Shrinking the carbon footprint and improving the bottom line

Close to 5 million tons of kerosene per year. That's the fuel savings the global fleet of aircraft could achieve with AeroSHARK coating technology. And we're well past proof of concept. The roll-out onto the first passenger and cargo airline fleets has begun.

Improving fuel efficiency – and the other directly related key benefit: lower emissions – starts with anything that helps the aircraft cut through the air with the least drag and the most lift – in addition to less weight, of course. Just like a shark cuts through the water.

Nature makes it look so easy

It's not just a streamlined body, optimal fin configuration and quite a few pounds of pure muscle that make sharks the most energy-efficient swimmers in the history of the planet.

What 450 million years of evolution also gave the shark is great skin. It consists almost entirely of small placoid scales that shift independently to reduce drag. They increase buoyancy while generating low-profile vortices that reduce hydrodynamic drag and even add a thrust component. The faster the shark moves through the water, the more efficiently it does so.

Theory shows that replicating this skin structure on the fuselage of an aircraft can reduce drag by up to 3 %. Extrapolated to the global fleet of aircraft, this translates into just under 4.9 million metric tons of fuel that could be saved each year.

Biomimetics meets aeronautics and chemical engineering

In partnership with BASF, the world's leading chemical and coatings manufacturer, Lufthansa Technik has developed a functional biomimetic technology: a film with a barely perceptible ribbed texture made up of small elevations – so-called riblets. The film has millions of these prism-shaped riblets, each 50 micrometers high, making it easy to apply in a targeted way. The film is selectively applied to the aircraft body depending on the type and function of the surface. When aligned with the airflow, the riblets reduce the skin drag and the associated drag, similar to their counterparts in nature, the denticles on sharkskin.

MORE THAN 1 % LESS FUEL BURN AND EMISSIONS

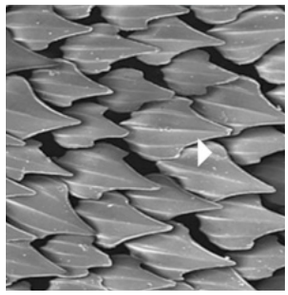
More than a cost-effective and scalable solution

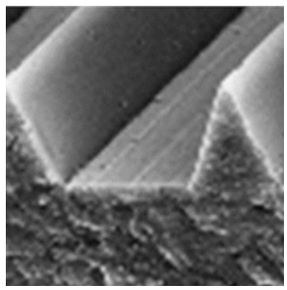
Combining BASF's advances in coating technologies and application processes with data gathered through Lufthansa Technik's extensive experience, research and testing resulted in a winning solution, one that is unique because it checks all the key boxes: cost-effectiveness, scalability, retrofittability and sustainability. And the latter not only because of its impact on fuel savings and emissions reduction, but also its lower manufacturing and application footprint compared to other technologies.

From proof of concept to first series application

The key to fast-tracking the project to test flights in record time was Lufthansa Technik's EASA Part 21 Subpart J certification as an aircraft design organization. While initial flight tests of sharkskin technology had focused on durability testing with small test patches of rarely more than a few square inches, Lufthansa Technik and BASF made a huge development step with the first ever large-scale application in late 2019. Back then, a Lufthansa Boeing 747-400 was fitted and certified with no less than 500 square meters of riblet film on its fuselage. In several thousand flight hours since then, this aircraft delivered the long-awaited real-world proof of concept that AeroSHARK is effective in daily operations: With proven up to 0.8 % fuel and emissions savings, it validated all previous CFD simulations and laid the foundation for the launch of the next bigger sharkskin configurations, this time on the Boeing 777. In December 2022, Lufthansa Technik achieved a common Supplemental Type Certificate (STC) for AeroSHARK on the Boeing 777-300ER passenger version and the Boeing 777 Freighter.

No hype. Results.
With Lufthansa Cargo and SWISS International Air Lines, two renowned airline brands from the Lufthansa Group have recently become the pioneers for the first series applications. While SWISS will be the first passenger airline in the world to employ AeroSHARK on its entire Boeing 777-300ER subfleet, Lufthansa Cargo will be the world's first freight airline using the riblet technology to make their Boeing 777Fs more fuel-efficient and less pollutant. With now up to 950 square meters of riblet film on the fuselage, the 777's fuel and emissions savings are around 1% (depending on operations). This means avarage anual savings of ~325 tons kerosene and more than 1020 tons of CO_2, just for a single aircraft. The combined 777 fleets of Lufthansa Cargo and SWISS, once fully modified with AeroSHARK, will help save more than 8,800 tons of jet fuel and more than 25,000 tons of carbon dioxide every year.





The detailed images show the microstructure of the riblets on a shark's skin (top image) and the AeroSHARK riblet film (bottom image).

Future plans: Even larger surfaces and more aircraft typesy
With the rollout at these two airlines now in full swing, Lufthansa Technik now looks forward to making this innovative technology available to more and more airlines as quickly as possible. As a first step, the AeroSHARK modifications for the Boeing 777-300ER, 777F and 747-400 are now officially offered to all interested airlines around the world. In parallel to that, Lufthansa Technik will intensify the further development of AeroSHARK with the aim to achieve certification for many more commercial aircraft types and for modifying even larger portions of their outer skin. In theory, the maximum possible modification could even reach fuel and emissions savings of up to three percent. That´s a lot of additional efficiency still to gain with the flying sharks.

The AeroSHARK effect

	**0.8 % drag reduction confirmed for one Boeing 747-400 equals per annum:**	**approx. 300 t** fuel savings	**>900 t** emission reduction	**>€ 230,000** cost savings
	**The expected 1% drag reduction on each Boeing 777F equals per annum:**	**325 t** fuel savings	**1,020 t** emission reduction	**>€ 250,000** cost savings
	**Estimated potential for the global commercial fleet at 1% drag reduction equals:**	**2 m. t** fuel savings	**6.3 m. t** emission reduction	**approx. € 1.6 bn** cost savings
	**Riblet film can be applied to any aircraft**	**180 g / m²** weight	**4+ years** durability	**<2 years** ROI

3 QUESTIONS TO ...

Jens-Uwe Müller, AeroSHARK project leader at Lufthansa Technik's main base at Hamburg Airport.

1

Why are you first equipping legacy aircraft types with AeroSHARK? Wouldn't newer aircraft have greater potential for fuel savings and lower emissions?

As an airline, you cannot buy a new, more efficient aircraft every day. As aircraft lifecycles can easily reach 30 years, our clear goal is to leverage additional savings potentials also for the in-service fleets. In 2019, the Boeing 747-400 was the perfect platform to demonstrate that significant savings are possible with tried and tested aircraft, so airline customers can directly see the benefits of retrofitting aircraft already in service. We also had decades of experience with this type, which was crucial to accelerating the testing and certification process. With the Bowing 777 series aircraft, a more modern and with more that 1000 aircraft in operations broadly spread aircraft series can provide contribution to save CO_2. Later the decade, AeroSHARK will also be available for the newest aircraft types like A350 and Boeing 787 which currently suffer from paint qualitiy and are therefor no good targets for film application.

> The fact is that our riblet technology can be applied to any aircraft with a similar effect.

2

So, the 747 and 777 tests have proven the effectiveness of the riblet film? What are the rollout plans?

Yes, the 747-400 with 500 square meters of riblet film and even more the 777s we equipped in 2022 and 2023 have demonstrated that AeroSHARK is effective in daily operations. Today, we are proud to have two renowned airline brands from the Lufthansa Group as our first customers. While SWISS is the first passenger airline in the world who employed AeroSHARK on its entire Boeing 777 subfleet, Lufthansa Cargo will be the world´s first freight airline using our sharkskin technology to make their 777Fs more fuel-efficient and less pollutant. We now look forward to making this innovative technology available to more and more airlines as quickly as possible. To realize the greatest possible savings potential with the greatest possible market penetration, we are now looking for more airlines to participate in the success of the AeroSHARK effect and to certify AeroSHARK for the next aircraft types.

3

How do you measure fuel savings before and after the modification? Does a 1% change even move the needle?

A multitude of factors can skew the result, hence we employ most modern data analyses. We use AVIATAR Fuel Analytics for accurate before and after comparisons. Using real-world consumption data from the flow rate sensors on the aircraft's engines, the software algorithm can filter out various potentially distorting factors. AVIATAR delivers precise measurements to within +/– 0.1%, so that the effect of AeroSHARK is clearly visible.