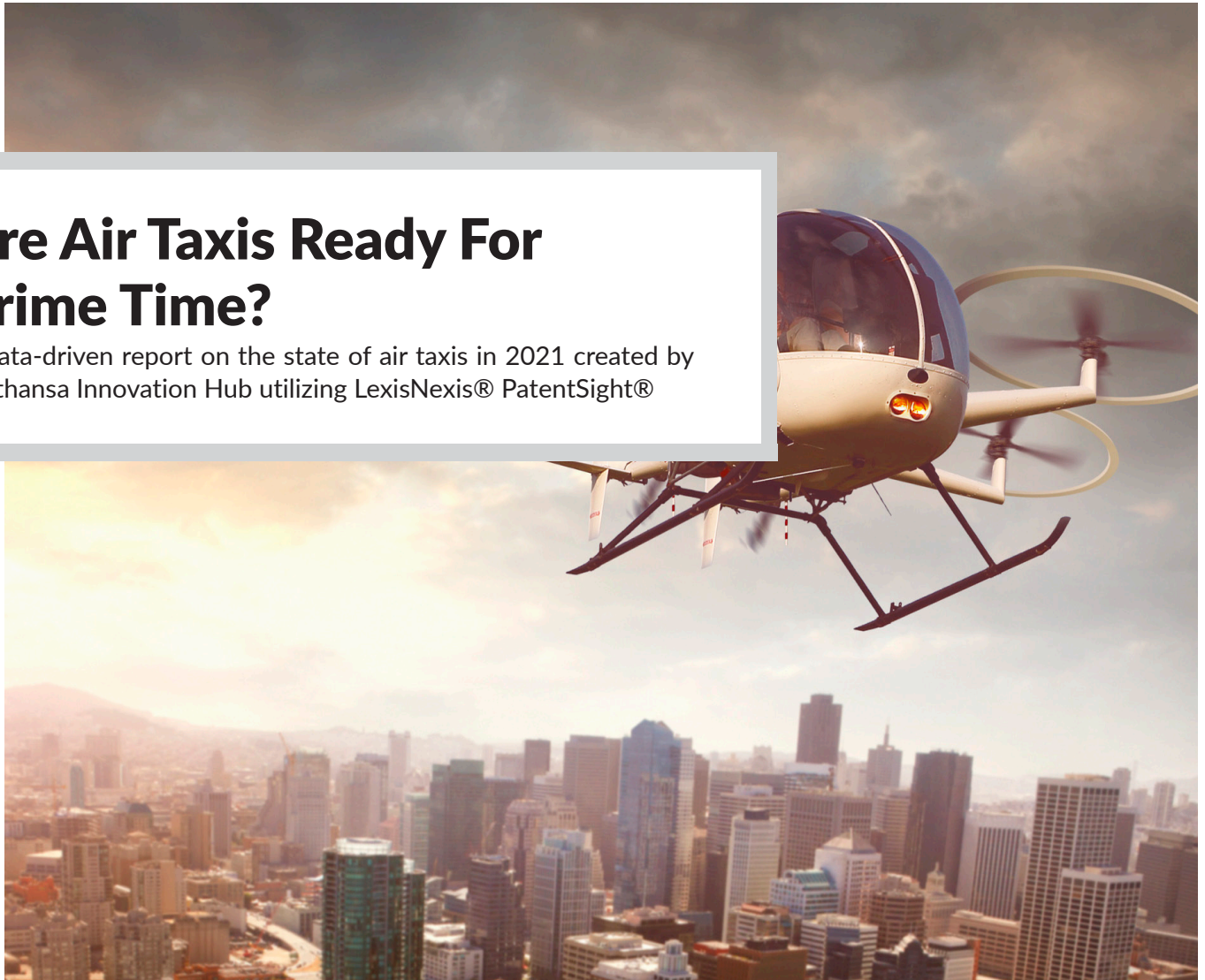


Are Air Taxis Ready For Prime Time?

A data-driven report on the state of air taxis in 2021 created by Lufthansa Innovation Hub utilizing LexisNexis® PatentSight®



What this report offers

Air taxis that can take off and land like helicopters while flying like airplanes with forward thrust could finally realize our vision of the future full of flying cars. Short-haul air transport is currently the domain of pricey helicopters, but electric vertical takeoff and landing (eVTOL) aircraft would be radically cheaper and more efficient.

Over 150 startups as well as a growing number of corporations around the globe are working eagerly

on innovative solutions to make eVTOL vehicles – or air taxis – become a reality, in the hopes of providing answers for pressing topics such as urbanization and sustainable travel.

In order to shed light on the accelerating innovation dynamics in the air taxi market landscape, this report rigorously analyzes the eVTOL platform models of evolving startups and corporates, as well as those designing and manufacturing their own air taxi vehicles. The data in this report is, unless otherwise stated, valid as of November 30, 2020.

Contents

What this report offers	1
About the authors	3
The Lufthansa Innovation Hub	3
Lufthansa Technik AG	3
Air taxis and the larger picture	4
Classification of air taxis in the wider Advanced Air Mobility (AAM) spectrum	4
The air taxi market landscape	4
Startups among the technology leaders	5
For context: glossary on important terminologies	5
For context: details on the methodology	5
Patent filings show strong growth	6
Startups with an impressive technology base	7
Many startups among the strongest patent filers	7
Software an important IP field	8
The U.S. is the driving force behind patent output	8
Boeing the current technology leader	9
Joby Aviation the most promising startup	10
Conclusion	11
More information on The Lufthansa Innovation Hub	11

This report is an extract of a much more comprehensive report. Here we only focus on patent analytics insights derived from utilizing LexisNexis PatentSight.

About the authors

At the Lufthansa Innovation Hub (LIH), a core belief is that innovation in the wider travel and mobility industry can no longer be accomplished through silo-like initiatives. We need to work together across the industry – startups tech giants, traditional travel operators, infrastructure providers, and regulators alike.

Hence, this report is meant for all who work at the forefront of innovation in the travel and mobility sector, specifically those trying to take electric transportation to the third dimension. This report is a contribution from the Lufthansa Innovation Hub to the creation of an industry-wide common understanding of the most important developments in the air taxi ecosystem.

This report has been created by the Lufthansa Innovation Hub with the support of Lufthansa Technik's Capability.

The Lufthansa Innovation Hub

The Lufthansa Innovation Hub – named “Germany's Best Digital Lab” by Capital Magazine – is the digital transformation spearhead of the world's largest aviation corporation, the Lufthansa Group.

The LIH discovers, evaluates, and implements new digital business opportunities in the context of Travel and Mobility Tech with industry-leading airlines such as Lufthansa, Eurowings, SWISS, and Austrian Airlines, the frequent flyer program Miles & More, as well as other renowned Lufthansa Group entities.

The Lufthansa Innovation Hub's mission is to create and capture value beyond flying. To do this, the Lufthansa Innovation Hub invests in startups, initiates partnerships with startups, and most importantly, incubates new digital services and products.

In their work, the Lufthansa Innovation Hub always follows the credo, “data beats opinion.” According to them, they want to act on facts rather than beliefs.

That's why exploring the Travel and Mobility Tech ecosystem is the crucial foundation on which all of the Lufthansa Innovation Hub's activities are built on.

Lufthansa Technik AG

Lufthansa Technik AG is the leading provider of aircraft maintenance, repair, overhaul and modification services for civil aircraft, from commercial to VIP and special mission aircraft.

Holding international licenses for maintenance, design and production, Lufthansa Technik provides tailored maintenance programs, modification, completion and conversion, as well as innovative cabin products, material pooling, digital fleet support, and engine services.

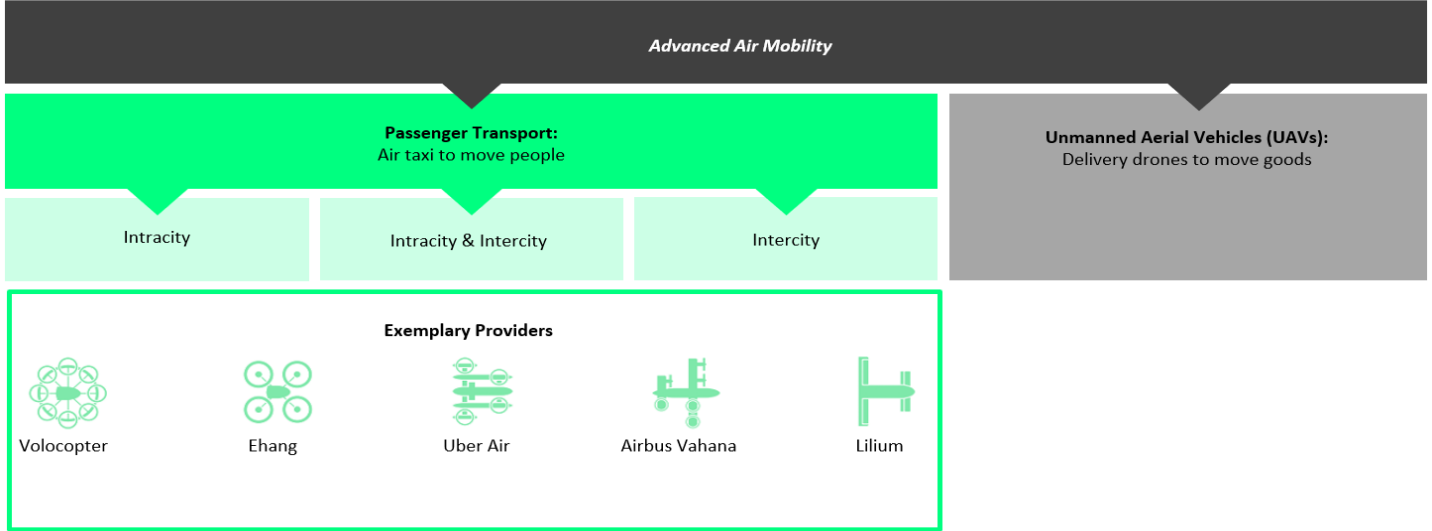
Lufthansa Technik's UAS capability center coordinates and facilitates all UAS-related activities of the Lufthansa Group.

Its role is to help transfer Lufthansa's tested and proven capabilities in conventional aviation to the emerging unmanned aircraft systems industry and support operational readiness through safe air traffic integration.

The full report can be found at: <https://tnmt.com/reports/are-air-taxis-ready-for-prime-time/>

Air taxis and the larger picture

Classification of air taxis in the wider Advanced Air Mobility (AAM) spectrum



Focus Area of This Report

Source: Adapted based on Roland Berger

The air taxi market landscape

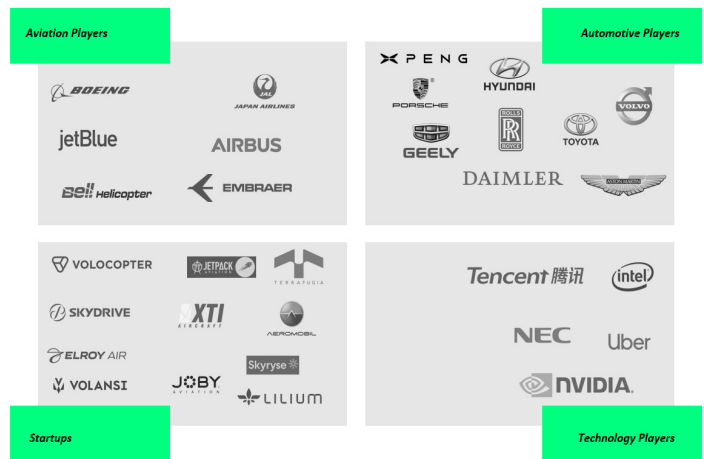
Participants in the air taxi ecosystem come from four major directions:

Classic aviation companies like Airbus and Boeing are actively developing new forms of electric-powered, driverless multi-copters for passenger transport. Major airlines have announced a drive toward respective programs to explore potential use cases.

Interestingly, many traditional automotive manufacturers have also entered the market, anticipating competition from flying vehicles above crowded streets in the longterm.

Additionally, several technology companies have joined the ecosystem, having identified an exciting opportunity to apply their respective fields of expertise – e.g., Intel’s autonomous driving capabilities or Uber’s urban mobility solutions – to expand their products and services “into the air.”

The majority of players making up the air taxi ecosystem are startups. In total, the count is more than 150 up-and-coming startups that are involved in the development of some type of air taxi technology. About a dozen are undertaking serious and relevant endeavors – many of which we will present throughout this report.



Source: Adapted based on Lufthansa Group Trend Research Analysis, Press and Consulting Research.

Notes: Selected firms only, non-exhaustive list

Startups among the technology leaders

For context: glossary on important terminologies

Patent Filing

The term patent filing refers to the legal and administrative proceedings of requesting the issuance of a patent for an invention by an entity that submits the required paperwork (e.g. content of the description and claims of the invention including visuals) at a patent office. The patent office then starts with the examination process of the application to decide whether to grant or refuse protection. The term patent filing is often used interchangeably with the term patent application.

Patent

A set of exclusive rights granted by law to applicants for inventions that are new, non-obvious, and commercially applicable. A patent is valid for a limited period of time (generally 20 years), during which patent holders can commercially exploit their inventions on an exclusive basis.

In return, applicants are obliged to disclose their inventions to the public in a manner that enables others who are skilled in the art to replicate the invention. The patent system is designed to encourage innovation by providing innovators with time-limited exclusive legal rights, thus enabling innovators to reap the benefits of their innovative activity.

Patent Family

A set of interrelated patent applications filed in one or more countries to protect the same invention.

Patent Count

The patent count refers to the number of patents owned by a single entity, also known as the portfolio size of the respective company. The patents in the portfolio may be related or unrelated to each other and can cover multiple technology domains.

The patent count may also include patent applications,

which have been submitted to the patent authorities but not yet granted – so-called “pending patent applications.” We count patents by patent families.

For context: details on the methodology

Technology Relevance

The metric measures the relevance of a patent for technical development. It is based on forward citations. Patent offices investigate all patent applications to reveal which prior patents new inventions are based on. If a patent is of significance for the technical development in a field, subsequent patents will build on it and frequently be cited as prior art.

Technology Relevance measures whether a patent has been cited more often than other patents from the same year and technology field. The total number of patent citations received not only depends on the relevance of the patented invention, but also on the time that has passed since the patent was originally published.

Recently published patents tend to receive much fewer citations than older patents. The time-dependency of citations is corrected by dividing the number of citations received by a patent by the average number of citations received by all patents published in the same year.

Technology Relevance also considers the fact that international patent offices follow different citation rules.

Market Coverage

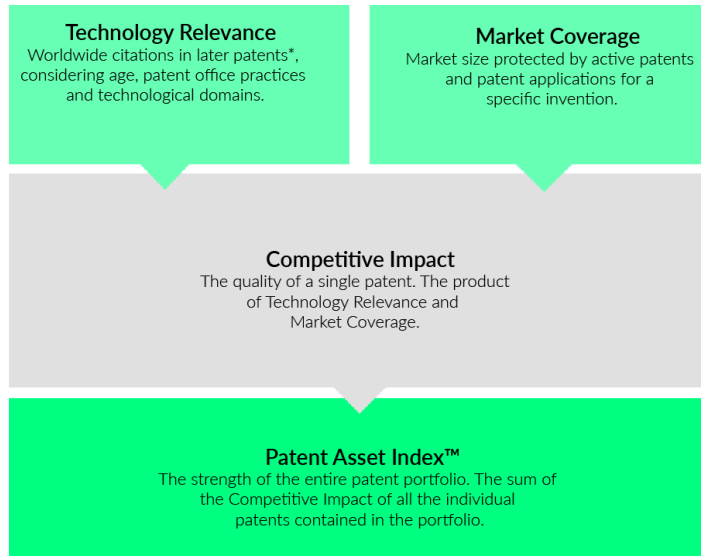
The Market Coverage metric measures the total size of the global market for which patent protection exists. The more patents companies own in key markets, indicated by high market coverage values, the more valuable patents are because innovators spend more on patent protection in multiple markets if they believe an invention is more valuable.

The extent of international patent protection is therefore an important indicator of the value of a patent. Market Coverage is calculated based on the granted and applied for (valid) patents per country and is corrected according

to the size of the respective market. The size of each market is estimated based on the countries' gross national income in relation to the U.S. gross national income.

Patent Asset Index™

The Patent Asset Index™ of a patent portfolio is defined as the total strength of all patents contained in a given portfolio. The performance of each individual patent is measured using the Competitive Impact. The Competitive Impact consists of two variables, Technology Relevance and Market Coverage, and represents the quality of a patent.



Source: Ernst, H. & Omland, N. (2011): The Patent Asset Index™ – A new approach to benchmark patent portfolios; PatentSight GmbH – A LexisNexis Company.

Notes: Citations from later patents are also called forward citations and considered a measure of a patent's importance.

“The Patent Asset Index™ is a highly valuable metric to differentiate between pure inventive activity and the technological impact of research results.”
 Kolin Schunck, Research & Intelligence Analyst at Lufthansa Innovation Hub

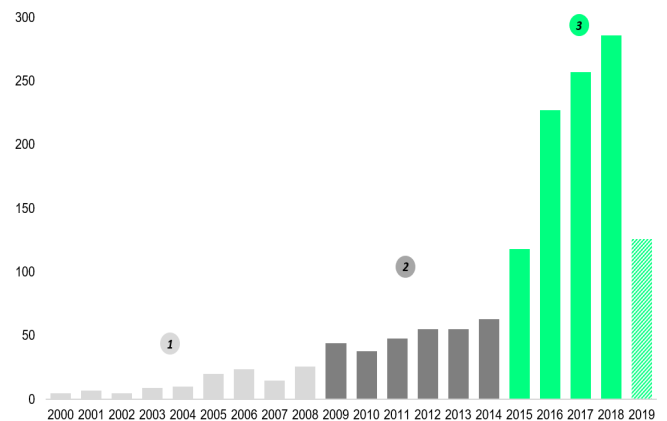
Patent filings show strong growth

1. Corporations as first movers. The first eight years of the 2000s were driven by the heavy patenting output of major corporations. Mitsubishi, URGRoup, Boeing, Toyota, Geely, GE, Rolls Royce, Airbus Group, Jaunt Air Mobility, and Lockheed Martin were the top 10 companies by patent filing output. These patents protect technology mostly in air taxi design, electric propulsion, and methods and systems for control and navigation of an electric VTOL aircraft.

2. The emergence of startups. The second phase was characterized by the emergence of today's well-known startups. KittyHawk, AeroMobil, Volocopter, and Joby Aviation lead the field of filings by protecting their very own, unique aircraft designs.

3. The takeover by startups. The patent propensity by startups accelerated to another level from 2015 onwards, with Ehang and KittyHawk showing the greatest growth rate of patent filings. Only one major corporation, Boeing, was able to keep its position within the top three patent filers. Three main technology areas were mainly sought for protection: (1) aircraft design, (2) flight control systems and telecommunications, as well as (3) power assembly and energy storage.

Number of patent filings related to air taxis worldwide

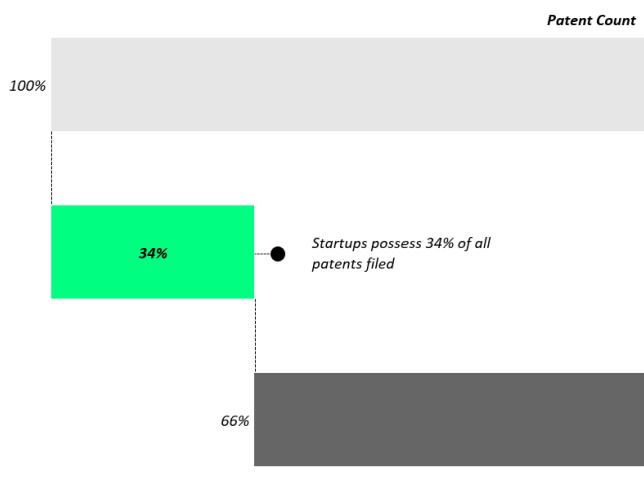


Source: Lufthansa Innovation Hub Analysis, TNMT.com, PatentSight GmbH – A LexisNexis Company

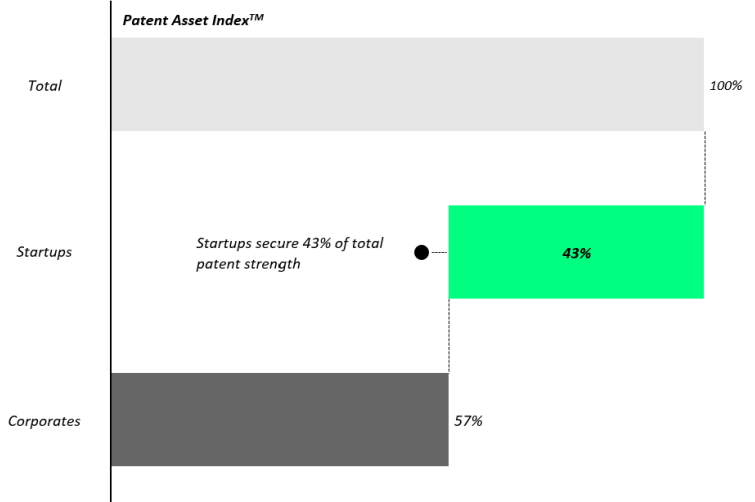
Notes: Patents are usually published 18 months after filing at the patent office, which is why data for 2019 is incomplete and 2020 data is missing.

Startups with an impressive technology base

Distribution of patent ownership by patent count



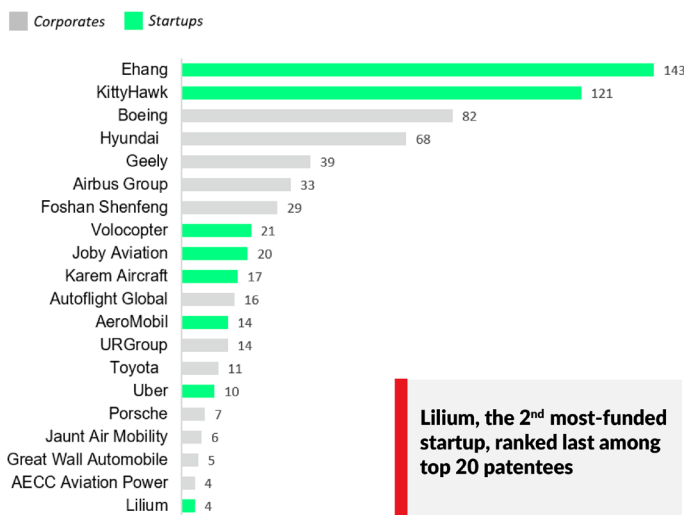
Distribution of patent ownership by Patent Asset Index™



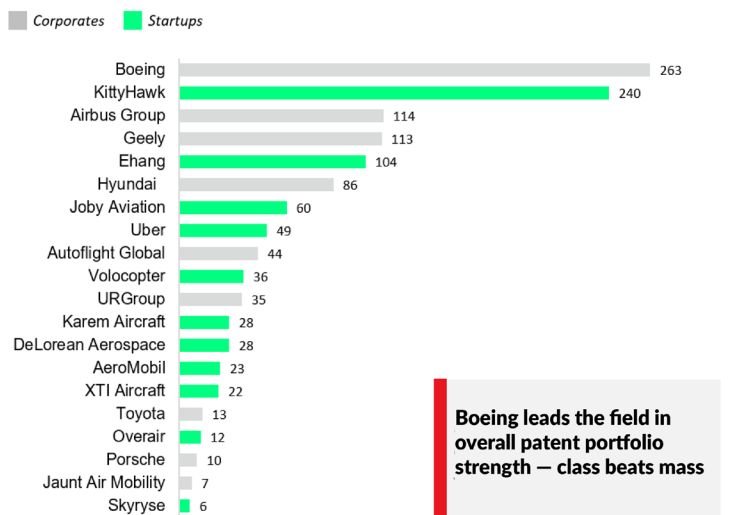
Source: Lufthansa Innovation Hub Analysis, TNMT.com, PatentSight GmbH – A LexisNexis Company.

Many startups among the strongest patent filers

Key players in air taxi technology by patent count



Key players in air taxi technology by Patent Asset Index™



Source: Lufthansa Innovation Hub Analysis, TNMT.com, PatentSight GmbH – A LexisNexis Company.

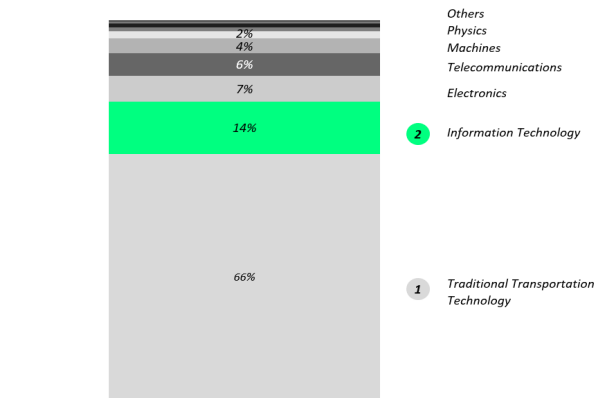
Notes: Time period covered: 2000 to 2020; the top 20 active air taxi patentees are selected as of December 31, 2020.

Software an important IP field

1. Traditional aircraft and automotive technology is mostly protected by patentees, focusing on VTOL aircraft, flight platforms and helicopter-related technologies. KittyHawk shows the highest patent count in this field, protecting multiple aircraft designs. The “personal aircraft” patent protecting “a safe, quiet, easy-tocontrol, efficient, and compact aircraft” is qualitatively the strongest patent (17.8x more relevant vs. the worldwide average). Moreover, Uber has the strongest overall patent portfolio in this segment, protecting a VTOL m-wing and quad-wing vertical takeoff and landing aircraft.

2. Moreover, **digital technologies** are heavily protected. This includes autonomous aerial vehicle software as well as reservation, image acquisition, and fault detection technologies. Ehang shows the highest patent propensity, focusing on autonomous systems and intelligent flight operation. Geely and Ehang both lead by patent count in digital reservation technologies, e.g. order delivery and online fee calculation methods. By contrast, Uber possesses the most relevant technologies (by Competitive Impact) in this segment. For example, Uber keeps patents on dynamic aircraft routing and intelligent systems for identifying a rider, an origin, and a destination to determine the optimal time of departure.

Protected air taxi related technology fields based on patent count



Source: Lufthansa Innovation Hub Analysis, TNMT.com, PatentSight GmbH – A LexisNexis Company

Notes: Time period covered: 2000 to 2020 including only active patent families as of December 31, 2020.

The U.S. is the driving force behind patent output

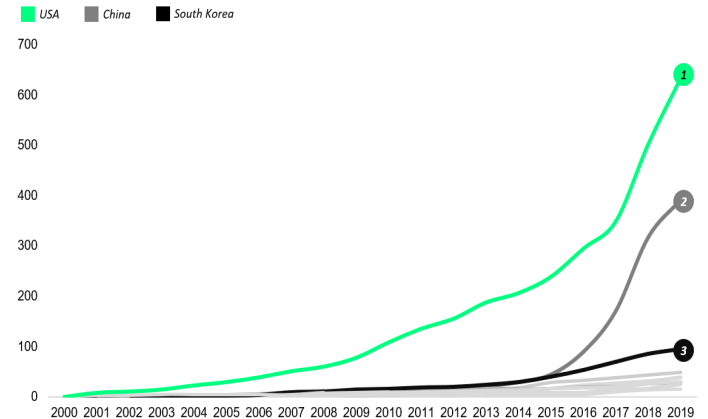
1. The United States. Most of the patented technology is invented by U.S.-based firms. These R&D investments are primarily funneled into the development of hardware and aircraft design technology, including rotary wing, ducted fan, wing arrangement, vertical control, autorotative arrangement, and rotor hubs.

2. China. Contrary to the U.S., China’s patent footprint is funneled foremost into digital technologies, e.g. unmanned vehicle flight control systems, optimal calculation of delivery and pick-up routes, and air vehicle communication using high-speed networks.

3. South Korea. Technology invented by South Korean firms show a balanced focus on hardware and digital technologies, e.g. rotary and fixed wing vehicles, interaircraft communication, and intelligent navigation and tracking.

The different priorities between the U.S. and China are symptomatic of their relationship. The different focus areas and the consequent unequal distribution of competences could ultimately lead to an increase in geopolitical tensions between these countries, especially when it comes to supply chain control.

Patent count related to air taxis by origin of the invention



Source: Lufthansa Innovation Hub Analysis, TNMT.com, PatentSight GmbH – A LexisNexis Company

Notes: Patents are used as an output proxy for R&D investments, as scientific studies suggest.

Boeing the current technology leader

The Air Taxi Technology Leaderboard provides unique insights into the race for technology leadership among major air taxi providers.

Ehang and **Kitty Hawk** are the most active innovators, measured by patent portfolio size – usually a sign for a viable long-term technology strategy. But their respective low average Technology Relevance scores (0.34 and 0.31) signal a lack of technological relevance. This may be explained by increasing obsolescence of their protected IP.

Overall, high Technology Relevance appears more important than a large patent portfolio as research studies indicate that firms with a strong technical

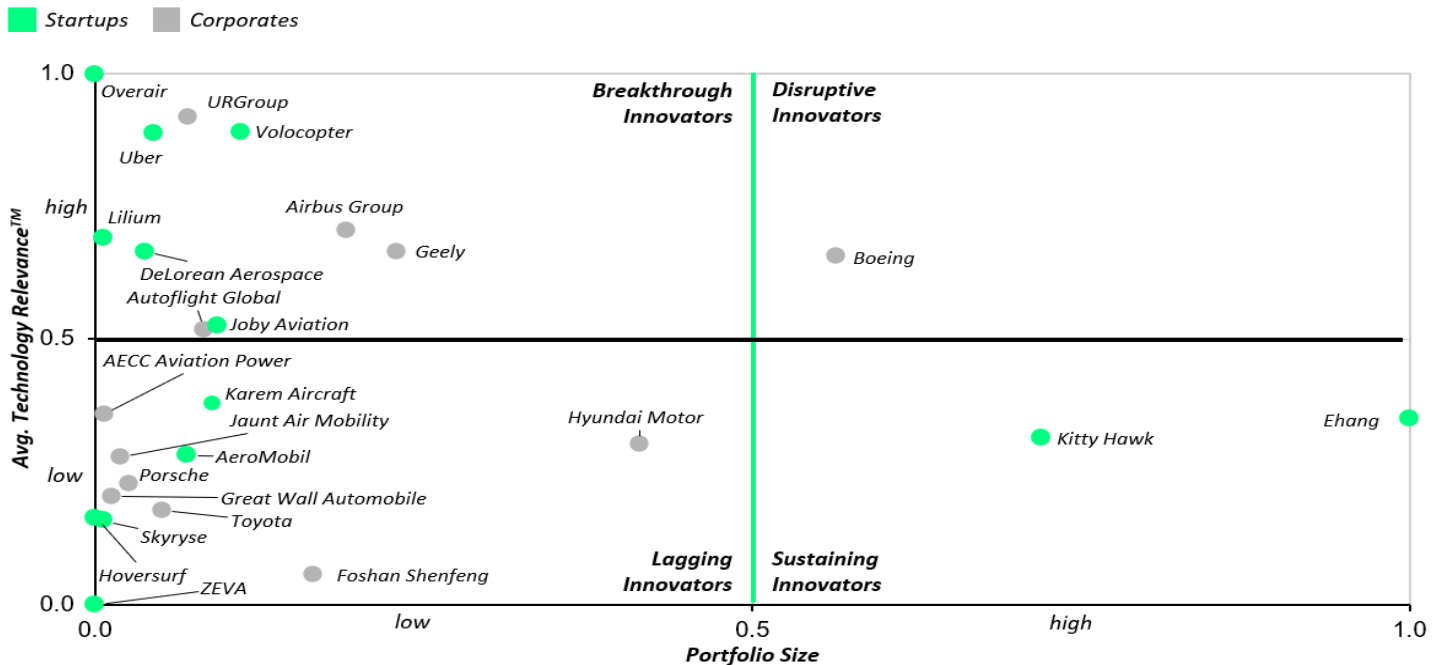
impact but lower patent activity prove to be more

successful in terms of financial performance than those that focus on mass instead of class, resulting in such error.

On the Technology Relevance front, **Overair**, **URGroup**, **Volocopter**, and **Uber** show the strongest performance. Based on the fact that these firms received more forward citations over time from later patents by others, we can conclude that they have come up with breakthrough technology.

Interestingly, only **Boeing** is able to offer a large portfolio in combination with a high Technology Relevance score, positioning the company as the current technology leader.

The air taxi technology leaderboard



Source: Lufthansa Innovation Hub Analysis, TNMT.com, PatentSight GmbH – A LexisNexis Company.

Notes: For comprehensibility values for portfolio size and Technology Relevance are normalized (value 0 to 1). The top 25 active air taxi patentees are selected holding three or more active patents as of December 31, 2020.

Joby Aviation the most promising startup

A startup’s competitive outlook is not only defined by technology strength (see previous page) but also by the interrelation of VC funding (= financial power) and average Competitive Impact (= patent quality).

The Air Taxi Startup Success Matrix provides us with an objective glimpse into the most promising air taxi startups of today from a more holistic view.

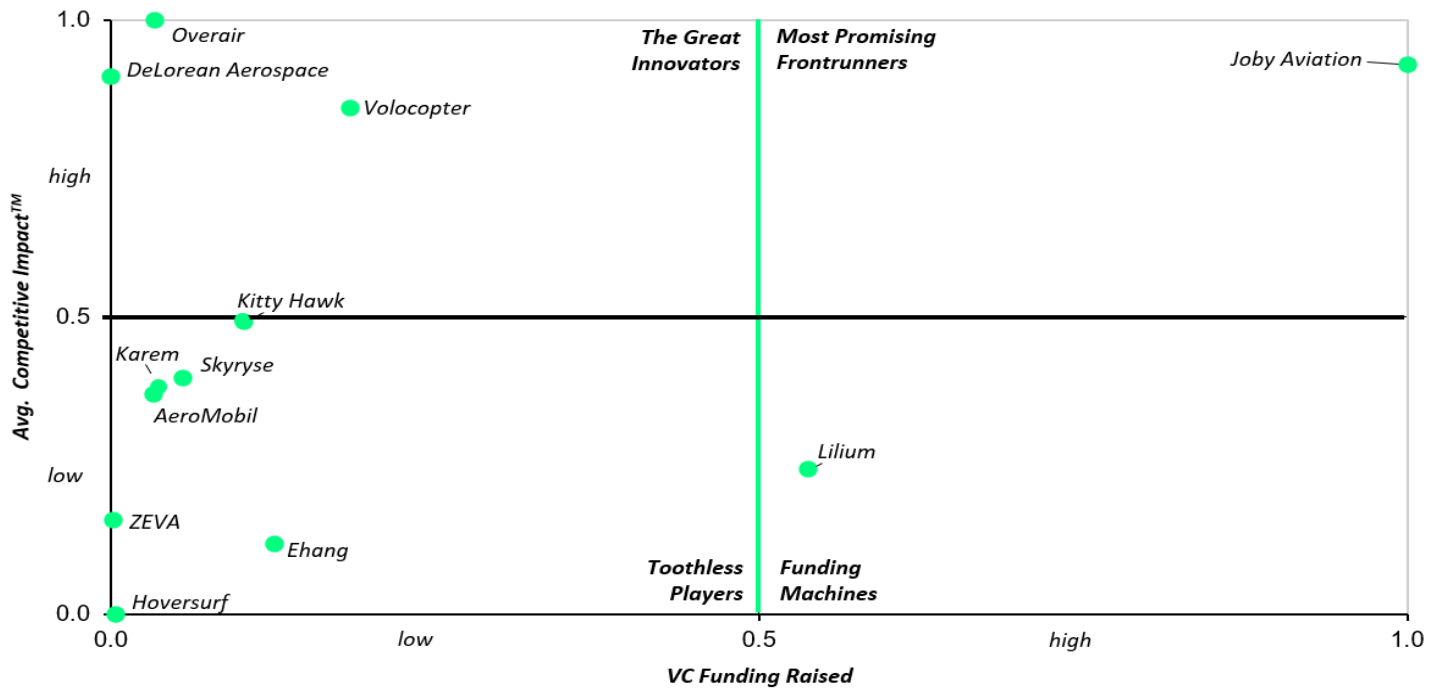
Joby Aviation is the only startup that secured massive VC funding and holds an overall strong Competitive Impact. The latter is based on the fact that the firm protects its technology across all major countries with

high economic relevance, e.g. China, Germany, Japan, and the U.S.

This strategy not only secures Joby access to the arguably most important future air taxi markets, but also protects its technology portfolio against imitation by its main rivals from these countries, namely Ehang, Lilium, and Volocopter.

Contrarily, Germany’s **Lilium** has raised significant funding but substantially lacks protection of its technology in many relevant markets. Most of their patents published are primarily pending for Germany.

The air taxi startup success matrix



Source: Lufthansa Innovation Hub Analysis, TNMT.com, PatentSight GmbH – A LexisNexis Company.

Notes: For comprehensibility values for VC funding raised and Competitive Impact are normalized (value 0 to 1). The top 12 funded startups are selected holding three or more active patents as of December 31, 2020.

Conclusion

The in-depth analysis of the air taxi patent landscape highlights the strong technology position of startups in this ecosystem – something very unusual at this magnitude indicating how much the development of air taxi technology is driven by up-and-coming young challengers. Nevertheless, the two traditional aviation legacy players, Boeing and Airbus, must also be considered highly promising first-movers.

We see fundamental differences in the technology focus surrounding air taxis at the country level. This is especially true for the U.S. (heavily focused on hardware components) and China (way more invested in software and digital technologies).

When comparing current air taxi providers more holistically, we identified Joby Aviation as the most promising air taxi startup at this point. Not only has the U.S.-based startup raised massive amounts of venture capital needed to develop the necessary technology stack, but it has also built a high-quality patent portfolio. In fact, Joby Aviation possesses one of the most important patents in the air taxi space of all (measured by Competitive Impact), which relates to aerial vehicle design and noise reduction technology. The latter appears to be of utmost importance to achieve public acceptance.

We thank the Lufthansa Innovation Hub for sharing this report supported by using our PatentSight analytics platform with us.

More information on the Lufthansa Innovation Hub

To learn more about The Lufthansa Innovation Hub, visit the [LIH website](#) or stop by the [LIH LinkedIn page](#).

Latest insights are regularly shared on LIH's dedicated market intelligence platform, [TNMT](#).

Any critical perspectives on the content and suggestions for analyses that you think are missing in the current debate are welcome.

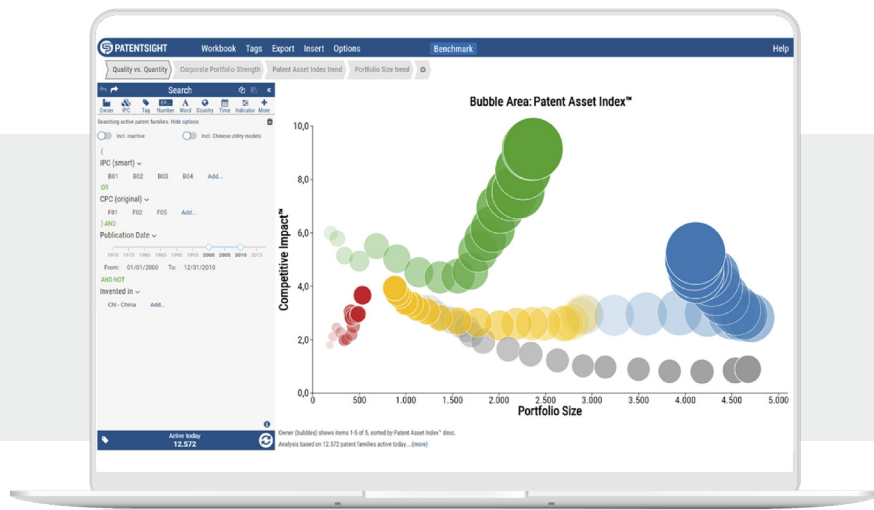
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PatentSight launched its first Business Intelligence Software in 2012. In 2018, PatentSight became part of LexisNexis® IP. Its platform provides unique, reliable and relevant insights into the patent landscape for decision makers and patent experts in the fields of:

- Competitive intelligence and benchmarking
- R&D strategy
- Disruptive technology scouting
- M&A and due diligence
- Licensing and monetization
- Portfolio optimization

Patent Asset Index™

PatentSight is known for its development of the Patent Asset Index™, a proven approach to assess patent quality and benchmark patent portfolios.

The Patent Asset Index™ is recognized by technology leaders to provide an accurate view of the strength, quality and value of patent portfolios to reveal the impact and efficiency of an enterprise's investment in innovation.

Analyses delivered by PatentSight are regularly reported to top executives of leading companies. Benchmarks are often featured in the shareholder annual reports of some of the world's largest corporations. Excellent data quality is our highest priority and a foundation of any analysis.



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