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Trends in eVTOL Aircraft Development: The Concepts, Enablers and Challenges

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By the second quarter of 2022, over 500 electric vertical take-off and landing (eVTOL) aircraft concepts have been unveiled. However, less than 30% of the concepts have achieved first flight due to the infancy of this industry. To keep track of these developments and the emerging urban air mobility landscape, a technical research database has been developed to categorize the concepts based on their propulsion architecture and compare them for performance and safety metrics based on published data and independent analyses. This paper presents the results of a study on 120 eVTOL aircraft concepts announced between 2014 and 2020. It reviews the current global eVTOL landscape and explores the technological progress enabling the development of these aircraft. Data on global eVTOL aircraft development show that eVTOL start-up companies are developing a majority of concepts at 68%. The USA, Europe and China account for over 70% of the concepts in development. The intensity of public announcements of new eVTOL aircraft concepts appears to have peaked after an exponential rise in the number of concepts unveiled between 2016 and 2018. This study intends to inform readers about the trends in eVTOL development and the dominant concepts that may be considered in trade studies.

Nomenclature

AAM = Advanced Air Mobility
CT = Combined Thrust
DEP = Distributed Electric Propulsion
EASA = European Union Aviation Safety Agency
ER = Electric Rotorcraft
ESC = Electronic Speed Controller
eVTOL = electric Vertical Take-Off and Landing
IT = Independent Thrust
LC = Lift + Cruise
LTU = Lift/Thrust Unit
MC = Multicopter

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PAV = Personal Aerial Vehicle
PL = Powered Lift
SRW = (Electric) Autogyro
TB = Tilt Body
TF = Tilt Fan
TP = Tilt Prop
TW = Tilt Wing
UAM = Urban Air Mobility
UAV = Unmanned Aerial Vehicles
V/STOL = Vertical and/or Short Take-off and Landing aircraft
VT = Vectored Thrust
W = Wingless

I. Introduction

The number of electric vertical take-off and landing (eVTOL) aircraft concepts, prototypes, and production vehicles has recently grown to over 500 [1]. This significant growth is reminiscent of the early development of powered flight, where engineers, entrepreneurs and amateurs attempted to design, build and fly the world's first powered aircraft. Improvements in battery technologies, electric motors and power management systems driven by the automotive industry and the need for green energy solutions enable electric-powered flight and have resulted in a proliferation of vehicles [2]. These proposed vehicles are capable of vertical take-off and landing (VTOL), are fully electric or hybrid-powered propulsion and energy storage systems, are typically designed to carry under ten passengers and are expected to have a take-off mass under 3,175 kg [3]. These eVTOL aircraft are believed to be the cumulative result of technological disruptions in energy storage [4], advancements in distributed electric propulsion (DEP) technologies [5], regulatory receptiveness [3, 6], advances in simplified vehicle operations and flight controls [7, 8] and the general progress in autonomous navigation [9].

Increasing urbanization and rapid growth of population centers continue to intensify the strain on the inhabitants' lives. Nowhere are these effects more noticeable than in traffic congestion and air pollution. As the impacts of climate change become more apparent, there is a growing consensus amongst industry leaders, researchers and governments regarding the need for clean and sustainable transport solutions for the cities of the future. A proposed concept to tackle this issue is urban air mobility (UAM). The National Aeronautics and Space Administration (NASA) outlines UAM as a concept which enables safe and efficient air operations in a metropolitan area for person-carrying and unhabituated aircraft systems [10]. A significant proportion of eVTOL aircraft is designed to provide UAM solutions. In addition, there are also numerous designs for personal aerial vehicles (PAV). Aircraft for both use cases are within the sphere of advanced air mobility (AAM) vehicles [11].

The air taxi mission is a typical UAM mission [12]. Air taxi missions may cover intra-city routes up to 50 km in the short term, then up to 100 km in the medium term and then inter-city routes with significantly greater distances in the long term [2, 10]. For example, a short-range inter-city UAM mission will be sufficient for a trip from the financial center of London to London Heathrow Airport. In contrast, a future long-range UAM mission can see routes like London to Birmingham. This is a 200 km trip that is too short for a commercial flight but could benefit from reduced travel times compared with similar rail travel on the same route. Inter-city missions that cover 100+ km are heavily dependent on progress in battery density technology levels for battery-powered concepts. The use of hybrid-electric propulsion in some concepts is a stop-gap solution to this energy density problem until the technological maturity and economic feasibility of fully electric battery-powered concepts are realized. There are ever-increasing potential use cases for eVTOL aircraft. Public and emergency services such as policing, firefighting, air ambulance and surveillance are among potential applications of eVTOL aircraft [13]. Other applications, such as corporate activities, logistics, entertainment, remote healthcare and agriculture, have also been identified [10].

This paper presents select trends in eVTOL aircraft development based on a study of 120 eVTOL aircraft concepts announced between 2014 and 2022. The concepts are categorized by their propulsion configurations, presented graphically in the paper's main sections, and listed in the appendix. The following sub-sections discuss the concept of distributed electric propulsion and its apparent benefits for eVTOL aircraft design. Progress in the eVTOL aircraft certification process in Europe is also covered. An overview of the different eVTOL aircraft classes and their propulsion configurations is presented in the following section. Finally, key trends in the global development of eVTOL aircraft are presented and discussed.

A. Distributed Electric Propulsion

Advances in energy storage technologies, electric motor capabilities and power distribution have enabled the concept of *distributed electric propulsion* [14-16]. DEP is likely to solve two challenging problems that have plagued conventional Vertical/Short Take-off and Landing Aircraft (V/STOL). These problems, power distribution and control, have hindered the maturity of VTOL aircraft. As a result, there has only been a handful of successful conventional V/STOL aircraft. These include the commonly known BAE Systems Harrier Jump Jet [17], its relatively new successor, the Lockheed Martin F-35 Lightning [18], the Boeing V-22 Osprey [19] and the most recent development, the Leonardo Helicopters AW609 tiltrotor [20]. The last two types are transport aircraft as opposed to the first two, which are fighter aircraft. These aircraft have stemmed from several years of development and are well-known for the time it has taken to develop and certify them. The common theme of extended development and certification times exemplifies the complexity of the conventional VTOL aircraft type.

The leading cause of the power distribution problem in conventional VTOL aircraft is using one or two jet engines to power and control the aircraft [21, 22]. Therefore, it becomes an engineering challenge to distribute this power to balance the aircraft in hover flight. DEP offers to solve this challenge by utilizing several smaller electric motors placed *strategically* around the aircraft to naturally balance the aircraft during hover or at least make the balancing problem significantly easier for flight control systems to augment. The controllability of eVTOL aircraft in hover mode has also been an issue for conventional VTOL aircraft because of the high moment forces expanded by the engine ducts. With DEP, it is possible to go around this problem by utilizing only a portion of the motors, those placed at the extremities of the eVTOL aircraft, for control. These are usually the end motors on either wing (lateral control or roll) or motors placed at the fore and aft of the aircraft (longitudinal control or pitch). At the same time, the majority of the motors remain to provide power. Also, due to the smaller mass of these motors, they have a higher impulse and smaller output force. This is advantageous for better response times in roll and pitch rates. It also allows for finer refinements in the aircraft's attitude control, especially during hover. Therefore, the controllability of eVTOL aircraft, especially in the hover phase, would need to be significantly less complex than that of conventional VTOL aircraft. The advantages of DEP, outlined so far, have considerably reduced the development complexity for eVTOL aircraft because the power distribution and control problem can be solved by incorporating DEP into the aircraft design. Thus there is a lower requirement for engineering resources to be devoted to developing an eVTOL aircraft. This has enabled the proliferation of several concepts by many eVTOL developers globally.

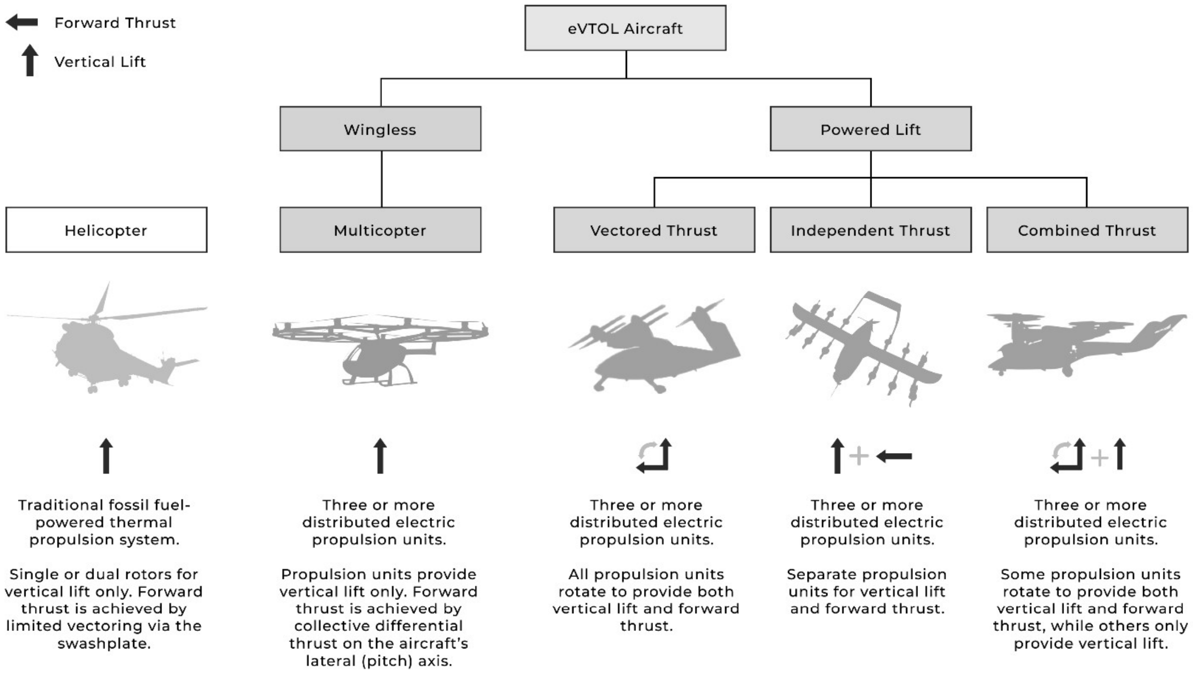
B. eVTOL Certification Efforts

Several manufacturers actively compete to be among the first to enter the eVTOL aircraft type into service. This is predictable as the projected global market size for UAM is estimated to exceed 80 billion dollars by 2035 [23]. Consequently, eVTOL aircraft developers are perceived to be tight-lipped in their design specifications and processes. These are seen as trade secrets currently because these aircraft are in a new category. However, it is expected that some of the proprietary design solutions, methodologies and innovative technologies employed in some proposed designs could be the determining factor for commercial success if proven. For this reason, eVTOL aircraft developers will likely continue developing their concepts in secrecy to preserve their competitive advantage.

By the end of 2022, over 500 eVTOL aircraft concepts were publicly unveiled. These designs vary widely but aim to address the same problem – achieving reliable and efficient electric VTOL capability. There is currently an absence of certification specifications for eVTOL aircraft due to its infancy. However, the initial reception from regulatory agencies has been positive. The European Union Aviation Safety Agency (EASA) published its proposed special condition for small-category VTOL aircraft in 2018 [24]. This was followed by a revised publication in July 2019 [3]. This document is not a full aircraft certification specification but a proposed means of compliance based on consultations with eVTOL developers. The document addresses the definition of eVTOL aircraft, the uniqueness of their distributed propulsion configuration, and attempts to prescribe airworthiness standards to issue a type certificate for these aircraft [3]. Initial conditions set out by the document include the requirement for these aircraft is a vertical take-off and landing capability. EASA also expects these aircraft types to utilize fully electric or hybrid-powered propulsion and energy storage systems and be typically designed to carry under ten passengers with a maximum take-off mass below 3,175 kg [3]. EASA has progressed on this by soliciting commentaries from eVTOL experts in industry and academia via its Comment-Response Tool (CRT). Finally, the need for a comprehensive aircraft safety analysis cannot be understated, given the relatively unfamiliar territory defined by eVTOL aircraft operating urban air mobility missions. Therefore, proactive safety approaches in hazard identification would be necessary to sustain or surpass current safety levels in commercial and civil aviation. Established safety analysis tools such as functional hazard analysis and failure modes and effects analysis have proved beneficial for aircraft safety analysis [25].

II. eVTOL Aircraft Architecture and Concepts

EASA, via its Special Condition for small-category VTOL aircraft [3], has outlined two distinct characteristics common to eVTOL aircraft. These are vertical take-off and landing (VTOL) capability and a distributed electric propulsion system [3]. The latter allows for less complicated implementations of propulsion systems for the *vertical lift* and *forward thrust* mode compared to jet engines and the complex thrust vectoring schemes employed by conventional VTOL aircraft. Subsequently, these propulsion units will be referred to as *lift/thrust units* (LTUs), in line with the EASA SC-VTOL nomenclature [3]. EASA establishes that the VTOL capability of these aircraft sufficiently differentiates them from conventional aircraft. Likewise, electric propulsion systems (of more than two LTUs) also adequately differentiate eVTOL aircraft from conventional rotorcraft [3, 26].



Traditional fossil fuel-powered thermal propulsion system.

Single or dual rotors for vertical lift only. Forward thrust is achieved by limited vectoring via the swashplate.

Three or more distributed electric propulsion units.

Propulsion units provide vertical lift only. Forward thrust is achieved by collective differential thrust on the aircraft's lateral (pitch) axis.

Three or more distributed electric propulsion units.

All propulsion units rotate to provide both vertical lift and forward thrust.

Three or more distributed electric propulsion units.

Separate propulsion units for vertical lift and forward thrust.

Three or more distributed electric propulsion units.

Some propulsion units rotate to provide both vertical lift and forward thrust, while others only provide vertical lift.

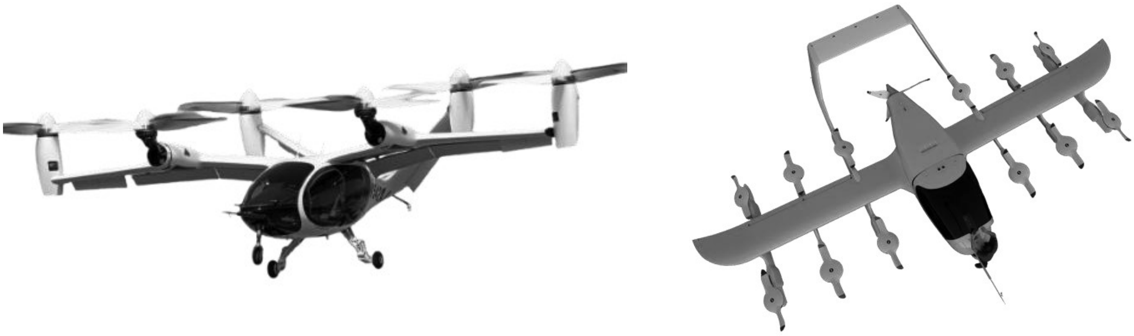
Figure 1. Propulsion architectures of eVTOL aircraft

A. Powered Lift eVTOL

All eVTOL aircraft can take-off and land vertically, thus requiring no need for a runway. However, only *powered lift* aircraft utilize wings (Figure 1). This allows them to cruise at similar speeds to conventional fixed-wing aircraft, a significantly higher altitude than *wingless* eVTOL aircraft and helicopters. This extra ability of powered lift aircraft naturally presents opportunities to carry out more extended-range missions more efficiently than the wingless type. Thus, allowing the aircraft designer flexibility to exceed the capabilities of wingless in terms of cruise speed, payload, and range. However, the advantages do come at a cost. Powered lift aircraft are significantly more complex to design. This is mainly due to two factors:

- The addition of a wing and its associated systems for aerodynamic lift during the cruise stage and
- the additional LTUs required for the forward mode and, in some cases, their associated vectoring systems.

The *independent thrust* eVTOL type entails separate propulsion for forward thrust during the cruise phase, while the LTUs for forward lift remain inactive. These LTUs are considered *deadweight* when inactive, directly contributing to increased drag and overall aircraft mass. eVTOL aircraft designers mitigate the drag issue by locking propellers parallel to the slipstream during cruise [27, 28]. While other designs feature stowing the unused vertical lift LTUs in aerodynamic pods or nacelles during cruise [29]. However, even incorporating this feature would add to the overall design complexity. The Wisk eVTOL (Figure 2b) exemplifies the independent thrust concept with its separate LTU for forward flight.



(a) Joby Aviation eVTOL [30] **(b)** Wisk Generation 5 [28]

(c) Vertical Aerospace VX-4 [31]

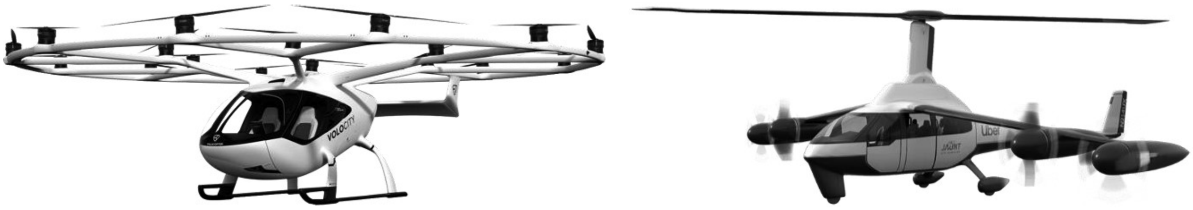
Figure 2. Powered lift eVTOL aircraft (a) Vectored Thrust (b) Independent Thrust (c) Combined Thrust

The *vectored thrust* types appear to have the most complexity, mainly due to the systems required for vectoring thrust between the vertical and forward regimes. This problem is not new, as it has existed since the early development of conventional VTOL aircraft in the 1960s [32]. As a result, many approaches for thrust vectoring have been developed over time and are now being adapted to eVTOL aircraft designs. *Tilt fan* and *tilt prop* designs rotate only the propulsion units, in this case, lift fans like the Lilium eVTOL [33] or propellers like the Joby eVTOL [34]. Rotating these propulsion units activate the vertical lift or forward thrust modes. The Joby Aviation eVTOL (Figure 2a) is an example of the vectored thrust and tilt prop categories, with all its LTUs utilized for forward and hover flight modes.

Finally, the *combined thrust* type design incorporates thrust vectoring for some propulsion units while the remaining units are fixed for the vertical mode. The advantage of this type lies in the fact that it lessens the deadweight problem seen in the independent thrust type because all the propulsion units are used during vertical mode while the unused propulsion units are *parked* during the forward mode. An example of this design is the Vertical Aerospace VX4 [31] (Figure 2c).

B. Wingless eVTOL

Wingless eVTOL aircraft rely solely on the thrust from their lift/thrust units for both vertical lift and forward flight. Multicopters, as the name suggests, possess multiple LTUs which can only provide vertical lift, akin to a helicopter.



(a) Volocopter VoloCity [35] **(b)** Jaunt Air Mobility [36]

Figure 3. Wingless eVTOL aircraft (a) Multicopter (b) Electric Rotorcraft

The multicopter type is the dominant secondary classification of wingless architecture. The VoloCity by Volocopter is a two-seat multicopter with 18 LTUs (Figure 3a). There are also electric helicopter eVTOL concepts. Some of these concepts contain additional LTUs for increased speed in forward flight (Figure 3b). Nevertheless, their behavior in flight remains closer to a helicopter than a fixed-wing aircraft. Many of the multicopter concepts proposed are designed mainly for use in air taxi services and emergency services. Personal Aerial Vehicles (PAV), although technically possessing a multicopter architecture, distinguish themselves from the previous subclass in carrying capacity. PAVs are usually single-seat eVTOL aircraft geared towards personal use, with some concepts capable of both ground-based transport mode and flight mode [37]. As the name suggests, PAVs are single-seat multicopter eVTOLs where the operator sits or stands to ride the aircraft. These aircraft are generally observed to be enthusiast vehicles with significantly lower utility when compared to multicopters. In addition, due to the low cost of off-the-shelf electric motors required in powering this weight class, PAVs are generally the least expensive to manufacture. For this reason, larger and more complex eVTOL designs usually start as PAVs until the propulsion architecture can be proven.

III. Development Trends

A technical research database has been developed to keep track of developments in eVTOL aircraft design and UAM [38]. A selection of the aircraft parameters is presented in the appendix section. In addition, 120 eVTOL aircraft concepts were assessed and categorized in the database. Data on the development of the concepts were collected from the developers' websites, press releases and articles from the Electric VTOL News website, run by the Vertical Flight Society [1]. This section presents a selection of data and metrics to provide insight into the development of eVTOL aircraft worldwide.

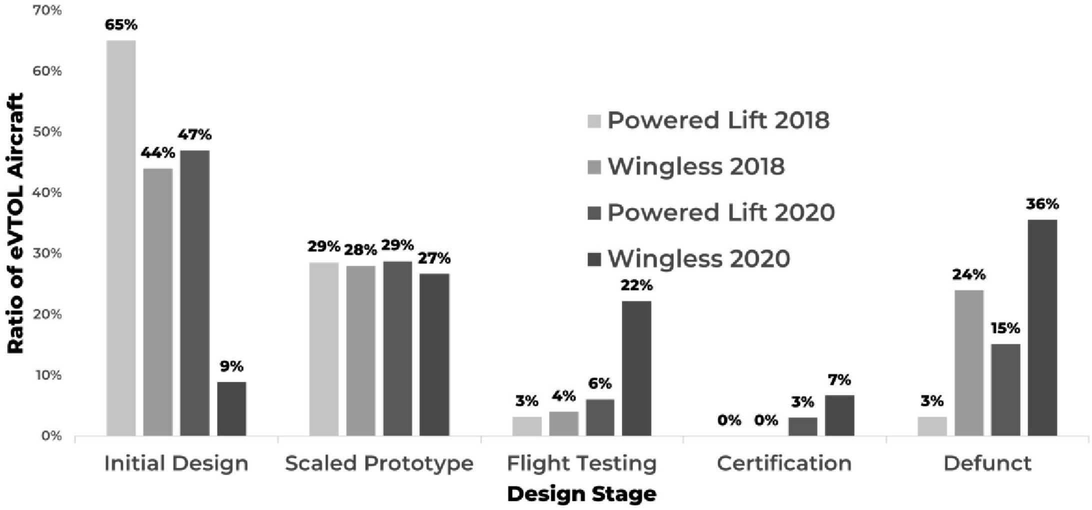


Figure 4. Overview of design maturities of eVTOL aircraft concepts between 2018 and 2020

In 2018, 7% of eVTOL aircraft achieved their first flight. However, this significantly improved by early 2020, as 28% of eVTOL aircraft had now achieved their first flight (Figure 4). These flights include the first flights of sub-scale and full-scale eVTOL aircraft prototypes in addition to piloted first flights. The increase in the number of first flights over the time period shows that eVTOL aircraft development is still in its infancy since over 70% of aircraft in development have not yet reached the flight-testing stage. Most of these flights occurred with wingless aircraft, 4% in 2018 and 22% by 2020, suggesting that the powered lift type development is indeed more complicated than wingless aircraft in practice. It can also be observed that most defunct aircraft are of the wingless eVTOL aircraft type. This suggests that the wingless aircraft may primarily be used to explore the business case and technological feasibility of an eVTOL aircraft concept before a go-to-market version is developed, which is more likely to be a powered lift eVTOL aircraft type.

One hundred and twenty eVTOL concepts were classified based on their propulsion configurations and presented in Figure 5. The methodology used to classify the eVTOL aircraft concepts by their propulsion configurations was adapted from the *V/STOL Wheel* in Ref. [39], which was initially developed by McDonell Aircraft in the 1960s [39]. A list of these aircraft and their key characteristics is also presented in the Appendix.

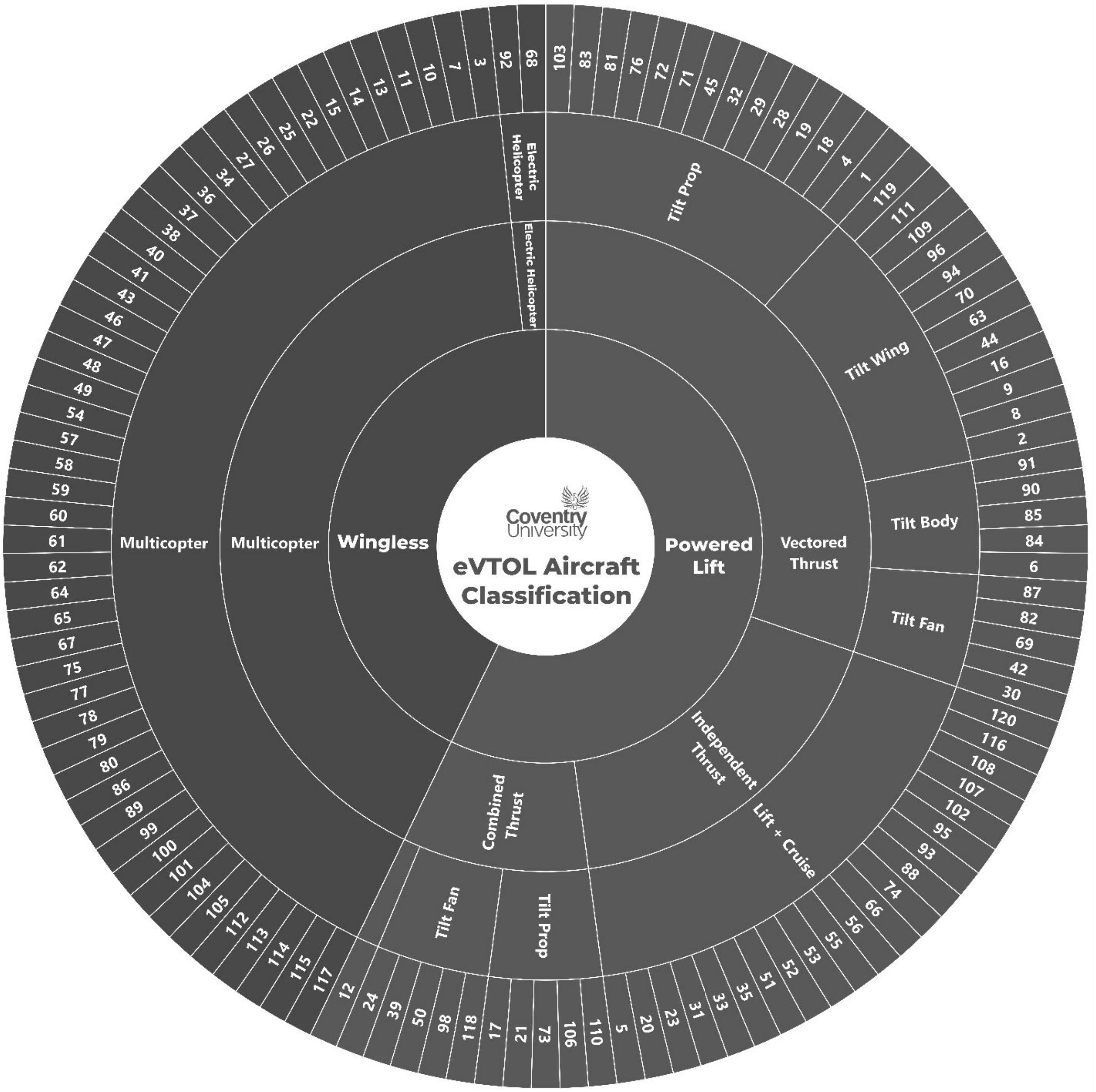


Figure 5. eVTOL Wheel – The classification of eVTOL aircraft concepts by their propulsion configuration

From the aircraft categorized so far, the powered lift eVTOL aircraft account for 57% with 68 aircraft. The wingless aircraft take the remaining 43% at 52 aircraft. The vectored thrust subfamily takes up 53% of the powered lift category with 36 aircraft. The independent thrust is at 30% with 21 aircraft, and the combined thrust takes up the remaining 17% with 11 aircraft. In the wingless eVTOL aircraft category, multicopters constitute 92% of the group with 48 aircraft. Electric rotorcraft take up the remaining 8% at 4 aircraft.

Examining the global development of eVTOL aircraft in Figure 6, the USA tops the list, commanding almost half of the global development efforts at 41%. The UK comes in second with a share of 12% of global vehicles in development. The USA, UK, Europe, China, and Russia account for over 70% of the global eVTOL aircraft development market. The majority of the companies developing eVTOL aircraft are start-ups at 68%. eVTOL aircraft development among major aircraft manufacturers like Boeing, Airbus and Embraer are split equally, with relatively smaller aircraft manufacturers like Pipistrel Aerospace at 8% each. Concepts in development by research institutes and universities account for 6% collectively. Finally, automotive manufacturers looking to diversify their offerings account for about 2%, while the remaining concepts are linked to individual enthusiasts.

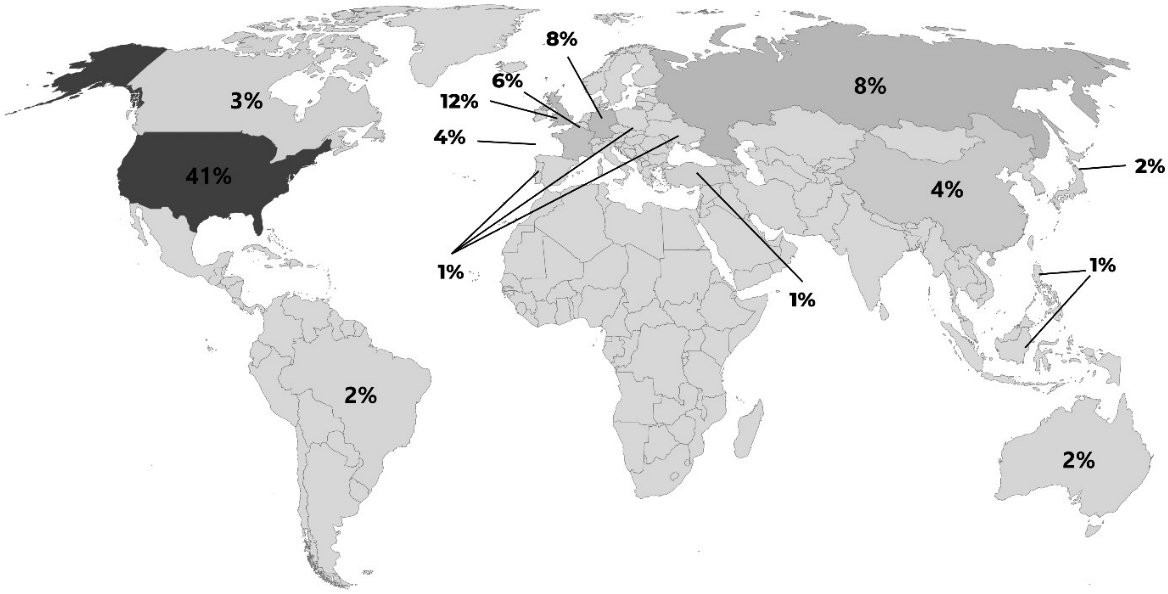


Figure 6. Global share of eVTOL aircraft development between 2014 and 2020

Figure 7 shows the cumulative announcements of eVTOL aircraft concepts over time. Initial hype for these aircraft types can be observed in the exponential increase from the end of 2016 to 2018. There were also significant jumps in announcements during the Uber Elevate summits in 2017, 2018 and 2019 as eVTOL developers used the opportunity to announce their concepts and prototypes publicly. However, it appears that expectations are beginning to peak as the intensity of announcements appears to subside while the eVTOL aircraft development industry converges to maturity.

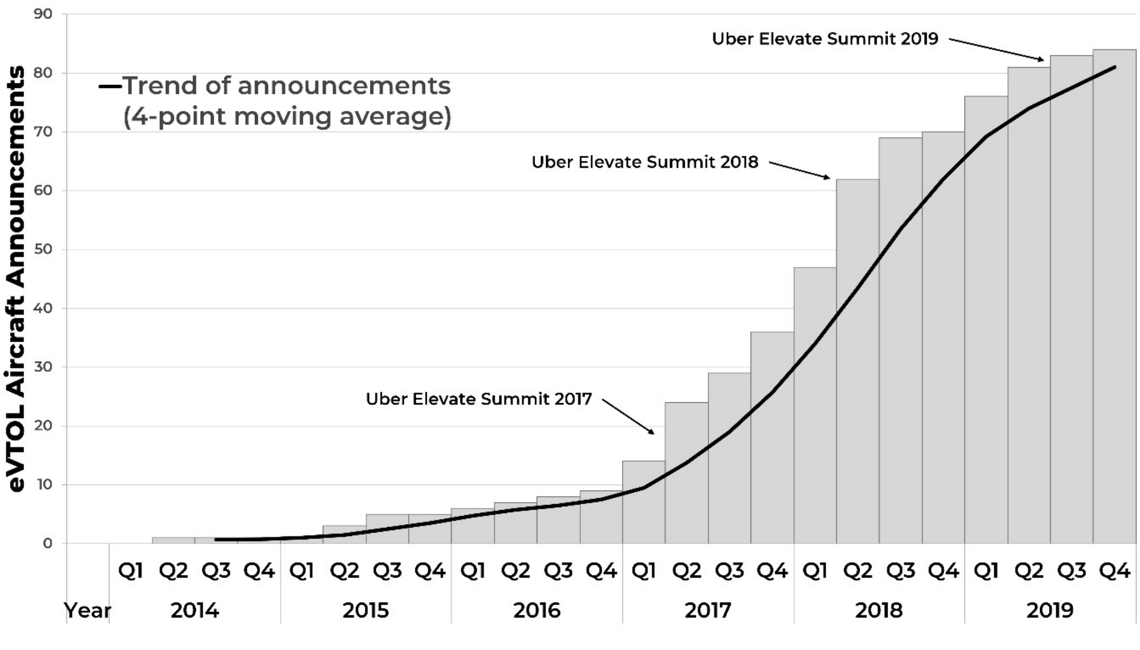


Figure 7. Cumulative announcements of eVTOL aircraft concepts from 2014 to 2019

IV. Conclusion

An exposition of the eVTOL aircraft development landscape has been presented in this paper. First, the different eVTOL types were reviewed. The main categories identified are powered lift and wingless eVTOL aircraft types. The former encapsulates all eVTOL concepts that can generate most of their aerodynamic lift in forward flight via the wing. While the latter are incapable of this because, as their name suggests, they do not employ wings for sustenance but rather downward thrust. The wingless eVTOL aircraft, although having a simpler architecture, performs poorly in cruise mode due to its lack of aerodynamic lift in forward flight. However, due to its apparent simplicity, the type appears to be the go-to choice for initial assessment and feasibility studies for eVTOL aircraft developers before a go-to-market version, likely now the powered lift type, is then developed from the initial wingless baseline.

Similar to the development of early powered aircraft in the 19th century, eVTOL aircraft design concepts are continuously evolving and are doing so quite rapidly. Over the last five years, there has been an exponential increase in research attention and funding for eVTOL aircraft design and UAM. A selection of data analysis on trends in eVTOL aircraft development from 2014 to 2020 has been presented. One hundred and twenty eVTOL aircraft concepts were assessed and categorized by their propulsion configurations. In addition, the eVTOL development landscape was studied. The results show that the USA, UK, Europe and China accounted for over 70% of eVTOL aircraft in development globally. The results also show that eVTOL start-up companies are developing the majority of new concepts (68%). Finally, the intensity of public announcements of new eVTOL aircraft concepts appears to have peaked after an exponential rise in the number of concepts unveiled between 2016 and 2018.

The eVTOL development landscape is still highly active. Thus, the results presented in this paper serve as an initial outlook on the eVTOL aircraft development landscape. Furthermore, the data used for this study is based on published aircraft data from several eVTOL developers, most of which are start-ups and non-traditional aerospace companies. Many of the proposed concepts have also not been proven commercially. Thus, the eVTOL aircraft information published by these companies should be treated with caution until widescale adoption and entry into service of these aircraft are achieved.

Nevertheless, further analysis on the topic is ongoing. The research database is continually updated as new vehicles are revealed, prototypes achieve their first flight, and more data is released by manufacturers, together with the results of academic research. This study intends to inform readers about the trends in eVTOL development and the dominant concepts that may be considered in trade studies. Which concepts will survive the test of time are still unknown, but those that will survive will likely need to employ innovative solutions and systems to tackle the limitations of actualizing eVTOL aircraft in the context of the pre-defined urban air mobility concept of operations.

Appendix

Table 1. eVTOL Aircraft Data

SN	Name	Developer	Country of Development (ISO2 [40])	Primary Class	Secondary Class	Tertiary Class
1	Aptos Blue	A2-Cal	US	PL	VT	TP
2	Z-300	ACS Aviation	BR	PL	VT	TW
3	X8	Aerial Vehicle Automation	US	WL	MC	-
4	aG-4 Liberty	aeroG Aviation	US	PL	VT	TP
5	AeroMobil 5.0	AeroMobil	SK	PL	IT	LC
6	Air-One	Air	IL	PL	VT	TB
7	Genesis	Airborne Motorworks	US	WL	MC	-
8	Vahana (Alpha)	Airbus	US	PL	VT	TW
9	Vahana (Beta)	Airbus	US	PL	VT	TW
10	CityAirbus	Airbus	DE	WL	MC	-
11	Pop.Up	Airbus, Italdesign & Audi	FR	WL	MC	-
12	MOBi-One V3	AirSpaceX	US	PL	CT	TW
13	Skai	Alaka'i Technologies	US	WL	MC	-
14	Airspeeder Mk4	Alauda	AU	WL	MC	-
15	Ambular 2.0	Ambular	CA	WL	MC	-
16	Vertiia	AMSL Aero	AU	PL	VT	TW
17	A2-Cal	Aptos Blue	US	PL	CT	TP
18	Midnight	Archer	US	PL	VT	TP

19	Maker	Archer	US	PL	VT	TP
20	Atea	Ascendance Flight Technologies	FR	PL	IT	LC
21	Volante Vision	Aston Martin	GB	PL	CT	TP
22	Elroy	Astro Aerospace	US	WL	MC	-
23	V600	AutoFlightX	DE	PL	IT	LC
24	Y6S	Autonomous Flight	GB	PL	CT	TF
25	Yurik	Aviation and Space Technologies	RU	WL	MC	-
26	Bartini	Bartini Aero	RU	WL	MC	-
27	Cezeri	Baykar Technologies	TR	WL	MC	-
28	Bell Nexus 4EX	Bell	US	PL	VT	TP
29	Bell Nexus 6HX	Bell	US	PL	VT	TP
30	Nexus	Bell Helicopters	US	PL	VT	TF
31	Alia-250c	Beta Technologies	US	PL	IT	LC
32	Ava XC	Beta Technologies	US	PL	VT	TP
33	Aurora PAV	Boeing	US	PL	IT	LC
34	Cargo Air Vehicle	Boeing	US	WL	MC	-
35	SkyCab	Braunwagner	DE	PL	IT	LC
36	Beccarii	B-Technology	PL	WL	MC	-
37	CAPS	CAPS	FR	WL	MC	-
38	Flying Taxi	Central Aerohydrodynamic Institute	RU	WL	MC	-
39	Mini-Bee	CollaborativeBee	FR	PL	CT	TF
40	ZeroG	Davinci Technology	US	WL	MC	-
41	ZeroG V3	Davinci Technology	US	WL	MC	-
42	DR-7	Delorean Aerospace	US	PL	VT	TF
43	Big Drone	Drone Champions AG	LI	WL	MC	-
44	aEro 2	Dufour Aerospace	CH	PL	VT	TW
45	aEro 3	Dufour Aerospace	FR	PL	VT	TP
46	EHang 116	Ehang	CN	WL	MC	-
47	EHang 184	Ehang	CN	WL	MC	-
48	Ehang 216	Ehang	CN	WL	MC	-
49	Whisper	Electric Aircraft Concept	FR	WL	MC	-
50	X01	Electric Visionary Aircrafts	FR	PL	CT	TF
51	Flexcraft	Embraer & Flexcraft Consortium	PT	PL	IT	LC
52	Lancer Epav	Esprit Aeronautics	GB	PL	IT	LC
53	Eve V3	Eve Air Mobility	BR	PL	IT	LC
54	Flutr	Flutr Motors	DE	WL	MC	-
55	PAC VTOL 420-120	Flyter	RU	PL	IT	LC
56	PAC VTOL 720-200	Flyter	RU	PL	IT	LC
57	Frogs 282	Frogs Indonesia	ID	WL	MC	-
58	KiiRA	Garudeus Aviation	US	WL	MC	-
59	Tusi Technology Demonstrator	Gelisim University	TR	WL	MC	-
60	Koncepto Millenya	Gravity X	PH	WL	MC	-
61	Gatri	Green Aerotechnics Research Institute	CN	WL	MC	-
62	S700	Hi-Fly	RU	WL	MC	-
63	Venturi	HopFlyt	US	PL	VT	TW
64	Formula 2 Prototype	Hover	RU	WL	MC	-
65	Scorpion Air Taxi	Hover	RU	WL	MC	-
66	Drone Taxi R-1	Hoversurf	US	PL	IT	LC
67	Technology Demonstrator	International Aviation Center	RU	WL	MC	-
68	Jaunt	Jaunt Air Mobility	US	WL	SRW	-
69	J2000	Jetoptera	US	PL	VT	TF
70	Joby	Joby Aviation	US	PL	VT	TW
71	S4	Joby Aviation	US	PL	VT	TP
72	Butterfly	Karem Aircraft	US	PL	VT	TP
73	OPPAV	KARI	KR	PL	CT	TP
74	Cora	Kitty Hawk	US	PL	IT	LC
75	Flyer	Kitty Hawk	US	WL	MC	-
76	Optionally Piloted PAV	Korea Aerospace Research Institute	KR	PL	VT	TP
77	Element Drone	Kovacs	HU	WL	MC	-
78	Heavy Duty Drone	Kovacs	HU	WL	MC	-
79	FD-One	Lazzarini Design Studio	IT	WL	MC	-
80	HEXA	LIFT Aircraft	US	WL	MC	-

81	Eagle	Lilium	DE	PL	VT	TP
82	Lilium Jet (5x)	Lilium	DE	PL	VT	TF
83	LimoConnect	Limosa	CA	PL	VT	TP
84	AIVA	Micor Technologies	US	PL	VT	TB
85	AMVA	Micor Technologies	US	PL	VT	TB
86	SureFly	Moog Inc.	US	WL	MC	-
87	MyDraco	MyDraco	UA	PL	VT	TF
88	VTOL	Napoleon Aero	RU	PL	IT	LC
89	Human Carrier Drone	Polytechnic Institute of Cambodia	KH	WL	MC	-
90	eOpter	Neoptera	GB	PL	VT	TB
91	BlackFly (V3 Intl)	Opener	US	PL	VT	TB
92	PA-890	Piasecki Aircraft	US	WL	SRW	-
93	eVTOL	Pipistrel	SI	PL	IT	LC
94	Transwing	PteroDynamics	US	PL	VT	TW
95	Ray VTOL Aircraft	Ray Research	CH	PL	IT	LC
96	eVTOL	Rolls-Royce	GB	PL	VT	TW
97	HUMA	Samad Aerospace	GB	PL	VT	TB
98	Starling Jet	Samad Aerospace	GB	PL	CT	TF
99	Cartivator	SkyDrive	JP	WL	MC	-
100	SD-03	SkyDrive	JP	WL	MC	-
101	SD-XX	SkyDrive	JP	WL	MC	-
102	TF-2-LPP	Terrafugia	US	PL	IT	LC
103	TF-X	Terrafugia	US	PL	VT	TP
104	FlyKart 2	Trek Aerospace	US	WL	MC	-
105	Esinti	Turkish Technic	TR	WL	MC	-
106	eCRM-001	Uber	US	PL	CT	TP
107	eCRM-002	Uber	US	PL	IT	LC
108	eCRM-003	Uber	US	PL	IT	LC
109	Personal Air Taxi 200	VerdeGo Aero	US	PL	VT	TW
110	VX-4	Vertical Aerospace	GB	PL	CT	TP
111	AAV Vimana	Vimana Global	US	PL	VT	TW
112	VoloCity	Volocopter	DE	WL	MC	-
113	Volocopter 2X Prototype	Volocopter	DE	WL	MC	-
114	VoloDrone	Volocopter	DE	WL	MC	-
115	NeoXcraft	VRCO	GB	WL	MC	-
116	Generation 6	Wisk	US	PL	IT	LC
117	Voyager X2	XPeng	CN	WL	MC	-
118	Trifan 600	XTI Aviation	US	PL	CT	TF
119	EOPA	Zenith Altitude	CA	PL	VT	TW
120	Zuri	Zuri	CZ	PL	IT	LC

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