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IDENTIFYING CYBERSECURITY VULNERABILITIES IN THE REALM OF URBAN AIR MOBILITY

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I. INTRODUCTION

Achieving personalized flight is one of humanity's oldest dreams, with accounts from Ancient Greek myths and legends,[1] to Leonardo da Vinci's notes and drawings,[2] to the Wright Brother's Flyer.[3] In modern times, illustration of what future civilization might look like often includes depictions of flying cars whizzing about the sky over a sleek urban skyline. Even a series of paintings created between 1899 and 1910, titled "France in the Year 2000," depicted personalized flying machines being habitually utilized by cab drivers, mail men, police officers and firefighters.[4]

Despite attempts throughout history, we are still a long way from the personal aero-car utopia left imprinted onto our imaginations by books, television and films. However, recent technological advancements and infrastructure planning have shifted the framework of urban air mobility away from the regulatory nightmare of personal aero-cars and towards the concept of public air transportation. According to a NASA urban air mobility market study conducted by McKinsey and Company, the global market for urban air

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[1] *Icarus: Greek Mythology*, ENCYC. BRITANNICA (last visited Dec. 21, 2020) https://www.britannica.com/topic/Icarus-Greek-mythology.

[2] Peter Jakab, *Leonardo Da Vinci and Flight,* NAT'L AIR AND SPACE MUSEUM (Aug. 22, 2013) https://airandspace.si.edu/stories/editorial/leonardo-da-vinci-and-flight.

[3] Tom D. Crouch, *Wright Flyer of 1903,* ENCYC. BRITANNICA (last visited Dec. 21, 2020) https://www.britannica.com/topic/Wright-flyer-of-1903.

[4] Ana Swanson, *What People in 1900 Thought the Year 2000 Would Look Like*, WASH. POST (Oct. 4, 2015), https://www.washingtonpost.com/news/wonk/wp/2015/10/04/what-people-in-1900-thought-the-year-2000-would-look-like/.

mobility is predicted to reach over 1.9 billion dollars by 2040;[5] there may be a viable market for air metro transportation by 2028.[6] Air taxi services have the potential for localized profit among wealthier individuals in densely populated markets by 2030,[7] but the market would require dense vertistop infrastructure to create true "door-to-door" service like other on-demand transportation alternatives. The best estimate for air taxi cost per trip poses a significant barrier as compared to air metro services, which also is assumed to carry more passengers per trip.[8]

The attainment of commercial flight in the 1930's helped create a global community and revolutionized nearly every aspect of our daily lives to a degree rivaled only by the conception of the Internet. While commercial and recreational flight may be considered as a completed steppingstone on humanity's march toward the stars, we are far from realizing its true potential. Ubiquitous and affordable urban air mobility options present several benefits to the current transportation landscape. Traffic decongestion alone warrants national support for this burgeoning industry. According to a 2019 urban mobility report, commuters spend an average of 54 extra hours per year in traffic from speed limits caused by congestion.[9] However, no benefits are accompanied without risks. Urban air mobility faces a wide array of drawbacks and hurdles ranging from infrastructure, cost, certification and pollution (noise and emissions). Each of these concerns warrants their own individual analysis, but they are not the sole concern of this article. Rather, the most pressing concern pertains to the cybersecurity vulnerabilities of both crewed and uncrewed aircraft that are likely to be in use for urban air transport by 2030.

Technology has become increasingly intertwined in nearly every facet of our daily lives. The computing power and connectivity of today's cell phones alone are more powerful than any state-of-

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[5] NAT'L AEORONAUTICS AND SPACE ADMIN., URBAN AIR MOBILITY (UAM) MARKET STUDY, 20 (2018) https://www.nasa.gov/sites/default/files/atoms/files/uam-market-study-executive-summary-v2.pdf [hereinafter NASA UAM STUDY].

[6] *Id*.

[7] *See id*.

[8] *Id*. at 23.

[9] DAVID SCHRANK ET AL. 2019 URBAN MOBILITY REPORT, 1 (2019), https://static.tti.tamu.edu/tti.tamu.edu/documents/mobility-report-2019.pdf.

the-art computer system of the 20th Century.[10] Data breaches and computer viruses appear to be inevitable occurrences in the digital age.[11] While cancelling a credit card or wiping a hard drive are certainly an inconvenience, the stakes are much higher at 5,000 feet. For instance, what happens when a malicious actor seizes control of the autopilot functions of an uncrewed air taxi that is filled with passengers in a population dense urban environment? This paper will explore the cybersecurity vulnerabilities of urban air transport, identify ways in which malicious individual and group actors may attempt to expose those vulnerabilities, and finally offer guidance on how cybersecurity should be approached to ensure personal safety above and on the ground.

Part I of this paper will discuss the history of Urban Air Mobility (UAM) and identify the current companies leading the way in achieving safe and efficient UAM. Part II will discuss the benefits and obstacles associated with UAM in general. Part III will explore the cybersecurity threats and obstacles uncrewed and crewed aircraft will face in terms of air metro urban air transport. Part IV will look to the automotive transportation industry for guidance on how to better protect their systems, and therefore their passengers, from outside actors. Part V will offer suggestions on what measures should be taken to help ensure stable cybersecurity for urban air transport. Part VI will conclude this paper.

II. BACKGROUND

A. History of Flying Cars

Inventors have been chasing the dream of flying cars for over a century. In 1911, Glenn Curtiss unveiled the Curtiss Autoplane,

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[10] *Your Device has More Computing Power,* NAT'L AERONAUTICS AND SPACE ADMIN. https://www.nasa.gov/mission_pages/voyager/multimedia/vgrmemory.html#.XpIzHtNKhbU (last visited Sept. 21, 2020) ("Voyager 1 and Voyager 2 have 69.63 kilobytes of memory each. For comparison, an iPhone 5 with 16 gigabytes of memory has about 240,000 times the memory of a Voyager spacecraft.").

[11] *See generally* Davey Winder, *Data Breaches Expose 4.1 Billion Records in First Six Months Of 2019,* FORBES (Aug. 20, 2019), https://www.forbes.com/sites/daveywinder/2019/08/20/data-breaches-expose-41-billion-records-in-first-six-months-of-2019/#3c0d7afebd54.

a three seat Autoplane that featured "removable wings and tail, an aluminum body, and a cabin heater," as well as a rear propeller and steerable front wheels.[12] The design never produced a sustained flight and ultimately failed due to a lack of financial backers.

Another notable creation in pursuit of flying cars came from Robert Fulton's Airphibian in 1946. Taking an alternate approach, "[i]nstead of adapting a car for flying, Fulton adapted a plane for the road."[13] Much like the design of the Curtiss Autoplane, Fulton's Airphibian utilized detachable features that allowed a transformation time of "only five minutes to convert the plane into a car."[14] However, unlike the Curtiss Autoplane and other aspiring contemporaries, Fulton's Airphibian was the first roadable aircraft to receive a type certification from the Civil Aviation Administration in 1950.[15] Despite its operational success, the Airphibian failed due to financial restraints.

The last breakthrough in roadable aircraft came in 1949 with the Taylor Aerocar. Designed by Molten Taylor and inspired by Fulton's Airphibian, the Aerocar replaced the Airphibian's removable wings with "folding mechanisms" that allowed for seamless transformation from flight to road use.[16] Despite being one of the most successful attempts at achieving a flying car, a limited amount were produced and the few that remain exist only as a unique relic of innovation in the mid 20th century. Andrew Glass, author of *Flying Cars: The True Story*, offered insight on why these machines, despite their success, ultimately failed in the long run:

> The biggest challenge according to engineers in creating a flying car, is to create a machine that is robust, rugged, and

[12] Stuart F. Brown, *Pie-in-the-Sky Flying Cars From the Past*, N.Y. TIMES (Aug. 22, 2014), https://www.nytimes.com/2014/08/24/automobiles/pie-in-the-sky-flying-cars-from-the-past.html.

[13] Kevin Bonsor, *How Flying Cars Will Work*, HOWSTUFFWORKS.COM https://auto.howstuffworks.com/flying-carhtm (last visited Dec. 21, 2020),

[14] *Id*.

[15] *Fulton Airphibian FA-3-101,* SMITHSONIAN NAT'L AIR AND SPACE MUSEUM, https://airandspace.si.edu/collection-objects/fulton-airphibian-fa-3-101/nasm_A19600127000 (last visited Dec. 21, 2020); *Original Design Approval Process,* FED. AVIATION ADMIN., , https://www.faa.gov/aircraft/air_cert/design_approvals/orig_des_approv_proc/ (last visited Dec. 21, 2020)
(A type certification is applied for and received under the regulations provided in 14 CFR §21.).

[16] Brown, *supra* note 12.

> probably heavy enough to withstand the rigors of the road, the bumps and the occasional fender benders, and at the same time a machine that is light enough and aerodynamic enough to be safe in the air. Most engineers claim that although it was an interesting problem, it was not a solvable one. The balance would always be wrong, or the weight would be wrong, and you could never do better than creating an inferior car that would also be an inferior airplane, and that you were much better off making an airplane and making a car and keeping them separate.[17]

Notwithstanding this candid assessment of the infeasibility of personal flying automobiles, many individuals and companies remain undeterred. The United States Patent and Trademark Office database yielded 170 results for the keywords: "flying cars" searched between the years 2001-2020.[18] Today, new emerging technologies and a recent surplus of willing benefactors have helped eliminate the financial and operational problems that plagued their predecessors, and UAM is finally appearing to become a reality.

B. Current UAM leaders and companies

The National Air and Space Administration (NASA) is one of the federal agencies facilitating the research and development of UAM. NASA has a history of increasing the "capacity and improv[ing] the efficiency, safety, and environmental compatibility of the air transportation system."[19] NASA's goal with the urban air mobility industry is the same as it has been for the aviation industry as a whole, which is setting the "long term vision for aviation and undertaking research and development that falls outside the

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[17] *The Future of Commuting May Be By Air, But Probably Not in Your Personal Flying Car,* CNBC (Mar. 8, 2020), https://www.cnbc.com/video/2020/03/06/why-dont-we-have-flying-cars-yet.html.

[18] US Patent & Trademark Office, http://appft.uspto.gov/netahtml/PTO/search-bool.html.

[19] *Urban Air Mobility – Are Flying Cars Ready for Take-Off?*, *Hearing Before the Comm. on Science, Space, and Technology*, 115 Cong. 14, 19 (2018) (Statement of Dr. Jaiwon Shin, Assoc. Adm'r Aeronautics Research Mission Directorate), https://www.govinfo.gov/content/pkg/CHRG-115hhrg30881/pdf/CHRG-115hhrg30881.pdf [hereinafter Shin Testimony].

scale, risk, and payback criteria that govern commercial investments."[20]

Three primary goals are among the elements included in NASA's holistic research and development strategy. The first is to provide market and technology analysis to determine the scope of the challenges, as well as their necessary solutions.[21] An example of this element in action can be found in a 2018 Urban Air Mobility Market Study sponsored by NASA and published in partnership with several consulting firms. The report provides insight on UAM through market analysis, public acceptance, the regulatory environment, potential barriers, as well as how to move forward.[22] Second, NASA plans to lead technology development in essential areas of UAM, such as noise reduction, air traffic management, autonomous flight systems, and partial or full electronic propulsion systems for vertical take-off and landing vehicles (eVTOL).[23] And lastly, NASA recently implemented a grand challenge to allow individuals and companies to "gauge their individual readiness and the overall system state-of-the-art."[24] NASA has currently signed Space Act Agreements with seventeen companies that have agreed to take part of the grand challenge.[25] The companies have been divided into three categories of participation: (1) developmental flight testing; (2) developmental airspace simulation; and (3) vehicle provider information exchange.[26]

Joby Aviation, a company founded in 2009 based out of Santa Cruz, California is the only company slated to participate in the first category, in which it will showcase its aircraft in the Grand Challenge Developmental Testing (GC-DT) and "demonstrate key integrated operational UAM scenarios as designed by NASA's UAM Grand Challenge team."[27] These scenarios will likely include communications, navigations, surveillance contingencies and air to air

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[20] *Id.*

[21] *Id.* at 20.

[22] NASA UAM STUDY, *supra* note 5, at 2.

[23] Shin Testimony, *supra* note 19, at 20.

[24] *Id.*

[25] *NASA's Urban Air Mobility Grand Challenge Advances with Agreement Signings,* NASA.GOV (Mar. 3, 2020), https://www.nasa.gov/press-release/nasa-s-urban-air-mobility-grand-challenge-advances-with-agreement-signings/.

[26] *Id.*

[27] *Grand Challenge Developmental Testing Partners,* NASA.GOV (Mar. 3, 2020), https://www.nasa.gov/aeroresearch/grand-challenge-developmental-testing.

conflict management.[28] Their proprietary craft is a piloted eVTOL capable of flying 200 miles per hour at a total range of over 150 miles on a single charge.[29] It is also touted as being 100 times more quiet than conventional aircraft and produces zero carbon emissions.[30] This impressive start-up not only warranted receiving the only slot for the first category, but it also recently received a $394 million investment from Toyota Motor Company.[31] Joby Aviation recently partnered with the Uber Elevate program for a "multi-year commercial partnership" with the ultimate goal of deploying air taxi services by 2023.[32]

In addition to their recent partnership with Joby Aviation, prominent transportation company Uber Technologies is a leading member of the second category, developmental airspace simulation, and will test its "UAM traffic management services in robust NASA-designed airspace simulations in the GC-DT and demonstrate key integrated operational UAM scenarios."[33] Uber is among the leaders in UAM and offers an extensive analysis of the market barriers in a ninety-eight page white paper, such as cost and affordability, safety and noise and carbon emissions.[34]

Bell Textron and Boeing are significant members of the third category, vehicle provider information exchange. They will "exchange information with the intent to prepare that partner for possible flight activities during the first Grand Challenge at a NASA-provided or other approved test range in 2022."[35] Both companies

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[28] *Id.*

[29] JOBY AVIATION https://www.jobyaviation.com/ (last visited Dec. 21, 2020).

[30] *Id.*

[31] Grant Martin, *Toyota Invests $394 Million in Electric Air Taxi Company Joby Aviation*, FORBES (Jan. 18, 2020), https://www.forbes.com/sites/grantmartin/2020/01/18/toyota-invests-590-million-in-electric-air-taxi-company-joby-aviation/#6429e4b88ea0.

[32] *Joby S4,* ELEC. VTOL NEWS https://evtol.news/joby-s4/ (last visited Dec. 21, 2020).

[33] *Grand Challenge Developmental Testing Partners, supra,* note 27.

[34] Uber Elevate, *Fast-Forwarding to a Future of On-Demand Urban Air Transportation,* UBER ELEVATE, 4-6 (Oct. 27, 2016), https://www.uber.com/elevate.pdf [hereinafter Uber Elevate White Paper]

[35] *Grand Challenge Developmental Testing Partners, supra,* note 27; *Flight Path for the Future of Mobility*, BOEING, http://www.boeing.com/NeXt/common/docs/Boeing_Future_of_Mobility_White%20Paper.pdf, 2 ("With increasing urbanization, a growing global population, aging infrastructure and the explosion of ecommerce, there is a need for new, sustainable and accessible modes of transportation. Urban air mobility (UAM) presents an opportunity to provide seamless, safe and rapid transportation to mitigate existing and future challenges faced by urban areas.").

have made great strides in achieving successful piloted, and even autonomous, urban air flight operations. Boeing's urban air mobility development department, Boeing NeXt, completed a controlled take-off, hover and landing with their autonomous passenger air vehicle (PAV) last year[36] and Bell Nexus recently unveiled a "four-passenger air taxi for the E-VTOL (electric vertical-takeoff-and-landing) market that's predicted to appear in the next five years . . . [and] looks like an all-black cross between a V-22 Osprey (also a Bell product) and a giant drone."[37]

The private sector is the largest force pursuing the realization of urban air mobility in the twenty-first century. While the public sector is necessary to explore and define the limits of the risks and rewards, it is the private sector that will likely bear the direct costs of trial and error. Executive Vice President of Technology and Innovation at Bell, Michael Thacker, celebrated this public and private union:

> Many of America's greatest accomplishments—from the Manhattan Project to the space program to the internet—were only possible through effective public-private partnerships. The promise of another great American accomplishment, true Urban Mobility in the vertical dimension, now lies before us, and along with it the promise of carrying on America's long legacy of leadership and innovation in aviation.[38]

One last prominent leader of urban air mobility is Kitty Hawk Corporation, which in 2017 announced the creation of the "Kitty Hawk Flyer."[39] The Flyer is "an amphibious, 10-rotor multicopter configuration that avoids many regulatory issues by operating as

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[36] *Boeing Autonomous Passenger Air Vehicle Completes First Flight,* BOEING (Jan. 23, 2019), http://www.boeing.com/features/2019/01/pav-first-flight-01-19.page.

[37] Michael Goldstein, *Bell Nexus VTOL Air Taxi Makes a Splash at 2019 Consumer Electronics Show,* FORBES (Jan. 14, 2019), https://www.forbes.com/sites/michaelgoldstein/2019/01/14/bell-nexus-vtol-air-taxi-makes-a-splash-at-2019-consumer-electronics-show/#5432d8712e31.

[38] *Urban Air Mobility – Are Flying Cars Ready for Take-Off?*, *Hearing Before the Comm. on Science, Space, and Technology*, 115 Cong. 54, 64(2018) (Statement of Michael Thacker), https://www.govinfo.gov/content/pkg/CHRG-115hhrg30881/pdf/CHRG-115hhrg30881.pdf.

[39] Kenneth H. Goodrich, *Dozens of Urban Air Mobility Projects Underway*, AEROSPACE AM. (last visited Sept. Dec 21, 2020), https://aerospaceamerica.aiaa.org/year-in-review/dozens-of-urban-air-mobility-projects-underway/.

an ultralight aircraft in the U.S."[40] Ultralight vehicles are single occupant vehicles used exclusively for sport and recreation and must conform to specific statutory requirements by meeting certain weight, fuel and seating limits.[41] The distinction between ultralight vehicles and traditional aircraft is extremely important as

> vehicles that meet the definition of an ultralight presently are not required to be registered or to bear markings of any type, are not required to meet airworthiness certification standards, and their operators are not required to meet any aeronautical knowledge, age, or experience requirements or to have airman or medical certificates.[42]

As previously mentioned, this paper is primarily concerned with VTOL aircraft to be used for air metro purposes, which due to their weight and passenger specifications will not be subject to the lax regulatory guidelines of ultralight vehicles. While there may be a concern regarding the potential for crowded and chaotic airspaces in urban environments between VTOL's and ultralight users, ultralight regulations mandate that "[n]o person may operate an ultralight vehicle over any congested area of a city, town, or settlement, or over any open air assembly of persons."[43] It will be important to maintain this regulation moving forward and to ensure the separation of air metro aircraft carrying passengers in urban environments and recreational ultralight users.

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[40] *Id.*

[41] 14 C.F.R. § 103.1 (2020).

[42] Ickes v. Fed. Aviation Admin., 299 F.3d 260, 264 (3d Cir. 2002) (citing 14 C.F.R. § 103.7). Petitioner in this case appealed the classification of his vehicle, Challenger II, as an aircraft rather than ultralight vehicle. Upon review the Third Circuit held that:

> [i]t is undisputed that the Challenger II has two seats, and that fact alone removes it from the ultralight category because it is not "used or intended to be used for manned operation in the air by a single occupant." 14 C.F.R. § 103.1(a). Furthermore, Ickes does not dispute the FAA's finding (nor did he ever appeal or petition for review of the findings in the earlier FAA proceedings) that his plane has an empty weight of 300 pounds, a fuel capacity in excess of 5 gallons, and a potential cruise speed of approximately 56–69 knots. See 14 C.F.R. § 103.1(e). Thus, based on its physical characteristics, Ickes' Challenger II is not an ultralight.

Id.

[43] 14 C.F.R. 103.15 (2020).

C. Intended benefits of UAM

All of the leaders and companies listed previously recognized one issue specifically to be a driving force in the pursuit of safe and affordable urban air mobility technology and infrastructure: traffic congestion.[44] According to a report by the United Nations Department of Economic and Social Affairs, 60.4 percent of the world's population will live in an urban environment by 2030, with estimates of up to 81. 4 percent of the population in more developed regions living in an urban environment by 2030 as well.[45] Necessity is indeed the mother of invention, and traffic and population congestion are reaching a critical stage far beyond mere inconvenience. Carbon emissions, lost productivity due to travel times, and general health concerns related to stress are important issues that the developing urban air mobility market are seeking to address.[46] Eric Allison, Head of Aviation Programs at Uber Technologies, Inc.

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[44] *See e.g., Joby Aviation*, SALINAS CHAMBER OF COM., https://business.salinaschamber.com/member-directory/Details/joby-aviation-1195905 (last visited Dec. 26, 2020) (Increased congestion, longer commute times, and rising emissions compelled us to pioneer a new class of electric aircraft that quietly soars above gridlock—getting you to where you are going up to five times faster than driving."); BELL NEXUS, https://www.bellflight.com/products/bell-nexus (last visited Dec. 26, 2020)("Turn a 45-minute drive into a 10-minute flight. The safe, convenient Air Taxi is designed to let you make the most of your commute. Its sleek cabin offers a comfortable space for you to relax. Or work. Or socialize. All while saving your most precious resource: time."); Uber Elevate White Paper, *supra* note 34, at 2 (Uber Elevate: "Every day, millions of hours are wasted on the road worldwide. . . .Last year, the average San Francisco resident spent 230 hours commuting between work and home—that's half a million hours of productivity lost every single day. . . ., that's less time with family, less time at work growing our economies, more money spent on fuel—and a marked increase in our stress levels. . ." (citations omitted)); BOEING, http://www.boeing.com/NeXt/index.html?TB_iframe=true&width=370.8&height=658.8 (last visited Dec. 26, 2020)("With increasing urbanization, a growing global population, aging infrastructure and the explosion of ecommerce, there is a need for new, sustainable and accessible modes of transportation. Urban air mobility (UAM) presents an opportunity to provide seamless, safe and rapid transportation to mitigate existing and future challenges faced by urban areas.").

[45] *World Urbanization Prospects: The 2018 Revision*, U.N., DEP'T OF ECON. AND SOC. AFFAIRS, POPULATION DIV., 21 (2019) https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf.

[46] Uber Elevate White Paper, *supra* note 34 at 2; *See also Long Commutes May Be Hazardous to Health,* U.N., DEP'T OF ECON. AND SOC. AFFAIRS, POPULATION DIV. (May 8, 2012) https://www.ajpmonline.org/pb/assets/raw/Health%20Advance/journals/amepre/AJPM%20Jun2012%20Hoehner%20Commuting%20Distance%20FINAL%20_2_.pdf
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succinctly described the dilemma UAM is attempting to solve: "[M]oments stuck on the road represent less time with family, fewer hours growing our economies, and more money spent polluting our world."[47]

Texas A&M Transportation Institute's *2019 Urban Mobility Report* offers several more troubling statistics that properly reframes the severe issue of traffic congestion.[48] In 2017 alone, congestion caused traveling Americans to spend an additional 8.8 billion hours on the road and also purchase an extra 3.3 billion gallons for a total congestion cost of $179 billion.[49] To put this into perspective for the individual, the "average auto commuter spends 54 hours in congestion and wastes 21 gallons of fuel due to congestion at a cost of $1,080 in wasted time and fuel."[50] Traveling during alternative times of the day has also proven unsuccessful, as around 33 percent of delays occur in midday or overnight (i.e. non-peak time periods).[51] Unfortunately, all trends indicate that this problem will only worsen over the next five years, as estimated delay times and fuel costs are expected to grow to 10 billion hours and 3.6 billion gallons in 2025.[52]

These problems have not been completely ignored, as conventional and alternative means of transportation reform have been introduced. In 2007, New York City Mayor Michael Bloomberg outlined the city's plan for addressing travel congestion issues.[53] In the report, he outlined several conventional reforms, such as promoting car-sharing; expanding and improving the ferry service; ensuring bicyclist safety and convenience; improving safe access for

[47] *Urban Air Mobility – Are Flying Cars Ready for Take-Off?*, *Hearing Before the Comm. on Science, Space, and Technology*, 115 Cong. 34, 34(2018) (Statement of Eric Allison), https://www.govinfo.gov/content/pkg/CHRG-115hhrg30881/pdf/CHRG-115hhrg30881.pdf..

[48] SCHRANK ET AL., *supra* note 9, at 1.

[49] *Id*.

[50] *Id*.

[51] *Id*. at 5.

[52] *Id*. at 12 (Additionally, the average commuter will spend up to 8 vacation days in traffic in 2025.).

[53] *See New York City Drivers Will Soon Have to Pay for the Privilege of Sitting in Traffic*, A.P. (Apr. 3, 2019), https://www.usatoday.com/story/news/nation/2019/04/03/congestion-pricing-new-york-city-drivers-soon-face-new-toll/3350401002/ ("New York City is set to become the first American metropolis that seeks to ease traffic congestion, cut pollution and boost mass transit by charging motorists a hefty toll for the privilege of driving into its most crammed areas.").

pedestrian walkways; implementing priced-based systems to reduce traffic congestion; and repairing damaged infrastructure (e.g. roads, bridges, subways, and bicycle and pedestrian paths).[54] These idealistic goals were not merely political rhetoric. In 2018, New York City Mayor Bill de Blasio released a progress report on his office's OneNYC initiative, highlighting massive improvements that have been successfully implemented to facilitate alternative forms of transportation throughout the city.[55]

Achieving a pervasive UAM infrastructure is not an instant cure for the ails of modern transportation. However, creating a safe, fast, efficient, accessible and quiet urban air transport vehicle that produces zero carbon emissions through electronic propulsion technology clearly possesses sizeable benefits for the nation's rapidly growing urban environments. While the industry is full of innovative companies and individuals willing to dedicate their time, expertise, and money to this revolutionary endeavor, the industry still faces its fair share of obstacles as well.

D. Obstacles in UAM

Cost and affordability regarding the production and accessibility of urban air transport is a key factor when assessing the feasibility of ubiquitous urban air mobility any time in the near future. Currently, the closest operational equivalent to eVTOL urban transport are helicopters, which are "energy-inefficient and very expensive to maintain, and their high level of noise strongly limits use in urban areas."[56] This is not to say that on-demand helicopter services are fruitless endeavors. Airbus recently ended Voom, an on-demand helicopter operation initiated in 2016 with air taxi companies in Mexico City, San Paolo, and San Francisco. The service recorded over 150,000 active app users, over 15,000 passengers, a 45%

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[54] CITY OF NEW YORK, *PLANYC, A GREENER, GREATER NEW YORK* 91 (2011), http://www.nyc.gov/html/planyc/downloads/pdf/publications/planyc_2011_planyc_full_report.pdf.

[55] CITY OF NEW YORK, ONENYC PROGRESS REPORT 2018, 32-33 (2018), https://onenyc.cityofnewyork.us/wp-content/uploads/2018/04/OneNYC_Progress_2018-2.pdf (Among other things, the report applauded the city's 2017 NYC Ferry system that carried three million riders in its inaugural year, the creation of eight additional select bus service routes to over 178,000 riders, and the addition of over 219.9 additional biking lane miles since 2015.).

[56] Uber Elevate White Paper, *supra* note 34 at 6.

customer return rate, and an "[a]verage ticket price equivalent to 2x the cost of a private ground taxi service for 1/10th of the time."[57] More importantly, it provided Airbus with a "wealth of valuable behavioural and operational data about urban air mobility (i.e. mission requirements and constraints, customer preferences, etc.) to inform a future vehicle design."[58]

Ultimately, on-demand helicopter ridesharing is unlikely to become a legitimate and widespread transportation alternative in the United States, as Uber's eight-minute, one-way helicopter taxi ride from downtown Manhattan to John F. Kennedy International Airport currently has a luxurious user cost of $200-$225.[59] UAM will therefore depend on the affordability of new eVTOL aircraft and infrastructure. The cost structure can be divided into three main categories: infrastructure, original equipment manufacturing (OEM) and operator costs.[60]

In terms of infrastructure, this will include several distinct levels of development including, but not limited to: air traffic management; service centers; distribution hubs; vertiports; and refueling/charging stations.[61] According to the white paper published by Uber Elevate, the estimated infrastructure costs necessary to accommodate 1,000 VTOLs across three to four cities would be approximately $121 million of initial costs alone.[62] The yearly costs of these vertiports would run an additional $86 million with expenses such as leases, maintenance, employee personnel, and security services.[63]

OEM costs include the total costs of individual aspects of urban air mobility such as costs relating to sensing systems, batteries, autonomous systems, certification costs.[64] Developing and

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[57] *Voom: An On-Demand Helicopter Booking Platform,* AIRBUS, https://www.airbus.com/innovation/urban-air-mobility/voom.html#key (last visited Sept. 21, 2020).

[58] *Id.*

[59] Stella Soon, *Uber's $200 Helicopter Taxi: Manhattan to JFK Airport in 8 Minutes Flat,* CNBC (Nov. 3, 2019), ; https://www.cnbc.com/2019/11/04/uber-copter-8-minute-helicopter-taxi-to-new-yorks-jfk-airport.html

[60] NASA UAM STUDY, *supra* note 5, at 14.

[61] *Id.*

[62] Uber Elevate White Paper, *supra* note 34, at 93 (Initial costs include the cost of retrofitting existing urban environments i.e. parking garages and heliports for use as heliports. This also includes the implementation of eVTOL charging capabilities).

[63] *Id.*

[64] NASA UAM STUDY, *supra* note 5, at 14.

manufacturing all of these intricate systems directly contribute to the total vehicle costs for individual eVTOL systems. Using the Uber Elevate initiative's estimations, the best case eVTOL costs with near-term manufacturing capabilities of 500 vehicles per year is a total of approximately $700,000 per vehicle.[65] The optimistic long-term cost scenario involves producing 5,000 vehicles per year for a total of around $275,000 per vehicle.[66] To put this ambitious manufacturing goal into perspective, "[i]n 2015 the Robinson R-44 piston engine helicopter ($473,000 price) was produced at *the highest rate of any helicopter that year with 196 units manufactured*, while a base model Bell 206 turboshaft helicopter had only 12 units produced ($900,000+ price)."[67] The cost estimates given by Uber Elevate are rough estimates based primarily on quantity of production and therefore they should not be taken as exact figures.[68] However, these estimates serve to illustrate the manufacturing requirements that will likely be necessary to provide ubiquitous and affordable urban air mobility transportation in a number of cities across the nation.

Lastly, operator costs pertain to any costs relating to the administrative or operational functions of urban air mobility.[69] This area is also referred to as indirect operating costs and is even more uncertain than the rough estimates pertaining to direct operating costs.[70] These costs may include operator certification,[71] corporate costs, energy costs, insurance, digital services (apps and websites) and payment systems.[72] Payment systems can refer to

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[65] Uber Elevate White Paper, *supra* note 34, at 87 (This total includes estimated piloting costs by professional helicopter pilot of $75,000/year, a vehicle unit cost of $600,000, and a battery cost of $28,000.).

[66] *Id*. (This total includes estimated autonomous piloting costs of $60,000/year, a vehicle unit cost of $200,000, and a battery cost of $14,000.).

[67] *Id*. at 91 (emphasis added).

[68] *Id*. at 62.

[69] NASA UAM STUDY, *supra* note 5, at 14.

[70] Uber Elevate White Paper, *supra* note 34, at 94.

[71] *Id*. at 17 ("VTOLs will be manufactured, flown, and maintained to meet the more stringent levels of control and FAA supervision covered under [14 CFR] Part 135. Additionally, VTOL operations, at least until autonomous operations become commonplace, will require commercial pilots who must have a higher level of training, experience, flight review, and medical certification than is the case for private pilots. Even if aircraft had equivalent failure rates, the control inherent in Part 135 operations will result in VTOL accident rates at least as low as operations within this section generally.").

[72] NASA, UAM STUDY *supra* note 5, at 14.

miscellaneous fees associated with credit card processing fees or other forms of monetary transactions.[73] In terms of current commercial aviation, "[m]uch of commercial aviation cost also resides in indirect taxes linked to fuel use, landing fees, and other airspace operation overhead [however, in] the case of VTOLs, the indirects are assumed to be relatively low due to the use of private infrastructure."[74]

III. FUTURE VULNERABILITIES

A. UAM Cybersecurity

Each of the elements and obstacles listed in the previous section do not exist in a vacuum, rather, they intersect and interact in conjunction with one another, especially in the arena of cybersecurity.[75] Ensuring secure cybersecurity systems for urban air transport is either directly related to, or dependent upon, the safety of passengers, costs of production and operation, and infrastructure. It is for these reasons that exploring urban air mobility's cybersecurity vulnerabilities and protections is the primary focus of this paper.

Additionally, because the air metro market appears to be more viable in the near future, as opposed to air taxis, due to lower costs and higher passenger quantities per trip, it is important to address the security concerns of individual VTOLs that will carry multiple passengers per trip over several trips over dense urban environments.

eVTOL's and the future of UAM are more prone to cyber threats due to their expanded and necessary interconnectivity and cyber computer systems. The OEM technology listed in the previous section detailing costs of production outlined the necessary system software of VTOL aircraft. An interview with Raytheon executive

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[73] Uber Elevate White Paper, *supra* note 34, at 87.

[74] *Id.*

[75] Anna L. Buczak & Erhan Guven, *A Survey of Data Mining and Machine Learning Methods for Cyber Security Intrusion Detection*, 18 IEE COMMS. SURVS. & TUTORIALS 1153, 1153 (2016) (The authors succinctly define cybersecurity as "the set of technologies and processes designed to protect computers, networks, programs, and data from attack, unauthorized access, change, or destruction.").

Todd Probert offers insight on how these systems have re-shaped the framework for metro transportation.[76] Probert notes that

> [t]here are a number of particular elements in the eVTOL domain that make it a unique cyber target . . . Many planned air taxis are set to be unmanned . . . meaning there is a degree of autonomy and a corresponding coordination with ground infrastructure in terms of air traffic management. However, air traffic management takes on a new meaning in this domain, as the vast majority of the systems are meant to fly in the relatively small, confined spaces of cities. This in turn means they demand sense and avoid systems to ensure air taxis avoid colliding with buildings or with other vehicles . . .. Such systems will need "some sort of cyber overlay" . . . .[77]

The long-term future of UAM certainly appears to be moving towards a fully autonomous "network of flying computers in the sky."[78] Boeing and SparkCognition company, Skygrid, envision an urban environment utilizing "blockchain technology, AI-enabled dynamic traffic routing, data analytics and cybersecurity features . . . enabling broad integration of autonomous air vehicles in the global airspace."[79]

While the pursuit of fully autonomous and interconnected flight systems would intuitively raise concerns of cyber threats, others view autonomous integration as an opportunity to minimize cyber intrusion. Airbus executive, Travis Mason, postulated that "increasingly automated systems in UAM also present new opportunities to minimize cybersecurity threats . . . because autonomous vehicles rely on fewer external resources and data."[80] However, as will be discussed in the next section, even current, non-automated forms of transportation with limited connectivity are still vulnerable to cyber-attacks.

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[76] Gerrard Cowan, *Protecting eVTOLs Against Cyber Threats,* EVTOL.COM, (Aug. 10, 2019), https://evtol.com/features/protecting-evtols-against-cyber-threats/.

[77] *Id.*.

[78] Amir Husain, *Urban Air Mobility in 2020: Four Trends to Watch*, FORBES (Dec. 13, 2019), https://www.forbes.com/sites/amirhusain/2019/12/13/urban-air-mobility-in-2020-four-trends-to-watch/#a74822c47110.

[79] *Flight Path for the Future of Mobility*, BOEING, *supra* note 35, at7.

[80] Husain, *supra* note 78.

To better understand the types of actions that may threaten the integrity of eVTOL cybersecurity we can look to industries that have anticipated, or have even already experienced, compromised operational abilities due to malicious cyber-attacks. The most analogous industry in terms of semi and fully autonomous research in public transportation are traditional and autonomous automobiles.

B. Cybersecurity in the Automotive Industry

The research and development of autonomous (self-driving) automobiles experienced a similar path as UAM over the last 40 years. The industry performed foundational research from the 1980's-2003, the "U.S. Defense Advanced Research Projects Agency (DARPA) held three 'Grand Challenges' that markedly accelerated advancements in AV technology and reignited the public's imagination," and there now has been an increase in collaboration in the commercial sector between manufacturers and researchers.[81]

Software and hardware advancements are now one of the numerous security challenges presented to autonomous vehicles (AV).[82] The necessity for consistent software updates in modern technology has created the potential for cybersecurity risks from unknown sources.[83] "Whether the entry point into the vehicle is the Internet, aftermarket devices, USB ports, or mobile phones, these new portals bring new challenges" as vehicle interconnectivity continues to grow.[84]

Prominent and concerning examples of compromised cybersecurity have already arisen due to software vulnerabilities of non-autonomous vehicles.[85] In 2015, 1.4 million vehicles were impacted

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81 JAMES M. ANDERSON, AUTONOMOUS VEHICLE TECH.: A GUIDE FOR POLICYMAKERS, 56-57 (2014).

82 *Id.* at 70.

83 *Id.* ("Software upgrades, for example, will likely require connection to the Internet, which creates the possibility of vehicles being attacked by computer viruses that corrupt the system; for example, a virus could enter the system by masquerading as a legitimate software upgrade.").

84 *Id.* (*quoting* former head of the National Highway Traffic Safety Administration, David Strickland).

85 Roland L. Trope & Thomas J. Smedinghoff, *Why Smart Car Safety Depends on Cybersecurity*, 14 SCITECH LAW. 8, 10 (2018), https://www.americanbar.org/groups/science_technology/publications/scitech_lawyer/2018/summer/why-smart-car-safety-depends-cybersecurity/. (The article references two additional incidents not discussed in this paper, such as software patches issued to 2.2 million BMW's after the car's

by "the first and only (at this time) cybersecurity-related recall"[86] after two hackers exposed the vulnerability of Chrysler's UConnect system.[87] The hackers were able to access and control a variety of functions, including the air-conditioning, radio, windshield wipers, and eventually even the transmission, causing a test driver to slowly come to a halt on a busy interstate.[88] This incident led to a class action suit against Chrysler, in which the Plaintiffs asserted that the UConnect system was "exceedingly hackable" and that there was no way to "quickly, automatically, safely, securely, and effectively download software patches that are critical for protecting vehicles from the types of attacks described."[89] The case ultimately dismissed due to a lack of standing.[90]

There are two additional issues in the arena of autonomous automobiles, each issue fostering disagreement within the industry, that are worth mentioning in relation to UAM. First is the debate between manufacturers regarding whether the automotive industry should pursue full-autonomy or semi-autonomy in its vehicles.[91] Second, is the National Highway Traffic Safety Administration's (NHTSA) hands-off regulatory approach of exclusively relying

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ConnectedDrive software displayed vulnerabilities allowing the car to be remotely unlocked. The second incident refers to software patches distributed to all Tesla Model S vehicles after it was revealed that if a driver accessed a malicious web page, a variety of systems could be affected by an outside actor.).

[86] *Vehicle Cybersecurity,* NAT'L HIGHWAY TRAFFIC SAFETY ADMIN.,, https://www.nhtsa.gov/technology-innovation/vehicle-cybersecurity . (last visited Dec. 22, 2020)

[87] Andy Greenberg, *Hackers Remotely Kill a Jeep on the Highway – With Me in It*, WIRED (Jul. 21, 2015), https://www.wired.com/2015/07/hackers-remotely-kill-jeep-highway/.

[88] *Id.*

[89] Flynn v. FCA U.S. LLC., No. 15-cv-855-SMY, U.S. Dist. LEXIS 53491, at *3 (S. D. Ill. 2020).

[90] *Id*. at *12 ("Moreover, Courts faced with similar standing challenges have found that a future risk of hacking is too speculative and that allegations of economic loss stemming from speculative risk of future harm cannot establish standing.").

[91] Arthur D. Spratlin, *The Autonomous Vehicle Revolution Expands to Trucks*, FOR THE DEFENSE (Dec. 2017), https://3epjwm3sm3iv250i67219jho-wpengine.netdna-ssl.com/wp-content/uploads/2018/01/The-Autonomous-Vehicle-Revolution-Expands-to-Trucks-Spratlin.pdf.

on its recall authority rather than issuing explicit Federal Motor Vehicle Safety Standards (FMVSS) regarding cybersecurity.[92]

The first issue is an important consideration for any future plans for autonomous eVTOLs. Semi-autonomous systems are systems that require the driver to be a backup in case of an emergency situation; therefore, the driver must still be attentive and available during the course of travel.[93] Semi-autonomous systems can already be found to some extent in cars that can park, "steer, accelerate, decelerate and change lanes without human intervention."[94] These features are becoming increasingly prominent in many companies, such as Mercedes, Volvo, and Nissan.[95] This level of autonomy seems to be combining the best of both worlds: the precision and security of automated systems for monotonous tasks with the option of human intervention in the possible event of system failure or malfunction. Unfortunately, this is likely not the case, as a "car with any level of autonomy that relies upon a human to save the day in an emergency poses almost insurmountable engineering, design, and safety challenges, simply because humans are for the most part horrible backups. They are inattentive, easily distracted, and slow to respond."[96] This has led other companies to take the approach of directly pursuing fully autonomous systems, such as Google's driverless car company, Waymo LLC.[97]

Despite concerns regarding semi-autonomous systems, UAM companies such as Uber Elevate are still pursuing "optionally piloted vehicles," in which "pilot control is unnecessary except for

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[92] Jeanne C. Suchodolski, *Cybersecurity of Autonomous Systems in The Transportation Sector: An Examination Of Regulatory And Private Law Approaches With Recommendations For Needed Reforms*, 20 N.C. J. L. & TECH. 121, 177-78 (2018).

[93] *Automated Driving Systems 2.0: A Vision For Safety 1*, NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., 4 (2017), https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13069aads2.0_090617_v9a_tag.pdf (This level of automation may also be referred to as "partial automation" or "conditional automation.").

[94] Will Kitson, *Driverless Cars with a Human Touch,* V1.CO (Feb. 7 2019) https://www.v1.co/story/driverless-cars-with-a-human-touch.

[95] Doug Demuro, *7 Best Semi-Autonomous Systems Available Right Now,* Autotrader (Jan. 4, 2018), https://www.autotrader.com/best-cars/7-best-semi-autonomous-systems-available-right-now-271865.

[96] Alex Davies, *The Very Human Problem Blocking the Path to Self-Driving Cars*, WIRED (Jan. 1, 2017), https://www.wired.com/2017/01/human-problem-blocking-path-self-driving-cars/.

[97] WAYMO, https://waymo.com/ (last visited Dec 22, 2020).

visual avoidance of obstacles and other aircraft."[98] Ultimately, in the event of a cyber-attack in which key functions are totally compromised, it is understandable for VTOL companies, and passengers, to wish to retain the option of human intervention either within the aircraft or perhaps remotely. The UAM industry should nevertheless take into the consideration the potential safety hazards of semi-autonomous vehicles.

The second issue pertains to the regulatory steps taken, or rather *not taken*, by the NHTSA regarding standard setting for autonomous vehicles. Regulatory oversight for the NHTSA is provided by two mechanisms: (1) auto manufacturers self-compliance with the FMVSS and (2) by the recall of vehicles deemed unsafe.[99] In essence, manufacturers "self-certify that they comply with the FMVSS before placing an automobile into public use. The NHTSA then randomly tests deployed vehicles to verify compliance with the FMVSS."[100] If the test deems the vehicle non-compliant or unsafe, the agency has authority to initiate a recall.[101] The use of self-compliance and post-production recalls is not an unusual form of compliance oversight, as the FAA utilizes a similar regulatory approach.[102]

However, in terms of standard setting, there currently are no mandatory FMVSS compliance standards regarding manufacturer's duties involving cybersecurity. Instead, manufacturers are encouraged to "follow a robust product development process based

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98 Uber Elevate White Paper, *supra* note 34, at 18.

99 Suchodolski, *supra* note 92, at 176-77.

100 *Id*.

101 *Id*.

102 *See* U.S. v. Varig Airlines, 467 US 797, 816-17 (1984):

> In the exercise of this discretion, the FAA, as the Secretary's designee, has devised a system of compliance review that involves certification of aircraft design and manufacture at several stages of production. See supra, at 2760–2761. The FAA certification process is founded upon a relatively simple notion: the duty to ensure that an aircraft conforms to FAA safety regulations lies with the manufacturer and operator, while the FAA retains the responsibility for policing compliance. Thus, the manufacturer is required to develop the plans and specifications and perform the inspections and tests necessary to establish that an aircraft design comports with the applicable regulations; the FAA then reviews the data for conformity purposes by conducting a "spot check" of the manufacturer's work.

Id.

on a systems-engineering approach with the goal of designing systems free of unreasonable safety risks including those from potential cybersecurity threats and vulnerabilities."[103] The NHTSA also encourages industry sharing, documenting cybersecurity implementations and incorporating the best practices and design principles from other leading entities, such as the National Institute of Standards and Technology (NIST)and the NHTSA.[104]

Among the espoused benefits of this hands-off regulatory approach are that this oversight does not stifle innovation and it prevents the "emergence of a cyber monoculture where vulnerabilities are uniform across the system."[105] Unsurprisingly, there are downsides to this approach as well. Unlike the FAA, which "utilizes consensus standards as an acceptable means to demonstrate conformance with an existing safety rule," the NHTSA has chosen to solely rely on voluntary industry standards, indicating that the NHTSA, "especially when contrasted with the regulatory approaches taken by other agencies, [is] a regulatory body captured by the industry it is intended to regulate."[106]

While it is unlikely that the FAA will abandon its stringent certification requirements regarding airworthiness of new VTOL aircraft, it is important to strike a regulatory balance that fosters innovation and diversity, and enforces, rather than merely encourages, uniform safety standards. Additionally, the UAM industry must address the proper level of autonomy for VTOL air metro and air taxi services, an important issue still left unresolved in the autonomous automobile industry. From cell phones, laptops and automobiles, the consequences of a cyber-attack have only continued to rise. Based on the seemingly limitless opportunities for system intrusion, VTOL and UAM cybersecurity must embrace an adaptable approach that allows security systems to keep up with evolving malicious attacks both during flight operations and routine maintenance procedures.

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[103] Nat'l Highway Traffic Safety Admin., *Cybersecurity Best Practices for Modern Vehicles,* 12 (Oct. 2016) (Report No. DOT HS 812 333).

[104] *Id*. at 13-14.

[105] Suchodolski, *supra* note 92, at 178-79 (*citing* Caleb Watney & Cyril Draffin, *Addressing New Challenges in Automotive Cybersecurity* 7, R ST. POL'Y NO. 118, 12 (2017), https://www.bafuture.org/sites/default/files/key-topics/attachments/Addressing%20Automotive%C20Cybersecurity%C20Nov%202017.pdf.).

[106] *Id*. at 178-81.

IV. RECOMMENDATIONS AND CONCERNS

The vulnerability of software updates and requirements for automobiles highlights the same potential for vulnerability within aircraft,[107] and therefore adequate steps must be taken to ensure the cybersecurity of VTOL aircraft used for urban air mobility. The current "applicable airworthiness regulations do not contain adequate or appropriate safety standards" for many design features that are vulnerable to cyber-attacks.[108] There are several short-term solutions that should be taken until the FAA can provide comprehensive cybersecurity compliance standards.

In terms of preventative security, UAM leaders must enact a number of "handshake" mechanisms "to ensure that the source of upgrades—and the upgrades themselves—are legitimate and uncorrupted."[109] These are mechanisms that confirm "the identities of the connecting systems and allows additional communication to take place."[110] Additionally, VTOL software should equip and utilize artificial intelligence or machine learning to aid hybrid intrusion detection systems (IDS).[111] Hybrid IDS combine misuse-based

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[107] *See, e.g.,* Special Conditions: Boeing Model 777-200, -300, and -300ER Series Airplanes; Aircraft Electronic System Security Protection From Unauthorized Internal Access, 78 Fed. Reg. 68985 (Nov. 18, 2013) (According to a rule published by the FAA, Boeing applied for an installation of an onboard network system and additional functionality to its Boeing Model 777-200, -300, and -300ER Series Airplanes that enabled "connection to previously isolated data networks connected to systems that perform functions required for the safe operation of the airplane. This proposed data network and design integration may result in security vulnerabilities from intentional or unintentional corruption of data and systems critical to the safety and maintenance of the airplane.").

[108] *Id.*

[109] Anderson, *supra* note 81, at 70.

[110] *Handshake*, TECHTERMS, https://techterms.com/definition/handshake (last visited Sept. 21, 2020).

[111] *See* Aimee Laurence, *The Impact of Artificial Intelligence on Cyber Security*, CPO MAGAZINE (Aug. 22, 2019), https://www.cpomagazine.com/cyber-security/the-impact-of-artificial-intelligence-on-cyber-security/ ("AI can also be used to detect threats and other potentially malicious activities. Conventional systems simply cannot keep up with the sheer number of malware that is created every month, so this is a potential area for AI to step in and address this problem."); Francisco L. Loaiza et al., *Utility of Artificial Intelligence and Machine Learning in Cybersecurity*, INST. FOR DEF. LAWS., 3 (2019), https://www.ida.org/-/media/feature/publications/u/ut/utility-of-artificial-intelligence-and-machine-learning-in-cybersecurity/d-10694.ashx (A summary of findings conducted by the Institute for Defense Analyses found that "[artificial intelligence/machine learning] is viewed as a necessary response to the continuing growth in the number and complexity of threats, the evolving nature of threats, and the need for rapid (and therefore substantially automatic) responses to detected threats.").

and anomaly-based cyber analytics.[112] "Anomaly-based techniques model the normal network and system behavior, and identify anomalies as deviations from normal behavior."[113] These systems are useful in that they are able to identify novel attacks, however they are often subjected to higher rates of false alarms.[114] Misuse-based techniques "are designed to detect known attacks by using signatures of those attacks."[115] These systems have fewer false alarms but require "frequent manual updates of the database with rules and signatures."[116] Most IDS usually utilize a hybrid of these two methods.[117] The biggest downside of the widespread implementation of these systems is the inevitable effect on OEM costs, as AI systems "require an immense amount of resources including memory, data, and computing power."[118]

In terms of software regulation, the FAA currently operates under the guidance of Order 8110.49A, which details the necessary level of involvement for software conformity inspections and software installation inspections.[119] To reduce unnecessary or redundant oversight for less complex software reviews, the Order outlines factors that will determine the scope and number of software reviews (i.e. level of involvement).[120] Such factors may include "[p]roduct attributes (such as size, complexity, system functionality or novelty, and software design), [u]se of new technologies or unusual design features, [p]roposals for novel software methods or life cycle model(s) . . . [and] [a]vailability, experience, and authorization of designees."[121] However, the FAA may want to consider mandating higher levels of involvement regardless of the complexity of the system updated or if new technologies are introduced. The fact that malware has the potential to infiltrate more complex systems by concealing itself within basic software updates should cause the

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112 *See* Buczak & Guven, *supra* note 75, at 1153.

113 *Id.*

114 *Id.*

115 *Id.*

116 *Id.*

117 Buczak & Guven, *supra* note 75, at 1153.

118 Laurence, *supra* note 111.

119 *Software Approval Guidelines*, FED. AVIATION ADMIN., 2-1 (2018), https://www.faa.gov/regulations_policies/orders_notices/index.cfm/go/document.information/documentID/1032976

120 *Id.* at 2-2.

121 *Id.*

FAA to err on the side of caution. At the very least, network security should also be a factor when determining the necessary level of involvement. Updates performed in more vulnerable locations or in a riskier method should require a higher level of involvement. While this may increase the regulatory burden, the FAA's recent realignment of the Aircraft Certification Service should hopefully improve system oversight and provide streamline certification.[122]

Lastly, UAM leaders, such as Uber, should guard against its ambition to achieve immediate semi-autonomy, as well as its goal to obtain full autonomy in the near future. While fully manual piloting and fully automated piloting each have their own set of pros and cons, the UAM industry must remain hesitant on lingering too long in the middle, where an amorphous combined role of pilots and automated system end up combining the worst of both worlds rather than the best. A fully autonomous network of vehicles purports to eliminate the risk of human error or incapacitation and unexpected variables such as weather and visibility,[123] but only when systems run properly without interference or malfunctions. A semi-autonomous system runs the potential risk of combining the inattentiveness and lower reaction capabilities of human pilots with the risk of system error, interreference, or malfunction. This is a lethal combination when transporting passengers at 200 miles per hour, one thousand feet above a dense urban environment.

V. CONCLUSION

There are still a number of hurdles standing between the current status of urban air mobility and the full scale aerial urban environment envisioned by society over the last century. While cybersecurity is far from the only issue needing to be addressed by the UAM community and regulators, it is certainly among the most important. Using artificial intelligence to detect and anticipate malicious attacks, increasing regulatory software oversight, and questioning the utility of semi-autonomous UAM provide a broad starting point in addressing the cybersecurity of new VTOL aircraft systems.

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[122] *Fact Sheet – Aircraft Certification Service,* FED. AVIATION ADMIN. (Jul. 20, 2017), https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=21315.

[123] Uber Elevate White Paper, *supra* note 34, at 18.