DOI: 10.13009/EUCASS2022-7362
9TH EUROPEAN CONFERENCE FOR AERONAUTICS AND SPACE SCIENCES (EUCASS)

An Assessment of Current and On-The-Horizon eVTOL Technologies for a Flying Car

*Burhan Saeed**
**School of Mechanical and Design Engineering, University of Portsmouth*
2.05a, Anglesea Building, Portsmouth, England

Abstract

This paper presents an assessment of current and on the horizon eVTOL technologies that may have the potential to develop into a useable flying car. The quest has shown a clear trend towards distributed propulsion system, the eVTOL aircraft tend to use three different configurations, multicopters, vectored thrust and lift+cruise, offering different payload and range performance. The highest payload and range performance is offered by the Lilium Jet that, also, deploys the largest span, 13.9 m, in its class. It is concluded that a true flying car, that is compact enough for the road and can take off vertically, does not exist yet. The solution may be in searching alternative energy sources such as hydrogen fuel and other sustainable aviation fuels.

1 Introduction

The new flying car ‘AirCar’ has won the certificate of airworthiness which has reignited the debate about the future and realisation of a commercial flying car. The AirCar meets the definition of a flying car, it being air and road worthy, but lacks the key feature ‘vertical take-off and landing (VTOL)’ to avoid the usual traffic on the road and be a more practical personal vehicle. It was established a decade ago [1] that a realistic future flying car must use non-jet propulsion systems, particularly electric powered ducted fans, to acquire a useful performance. Also, a true flying car should be VTOL capable, this imposes certain limitations such as the size, the current range of electric propulsion system’s power-to-weight density allows smaller vehicles, such as drones, to acquire a desired performance. For a relatively larger size vehicle a thermal engine is still more appealing [2]. However, the future must be made carbon free and we need to find solutions to cater this imperative global goal, hence, the focus should be electric or other green energy sources. The pilot mode and safety are other challenges associated with realising a flying car [3].

Figure 1: Photographs showing the AirCar in different configurations [4].

Herein, current and on-the horizon electric VTOL technologies are explored, analysed and technology trends are highlighted to realise a useable flying car. The rise of high power density lithium batteries and efficient motor-rotor solutions are encouraging eVTOL capable aerial vehicles; the large scale drones are on an upward trajectory [5], these technologies are giving way to a useable passenger air vehicle. The eVTOL technologies are analysed with regard to payload, range and cruise velocity. The presented review, also, highlights hydrogen fuel for a relatively small aircraft, so far hydrogen fuel is primarily being investigate for jetliners.

2 VTOL The Challenge

Upon achieving powered flight in 1903 the quest has been to improve aircraft performance with regards to payload, endurance, range, fuel consumption and take-off and landing distances. Although, there have been significant improvements in most performance parameters, the take-off run has been trapped between several trade-offs. Let's consider the take-off velocity, v_{TO}, of an aircraft given by the following equation,

$$v_{TO} > v_{stall}, \quad v_{stall} = \sqrt{\frac{2W}{\rho S C_{L_{max}}}} \tag{1}$$

The take-off velocity must be greater than the stall velocity which depends on the wing loading, W/S, and the maximum lift coefficient $C_{L_{max}}$. In order to increase the take-off velocity wing loading is increased and on the other hand if the take-off distance, D_{TO} , is to be reduced the wing loading should be lowered as dictated by the following equation.

$$D_{TO} \propto \frac{W/S}{C_{L_{max}}(T/W)} \tag{2}$$

The take-off distance, D_{TO} , is proportional to wing loading, W/S, inversely proportional to maximum lift coefficient, $C_{L_{max}}$, and thrust-to-weight ratio, T/W, or thrust loading. This implies that in order to minimise the take-off distance an aircraft may deploy bigger engines, increase the maximum lift coefficient using high lift devices or reduce the wing loading. This trichotomy invokes performance trade-offs among range, payload and fuel consumption. Hence, there hasn't been a straight forward solution to reducing take-off distance, instead driven by performance goals. The evolution of short take-off and landing aircraft STOL is displayed in Figure 2, it can be seen that over the years the take-off distance has not significantly improved, in fact, it's more about the overall size of the aircraft. The Javelin in 1949 could take off in 46 meters, and Antonov AN-72, much larger aircraft, in 1977 needs 400 meters to take-off. Hence, it can be concluded that for aircraft classified as STOL the overall size reflects on the take-off distance.

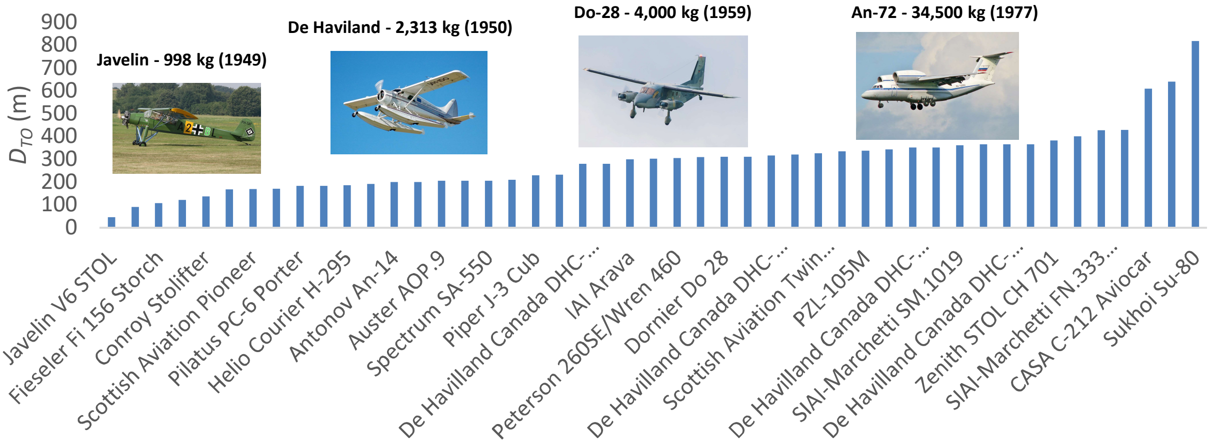

Figure 2: Take-off distance of different STOL aircraft.

A conventional take-off and landing CTOL aircraft works against the aerodynamic drag while a VTOL aircraft works against gravity to obtain an altitude. The four forces of flight, Lift, Drag, Weight and Thrust, dictate each mode of flight. A typical wing section generates 100 N of lift force at the cost of a drag force of 5 N [6], this suggests that in order to achieve flight a thrust force is twenty times less than the lift or weight of the aircraft, as the propulsion system needs to overcome the aerodynamic drag. For vertical take-off the force generated by the propulsion system must be greater than the weight of the aircraft. This immense disparity in thrust force for conventional and vertical take-off is the main challenge with achieving a useable aircraft. In general, the aerodynamic efficiency of an aircraft is measured by lift-to-drag ratio, this parameter has evolved over the past century. The first powered aircraft the Wright Flyer in 1903 had a lift-to-drag ratio of 8.3 and the recent jetliner Airbus A380 has a ratio of 20, see Figure 3. In parallel to the mainstream aviation technologies a special category of aircraft 'high altitude long endurance (HALE)' has seen a significant rise in the lift-to-drag ratio in recent years, the Virgin Atlantic Global Flyer has a lift-to-drag ratio of 37.

DOI: 10.13009/EUCASS2022-7362

The continuous improvement in aerodynamic efficiency has reduced the toll on fossil fuel consumption and the modern propulsion systems are very well enabling the short/long haul flights but the requirement now is to completely eliminate carbon emissions.

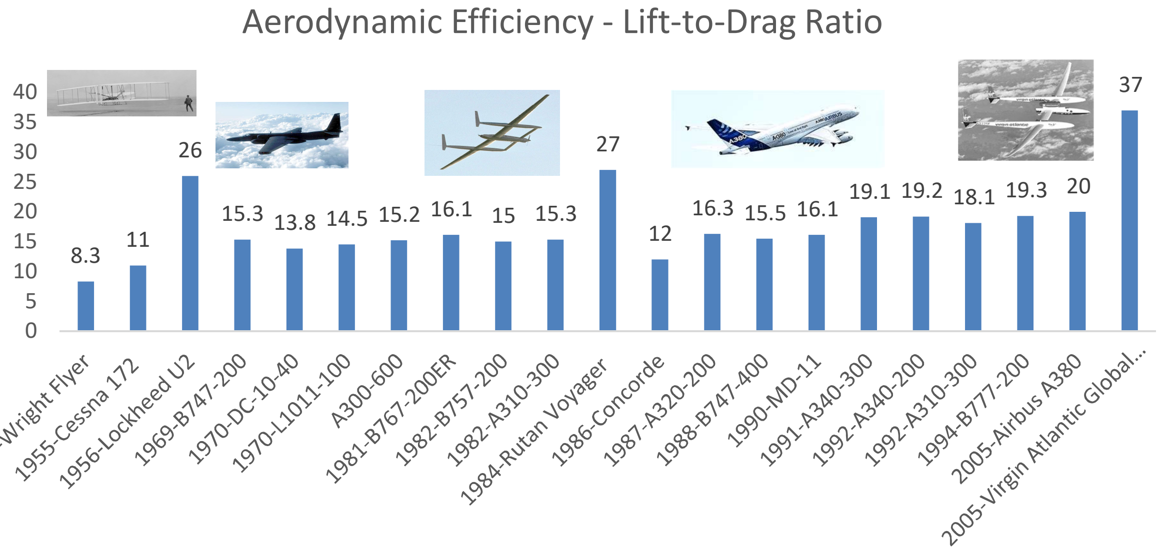

Figure 3: Lift to drag ratio evolution for the jetliners in the past century – data adapted from [7].

When it comes to VTOL efficiency the disk loading, ratio of gross aircraft weight to fan/thrust area, becomes a crucial parameter as the hover efficiency, ratio of gross weight to power, is a function of disk loading. This implies that larger the disk/thrust area for a given weight the lower the power required to vertically take-off, for example a helicopter. The disk area is limited to tip losses, which may be improved by ducted fans [8]. The following VTOL category the tilt rotor can achieve similar hover efficiency as helicopters, however, the added weight of actuation system reduces the payload capability. Similarly, the tilt wing aircraft loses hover efficiency for tilting the whole wing along with the rotors. The last two categories, the lift-fan and direct lift, possess the lowest hover efficiency as the disk loading increases to lift the aircraft. However, these aircraft have been designed to enhance the cruise flight performance with VTOL capability. The addition of wings that allows range and endurance performance enhancement when compared to a helicopter. In addition, to set the perspective, the Sikorsky CH-53 helicopter weighs around 15,000 kg and has a range of 1000 km, Bell Boeing V-22 Osprey (a tilt rotor aircraft) can carry a mass of 21,000 kg for a distance of 1600 km and a Harrier Jump Jet weighing 14,000 kg can travel up to 1100 km.

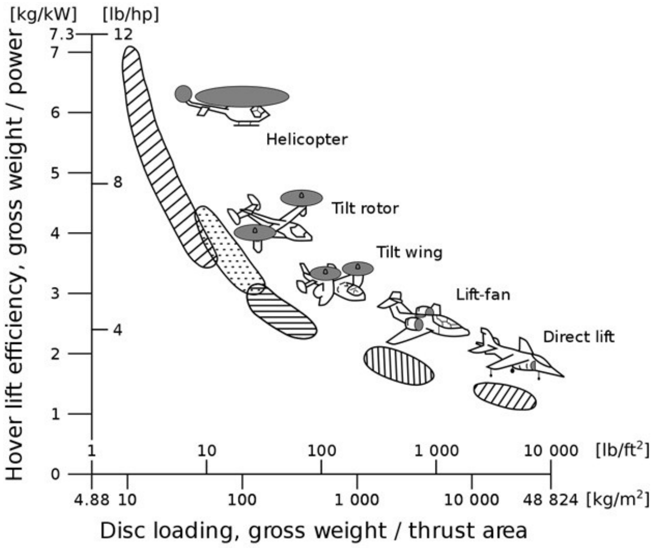

Figure 4: Hover efficiency versus disk loading for different VTOL configurations [9].

DOI: 10.13009/EUCASS2022-7362

3 Power Density and Aircraft Performance

The energy density, energy in Watts hour per kilogram, of different propulsion systems is displayed in Figure 5 along with performance characteristics of corresponding aircraft. High by pass turbofans provide the highest energy density and take-off power while battery based propulsion is at the lowest end of the graph. Hence, the modern Joint Strike Fighter F35B and the large commercial jetliners use turbofans to achieve vertical take-off or high payload and range performance. The electric propulsion is starting to make its way into relatively smaller aircraft, these aircraft are offering similar payload to maximum take-off weight ratios, however, the range performance is significantly less than an equivalent piston engine powered aircraft. These are current trends indicated by a recent study [10] suggesting that the electric propulsion is predominantly focused on small scale aircraft such as drones and 4/5 seater aircraft. The larger aircraft such as the commercial jetliners are focusing on hydrogen fuel which offers much higher energy density, the hydrogen fuel is discussed in the next section.

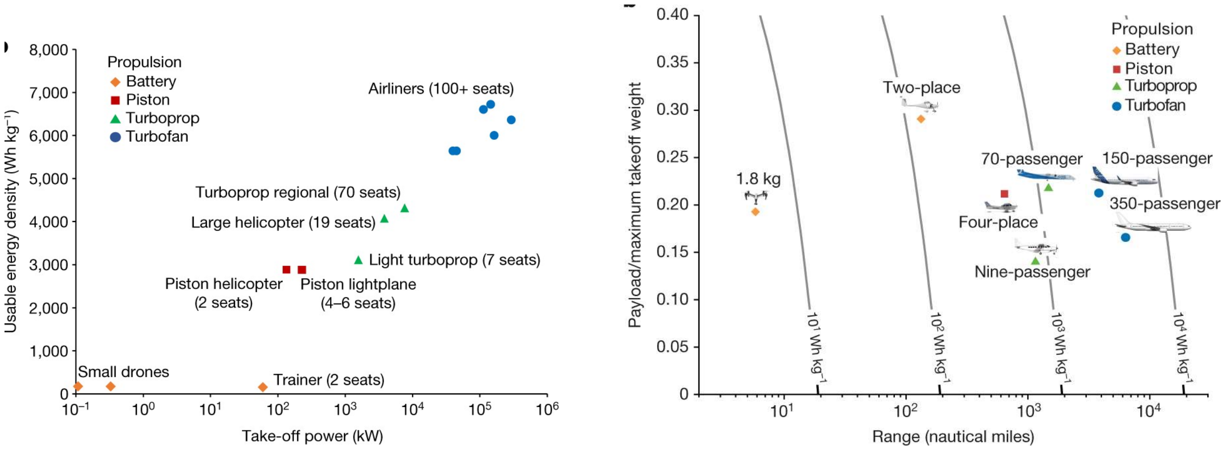

Figure 5: Power densities and performance of different propulsion systems – derived from [10]

Since the advent of thermal power engineers and scientists have been trying to find solutions to increase power density for larger faster aircraft and to improve thermal/propulsive efficiency for the powered flight. This triggered an evolution in the aerospace propulsion sector. There have been mainly three different propulsion configuration using gas turbine cores including the unducted fans UDF (can be powered by an internal combustion engine), turboprops, high, medium and low bypass ratio BPR turbo fans, and turbojets; these come at an increasing fuel consumption respectively. Turbojets or engines without a bypass ratio offer high thrust and Mach numbers at a severe cost of core thermal efficiency and fuel consumption [11]. The maximum core thermal efficiency achieved so far is 80%, the propulsive efficiency has reached as high as 85% which gives a maximum overall efficiency a threshold of 65%, see Figure 6. The aviation is industry is moving away from thermal power to enforce zero carbon emission solutions.

The electric propulsion offers significantly higher overall efficiency, the electric motors are typically 94% efficient [12] and combining this with 85% propulsive efficiency gives and overall electric propulsion efficiency of approximately 80%. The significant advantage of efficiency over the thermal power still isn't enough to compensate for the relatively low energy density of batteries. However, it is observed that NASA is developing a high-efficiency megawatt motor HEMM offering at least three times higher specific power to the current electric motors used for aircraft propulsion, a comparison of different electric motors is displayed in Figure 7. This significant rise in specific motor power, if realised, may well improve the performance of future eVTOL aircraft.

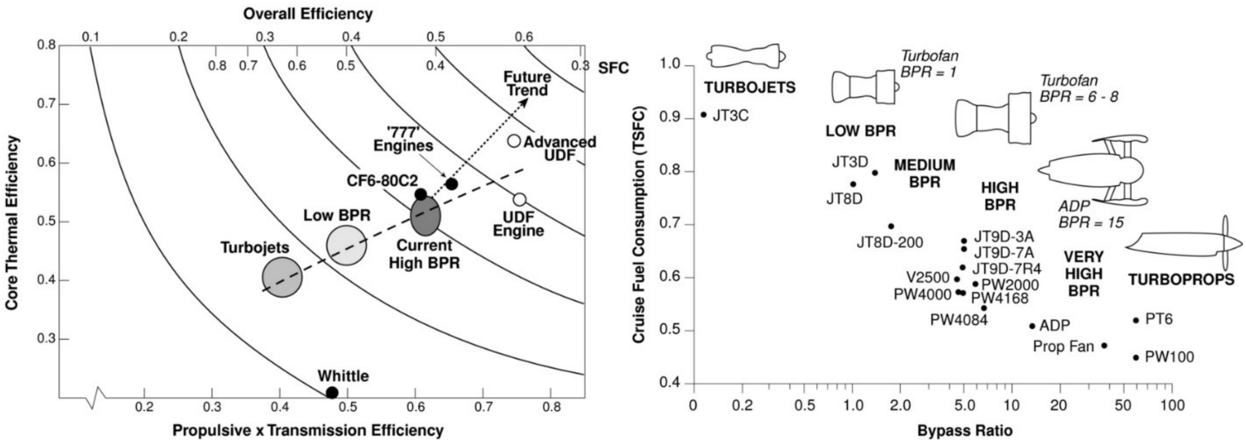

Figure 6: Thermal and propulsive efficiency of different propulsion systems – adapted from [13].

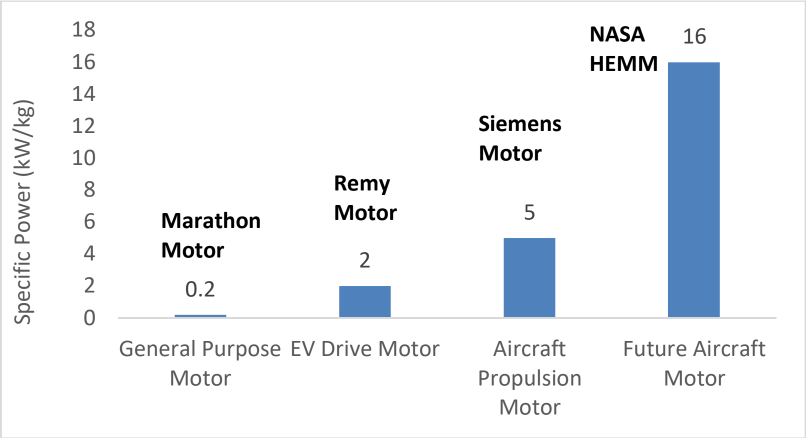

Figure 7: Power trend of electric motors for aircraft propulsion – data adapted from [14, 15, 16]

3.1 Hydrogen Fuel – The Answer to a Flying Car?

The immense disparity in the specific electric power, 200 Wh/kg, and conventional fuel powered propulsion, 12 kWh/kg, is one of the obstacles to achieving a useable flight performance for eVTOL aircraft. Alternative green fuel such as the hydrogen fuel is being investigated for the aviation industry, the hydrogen fuel in liquid or gas form offers a gravimetric density or specific energy of 120 MJ/kg which is significantly higher than that of the conventional fuels. The major downside of hydrogen fuel is that the volumetric density of compressed or liquid hydrogen is significantly smaller than the conventional fuels such as the gasoline or diesel, see Figure 8. The hydrogen fuel demands bulkier tanks and, hence, the whole aircraft design needs to change where one trade-off would be the excessive drag [17]. The feasibility of hydrogen fuel is predominantly being investigated for large commercial jetliners, however, the hydrogen fuel has started to show positive signs for smaller aircraft as well such as the HY4 (4 passengers) [18] and the HyFlyer II (19 passengers) [19]. The hydrogen fuel, particularly, for a VTOL flying car has not been assessed yet, nevertheless, it has the potential to be the alternative fuel source, thus, must be investigated further. It is reported [20] that in order to use hydrogen fuel it must be incorporated into the design stage of an aircraft. Hence, a design feasibility study is needed to realise the potential of hydrogen fuel as alternative energy source for a future flying car.

DOI: 10.13009/EUCASS2022-7362

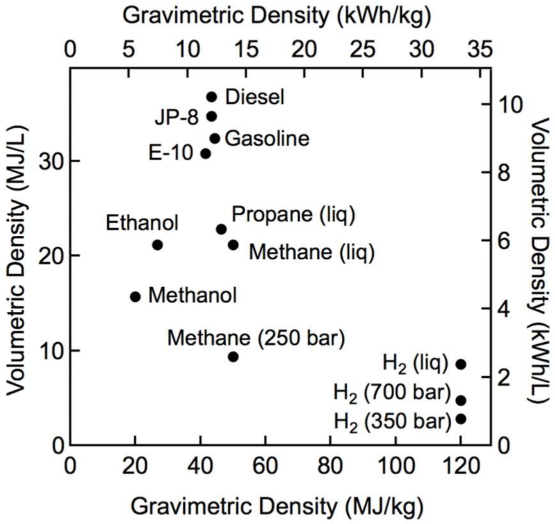

Figure 8: Specific energy or energy density versus the volumetric density of different fuels – taken from [21]

4 Current and on-the-horizon Flying Cars

There are over three hundred experimental aircraft, prototypes and conceptual designs in the database for eVTOL [22]. Many have been defunct, more are being added and mostly are in the prototyping stage. Herein, the most promising eVTOL aircraft, with a potential to be realised as a flying car, are explored and analysed with regards to the overall claimed flight performance. The electric vertical take-off and landing eVTOL technologies are categorised into four different configurations including vectored thrust VT or tilt rotor, lift plus cruise LC and multicopters MC, these configurations are sketched in Figure 9.

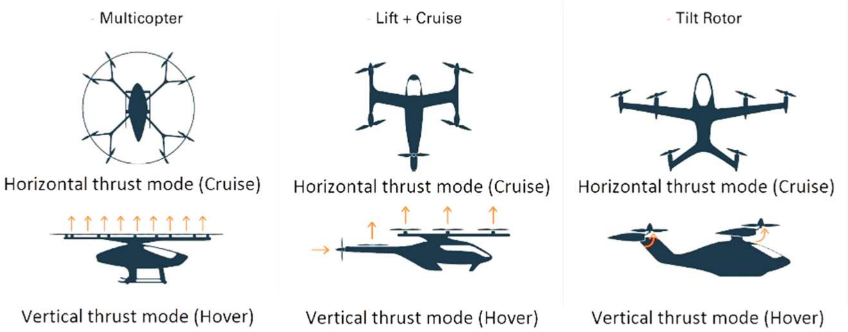

Figure 9: Different configurations for VTOL aircraft – derived from [23]

4.1 Multicopters

Multicopters are usually relatively small wing less flying vehicles, these can be manned or unmanned. The multicopters fall in the distributed propulsion systems category that are projected to be the future of electric aircraft [24] for their performance attributes such as low noise, shorter take-off distances and specific energy consumption. The multicopters are aimed at urban mobility as they possess relatively small range. A couple of futuristic multicopters are displayed in Figure 10, the eHANG-216 deploys eight rotors and the VoloCity boosts eighteen rotors.

DOI: 10.13009/EUCASS2022-7362

Figure 10: Photos of eHANG and VoloCity multicopters – taken from [25, 26].

4.2 Vectored Thrust

Vectored thrust configuration uses same propellers to lift and move forward by tilting the propellers. Figure 11 depicts a couple of the most advanced eVTOL aircraft using vectored thrust configuration, the Lilium Jet uses 36 electric powered ducted fans and MOBI-ONE deploys four pair of counter rotating propellers. The Lilium jet is the most advanced in its class it builds on the concept of Blended Wing Body offering certain benefits such as low noise and up to 20% better efficiency compared to a conventional aircraft body [27]. The Lilium Jet uses the largest wing span, 13.9 m, in its class which enables it to achieve the highest range performance.

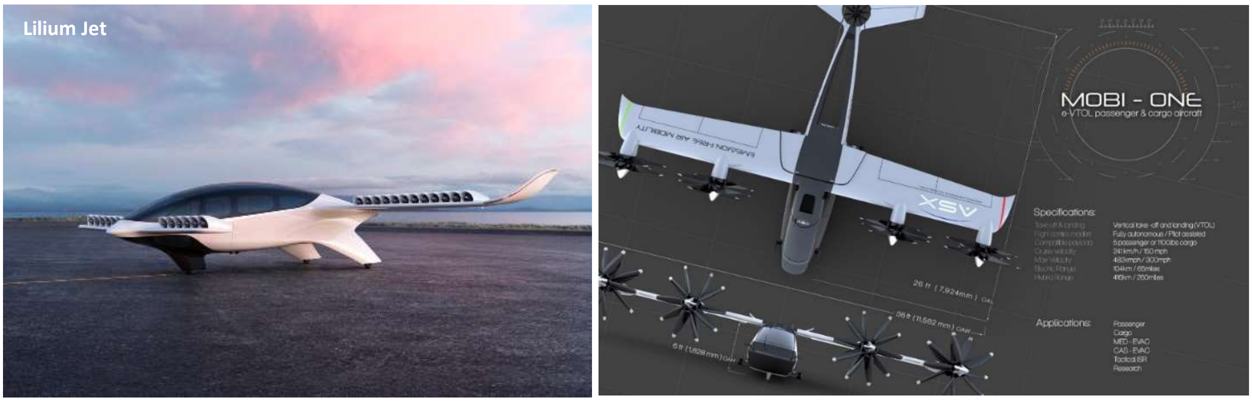

Figure 11: Photographs showing Lilium Jet (left) and MOBI-ONE (right) – taken from [23, 22].

4.3 Lift + Cruise

In this category of vehicles separate propulsion is deployed for lift and cruise, there are a number of trade-offs in this configuration. The main advantage of this configuration is that it eliminates the need of an actuation system to rotate the rotors or the wings, this makes the configuration relatively simple. however, if in cruise the propeller is not generating lift at their optimum level, it could take away the payload benefits.

- Since the rotors for lift and propellers for forward flight are separate, it allows them to have different characteristics such as the rotor diameter, tip speed, pitch angle and rpm, enabling the rotors to operate at optimum efficiency.

- Separate rotors for lift enables large aspect ratio wings to be integrated onto the aircraft which delivers high aerodynamic efficiency, lift to drag ratio, as it reduces induced drag.

DOI: 10.13009/EUCASS2022-7362

- Although, fewer larger rotors (lower disk loading i.e. helicopter rotor) provide higher hover efficiency, see Figure 4, having separate multiple rotors for lift and cruise improves safety features of aircraft. For example, when there are at least two rotors on either side of the fuselage, in the case of one rotor failing, the remaining three can adjust the lift to maintain level flight.

The Aurora's PAV deploys eight counter rotating propellers for VTOL and one tail mounted pusher propeller for cruise flight, see Figure 12. The rotors sit on bars connecting the canards to the tail wing which gives it a structural strength, however, results in parasitic drag. The vehicle asserts a large foot print with a fuselage length of 9.14 m, 8.53 m span. Its targeted to be an air taxi and the company has partnered with Uber under the umbrella of an ambitious project Uber Elevate Mission. In 2017 a scaled down model was flown to demonstrate the concept, in 2019 a full scale prototype successfully achieved unmanned take-off, hover and landing [28]. The Uber eCRM-002 deploys five pairs of counter rotating rotors for lift and two propellers for forward flight. It uses a high aspect ratio wing similar to the Aurora PAV and a high tail wing.

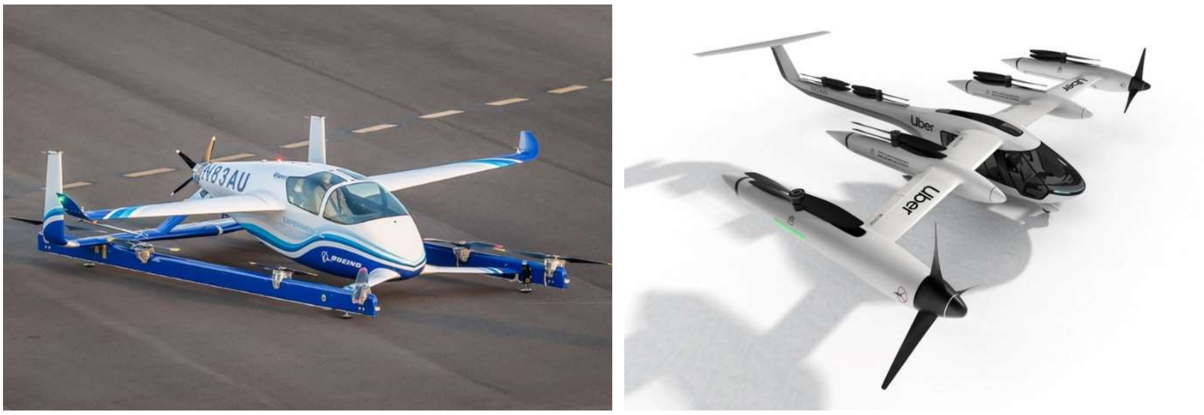

Figure 12: Aurora Pegasus Passenger Air Vehicle PAV (left) and Uber eCRM-002 (right) – photograph taken from [28].

4.4 Performance Analysis of Potential Flying Cars

The performance data of the selected eVTOL aircraft is presented in Table 1. The data is collected from the respective aircraft company/manufacturer websites which is limited and often missing some of the crucial performance data. Hence, only the aircraft for which the data is available are analysed. Figure 13 displays plots of range versus payload for different categories of eVTOL aircraft. From the figure it can be seen that range increases approximately linearly with payload for all three configurations. The vectored thrust configuration achieves the highest range and payload performance, within this configuration the ducted fan aircraft, such as the NeoXCraft and Lillium Jet, attain the best performance. The MOBi-One aircraft achieves similar payload compared to the Lilium Jet but at two thirds the range. This is due to the fact that the Lilium Jet uses distributed propulsion, tilting rotor plus part of the rear wing and has a relatively large wing area/span. While the MOBi-One tilts the entire wing and the rotors which requires a heavier actuation system leading to a toll on the performance. Furthermore, the MOBi-One uses hybrid propulsion system which could increase the range to 416 km from 104 km of pure electric range, although, this may not qualify as an eVTOL performance. The lift+cruise configuration is the second best, it can carry similar payloads, however, the range is approximately half compared to vectored thrust aircraft. The Uber eCRM-002 achieves the highest performance in this category. The multicopters achieve the lowest performance with only 50 km of Range and about 200 kg of payload. The Skai with multicopters achieves a significant higher performance in its class as it deploys a hybrid propulsion system.

Figure 14 compares eVTOL to past or previous generation of VTOL flying cars, using thermal power, with regard to their range performance and span. The Figure shows that the thermal powered VTOL aircraft achieved much higher range performance with a significantly smaller overall size. The eVTOL vehicles, even with the highest span of 13.9 m (Lilium Jet), only manages a Range of 300 km while the lowest performing thermal powered VTOL aircraft (X-

DOI: 10.13009/EUCASS2022-7362

Hawk) offers 900 km range. This disparity in range performance is reflective of the huge gap in energy densities of fuel and batteries as discussed above. In addition, the span of these thermal powered flying cars is less than 3.65 metres, the designated lane width in the UK, the limited span suggests that the intention of the respective companies have been to seek air and road worthiness to realise an operational flying car of the future. However, it is self-evident that the thermal powered flying cars may not go ahead as the focus is on eVTOL for any new technologies.

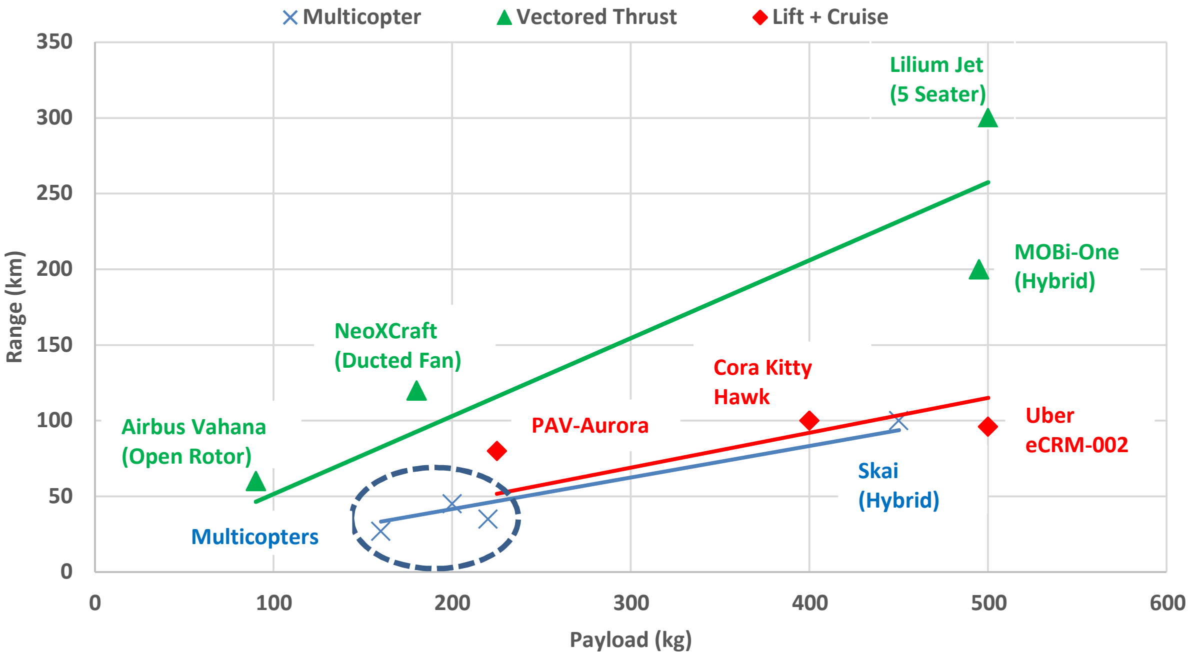

Figure 13: Payload and range performance of different eVTOL aircraft.

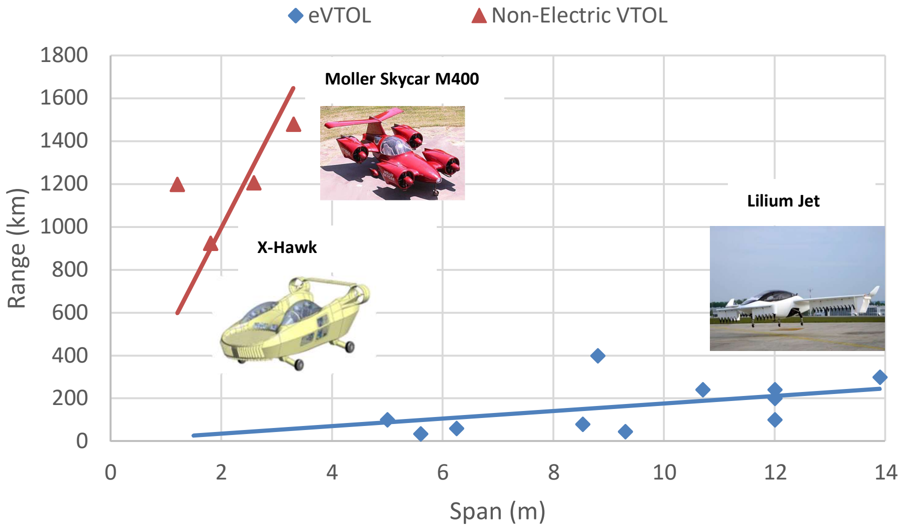

Figure 14: Range and size comparison of eVTOL aircraft and non-electric VTOL aircraft.

DOI: 10.13009/EUCASS2022-7362

Table 1: Performance data of selected eVTOL aircraft (MC: Multicopters, VT: Vectored Thrust, LC: Lift + Cruise).

Year	Aircraft	VTOL Type	MTOW (kg)	Payload (kg)	Power (kW)	Range (km)	Endurance (min)	Speed (km/h)	Length (m)	Span (m)	Passengers	Reference
2010	Volocopter	MC	450	160	-	27	-	100			2	Volocopter
2011	VoloCity	MC	900	200	-	45	-	90	11.3	9.3	2	Volocopter
2014	E-Hang	MC	-	220	-	35	-	100	5.6	5.6	2	eHang
2016	Lilium Jet (5 Seater)	VT	3175	500	1490	300	48	300	8.5	13.9	-	Lilium
2017	Jetson	VT	180	85	88		15	102	2.48	1.5	-	Jetson Aero
2017	PAV - Aurora	LC	800	225	600	80	-	18	9.14	8.53	-	Aurora
2017	MOBI-One (Hybrid)	LC	-	495	-	104	-	240	9	12	5	iFlyasx
2018	Aeromobil	LC	-	-	224	400	-	260	6.1	8.8	-	Aeromobil
2018	Airbus Pop Up	MC	600	-	136	100	-	100	4.4	5	-	iTaldesign
2018	Airbus Vahana	VT	815	90	360	60	-	200	5.7	6.25	-	Vahana
2019	Cora - Kitty Hawk	LC	1224	400	-	100	36	160	7	12	2	Cora
2019	NeoXCraft (Ducted Fan)	VT	450	180	-	120	21	338	-	-	2	vrco
2019	Nexus 6HX (Ducted Fan)	VT	2720	-	-	241	50	288	12	12	4	Bell Flight
2019	Skai (Hybrid)	MC		450	-	644	240	190	-	-	5	Skai
2020	Joby S4	VT	1815	-	-	241		322	7.3	10.7	5	Joby Aviation
2020	Supernal SA-1	VT		-	-	97	20	290		-	5	Hyundai
2021	Flying Ca PR-DC	MC		100	200	-	-	-	4.82	3.59	1	Pr-Dc

DOI: 10.13009/EUCASS2022-7362

5 Conclusions

The assessment of current and on the horizon flying cars has resulted in the following findings.

- Three propulsion configurations are predominantly deployed for small scale eVTOL aircraft including vectored thrust, lift+cruise and multicopters. Each configuration offers a different range and payload performance and the best performance is offered by the vectored thrust configuration.
- The range performance of eVTOL aircraft is directly dependent on the wing span, the winged aircraft such as the MOBi-One, Lilium Jet and Cora Kitty Hawk achieve much higher payload and range performance compared to the wingless multicopters.
- The overall performance of eVTOL vehicles is significantly less than that of previous generation of flying cars using thermal power.
- Hydrogen fuel may be an alternative zero carbon fuel for the future flying car and may also address the low range issues of eVTOL with its significantly high energy density of 120 MJ/kg.
- Further enhancement in electric motors, such as the NASA HEMM, could improve performance of eVTOL in the future.

It is concluded that a flying car does not exist yet which could be everyone’s personal vehicle, however, if we define further categories for a personal flying vehicle, there are many promising technologies in the pipeline. For example, an electric VTOL vehicle such as the Airbus Popup may be feasible for city wide commute and for inter-city travel a vehicle with a higher glide ratio, such as the NeoXCraft or the MOBI-ONE, may be a better option. From the technologies considered the Lillium jet promises the best overall range, endurance and payload performance which may be used as an air taxi flying between designated launch pads.

The future work to be done for realising a more practical flying car would be to find alternative zero carbon energy sources other than the electric energy such as the hydrogen fuel. Also, sustainable aviation fuel SAF promising 80% reduction in emissions and a specific energy of 42.8 MJ/kg comparable to gasoline or diesel [29] may also be explored.

References

[1] Saeed, B. and G. Gratton. 2010. An evaluation of the historical issues associated with achieving non-helicopter V/STOL capability and the search for the flying car. *The Aeronautical Journal* 114 (1152), 91-102.

[2] Turcksin, T., P. Van Den Bossche and P. Hendrick. 2019. Battery Weight Optimisation for Hovering Aircraft. *8th European Conference for Aeronautics and aerospace Science (EUCASS).*

[3] Pan, G. and M. Alouini. 2021. Flying Car Transportation System: Advances, Techniques, and Challenges, IEEE Access, Volume 9 (2021).

[4] Newsroom. Aircar - The Flying Car Passed Flight Tests. Next Stop: Driving a New Market2020. www.kelvin-vision.com. Retrieved 07/06/2022

[5] Straubinger, A., R. Rothfeld, M. Shamiyeh, KD. Buchter, J. Kaiser and K. O. Plotner. 2020. An overview of current research and developments in urban air mobility – Setting the scene for UAM introduction. *Journal of Air Transport Management.* Volume 87.

[6] Abbott, I. H. and A. V. Doenhoff. 1959. Theory of Wing Sections. *Dover Publications, INC. New York.*

[7] Martinez-Val, R., P. Emilio and J. Palacin. 2005. Historical Perspective of Air Transport Productivity and Efficiency. *43rd AIAA Aerosapce Science Meeting and Exhibition*. AIAA 2005-121.

[8] Abrego, A. I. and Bulaga, R. 2002. Performance study of a Ducted Fan System. *NASA Ames Research Centre: Aircraft Propulsion and Power.*

[9] Senipek, M. 2017. Development of an Object Oriented Design, Analysis and Simulation Software for a generic air vehicle. DOI: 10.13140/RG.2.2.24882.15042.

[10] Vishwanathan, V., A. H. Epstein, Y. M. Chiang, E. Takeuchi, M. Bradley, J. Langford and M. Winter. 2022. The challenges and opportunities of battery-powered flight. *Nature* 601, 519-525.

[11] Bushell, K. W. 2003. Jet and Gas Turbine Engines. Encyclopedia of Physical Science and Technology (Third Edition).

[12] Sripad, S. and Viswanathan, V. 2021. The promise of energy-efficient bettery-powered urban aircraft. https://www.researchgate.net/.

[13] Epstein, A. H., Greitzer, E. M., Guenette, G., Kerrebrock, J., Paduano, J., Tan, C. S., and Waitz, I. 1998. MIT Gas Turbine Laboratory. Japan: N. p.

[14] Jansen, R.H. et al. 2019. High Efficiency Megawatt Motor Preliminary Design. *AIAA/IEEE Electric Aircraft Technologies Symposium.* Available at https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20190029589.pdf

[15] Remy Electric Motors: 'REMY HVH410-075-DOM ELECTRIC MOTOR brochure', 2011, Available at https://cdn.borgwarner.com/docs/default-source/default-document-library/remy-pds---hvh410-150-sheet-euro-pr-3-16.pdf?sfvrsn=7

[16] Siemens AG: 'Siemens develops world-record electric motor for aircraft', 2015, Reference number: PR2015030156COEN. Available at https://www.siemens.com/press/en/feature/2015/corporate/2015-03-electromotor.php?content

[17] Integration of Sustainable Aviation Fuels into the air transport system. 2022. A report by Aerospace Technology Institute.

[18] HY4 Aircraft Specification. https://www.aerospace-technology.com/projects/hy4-aircraft/ (retrieved 16/06/2022)

[19] HyFlyer Project Overview. https://www.emec.org.uk/projects/hydrogen-projects/hyflyer/ (retrieved 16/06/2022)

[20] Gardi, A. Kapoor, R. and Sabatini, R. 2017. Benefits and challenges of liquid hydrogen fuels in commercial aviation. International Journal of Sustainable Aviation. DOI: 10.1504/IJSA.2017.086845.

[21] Hydrogen Storage. 2022. Office of Energy Efficiency and Renewable Energy. https://www.energy.gov/eere/fuelcells/hydrogen-storage (retrieved 16/06/2022).

[22] eVTOL Aircraft Directory. https://evtol.news/aircraft. Retrieved 15/06/2022.

[23] What it takes to design an aircraft. 2020. https://lilium.com/newsroom-detail/lilium-architecture-design-principles (retrieved 13/06/2022).

[24] Gohardani, A. S. Doulgeris, G. and Singh, R. 2011. Challenges of future aircraft propulsion: A review of distributed propulsion technology and its potential application for the all-electric commercial aircraft. Progress in Aerospace Sciences. 47, 369-391.

[25] The Future of Transportation: White Paper on Urban Air Mobility Systems. 2020. Ehang.com.

[26] Volocopter Flies at Paris Air Forum. https://www.volocopter.com/newsroom/volocopter-flies-at-paris-air-forum/ (retrieved 16/06/2022).

DOI: 10.13009/EUCASS2022-7362

[27] Blended Wing Body – A potential new aircraft design. nasa.gov/centers/langley/news/factsheets/FS-2003-11-81-LaRC.html (retrieved 19/06/2022)

[28] Urban Air Mobility, Shaping the Future of Air Mobility. https://www.aurora.aero/urban-air-mobility/ (retrieved 15/06/2022).

[29] Zhang, L. Butler, T. L. and Yang, B. 2020. Recent Trends, Opportunities and Challenges of Sustainable Aviation Fuel. https://doi.org/10.1002/9781119152057.ch5.