Developments in the Federal Regulation of Personal Air Vehicles

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The objective of this paper is to enumerate the current regulatory framework that impede the development of the Personal Air Vehicle. (PAV). It covers a brief overview of US regulation and how it has affected technological development historically. It furthermore expounds on the current environment and the setbacks therein. It compares specific instances that currently exist as of 2022 and early 2023.

I. Introduction

PERSONAL AIR VEHICLE (PAV) development is a growing market in the aviation industry. With the advancement in battery technology, electric air taxis are becoming ever more feasible. These vehicles are envisioned in various shapes and sizes, being primarily electric, with many claiming to be the future. Companies like Boeing [1] and Airbus [2] are sponsoring development of these vehicles along with many new startups like Joby [3], Kitty Hawk [4], Wisk [5], Archer [6] and Jetson One. [7] With growing interest in PAV development, it has become clear that the current architecture of airworthiness certification standards and operational regulation are inadequate. In fact, the current standards and rules may actually hamper innovation. In the past, the regulatory environment changed to keep up with technological advancements. This paper will attempt to identify what certification requirements and operational rules need to change in order to accommodate the development of the personal air vehicle.

Personal air vehicles have many legal and technical obstacles to overcome. Safety, airspace management, noise, payload, and range are just a few of the challenges PAVs face. This paper will cover only some of the regulatory hurdles impacting PAV development. The technological complexities are a subject for other authors.

On one hand, any attempt to envision the legalities of future personal air vehicles appears difficult from our current viewpoint; analogous to the perspective of an individual from the early 1900's, who was the first person to own an automobile in his town. On the other hand, Federal Aviation law has been remarkably stable for nearly 100 years. The reader should understand that the initial attempts to regulate aviation stem occurred during the barnstorming era, where aircraft were not only small, short range and "personal" but were constructed from wood and fabric and powered by extremely primitive engines.

In this paper, we will show how durable many of the precepts from the 1920's have been and how this framework may be extended to cover emergent personal air vehicle technology. At the same time, we acknowledge that the concept of a personal air vehicle does not necessarily fit neatly into current established categories where a mature regulatory environment exists.

Consider this example which highlights the difficulty to define which set of certification and operational rules that PAVs fall under. A company proposes to design and built an autonomous, non-piloted, very light weight, personal air taxi. It will only carry one passenger and the passenger won't be a certified pilot. Therefore, it might be certified under 14 C.F.R. § 103 [8] due to the passenger not being a certified pilot. However, 14 C.F.R. § 103 is strictly for ultralight and recreational (i.e., non-commercial) vehicles; this PAV will be used for commercial air-taxi purposes. Alternatively, 14 C.F.R. § 107 [9] addresses unmanned aircraft systems operations but requires a remote pilot. The more general airworthiness requirements 14 C.F.R. § 23 [10] and/or 14 C.F.R. § 25 [11] address safety equipment and performance, but operation by a single or pair of certified pilots is implied. The PAV does not fit into any of these categories. How can this regulatory uncertainty be resolved?

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II. What is a Personal Air Vehicle

In order to clearly identify the certificate requirements surrounding PAVs, a PAV needs to first be defined. Defining the vehicle is a bit difficult as designs and concepts are constantly evolving.

The European Commission describes, "The personal air vehicle is analogous to the private car in terms of accessibility and ease of operation yet delivers the benefits of speed and routing efficiencies that are only possible via direct-to-destination flight. It differs from general aviation aircraft by making the air vehicle usable by non-pilot passengers." [12]

Other definitions of PAV refer to vehicles that are strictly single person operated with the operator not being a pilot. If a PAV is meant to provide the convenience of private car, then this could be catch all for all current Electric Vertical Takeoff and Landing (eVTOL) vehicle initiatives. If it is defined by the passenger quantity, being a "personal" vehicle, or their qualifications as or pilot or better stated as the lack thereof, then it would basically encompass smaller vehicles such as Hover-bikes or smaller single personal eVTOLs. [12]

PAVs like the Jetson One [7] and/or the Zeva Zero [14] are intended for individual personal usage, accommodating only one passenger. The larger eVTOLs like the VoloCity [15] or Wisk [5] are intended for two to five passengers and provide the convenience of direct point-to-point flying.

FIGURE 1 – Represents various PAV in development. [13][14][15]

The precise legal definition of a PAV as it currently exists within the C.F.R.s is still evolving. Commonly held definitions above ultimately identify two basic classes of vehicles. [15] One class that is for single occupants, and larger that provide ease of transportation for multiple passengers.

For this work, we will consider the intended usage of the vehicle and the quantity of passengers. This is done because of the wide swath of vehicles currently being developed that cross over into both definitions. Some being larger vehicles for multiple passengers and/or having a larger footprint while carrying a single occupant or a truly personal vehicle like hoverbikes. The definition of the vehicle is important because it will dictate the certification that would be sought after and therefore needing to change.

III. Personal Air Vehicles as opposed to Helicopters

Personal air vehicle development has been in works for 20 years. NASA in 2002 began the Personal Air Vehicle Sector Project. [16] In conjunction with NASA, the EU also began the early research in PAV but referring to them as the Personal Air Transportation. [12]

The idea of point-to-point transportation has existed even longer. In places like New York City, Sao Paulo, and Tokyo, where surface traffic is heavy, helicopters have been used to shuttle passengers from building to building for many years. [17] Urban heliports have been used to provide local access to helicopters since their inception; to this day New York city maintains three public heliports with full IATA and ICAO designations. [18] Many buildings have helipads to afford ease of transportation.

As useful as helicopters are, they do have limitations. Complexity, operation, and cost are some of the limitations. In order to operate helicopters, pilots are required, and pilots require many hours of training. There is no way a non-pilot can jump into a helicopter, pilot it, and fly to a destination safely. Chartering a flight is an option, but availability and cost are barriers to widespread, common use. Substantial ongoing intensive maintenance is a necessity, driving up hourly costs. In addition to maintenance and pilot training, fuel is also expensive. All these factors together make helicopters an expensive commodity. [19]

Contrasting the helicopter to the PAV, the modern PAV is envisioned as an electric aircraft with enhanced capabilities that distinguish it from a classic helicopter. NASA states that, "The development of distributed electric propulsion (DEP) appears to enable cheap, quiet, and reliable short-range VTOL aircraft. Indeed, a substantive operating cost improvement is hypothesized as a result of decreases in the cost of energy for flight propulsion, reduced maintenance hours, and reduced unique part count for

eVTOL aircraft." [20] In the same report, they say, "This is why, with DEP, a new era of transformational vertical flight could commence with flying cars being a "hot ticket" item of late." [20]

Since 2010, many researchers, companies, and startups have started to work on eVTOL aircraft solutions. [20] Today, most of the major aircraft companies are directly developing their own eVTOL aircraft or have subsidiaries doing it. [1] [2] Uber, with its Uber Elevate program, coordinated the development eVTOL aircraft and their operations [21]; before winding up development and transferring most assets to Joby Aviation. [22]

NASA said, "Aircraft manufacturers such as Kitty Hawk (US) [4] have developed and is now testing two vehicles: Cora, the lift cruise air taxi and the Flyer, a hoverbike. Lilium (Germany) [23] has developed different electric ducted fan eVTOL prototypes, including a two- and a five-seater air taxi). [24] Joby Aviation (US) has performed tests on electric propulsion and is building an eVTOL prototype. [3] PAL-V (The Netherlands) has developed the world's first flying car production model (see https://www.pal-v.com/)." [25] [20]

The competition with helicopters does not mean that PAVs or future eVTOLs will replace them anytime soon. Although there is substantial cross over in operation and work, the helicopter will still have missions that eVTOLs cannot fulfil. Currently, combustion engines provide for longer flights, heavier load carrying, and better all-weather performance.

Similar to helicopters in current urban heliport operations, PAVs of larger sizes, akin to multi-passenger eVTOLs, are anticipated to operate in urban areas. The effort to modernize communities and prepare for the implementation of PAVs into local level usage is called Urban Air Mobility. (UAM).

Ehang, a current PAV development group, worked to describe UAM in a White Paper in 2020; see FIGURE 2.[26] Ehang wrote, "Urban Air Mobility (UAM) as a concept was defined by NASA as 'safe and efficient air traffic operations in a metropolitan area for manned aircraft and unmanned aircraft systems' (Urban Air Mobility

Airspace Integration Concepts and Considerations). With governments, enterprises and research institutes paying increasing attention to UAM, this new concept has caught on quickly." [26]

"As a disruptive industry, UAM is expected to revolutionize existing transportation modes including on highways, railways, airways, and waterways. A 2018 Morgan Stanley blue paper estimates that the global UAM addressable market would reach US$1.5 trillion by 2040." [26][27]

FIGURE 2 – Ehang PAV concept [26]

"As the size of urban populations grows, traffic congestion and air pollution remain as major threats that take a toll on economic growth. It is imperative for governments to seek alternative solutions by making strategic moves to promote UAM system development as an alternative to existing ground transportation." [26]

Ehang also summarized the key differences in UAM using PAVs and the current airline model. [26] Although they serve two different purposes, the comparison still provides some insight to the basic understanding of PAV operations. They show that:

> "Flight range – UAM provides short-to-medium range (3km – 100km) air services designed for city residents, effectively solving the "last-50km" problem that current airlines cannot offer.
>
> Flight elevation – The short distances covered by UAM means that vehicles remain at below 800 meters. They therefore will not interfere with airspace trafficked by traditional airlines at an altitude of 8,000-12,000 meters.
>
> Command-and-control system – A centralized command-and-control platform makes UAM trips completely autonomous. While autopilot techniques are being developed for the airlines, it may still take time for traditional aircraft to be completely autonomous.
>
> Power system – The fully electrically-powered motors with zero emissions make UAM vehicles more eco-friendly than the traditional aircraft, which run on jet fuel.
>
> Capacity – One-and two-seater UAM vehicles allow for more privacy and quietness for passengers than normal flights, which carry up to 500 passengers at a time" [26]

Considering all the increasing interest in PAV and UAM in the last few years, it would make sense that the associated laws and regulations are still evolving. PAV development is projected to be a large market, with many innovators eager to be at the forefront. NASA sponsors development of the PAV. Within the industry developers, competition is already heavy. Uber Elevate was trying to roll out the PAV as soon as they can. Even so, the introduction of PAV operations must be measured. [28]

IV.Why do we Regulate in the First Place?

Law and aviation technology have been entangled since the inception of our republic. Although the law of the air is not expressly called out in our Constitution, its omission was not due to ignorance. On November 21, 1783, Benjamin Franklin was in Paris, France and personally observed the Montgolfier brother's first manned hot-air balloon flight. [29] Franklin may not have been aware that the pilots averted near disaster when their balloon envelope began to smolder and catch fire. [30] Although the press acclaimed this first manned flight as a success, it could have ended in tragedy with the balloon either striking houses or catching on fire. Airships, balloons and aircraft cause considerable personal and property damage wherever they crash.

The need for comprehensive Federal aviation law became evident in the aftermath of the First World War. During this conflagration, it became abundantly clear that aircraft could be used for offensive as well as defensive use. Airships and airplanes crossed international boundaries at will. Airships and airplanes caused considerable personal and property damage wherever they attacked.

Upon the conclusion of hostilities, members of the peace conference authored a draft *International Convention Relating to the Regulation of Aerial Navigation*. [31][32] Among its provisions was an agreement that every Nation-state "has complete and exclusive sovereignty in the air space above its territory and territorial waters." [31] Although the United States never ratified this treaty, it serves as the foundation of modern American aviation law.

A. Modern Federal Aviation Law Traces Its Roots to the Air Commerce Act of 1926

The United States was founded on a unique Federal form of government. Because Federal aerial jurisdiction is not expressly enumerated in our Constitution, any national aviation law must consider States' rights. [33] During the 1920's, a legal consensus developed that a large amount of uncertainty might be eliminated if aviation law were to be trifurcated to comprise: 1) common law (at the Federal and State level), 2) statutory law (at the Federal and State level) and 3) regulatory law. [34] At the time experts drafted the *Air Commerce Act of 1926*, United States aviation law lacked any form of Federal regulation. [35] It had developed unevenly in only two directions: common (i.e., "judge-made") law from state and local court holdings and statutory (i.e., codified regulations arising from the legislature of from a governmental agency following prescribed rulemaking procedures) law enacted at the state level. [34] Nonetheless, from the very start, American Federal aviation law broadly incorporated ideas enumerated in the draft *International Convention*. [32]

Our current system forms a practical compromise consistent with American Federalism: the national government promulgates regulatory legislation for design, manufacture and operations, while state and local governments promulgate non-regulatory legislation for enforcement.

Subsequently, Congress passed the *Civil Aeronautics Act of 1938*, [36] the *Federal Aviation Act of 1958 [37]* and the *Department of Transportation Act of 1966*. [38] These Acts administratively reorganized the Bureau of Air Commerce ultimately into the Federal Aviation Administration. Despite the changes in name, the scope of agency regulations has remained remarkably consistent and broad.

B. A Broad Federal Regulatory Framework for Flight Has Been in Place Since 1926

Since 1926, local governments enforce owners, mechanics and pilots compliance with the law. [39] The national government, represented by the Federal Aviation Administration, regulates the design, maintenance and operation of all manned aircraft. [39]

Today congressional authorization for the Federal Aviation Administration is found in Title 49 of the United States Code. [40] The general policy of the FAA (part of the Department of Transportation) has been to maintain safety "as the highest priority in air commerce." [40] Historically, Congress intended the FAA to move cautiously to "maintain the safety vigilance that has evolved in air transportation … and has come to be expected by the … public." [40]

Under the commerce authority granted by the constitution, federal regulations impact: 1) the instrumentalities of aviation (the aircraft), 2) the airmen involved in the operation of the aircraft (the pilots and the mechanics), and 3) the rules of the sky. [41][42][43][44] When the FAA certifies designs as to their inherent airworthiness, [45] the burden of proof falls upon the designer and the manufacturer. When the FAA certifies a repair station, the burden of proof demonstrating skilled workmanship falls upon the individual business. [46] When the FAA certifies pilots (this could be extended to certify a robotic AI pilot), the burden of proof demonstrating safe operation falls upon the individual. [47]

C. The Federal Regulatory Framework Has Always Been Flexible

Historically, certification standards for aircraft have been based on size and capability. 14 C.F.R. § 23 regulates "general aviation" aircraft suitable for personal and commercial flight that weigh less than 17,500 pounds, fully loaded. [48] 14 C.F.R. § 25 regulates aircraft of any size suitable for commercial "transport category" operations. [49] 14 C.F.R. § 27 regulates helicopters that weight less than 7,000 pounds fully loaded. [50] 14 C.F.R. § 29 regulates larger, "transport category" helicopters. [51]

Traditionally, Congress gave the FAA flexibility to "grant an exemption from a regulation prescribed … when the Administrator decides the exemption is in the public interest." [52] When faced with a "nonconventional aircraft" to certify, existing regulations encourage the FAA to use its discretion to mix and match regulations from existing standards. [53] Where no existing text addresses a proposed technology, further regulations permit the FAA to prescribe, on a case-by-case basis, "special conditions and amendments." [54]

There seems to be little reason for the FAA not to certify an airworthy PAV: the agency "has a process and regulations in place for certifying any new aircraft type." [55] Moreover, most existing certification regulations neither differentiate between the commercial or non-commercial utility of a design, nor explicitly require a pilot to be aboard the aircraft. [48][49] 14 C.F.R. § 103 for Ultralight Aircraft is a notable "exception that proves the rule;" it has relaxed standards for the design and operation of short range, low speed, low altitude, light weight aircraft used solely for personal non-commercial flight. [8]

It is understandable that the FAA would be reluctant to certify aircraft which clearly do not conform to promulgated regulations. It is also understandable that PAV start-up designers would find certification daunting and/or costly. However, we must remain vigilant and avoid being deluded to think that PAV systems are exceptional and don't need to satisfy established requirements (or their analogies) for airworthiness, maintenance and operation that other flying machines are subject to.

Federal regulation of aviation relies upon the Commerce Clause of the Constitution.[55] Because "Federal regulation of interstate and foreign commercial air navigation would accomplish little unless it applied to … corresponding regulation of intrastate and non-commercial air navigation," each state voluntarily adopted a "uniform state law for aeronautics" that "expressly prohibits the navigation of any aircraft otherwise than in conformity with the [Federal] air traffic rules." [56] Thus, since 1926 the United States operates under a uniform Aviation law system. Federal rules are "applicable to all flying, commercial, non-commercial, intrastate and interstate." [57] This situation "obviates the necessity of a separate State inspection, licensing and approval system with its attendant difficulties, complications and expenses." [56]

D. The Current Federal Regulatory Framework Has Withstood Many Legal Challenges Over 100 years

Future PAV regulations will need to address two broad issues: 1) does the FAA have the authority to regulate the design and manufacture of PAV aircraft based upon the airworthiness of the design? 2) does the FAA have the authority to regulate the operation and maintenance of PAV aircraft for use in and beneath Federal, navigable airspace? The answer to each question is **yes**.

Because Federal Aviation Regulations were initially promulgated during the *Lochner* era of Commerce Clause jurisprudence, the power of the FAA to regulate aviation traces to an older, narrower view of Congressional power. Although the Court's recent holding in *NFIB v. Sebelius* narrowed the constitutionally permissible breadth of Commerce Power of Congress, [58] from the more expansive view granted by *Wickard v. Filburn,* [59] most Federal Aviation Regulations will never exceed the commerce power of Congress.

Shortly after President Coolidge signed the *Air Commerce Act of 1926* [35] into law, its constitutionality was challenged. In *Swetland v. Curtiss Airports*, the Sixth Circuit Court held that "there can be no doubt of the power of Congress to authorize the Secretary of Commerce to promulgate regulations … [;]such regulations have the force of law."[60] Similarly, in *Neiswonger v. Goodyear*, the District Court held that the Federal Aviation Laws would apply to intrastate commerce insofar as was "necessary." [61] *Neiswonger* invoked the Supreme Court's ruling in *Railroad Commission of Wisconsin*, a late *Lochner*-era case affirming the Federal power to regulate instrumentalities of intrastate commerce when they are also used as instrumentalities of interstate commerce.[62] Thus, the FAA has clear authority to regulate the design and manufacture of aircraft – with human or robotic pilots – used privately as well as in inter or intra-state commerce.

Historically, Congress did not intend for the FAA to hamstring technological development. The FAA is supposed to encourage developments in "civil aeronautics, including new aviation technology." [63] When the *Air Commerce Act of 1926* was enacted, aircraft were made of wood and cloth; radio communication was limited to long-wave amplitude modulation transmissions; instruments were made using jewels, brass and leather. Today, after 96 years of pervasive regulation, aircraft are made from exotic alloys and graphite-epoxy composites; they feature sophisticated air-to-ground, air-to-air and satellite-based communications systems; they may be controlled by intricate computer systems. Commercially successful, technologically advanced flying machines arose as the byproduct of regulation. Provided that PAVs can be made truly airworthy, the FAA should be able to certify them for use in commerce.

The Federal Government regulates controlled airspace (class A, B, C, D and E) more than 1,200 feet above ground level as an instrumentality of interstate commerce; see FIGURE 3. [64]

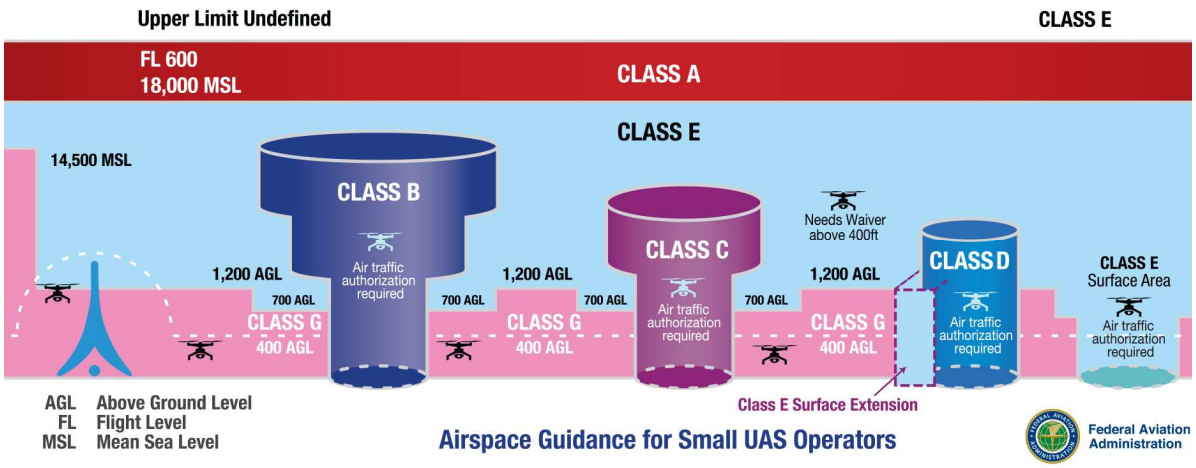

FIGURE 3 – FAA Airspace Jurisdiction

The Federal jurisdiction of uncontrolled Class G airspace has been subject to some controversy. Common law holds that a "landowner's rights are not limited to the surface of the earth but extend into the space above it;" [60] that it is a "trespass to thrust one's arm into the space over a neighbor's land." [65] One hundred fifteen years ago, the Supreme Court held that that the shooting of ordinance across the land of an adjoining owner constituted a trespass. [66] Thus a trespass occurs when someone "fire[s] a missile … or drive[s] an airplane through the air, over the land of another, sufficiently low to invade that space which the owner of the soil may effectively possess." [67]

In *Swetland*, the Sixth Circuit Court held that a landowner [does not have] "the exclusive right to occupy all of the air space above his property to an indefinite extent. [60] However, "passage through the air space superjacent to land, at a height beyond that at which the owner of the soil can exercise effective possession, will not be treated as a trespass, though dropping objects onto the land, or falling onto the land would constitute such trespass."[60] Because Federal regulations in effect at the time of that suit expressly regulated safe flight to a minimum altitude of 500 feet, [68] the Court ruled that the plaintiffs could obtain relief enjoining the defendants from "navigating over the property of plaintiffs or any part thereof unless at altitudes of 500 feet or in excess thereof." [60]

PAV operators should take note that if they fly an aircraft less than 500 feet above the ground, they risk potential liability in state or local court. Legal damages may be sought based upon a nuisance or trespass theory. Local property rights do not fully preempt Federal regulation because the FAA is specifically expected to control "the use of the navigable airspace and regulate[e] … operations in that airspace in the interest of … safety and efficiency." [63] Case law does not question the authority of the Federal Government to regulate the national airspace from earth to the heavens.

Because the precise lower boundary of Federally regulated airspace is vague, the FAA has "fuzzy" jurisdiction over operations under 500 feet. Moreover, the arguments of the 1920's-era Federalism debate over airspace have largely receded from the public's eye. Nonetheless, current jurisprudence seems to indicate that new Federal regulation of commercial PAV operations in uncontrolled non-commercial airspace (i.e., below 500 feet AGL) is immune to a challenge as an act that exceeds the Commerce power of Congress. [69]

V. Regulatory Considerations for PAV's

Dan Elwell, acting administrator for the FAA 2018-2019, spoke at the Uber Elevate conference in 2019 and said, "We understand your desire to sprint out of the starting gate, but you have to understand our safety mandate. Let's begin this integration by working with industry to start crawling, with low-risk operations in remote areas, gathering data and evaluating safety all the while. When we're ready, we'll systematically graduate to high-density urban areas with semi-autonomous operations – the walking phase. And, eventually, the system will mature to fully autonomous operations in busy urban airspace – running. And that's where – given the level of safety that we have in the National Airspace System – we can't fail." [70]

The current airspace usage is made up of mostly airplanes and helicopters. *FlightAware.com*, [71] a website that tracks aircraft, shows an average of about 9700 aircraft in the air at any given time. [72] Commercial aircraft usually fly between 18,000 feet MSL and 41,000 feet MSL (FL180 through FL410) which is well beyond the current flight envelopes of PAVs. [74] It is projected that

air traffic will increase dramatically. However, many aircraft, mostly helicopters, fly in the uncontrolled airspace close to the ground.

Airbus says, "By 2030, 60% of the world's population will be urban. This significant population growth is expected to create a real need for innovative mobility options as ground infrastructure becomes increasingly congested. Providing people with a safe, sustainable and convenient solution that leverages the airspace above cities could be a solution." [2][20] In the airspace where PAV are anticipated to operate, which currently has little air traffic, traffic volume will increase as PAV begin to share that airspace with other users. With the predicted increase in operations, it would be most prudent to regulate the vehicles.

The current expansion of the PAV is illustrated in a NASA White paper. [20] Note that it refers to eVTOLs which are used to describe PAVs. The paper states how the increase in demand is driving the need for and their responsibility to develop the aircraft. It says, "According to the 2019 Annual Review of IATA (International Air Transport Association), due to an expected increase in air transport traffic by 5% every year and a doubling of air transport passenger numbers to 8.2 billion by 2037, significant challenges are posed to the aviation industry. Furthermore, this report does not factor in the expected demand for shortrange (intra-city) air transportation, which is in development and yet to be operational. The increased demand to fly creates a responsibility to expand in a sustainable manner and an endeavor to develop more environmentally friendly aircraft. eVTOL aircraft, either piloted or autonomous, is gathering considerable interest worldwide. Modern and novel full-electric or hybrid-electric eVTOL configurations enable a new paradigm shift in air transportation as the aviation industry remains committed to its goals of carbon-neutral growth from 2020 onwards and cutting CO2 emissions to half 2005 levels by 2050."

The conclusion by NASA is that they need to help lead the development of the PAV and be on the forefront of innovation in order to lead in the regulation and operation of the vehicles. This is concluded in their own words. "The revolutionary infrastructure currently being built for on-demand urban eVTOL aircraft needs to be considered for the next decades of Public Services operations. For a future safe and efficient air transportation system in Public Services, we need to fully comprehend and predict this urban air transportation of the future." [20]

The safety oversight is maintained by the FAA. For the PAV to be used to its fullest extent, it must be able to prove its safety, durability, and survivability. This is illustrated in FIGURE 4 from a VTOL.org presentation in regard to a similar topic. [73]

It is interesting to note that for vehicles where there is low public demand for safety, there is less corresponding regulation. Conversely, it illustrates how society won't utilize mass transportation vehicles when there isn't a high expectation safety. In the case of 14 C.F.R. § 25 Transport Category aircraft, they are the most highly regulated due to public demand for an extremely high level of safety. This will be similar to the public safety demands for Urban Air Mobility.

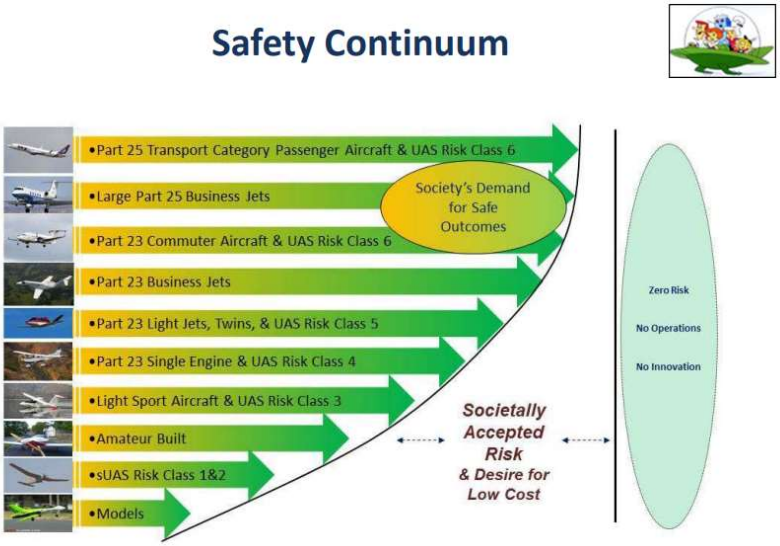

FIGURE 4 – Diagram shows how public demand on safety correlates to the level of interaction with vehicle. [73]

Since public safety oversight is the responsibility of the FAA, it would be in its best interest to regulate operations. With possibly hundreds of vehicles sharing the same airspace in uncontrolled environments a very hazardous situation could develop. A harmonized set of operational rules are imperative to creating a safe airspace system. The UAM efforts include attempts to regulate this emerging challenge.

The objective of PAV and the UAM Transformation is to provide on demand point-to-point transportation. The initial vision would include localized centers in which people may be able to catch an air taxi, similar to a bus stop or taxi stand. This increase in air traffic will drive the need for a safe airspace environment, and some sort of traffic control. Hence regulation will be necessary to ensure that all the vehicles are operating on the same set of rules with the same standards, even though they may be different in their own designs and capabilities.

Aviation administrators have begun developing methods to regulate PAV and UAM operations. The FAA has the new Unmanned Aircraft System Traffic Management (UTM), the EASA and started the "Special Condition for Small-category VTOL Aircraft," and worldwide, there is JARUS or Joint Authorities for Rulemaking Unmanned Systems. All these regulatory bodies are beginning to incorporate oversight into unmanned systems and PAV, in accordance with their responsibility to provide a safe airspace. [26]

Ehang has already partnered with the Chinese megacity Guangzhou. They say, "The government of the Chinese megacity of Guangzhou recently entered into a strategic agreement with Ehang for UAM development. This cooperation may make Guangzhou the first city to launch real passenger UAM services in the world… In general, we see three key factors as critical in determining the success of the UAM industry: regulations, technology and capital." [26] Here it is evident that they believe that regulation could either impede or enhance the success of UAM and the PAV.

VI. What are the Certification Requirements?

The Code of Federal Regulations (C.F.R.) Title 14 covers the government standards for Aeronautics and Space. While regulations cover broad topics, rules get into the details. The regulations of the C.F.R.s are comprised of many very specific, detailed rules. These rules are what are used to regulate and enforce aviation law. The regulations found in C.F.R. Title 14 are used for certifying an aircraft as Transport Category, Normal Category, Ultralights and Recreational Vehicles, and small Unmanned Aerial Systems.

PAVs have roadblocks to their development with current regulations providing some unique issues. The regulations control key aspects of the vehicle and, based on the characteristics and intended usage, will be placed into one of the C.F.R. certification categories, such as Normal, or Transport, etc. If the vehicle does not fit neatly into one of the legally defined categories, it may not be able to operate.

14 C.F.R. § 21.17(b) states that, "For special classes of aircraft, including the engines and propellers installed thereon (e.g., gliders, airships, and other nonconventional aircraft), for which airworthiness standards have not been issued under this subchapter, the applicable requirements will be the portions of those other airworthiness requirements contained in Parts 23, 25, 27, 29, 31, 33, and 35 found by the FAA to be appropriate for the aircraft and applicable to a specific type design, or such airworthiness criteria as the FAA may find provide an equivalent level of safety to those parts." [75] This qualifier would appear as a catch all for all "nonconventional aircraft." However, it is important to see that 14 C.F.R. § 103 is not included. This is important as many smaller PAVs that are similar in size to hoverbikes may not be certified under 14 C.F.R. § 23, 25, 27, 29, 31, 33, and 35. Therefore, they may have specific issues related to their operations. A direct comparison to 14 C.F.R. § 103 will be addressed herein as to the potential applicability that it may have.

Furthermore, 14 C.F.R. § 103 is used for unregulated aircraft and defines what they are. [8] However, a PAV similar in size to a hoverbike provides a unique issue in regard to whether they too will need to be regulated. The question of whether they need to be regulated for commercial operation is unclear.

Hoverbikes are intended such that they may be owned and operated by a private individual, in controlled airspace and overpopulated areas. There are companies offering hoverbike type PAVs for sale as potential commuting vehicles. At this moment their integration into the C.F.R.s is unclear.

It is our opinion that the definition of hoverbike will need to be decided regardless of operational intent. It will need a C.F.R. equivalent and as it stands; 14 C.F.R. § 103 is the most similar. [8] 14 C.F.R. § 21.17 will allow for adaptation of regulation of the emerging eVTOL and PAV operations based their similarities to 14 C.F.R. §§ 23, 25, 27, 29, 31, 33, and 35. [75] Other PAVs sized similar to hoverbikes could be compared to 14 C.F.R. § 103 requirements based on their similar characteristics.

We discuss 14 C.F.R. § 103 in further detail. It is used for regulation of uncertified, recreational, and ultralight aircraft. Even though it is used for operation of uncertified aircraft, it is still used in defining the vehicle. Hence, a comparison to hoverbikes is still valid as it could substantiate the possibility of a regulated definition.

A. Single Occupant PAVs do not easily fit within existing 14 C.F.R. § 103 regulations

14 C.F.R. § 103 controls the requirements of Ultralight Vehicles. [8] Part 103 is considered here due to its "intended use" applicability. It is furthermore considered because the Jetson One PAV is intending to be certified as a Part 103 aircraft. It is therefore a perfect example of the obstruction to development that current C.F.R. regulations present to PAVs of similar size.

14 C.F.R. § 103 states that it, "is used or intended to be used for manned operation in the air by a single occupant. This would cover the Jetson One design and other similar hoverbike or vehicles like Zeva Zero. Zeva Zero is also pursuing an experimental vehicle as of the date of writing, subject to change. However the usage of these vehicles have no conflict with Part 103.1 (a). [8]

14 C.F.R. § 103.1(b) says, "Is used or intended to be used for recreation or sport purposes only." [8] Here is the first point of conflict. In the case of Jetson One, they make no overt claim for it to be the next air taxi or used in cases outside of recreation. However, they have images of the vehicle in a driveway of a suburban home. [7] Thus, potentially indicating that a use may be in commuting or over civilian populations. Zeva Zero on the other hand, states that their vehicle will be "multi-mission capable." They say it can provide first responder, search and rescue, law enforcement, and cargo delivery. [14] None of these operations can be considered recreational. So, in the case of Zeva Zero the recreational condition would have to be waived.

14 C.F.R. § 103.1(c) states that it, "Does not have any US or foreign airworthiness certificate." [8]

This is hard in comparing whether the hoverbike or similar sized vehicle will require as much. Further regulation may be needed in order for the vehicles to operate over civilian areas. This restriction could be problematic.

14 C.F.R. § 103.1 continues, “(e) if powered (1) weighs less than 254 pounds empty weight, excluding floats and safety devices; (2) has a fuel capacity not exceeding 5 US gallons; (3) is not capable of more than 55 knots calibrated airspeed at full power in level flight; (4) has a power-off stall speed which does not exceed 24 knots calibrated airspeed.” [8] Fuel capacity will not be an issue considering that these mostly are electrically powered. Since most of these vehicles are vertical take-off and landing, and are hover capable, there is no power-off stall speed. The major issue here will be in regard to the weight.

Many of the PAVs exceed the 254-pound empty weight requirement in powered flight. The Jetson One weighs about 400 pounds fully loaded, with an empty weight of 190 pounds. [7] Zeva Zero weighs around 700 pounds fully loaded, with no empty weight published. Assuming a payload capacity of 300 pounds, the empty weight will be at least 400 pounds, most certainly exceeding the 254-pound regulatory limit. However, in the case of weight there is a qualifier. That being the exclusion of safety devices. Those may be hard to distinguish between the chassis and frames, safety harnesses, parachutes, etc. on such small vehicles. Therefore, this weight requirement may also require a waiver for operation.

Furthermore, the speed requirement may also need be waived for these operations. The Jetson One claims that it will cruise 63 mph or 54.7 knots which is barely on the edge of the limit. [7] The Zeva Zero will cruise at 160 mph or 139 knots which exceeds the requirement substantially. [14] The speed range of vehicles of this size can vary and may not fall under the Part 103 operations stipulations.

Of the eight sections of 14 C.F.R. § 103.1 Applicability section, PAVs of these sizes would need at least four sections waived. Up to two more sections may require waivers if they decide to be autonomous for some portion of the flight. That would be half or more of the sections of Applicability alone for usage as a Part 103 vehicle.

14 C.F.R. § 103.7(a)-(c) have a huge impact on why one would want to be defined as a Part 103 vehicle. The reason is found more specifically in 14 C.F.R. § 03.7 (B). It says, “Notwithstanding any other section pertaining to airman certification, operators of ultralight vehicles are not required to meet any aeronautical knowledge, age, or experience requirements to operate those vehicles or to have airman or medical certificates.” [8] The ability to have the operators not required to be airman or hold a medical certificate is why applicability to this section is desirable.

Jetson One says on their website, “Jetson is a Swedish company with a mission to change the way we travel. We aim to make the skies available for everyone with our safe personal electric aerial vehicle…That project resulted in Jetson ONE, a commercially available personal electric aerial vehicle that you can own and fly... We intend to make everyone a pilot.” [7] Here it is clear that they want everyone to fly. Therefore 14 C.F.R. § 103.7 would be key due to its inherent advantage to their mission objective.

If the waivers required for the Part 103.1 operations were granted, would Part 103 provide any more impedance as is? Yes.

14 C.F.R. § 103.9(a) states, “No person may operate any ultralight vehicle in a manner that creates a hazard to other persons or property.” [8] 14 C.F.R. § 103.9(b) says, “No person may allow an object to be dropped from an ultralight vehicle if such action creates a hazard to other persons or property.” [8] This section wouldn’t need to be waived as much as considered in the design process and may be hard to ensure. This subject is similar to the safety subject, which is kind of hard to comprehend when the environment is still developing. In the case of the Jetson One, which has similarities to vehicles like the Malloy Aeronautics Hoverbike or the Fly Cart, the open frame isn’t conducive to preventing objects falling from the vehicle. This requirement may need to adapted or be waived for individual designs.

14 C.F.R. § 103.11 and 103.13 wouldn’t provide any issues but 103.15 would conflict with the intended use. 14 C.F.R. § 103.15 states, “No person may operate an ultralight vehicle over any congested area of a city, town, or settlement, or over any open-air assembly of persons.” [8] With the intended use of the aforementioned PAVs being used in direct point to point transportation over cities and congested areas, like the use case for Zeva Zero, the 14 C.F.R. § 103.15 restriction would come in conflict with the PAVs objectives and mission. This would be needed to be waived for the PAV operations.

Likewise, the 14 C.F.R. § 103.17 – Part 103.21 would be providing some push back. These areas are 14 C.F.R. § 103.17 – Operations in certain airspace, 103.19 – Operations in prohibited or restricted areas, 14 C.F.R. § 103.20 - Flight Restrictions in the proximity of certain areas designated by notice to airman, 14 C.F.R. § 103.21 - Visual reference with the surface, and 14 C.F.R. § 103.23 - Flight visibility and cloud clearance requirements. [8] These areas can’t be waived like other previously mentioned requirements, but they would require a lot of work to implement and adhere to.

Considering 14 C.F.R. § 103.17, it says, “No person may operate an ultralight vehicle within Class A, Class B, Class C, or Class D airspace or within the lateral boundaries of the surface area of Class E airspace designated for an airport unless that person has prior authorization from the ATC facility having jurisdiction over that airspace.” [8] The usage of PAVs and the airspace management is a topic that could be consider in its own paper. Segregating the airspace is very complex and in regards to this paper could be considered an impediment.

In the above cases, waivers are not necessary. These circumstances only require authorization for operation. Such operations within controlled airspace will require a real-time air traffic control authorization, hence the complexity. If the PAV has no way to receive authorization, it cannot operate therein. Furthermore, with the increase in airspace congestion, such authorizations may become hard to manage. Aircraft separation through all airspace classes will be difficult especially when dealing with autonomous vehicles and the everyday common passenger who is not a pilot. Operators will have to adhere to FAA requirements and PAVs will not be

exempt in operation. Therefore, an architecture for operations within controlled airspace will need to be developed to allow for widespread use and implementation of PAVs in such areas. These controlled airspace environments tend to be over and around the congested urban areas where the PAV could be most useful. This is also an issue seeking solutions by UAM advocates.

Upon review of 14 C.F.R. § 103 we see that vehicles such as the Zeva Zero and Jetson One are likely to be overweight, too fast, autonomous in some cases, and intended to be used outside of the definition of the Part 103. Most situations can be waived, but if more than half of the Applicability section needs to be waived for operation, is it still applicable? That is up for debate. It could be concluded that although relevant and applicable due to the single pilot operator and lack of pilot requirements therein, the PAV does not meet the ultralight definition and therefore needs its own standards.

B. Multi-Occupant PAVs will need to be certified under 14 C.F.R. § 23 inspired rules

Because PAVs can be defined as vehicles that carry a single passenger or provide the convenience of point-to-point transportation. This basically covers two vehicle sizes, hoverbikes or similar sized vehicles and larger multi passenger vehicles. The previous part relates the personal smaller vehicles and primarily to the Part 103 requirement. This was done because some claims have been made that the PAVs will try to classify as an ultralight. As we saw above, smaller personal vehicles might fall under Part 103 as is but require partial regulatory exemption and waivers. However, the larger PAVs, those carrying more than one passenger, or retaining a larger footprint, will be difficult to compare due to the lack of official definition.

14 C.F.R. has multiple parts to address diverse aircraft types; 14 C.F.R. § 23 – Airworthiness Standards: Normal Category Airplanes; 14 C.F.R. § 25 – Airworthiness Standards: Transport Category Airplanes; 14 C.F.R. § 27 – Airworthiness Standards: Normal Category Rotorcraft; and 14 C.F.R. § 29 – Airworthiness Standards: Transport Category Rotorcraft. None of these sections clearly describe personal air vehicles under current development.

The definition section of the C.F.R. do not include any description of a PAV. They include the idea of "non-standard" aircraft which provide some leeway. However, in order to identify the legal impediments, the definition or simple identification of applicable regulation needs to be done.

FIGURE 5 – Airbus "CityBus"

In July of 2019, the Airbus CityBus received a "EASA SC-VTOL Enhanced Category" in Europe; see FIGURE 5. [76] The EASA SC-VTOL Enhanced Category from the European Union Aviation Safety Agency (EASA) is important to the development of this new vehicle category. The special condition for small category VTOL aircraft says, "The Agency has received a number of requests for the type certification of vertical take-off and landing (VTOL) aircraft, which differ from conventional rotorcraft or fixed-wing aircraft. In the absence of certification specifications for the type certification of this type of product, a complete set of dedicated technical specifications in the form of a special condition for VTOL aircraft has been developed. This special condition addresses the unique characteristics of these products and prescribes airworthiness standards for the issuance of the type certificate, and changes to this type certificate, for a person carrying VTOL aircraft in the small category, with lift/thrust units used to generate powered lift and control." [76]

The description of the "special condition" is not unique to only the Airbus PAV. The description states that they "differ from conventional or fix-wing aircraft." [76] It furthermore states why the special condition is needed and says, "In the absence of certification specifications." [76] This clearly indicates that the EASA did not have any current specifications for these PAVs. The Airbus CityBus [77] falls in a similar size category and operation as others like the Archer eVTOL, [78] Volocopter X2, [79] Bell Nexus, [80] NextGen, [81] and EmbraerX.[82]

The special condition by the EASA paved the way for future development but clearly identifies the lack of definition within the current regulatory framework. Just as the smaller PAVs, like the hoverbikes and such, have issues fitting in to the Part 103 definition, the larger vehicles requirements were drawn from requirements similar to other vehicles. For the special condition case for the CityBus, it is said that "The VTOL Special Condition is largely based on EASA's Certification Standard (CS) for Normal, Utility, Aerobatic and Commuter Category Aeroplanes (CS-23 Amendment 5), along with elements of its rules for Small Rotorcraft certification (CS-27) 'where deemed appropriate'." [76] The appropriation of existing requirements of similar performing aircraft indicates both the limitations of regulation but the adaptability of it.

As of May 2020, the EASA published a "Proposed Means of Compliance with the Special Condition VTOL." This document is meant to help provide further clarity to the topic of VTOL aircraft. The website eVTOL.com reported on this and said, "European Union Aviation Safety Agency (EASA) has now published its 'Proposed Means of Compliance with the Special Condition VTOL.' This gives further clarity on the certification pathway being formed in Europe for novel eVTOL aircraft… The accompanying statement of issue explains that the means of compliance (MOCs) are meant to address applicant's requests for clarification of how EASA interprets the safety and design objectives in SC-VTOL. Some of the MOCs may be considered to be

guidance material to assist with understanding an objective, rather than providing the sole means of compliance. The aim is to establish a level playing field that ensures that a comparable safety level is achieved by all designs…. As the concepts continue to develop, it is expected that SC-VTOL and these means of compliance will morph into a new certification specification (CS)." [83]

An article from eVTOL.org compares the EASA and the FAA to the approach by which the plan to certify and regulate PAVs. [84] The article goes on to say, "The approach of the U.S. Federal Aviation Administration (FAA) is radically different in execution from that of EASA, but not in objective. Rather than starting off with a one-size-fit-all approach, the provisions of 14 Code of Federal Regulations C.F.R. § 21.17 (b) will be used for a more tailored process. After a detailed evaluation of the concept of operations for a particular aircraft, the FAA will then stipulate what certification standards must be used, extracted from 14 C.F.R. § 23, 25, 27, 29, 31, 33, and 35." [75][84]

The approaches of the FAA and EASA show that the PAV is still being defined. This fluid definition is showing how the law is limiting advancement and needs to evolve to meet the current demands. Patrick Ky, executive director of EASA said, "We are actively engaging with the industry to develop the *right technical requirements* to take benefit of the new technologies bringing safety and environmental benefits to the community," [84] The emphasis here is the active engagement and the term "right technical requirements." This would imply that they are still defining the vehicles. A major issue with the FAA approach, is the potential lack of consistent implementation requirements. If 14 C.F.R. § 21.17 is used as a case-by-case basis in conjunction with industry partners, then the implementation may be rocky due to inconsistent requirements as they may tailor their requirements to individual situations and may lose sight regarding the "big picture."

As of March 2022, the FAA has stated that it is working to validate new eVTOLs. They said, "The Federal Aviation Administration (FAA) and the United Kingdom Civil Aviation Authority recognize the potential of electric vertical take-off and landing (eVTOL) and other Advanced Air Mobility (AAM) aircraft to significantly benefit the public. To support future eVTOL aircraft development and operation, the US and UK civil aviation authorities are engaged in a range of bilateral and multilateral discussions focused on facilitating certification and validating new eVTOL aircraft, production, continued airworthiness, operations, and personnel licensing. As these aircraft enter into the aviation ecosystem, we must continue to maintain the high safety standards that the public expects. To streamline and expedite integration, this technology should use existing regulatory frameworks on which that strong safety record is founded." [74]

Likewise in March more government regulation was introduced. "The West Virginia Legislature passed two pieces of legislation aimed at encouraging future AAM operations. House Bill 4667 prohibits county and local jurisdictions from creating restrictions on AAM operations or aircraft, while House Bill 4827 promotes the development of public-use vertiports, among other conditions. West Virginia Governor Jim Justice signed the two bills into law later in the month" [85]

"On May 18, (2022) two US senators introduced legislation designed to help local communities prepare for the introduction of advanced air mobility (AAM) technologies. The Advanced Aviation Infrastructure Modernization (AAIM) Act, The AAIM Act directs the Secretary of Transportation to establish a pilot program that would provide grants to local, state and tribal jurisdictions to develop plans for AAM infrastructure. Some of these plans could include the identification of planned vertiport sites or of the physical and digital infrastructure required to support AAM operations." [85]

"On Sept. 26, (2022) the Senate Commerce Aviation Subcommittee held a hearing on new entrants to aviation, including electric vertical takeoff and landing (eVTOL) aircraft and other AAM vehicles. It was the first Senate hearing on the planned FAA legislation. In a statement, committee chair Sen. Kyrsten Sinema (D-AZ) stressed the central role that Congress is expected to play in guiding the incorporation of these technologies." [86]

"On Oct. 17, (2022) President Biden signed into law the Advanced Air Mobility Coordination and Leadership Act. The bipartisan legislation, Senate Bill S.516, directs the Secretary of Transportation to establish an interagency working group to identify the elements needed to mature the advanced air mobility (AAM) industry. The new law represents a milestone in the federal government's efforts to act on emerging AAM concepts and technologies such as electric vertical takeoff and landing (eVTOL) aircraft…The passage and signing of the AAM Coordination and Leadership Act comes amid increasing momentum in Congress surrounding AAM issues. On June 14, the House passed the Advanced Aviation Infrastructure Modernization Act (HR 6270), which would provide grants to state and tribal jurisdictions to develop plans for AAM infrastructure." [86]

It is seen above that both the FAA, EASA, and other regulatory bodies are trying to implement the PAV. They are trying to develop requirements as soon as they can, such that they don't interfere with the development. However, the scramble to define the vehicle is evidence of the current impediments, that the regulations as they currently exist, present. Although the regulation is adaptable, as evident in 14 C.F.R. § 21.17 (b) the operational requirements are still evolving. [75]

The evolution of the regulations with changes in technology is not bad. Often as technology develops, regulation will follow suit. This is due to the risk that the one is willing to take in the operation of the vehicle. This is a pattern throughout history. In 1886 the first car was made and later was followed by the first paved road in 1901, the first driver's license in 1903, and the Autobahn in 1929. The first airplane was flown in 1903. Likewise, the first airport in 1909, the first pilot's license in 1927, and first US airliner ILS landing in 1938. The first helicopter was introduced in 1939. Then, followed by the first purpose-built heliport in 1956. Granted, all these innovations occurred first, which spurred the need for regulation.

In the current case, regulations aren't necessarily restricting advancement of the technology as much as they are impeding the implementation of such. Technology has developed beyond the scope of current regulatory definition and needs Special Conditions. As technology matures, the regulations will follow suit, albeit somewhat delayed.

VII. Conclusion

There are current limitations due to the lack of regulatory definition of the PAV. Although the vehicles can be classified into two groups, those being used as personal vehicles for people without licenses for direct point to point operations, and those carrying several passengers in a UAM type scenario, the vehicle's lack of legal definition is limiting the implementation. Notwithstanding, the aviation industry is adapting. The FAA is working with EASA to develop requirements to implement the PAV. They are adapting current C.F.R.s and requirements to be able to meet the growing industry. Major aerospace giants like Boeing, Airbus, Embraer, and NASA are all working to develop the vehicles. Smaller startups are pushing the limits and doing their best to further advance technology.

The major issue in all this development is the shifting definition of the vehicle and the wide variety of operations. NASA even says, "the eVTOL configurations vary from hover bikes to electric ducted fans." [20] The wide variation in vehicle design needs to have a definition to resolve legal implementation.

For every potential multi-passenger operation in the PAV space, there will remain questions regarding the subset of single passenger vehicles. Whether they are hoverbikes or altogether different like the Zeva Zero, they will need their own regulatory definition if they will ever reach their potential. Much like the ultralight's usage is different than normal and transport category aircraft, the personal PAV versus the multi-passenger usage will have to be distinguished.

The development of the PAV is akin to a world like Star Wars. People zipping around on speeder bikes, speeder craft, starfighters, and large space transports on Tatooine or Coruscant, would be no different than people on Planet Earth using hover bikes and PAVs, with private planes and larger transport aircraft in the airspace overhead. The PAV is redefining the future or personal mobility, and the future is bright.

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