HOW AI CAN REDUCE FUEL EMISSIONS IN AVIATION

The Lufthansa Group's Platform With Google Cloud Sets New Standards.

Google Cloud

LUFTHANSA GROUP

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THE URGENCY TO BECOME MORE SUSTAINABLE

Decarbonization has become an imperative for companies and societies at large, kicking off the race to identify and scale the most impactful innovations. Lufthansa Group builds on a strong commitment to its corporate responsibility in tackling the #1 challenge of our time as a global thought leader. Demand pressure from customers and regulatory targets usher in a new era racing to identify and scale commercially viable clean technologies. As a hard-to-decarbonize industry[1], aviation accounts for 2.8 % of total human-induced emissions released into the atmosphere globally[2]. It faces the existential challenge of working towards its net-zero pledge by 2050[3].

Today, this ambitious goal is enshrined at all levels, from Lufthansa Group corporate strategy[4], to the ratification by 158 States at the United Nations body for Civil Aviation in October 2022[5]. This effort is especially challenging due to the industry's unique technological and regulatory complexity as well as the prospect of increased demand for air travel globally over the next decades[6]. But the outlook of carbon-neutral air travel promises to reveal additional positive economic and cultural benefits through global development representing 36 million jobs globally[7] during the industry's transition to a greener, cleaner, and more innovative future. Environmentally conscious action must become a core value of any aviation company to safeguard future consumer markets as sustainability goes from a nice-to-have to a must.

1 US Department of Energy, 2021 **2** International Energy Agency (IEA), 2019 **3** IATA, 2010 **4** Lufthansa Group, n.d. **5** ICAO, 2022 **6** "Between 2019 and 2040 the IATA forecast that air passenger numbers will increase at an average annual rate of 3.3%, rising to 7.8 billion passenger journeys per year at the end of our forecast horizon". IATA, 2022 **7** AERTEC, 2020

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DECARBONIZING AVIATION; THE JOB TO BE DONE

The challenges faced by Lufthansa Group are shared with all industry players inspiring a business climate of coopetition, with higher levels of exchange and dialogue between competitors to understand which technologies will be feasible and the regulatory prerequisites to achieve their implementation. Breakthrough technologies are set to revolutionize much of the assets and infrastructure of current aviation, and competitors are exchanging and discussing with counterparts from academia, institutes, suppliers and governments to determine which technologies have a better chance of realizing transition in several areas of the business, i.e. new propulsion systems, new aircraft designs, carbon offsetting technologies and ground operations infrastructure and energy supply (i.e. Sustainable Aviation Fuel, hydrogen and battery). The aviation industry is starting to bet on future technologies and shaving off efficiency gains across the entire operations through intelligent data strategies.

But the path to carbon neutrality by 2050 is paved with pitfalls often outside the spectrum of influence of airlines. There are long certification cycles, extensive safety-related testing periods of technology, and inert scaling of technology in Sustainable Aviation Fuel or hydrogen infrastructure. Equally challenging is a partial political misalignment between states in terms of airspace management, regional differences in fossil fuel taxation, or how green investments are incentivized. With great progress being made on many fronts, a synchronized and heightened stakeholder alignment is the burning urgency. Urgency is required not least because decisions taken, and innovation implemented today create lasting impact for decades. For example, more efficient planes ordered today take years to finally lift off and will operate often over two decades.

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THOUGHT LEADERSHIP AND ACCOUNTABILITY IN LUFTHANSA GROUP'S CLIMATE PROTECTION

To underscore its commitment and accountability to being measured on its path towards achieving its targets, Lufthansa Group has committed to reducing its CO_2 intensity by 2030 in concrete terms and has become the first European airline to receive the seal of the Science Based Target Initiative (SBTi) for this purpose. The SBTi targets are aligned with the decision of the Paris Climate Agreement to limit global warming and require reporting of company-wide emissions and progress against targets on an annual basis.

Lufthansa Group has pledged to lower its net carbon emissions to half by 2030 compared to 2019 and aims to be carbon-neutral by 2050. In doing so, it is focusing in particular on accelerated fleet modernization, continuous optimization of flight operations, and the use of Sustainable Aviation Fuels (SAF). Currently, the biggest lever for saving CO_2 is introducing new aircraft.

A latest-generation aircraft consumes up to 30% less fuel than its predecessor. In addition to continuously investing over €2 billion p.a. in fleet renewal with the introduction of more than 200 short-, medium- and long-haul aircraft by 2030 the group is strategically analyzing what smaller novel aircraft types powered by hydrogen or batteries could mean for future business models.

Lufthansa Group has invested millions of euros into SAF as a genuine alternative to fossil fuel in the short- and mid-term. Lufthansa Group is the pilot customer of the world's first Power-to-Liquid facility in Wertle, Germany and is keen on driving the commercialization of this promising future supplier base. Furthermore Lufthansa Group airline SWISS has invested in the world's first production of carbon-neutral solar fuels derived from grid-independent solar heat in a similar breakthrough technology called Sun-to-Liquid.

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"At Lufthansa Group, we are tasked with searching and connecting clean tech opportunities for driving our sustainability agenda. With our collaborative approach, we create and drive pilot tech-driven innovation projects internally as well as together with thought-leading partners and research. We identify and monitor upcoming technologies such as lightweight materials, soft- and hardware innovations along the entire emission chain of Lufthansa Group – from waste recycling in our onboard catering to new propulsion trends and data-driven flight efficiency optimization. With this mission, we explore and broaden the intersection of what is imaginable with what is executable in clean tech for Lufthansa Group."

Caroline Drischel
Head of Corporate Responsibility, Lufthansa Group

This whitepaper introduces a lighthouse project to highlight the role of data and AI as a crucial lever in one of the world's most complex industries. Within a generally low-margin industry with ultra-high complexity, the smallest efficiency gains unlock wide-ranging opportunities for Lufthansa Group's three core objectives of reducing emissions, increasing profitability, and perfecting the customer experience while retaining its high safety standards.

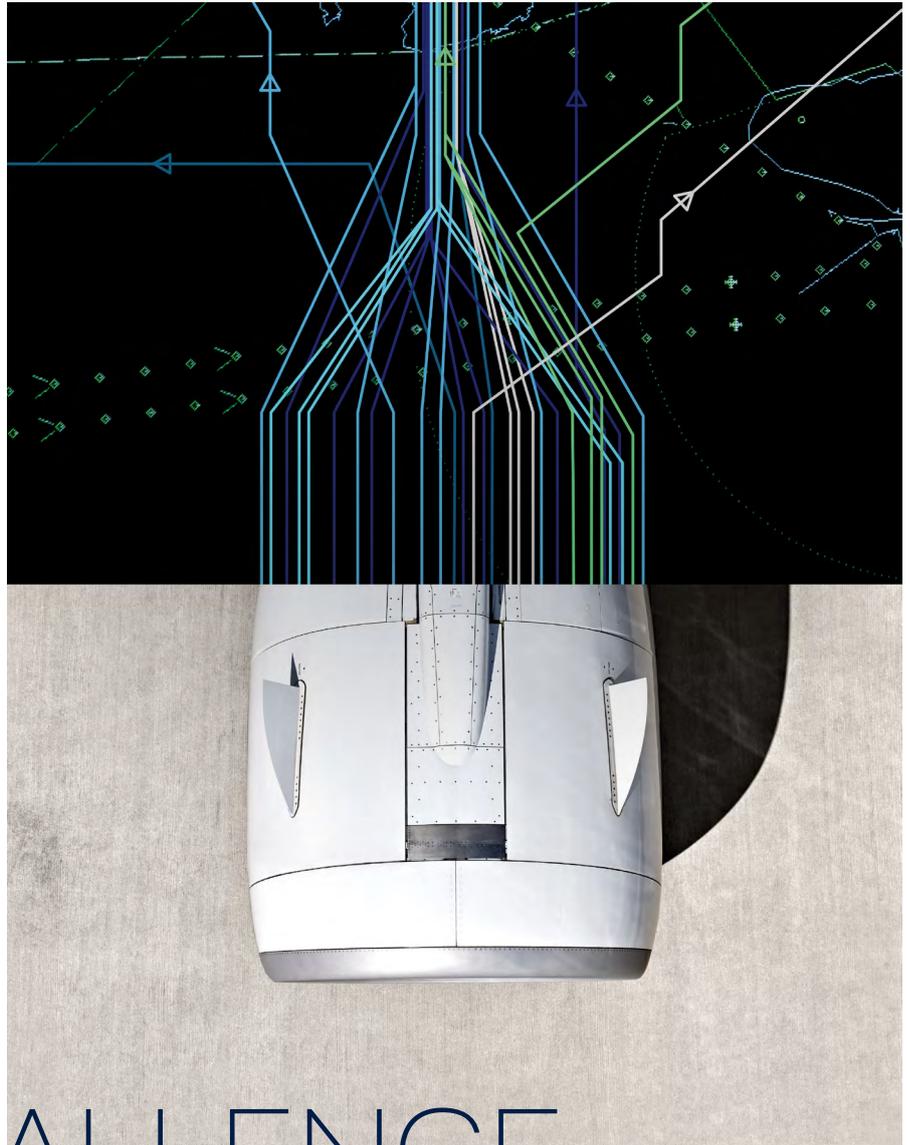"Every flight is a highly complex subject with thousands of different variables, and it even becomes more complex over time. But we are committed to investing in new technologies to explore previously untapped opportunities to improve safety, reduce emissions and enhance the customer experience."

Marcus Schnabel
SVP Flight & Ground Operations and Security, Lufthansa Group

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THE CHALLENGE

Managing Hyper-Complexity at Scale in Real-Time

Smooth flight operations are enabled by a hyper-complex network of dependencies between hundreds of individually synchronized procedural elements. For the hubs in Frankfurt and Munich, for example, there are 1,200 Lufthansa Group flights a day with up to 170,000 passengers. Each of these elements unfolds in real-time, and each of them triggers a chain of far-reaching implications that, in turn, have an impact on the entire flight operations system. If a lightning strike triggers a routine safety check, thousands of passenger routes are immediately reevaluated, crew deployments, aircraft rotation, air traffic control, catering, cleaning, loading, and passenger flows are affected. Hundreds of dedicated problem solvers across Lufthansa Group's eight

Operations Control Centers manage such unpredictability by governing experience-based decisions over flight cancellations, individual passenger re-routing, and ground-related mitigation strategies – from optimizing slots or gate locations decreasing transfer time for passengers to hotel bookings or luggage handling. Previously, to resolve each irregularity, it could take up to five experts for several hours to reassign all aircraft and passengers to their onward journeys. Time is the costliest factor in a system affecting thousands of people and processes, and complexity rises to staggering levels when sustainability is embedded as an additional KPI.

05

THE STATUS QUO

Operations Research Shifts the Horizon in Making Optimal Decisions

Having made use of the benefits of digitization and data-driven solutions early on, Lufthansa Group has long invested into strong IT capabilities for its operations. The specialists in the Operations Control Centers make use of a set of core IT systems coordinating aircraft rotation, passenger management, crew deployment, and technical units. In case of a storm with an airport closure for instance, tens of thousands of possible mitigation strategies are to be considered, evaluated, and prioritized quickly. Considering the scale of implications each decision represents, combining operational research capabilities with Big Data enables better decisions faster. With this opportunity on the technological horizon, Lufthansa Group identified a powerful use case for driving sustainability through a data-centric technology approach.

"Data and AI transform our Lufthansa Group businesses, customer service, and operations. With our data scientists, AI engineers, business and digital experts we engage on a journey to test, learn, scale, and create value for all our group companies' stakeholders. At the core of this mission is transforming the Lufthansa Group towards data-centricity. No matter which area of innovation we will venture into, data is at the core of gaining a more comprehensive understanding of how we can drive sustainability."

Xavier Lagardère
Chief Data Officer, VP Innovation Management, Lufthansa Group

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THE GOAL

Data-Centric Decision Support to Drive Efficiency and Sustainability

Conceptualizing an application of real-time data analytics for advanced decision support, Lufthansa Group bundled all relevant expertise from flight to ground operations, from touchpoints with airports and air traffic controllers to catering and maintenance. Conceptually equivalent to an advanced navigation system that provides suggestions for various means of transportation and routes to reach the same destination, Lufthansa Group envisioned a ground-breaking cloud-based solution to provide real-time intelligence to its decision-makers in operations control.

The difficulty for human decision makers is to be able to map out and prioritize a multitude of maneuvers, which can be in the thousands. For the given example of an unpredictable lightning strike of an aircraft, the number of mitigation scenarios available can reach a total of over 100,000 options, each representing varied priorities for different passenger groups as well as their economic and sustainability factors. Through predictive operative research intelligence, using real-time data, the Operations Decision Support Suite (OPSD) developed with Google Cloud now autonomously suggests within minutes the optimum scenario based on cost, CO_2, passenger satisfaction, operation stability, or profit. Ops controllers can now make the best holistic operations decision in terms of moving passengers, crew, and aircraft instead of optimizing one single flight to the hidden detriment of the rest.

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THE PARTNERSHIP

Lufthansa Group & Google Cloud
Kick-Off a Group-Wide Innovation

Managing and leveraging a complex landscape of data sources at scale and speed requires cutting-edge cloud computing with some of the most advanced Operations Research (OR), Artificial intelligence (AI), and Machine Learning (ML) capabilities. Lufthansa Group entered a groundbreaking partnership with an outstanding cloud computing services provider in 2019 with the aim of driving sustainability through efficient operations. Following a philosophy of creating the biggest positive impact as quickly as possible, the Lufthansa Group opened a competitive Request for Proposal (RFP) aimed at qualifying potential partners ready to rise to the challenge.

While such extensive cross-industry partnerships between tech and aviation at eye level are a novelty, the urgency to act for sustainability requires no less than bold and concerted collaboration of thought leaders from both industries.

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"Being impressed with Google's technology and prowess in the field of AI and machine learning, we were certain that working together to combine our unique business expertise with their abilities, we would achieve the best results possible."

Christian Most
Senior Director, Digital Operations Optimization, Lufthansa Group

Google Cloud has proven to be most qualified and innovative for the scope of this joint venture, bringing in especially their world-leading Operations Research team across the globe as well as piloting innovation in the fields of AI and ML with extensive experience in execution. Within the network of Airlines, SWISS – a smaller airline with a less complex fleet – became the Group's pilot airline in the summer of 2021, before the technology gets rolled out to the other Group airlines.

With its bold approach, the partnership materializes a real paradigm shift. With sustainability rising to be the winning factor in the global competition for leadership in the future of mobility, traditional silos of industry knowledge and expertise have to be transcended in favor of a new era of collaboration.

Operationally, Google Cloud and Lufthansa Group have created a powerful joint team, bringing together all relevant expertise from both organizations tasked with building one of the industry's most advanced cloud-native systems of its kind.

"Google Cloud is proud to partner closely with organizations to help them become the best at leveraging the value of tech in their industry and accelerate company transformations through data, collaboration, and by leveraging a secure clean cloud. The way Lufthansa Group has taken advantage of this to both drive more sustainable and efficient operations, manage costs and even position them incredibly well to adapt to market changes and customer needs and secure top line growth too. The collaboration is a prime example of expertise coming together where Google's products are brought into a business context and the collaboration has enabled the aviation industry to see a way to a more sustainable and efficient future."

Louisa Loran
Global Director of Strategic Industries, Transportation & Logistics, Google Cloud

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THE OPSD PLATFORM

A Powerful Cloud for Centralized Decision Making in Operations Control in Real-Time

The core promise of the Operations Decision Support Suite is to build a centralized data repository and powerful cloud-computing infrastructure on top of SWISS' existing IT landscape. With this non-invasive approach to existing highly-complex IT infrastructure, OPSD takes advantage of Google Cloud's ↗ **BigQuery**, ↗ **Vertex AI** and ↗ **Cloud Spanner** for analytics and modeling and derives predictive intelligence from hundreds of data sources in real-time, suggesting scenarios for the airline's operations.

Data is ingested autonomously in varying cycles from every second to yearly updates from over 300 sources. The landscape of sources ranges from relatively stagnant factors like aircraft seat configuration datasets to live slot and gate scheduling updated every second for hundreds of airports worldwide. Fuel consumption data, historical weather data, and passenger route data are also added to the repository, creating a constantly evolving comprehensive digital twin picture of the airline's complex operations.

OPSD then applies strong computing capabilities to the data lake, using Google Cloud's core features of AI and ML and the co-innovated and applied OR capabilities. OPSD takes a mathematics and statistics-based approach as a way of applying rigid functions

to model optimal or near-optimal solutions to decision-making problems for SWISS' operations. Its Artificial Intelligence and Machine Learning based on Google Cloud's Vertex AI connect the ingested data with predictive analytics, such as predicting disruptive weather conditions and their best response by network controllers in the Operations Control Center at high precision and temporal granularity.

As an independent cloud layer on top of existing operational IT systems, OPSD functions as an agile tool, able to be relatively easily rolled out and customized to particular airlines and airports. This way, it leverages the flexibility of an independent cloud-native platform for the solution of complex operations being actively managed simultaneously without the ability for an interruption for implementing new technology. Being built in modular form, individual modules fulfill stand-alone functionalities but also integrate with other modules, synchronizing the impact of fuel efficiency while assigning the optimal aircraft to every flight or optimizing flight speed for a particular scenario. As the central optimization engine, the OPSD's "Grand Solver" brings together all modules and combines their functionality into a holistic optimization.

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THE IMPACT

Driving Sustainability Through Efficiency

With OPSD, Lufthansa Group has brought the capabilities of its airline operations teams to a new level by making use of the utmost innovative technology available. The Operations Control Center makes better decisions by utilizing all data resources and the most powerful computational tools informed and rooted in more factors ranging from historical, live, and predictive understanding. While the core category of optimization is efficiency gains, this drive for optimization ultimately enables strategic aims such as customer satisfaction and sustainability.

Being able to factor in the most sustainable solution requires a holistic understanding of dependencies behind fuel consumption, aircraft weight, and speed, as well as route optimizations and much more. For example, when a blizzard hits New York and the airport will likely close, weather data combined with AI-backed forecasting will suggest the aircraft fly slower and reduce fuel burn, as opposed to receiving information upon landing and circling until the runway is cleared of snow to land.

Considering the scale of operations, even small optimizations of this kind add up to a significant impact, shedding light on sustainability opportunities in often overlooked areas. Optimizations of efficiency exemplify this approach and showcase that obtaining a data-powered holistic perspective unlocks otherwise untapped areas of possible emission reduction, profitability gains, and improvement of customer experience.

Since working with Google Cloud on the OPSD, better decisions taken faster have created a tangible impact. Calculating the total operation efficiency gained in this relatively small airline network of SWISS with 90 aircraft and 380 number of legs per day, the sustainability impact already adds to reduced CO_2 emissions of an estimated 7,400 tons per year – the equivalent 370 flights between London and Zurich.

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CO_2 ↘ **50,000 t**

the equivalent of about

2,500 x

ZRH → LHR

London

Airbus
A320neo

Zurich

THE BIGGER PICTURE

## Transforming Aviation Through Clean Tech

OPSD and the collaboration between Lufthansa Group and Google Cloud is about ambition, innovation and speed-to-market. This process requires transformation and learning on both sides of the partnership – both in industry specialization as well as the culture in which innovations are envisioned, tested, and scaled. With the application of the OPSD within SWISS, Lufthansa Group has proven to be able to create a substantial and measurable impact as well as steer its execution successfully. This outlines the immense scale of opportunity that lies in rolling out the technology across all airlines of the group. With SWISS accounting for only approximately 15 % of Lufthansa Group's flights[8], the potential emission savings of OPSD with its present capabilities will equal 50,000t CO_2 savings p.a. for Lufthansa Group in total, or 2,500 A320neo flights between Zurich and London.

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Every feature of the OPSD can save emissions. The Tail Optimization feature launched in July 2021 was the first use case at SWISS, identifying the optimal individual aircraft for route planning in the airline fleet rotation, taking into account variable aspects such as passengers, kerosene consumption of the specific aircraft, cargo, etc. The data is constantly recalculated. A tail sign – like a fingerprint – is an aircraft's individual identification and represents a unique technical profile. While under manual conditions, only meta-factors like type, average costs and capacity can be integrated into decision-making, a data-based approach integrates multifactorial conditions in real-time. Variable costs are tail sign-dependent e.g. airport charges, individual engine status, the aircraft drag, center of gravity, individually reduced performance through regular lifecycle attrition (an old plane is up to 10 % less efficient than when is was delivered new), OPSD factors in all this changing data in real-time to manage aircrafts as the individuals they are.

Example of a tail number GANTT map for a day around 8am using the A320 neo as an example to illustrate the complexity
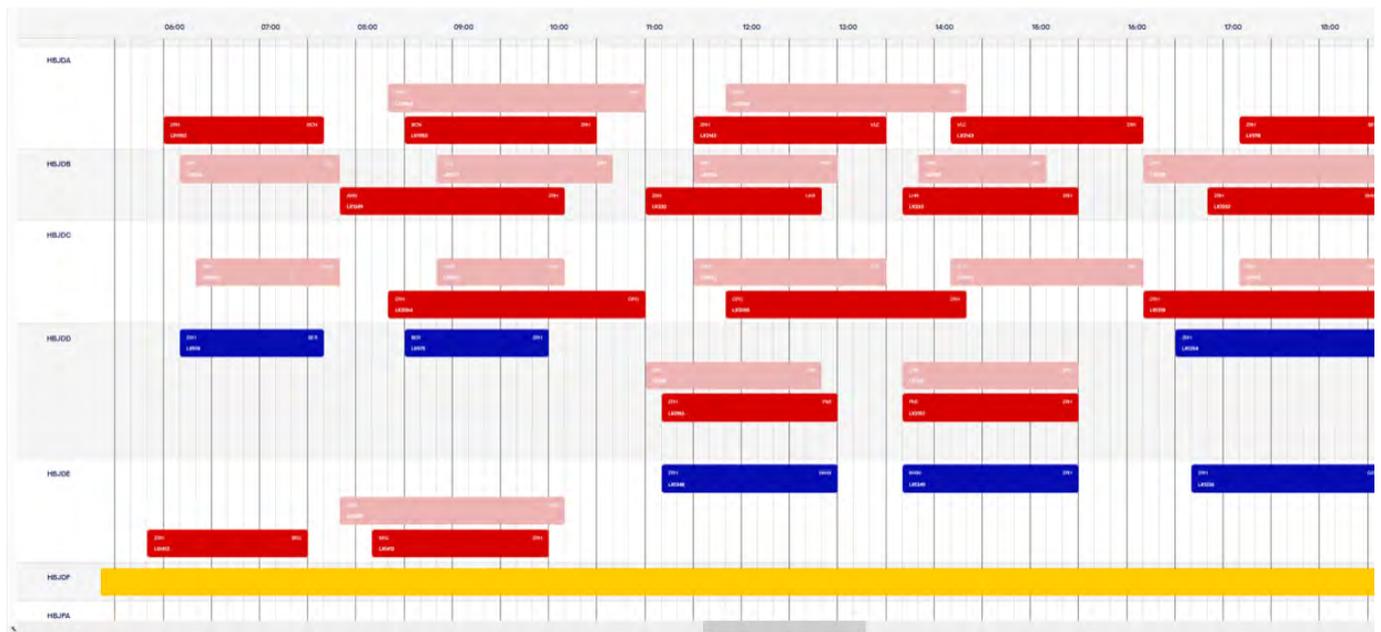
In total, this data-driven tail optimization has saved approximately 2,000 t of kerosene and 8,700 t of CO_2 per year, which corresponds to approximately 16 × A350 round-trip flights from Munich to New York.

Thinking of the OPSD's impact beyond aviation, the project fulfills a lighthouse function for all large logistics networks facing similar technological challenges. In order to really build new levels of research and results to the benefit of many industries, both Google Cloud and Lufthansa Group embarked on a mutually challenging and auspicious learning experience in order to accomplish the successful use case. Making tangible progress in this field shifts the horizon for other industries and creates a best practice that is able to radiate into impact-driven cleantech solutions much beyond aviation alone.

Explanation Yellow: inactive aircraft due to maintenance, blue: routes that the optimizer did not change, light-red: originally planned routes & rotation, red: aircraft optimized for today & the next 3 days.

"We are creating a proof of concept for a truly unique industrial cloud. At the core of this is a new paradigm in which diverse stakeholders work together and share information in order to optimize a system collaboratively rather than optimizing individually, avoiding bottlenecks and limiting the possible impact. That's the ultimate vision we are pursuing."

Christian Most
Senior Director, Digital Operations Optimization, Lufthansa Group

Overall, OPSD as the result of the game-changing collaboration of Lufthansa Group, Google Cloud, and Google Research has shifted the horizon of sustainability-driven operations optimization through predictive intelligence. The digital contribution towards becoming carbon-neutral has been estimated at 5 % for airline ops-related improvements, for instance, predictive maintenance, automated slot allocation, real-time flight planning, flight profile optimization, direct approach, optimized runway use, and decision support software. As OPSD continues to evolve, it becomes a cornerstone of Lufthansa Group's concerted actions to help decarbonize the group's airlines and the aviation industry at large. The Group's already-launched projects and initiatives highlight the vast opportunities that lie in the clean transformation of an industry that is a fundament of global mobility and both economic and cultural connectivity. Due to the scale of the task, the project sets an example of collaborative thinking and cross-industry pollination of cutting-edge technologies, which proves that real progress can be made toward the urgent quest of carbon-neutral aviation.

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