulsion while also reducing carbon emissions.

"CFM is celebrating its 50th anniversary by looking to change the way that people fly," he says. "The CFM RISE program activity is moving from component-level evaluations to module-level tests. More than 250 tests have been completed, new research partnerships formed, and the technologies continue to mature."

Open Fan comes of age

One of the main pillars of the RISE program is the Open Fan engine architecture, which increases fan size and removes the engine casing. Weight and drag are reduced for greater propulsive efficiency results. The technology has moved a long way in recent years and one of the main problems—noise—has been overcome.

"Noise is all to do with air flow," Hegeman explains. "Thanks to supercomputing, we now understand in detail what happens around the blades. We can truly tackle turbulence in air flow, which is how we can improve acoustics and efficiency."

"Testing has taken place on combustor materials as well as how combustion impacts contrails, fuels, and emissions."

Testing on Open Fan is ongoing and maturing toward a level where a prototype engine is tested in flight conditions. More than 200 hours of wind tunnel testing have been completed at the French Onera Aerospace Lab using a 1:5 scale model of an Open Fan, including a version of the model mounted on a demonstrator plane wing section for testing with Airbus.

A high-speed, low-pressure turbine (LPT) test campaign with advanced turbine blades has also been run and a second high-pressure turbine (HPT) blade and nozzle test campaign has started.

Once all the technology is proven in terms of safety, durability, and performance through ground and flight tests, a new engine product could be launched. Entry into service is anticipated in the mid-2030s.

"We have made significant progress in our testing plan, which confirms the benefits of the Open Fan propulsive system for the next generation of single-aisle aircraft," said

Investing in supercomputing

GE Aerospace—part owner of CFM—and the US Department of Energy's Oak Ridge National Laboratory have reached a new Cooperative Research and Development Agreement (CRADA) on supercomputing, expanding the company's capabilities to design such next-generation aircraft engine technologies as Open Fan.

GE Aerospace and Oak Ridge will collaborate to develop new, state-of-the-art computational modeling and simulation capabilities. Oak Ridge's expertise will help GE Aerospace better manage large simulations, more efficiently extract information, incorporate cutting-edge artificial intelligence (AI) tools to improve understanding of results, and streamline the process to visualize the physics.

Oak Ridge National Laboratory is home to Frontier, the world's fastest supercomputer, capable of crunching data at exascale speed, or more than a quintillion calculations per second. It is also renowned for its computing expertise.

"Supercomputing and access to Frontier is changing the way we design jet engines, allowing us to solve previously impossible problems. We're now able to digitally fly components of an Open Fan at full-scale in a simulated environment before the hardware is built," says Mohamed Ali, SVP of Engineering for GE Aerospace.

"Our expanded research collaboration through a new cooperative agreement with Oak Ridge National Laboratory will accelerate our engine design and testing, building confidence that Open Fan architecture is the most promising engine technology to help the aviation industry meet its net zero ambitions," Ali added.

GE Aerospace's use of supercomputing power and software tools are helping engineers understand Open Fan aerodynamic and acoustic physics in new ways. For example, Frontier unlocks the ability to better evaluate new engine technologies at flight scale in the design phase. As a result, GE Aerospace can improve test hardware designs and better optimize engine performance and airframe integration.

IMAGE: SAFRAN

Wind tunnel tests on Open Fan

Safran Aircraft Engines—one of the parent companies of CFM—and France's national aerospace research agency ONERA are performing wind tunnel tests with the ECOENGInE, a 1:5 scale demonstrator of the future Open Fan.

Open Fan is a key pillar of the CFM RISE technology demonstration program that promises a 20% reduction in CO_2 emissions compared with today's commercial engines.

Safran Aircraft Engines and ONERA signed a framework agreement for an ambitious test plan from 2024 to 2028, building on previous trials with the ECOENGInE.

In total, over 200 hours of testing have been performed during this campaign, including simulation tests with the engine mounted on a demonstrator plane wing section.

"This series of wind tunnel tests is a major milestone in our research and technology (R&T) roadmap, which aims to develop the technological building blocks for the next breed of commercial jet engines," says Pierre Cottenceau, VP Engineering and R&T for Safran Aircraft Engines. "With the RISE program, Safran Aircraft Engines is contributing our long-standing expertise to the development of the fan module to demonstrate the benefits of an unshrouded engine architecture on the ground and in flight by mid-decade."

Safran is also coordinating demonstration of the Clean Aviation OFELIA project (Open Fan for Environmental Low Impact of Aviation), which involves 26 European partners, including ONERA. Moreover, the company is working on other major technological building blocks in conjunction with the Open Fan architecture, such as hybrid propulsion.

Developing hybrid electric systems with NASA

GE Aerospace is developing a hybrid electric demonstrator engine with NASA that will embed electric motor/generators in a high-bypass commercial turbofan to supplement power during different phases of operation.

This includes modifying a Passport engine with hybrid electric components for testing through NASA's Hybrid Thermally Efficient Core (HyTEC) project.

Embedded electric motor/generators will optimize engine performance by creating a system that can work with or without energy storage like batteries. This could help accelerate the introduction of hybrid electric technologies for commercial aviation prior to energy storage solutions being fully matured.

"Together with NASA, GE Aerospace is doing critical research and development that could help make hybrid electric commercial flight possible," said Arjan Hegeman, General Manager of future of flight technologies at GE Aerospace.

Results of the hybrid electric component and baseline engine tests are being used to evaluate and update models in preparation for a ground test.

"We're advancing state-of-the-art propulsion systems for next generation commercial aircraft with an important aim—to drive industry efforts to improve efficiency and reduce emissions compared to today's aircraft engines," Hegeman said.

NASA recently awarded GE Aerospace a contract for Phase 2 of the HyTEC project to continue developing technologies for an aircraft engine core demonstrator test later this decade. Phase 2 builds on work completed in Phase 1 of HyTEC for high-pressure compressor and high-pressure turbine advanced aerodynamics, as well as the combustor.

In 2022, GE Aerospace completed the world's first test of a MW-class and multi-kilovolt (kV) hybrid electric propulsion system in altitude conditions up to 45,000 feet that simulate single-aisle commercial flight at NASA's Electric Aircraft Testbed.

Pierre Cottenceau, Executive Vice President of Engineering and Research & Technology for Safran Aircraft Engines. "We successfully completed key tests on fan acoustics, aerodynamics, and blade ingestion, and the high-speed, low-pressure turbine, while advancing hybrid electric tests for our suite of pioneering technologies."

Hybrid electric

Other important technology pillars in the RISE program include hybrid electric systems. This provides an alternative source of power during certain phases of flight. Early testing has been conducted towards demonstrating turbofan and electric machine control with a Passport engine.

A demonstration of megawatt-class, flight-quality electric power components is the target for the RISE program and other GE Aerospace projects support this aim, such as the NASA Electrified Powertrain Flight Demonstration (EPFD) program, which calls for ground and flight tests of the hybrid electric system this decade.

GE Aerospace is also working with NASA on compact core technologies through the Hybrid Thermally Efficient Core (HyTEC) program. The compact core needs to feature new materials and advanced cooling but Hegeman says that feasibility isn't the issue. "Testing has taken place on combustor materials as well as how combustion impacts contrails, fuels, and emissions," he notes.

Meanwhile, compressor rig tests have focused on validating new aerodynamic and aeromechanic technologies.

From supercomputing to sustainability

Supercomputing is playing a vital part in RISE program testing and modeling. Previously, computer-run simulations had to have some "wiggle room", but supercomputing enables models to be extremely accurate, which, in turn, ensures work on such factors as noise and performance are exacting from the outset.

Ultimately, it will allow all technology pillars to dovetail into a game-changing engine that redefines aviation.

Also integral to every facet of the RISE program is how to make the technology more sustainable. The target for this game-changing program is to improve fuel burn and reduce CO2 emissions by more than 20% compared with the most efficient commercial aircraft engines in service today. Engine technologies are being designed for compatibility with 100% or unblended Sustainable Aviation Fuel (SAF). CFM is also advancing hydrogen combustion technologies—and all technologies are being validated to meet the most stringent non-CO2 and noise emission requirements.

"We are convinced that climate change is a major issue and any product that is truly more sustainable will have a competitive edge," says Hegeman. "It's not just about reducing carbon emissions. We're also looking at a lean burning combustor to reduce NOx particles (nitric oxide (NO)) and nitrogen dioxide (NO2) and improved manufacturing techniques, among many other initiatives."

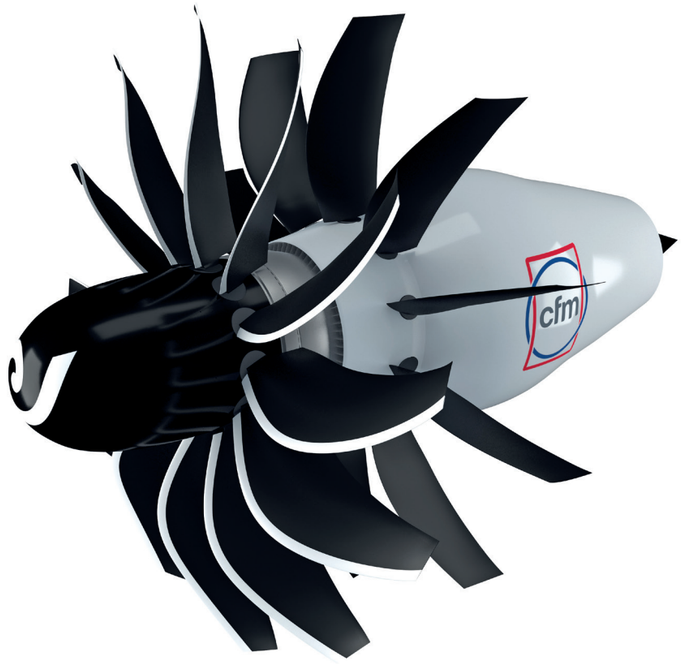
Hegeman concludes that the RISE program's suite of pioneering technologies being pursued by more than 2,000 engineers represents a pivotal moment in aviation history as it transitions from ideas to reality.

"It should not be underestimated how committed we are to the RISE program, Open Fan, and all the other innovative technologies," he sums up. "We have been working on these ideas for a long time, we have done a lot of testing and modelling with the most advanced computers and simulations in the world, and we know no technical reason why this wouldn't work.

"It is real, and it is going to happen."

"Thanks to supercomputing, we now understand in detail what happens around the blades. We can truly tackle turbulence in air flow, which is how we can improve problems with acoustics and efficiency."

IMAGE: GE AEROSPACE



RISE tackles maintenance issues

Reducing the maintenance burden is a key consideration for the RISE program. Arjan Hegeman, Future of Flight Technologies Leader, GE Aerospace, reveals that the biggest challenge is durability in the combustor, the hottest part of the engine.

But advanced cooling techniques are developing rapidly and will ensure combustor durability and engine time on wing. This is a key consideration for airline clients in a highly competitive market where aircraft utilization is key.

After conducting its first test run of next-generation HPT blades and nozzles using a demonstrator engine, GE Aerospace has started a second HPT airfoil test campaign focused on endurance, demonstrating the RISE program's focus on durability.

Open Fan also means no nacelle or thrust reverser. Indeed, whole subsystems will be removed that have traditionally taken up maintenance time and costs.

"Every aspect of operations is examined through the RISE program," says Hegeman. "The economics have to be viable and the substantial performance improvements available through the RISE program will produce an engine that makes financial sense for our clients."

100%

Engine technologies are being **designed for compatibility** with 100% or unblended **SAF**. CFM is also advancing **hydrogen** combustion technologies

CFM RISE PROGRAM

100%
SAF Compatibility

250+
Tests Completed

20%
Better Fuel Efficiency Target

2000+
Engineers

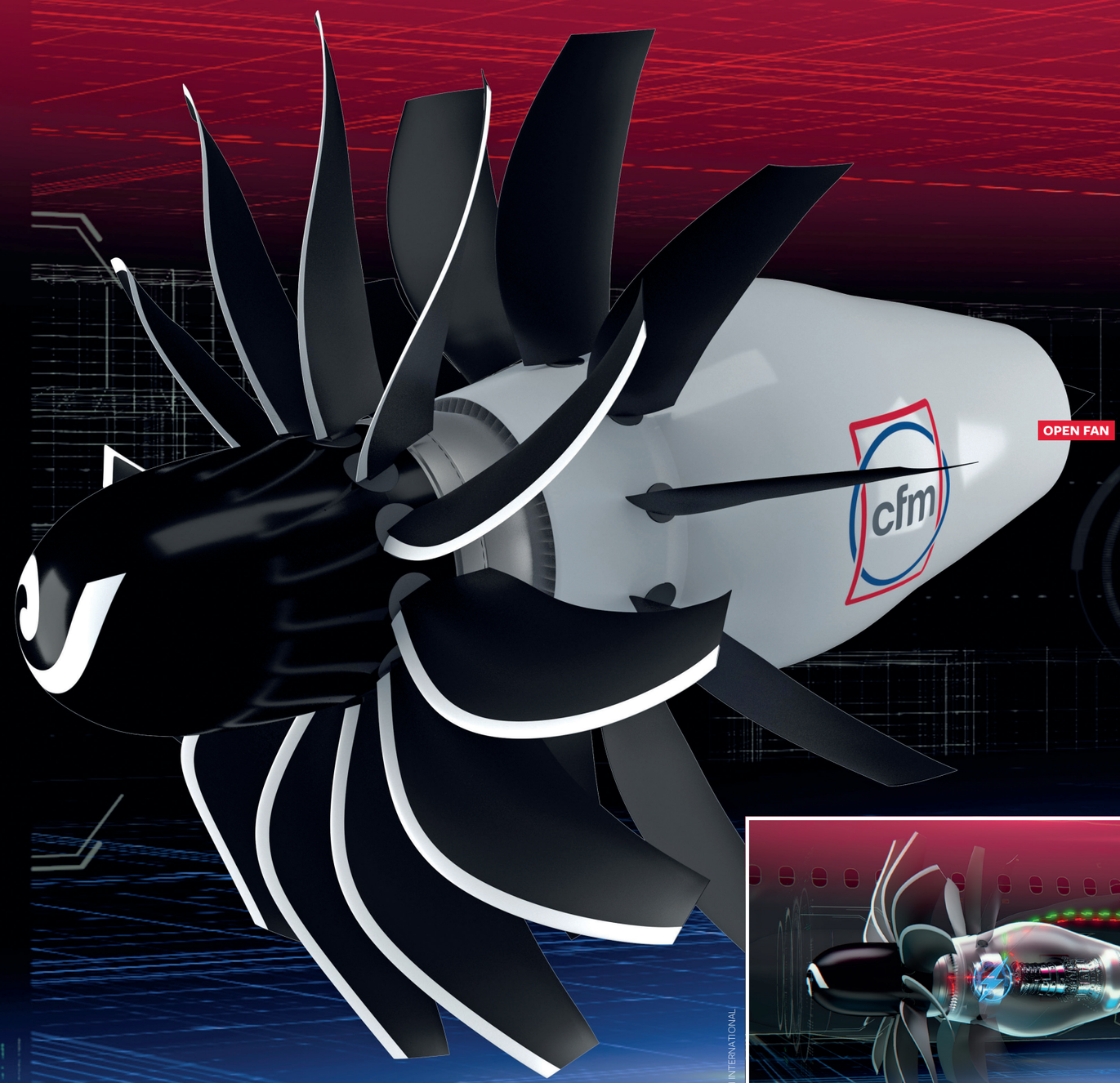


IMAGE: CFM INTERNATIONAL

About CFM RISE

The CFM RISE (Revolutionary Innovation for Sustainable Engines) program will demonstrate and develop a range of innovative, disruptive technologies for aircraft engines that could enter service in the mid-2030s.

OPEN FAN
Open Fan technology removes the engine nacelle, allowing for larger fan blades and reducing drag. The improved aerodynamics and increased air flow significantly enhances fuel efficiency.

HYBRID ELECTRIC
Hybrid electric engines use alternative power during certain phases of flight to reduce emissions. As part of the RISE program, GE Aerospace is working with NASA on a hybrid electric demonstrator that embeds electric motor/generators in a high-bypass turbofan.

SUSTAINABLE AVIATION FUELS
All CFM engines work with blended SAF, and the RISE program is researching and supporting development of standards for 100% or unblended SAF, which has the potential to reduce fuel lifecycle carbon emissions.

ADVANCED MATERIALS
Through the RISE program, CFM continues to advance composite materials, such as carbon fiber and ceramic matrix, which are lighter and stronger than their metal counterparts. This not only improves durability but also fuel efficiency.

CFM International is a 50-50 joint company between GE Aerospace and Safran Aircraft Engines.

airlines.iata.org


cfm
50 YEARS
Thank you,
to the greatest team in aviation.
Together, you make CFM extraordinary;
the future is in very good hands.
Gaël Méheust
President & CEO, CFM International