ROBOTS IN SPACE: SHARING OUR WORLD WITH AUTONOMOUS DELIVERY VEHICLES

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Dear We Robot Attendees,

This paper is an early draft and is very much a work-in-progress. I appreciate your time and look forward to hearing your comments as I work to improve it. I am particularly interested in your thoughts on the social risks and benefits of autonomous delivery vehicles.

-Mason

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INTRODUCTION

The title of this article, *Robots in Space,* may conjure characters from science fiction such as R2-D2 and his antics in *Star Wars* or the HAL 9000's hijacking of the Discovery One spacecraft in *2001: A Space Odyssey.* Though humanity has launched several autonomous robots into outer space,[2] at least for now, most robots operate in factories, warehouses, and other commercial spaces here on Earth.[3] They originated in factories of the mid-20th century where they improved efficiency in manufacturing.[4] Recent advancements in sensors, actuators, and artificial intelligence have increased their autonomy.[5] They can now move independently and sense and react to their environments, allowing them to migrate out of private commercial spaces and into public roads, sidewalks, and airspace, putting them into close contact with every day people.[6] An increasing percentage of robots serve as autonomous delivery vehicles (ADVs) that perform "last-mile delivery," the final step of the delivery process that ends at the customer's door.[7] This article focuses on those ADVs, and how they navigate public spaces and interact with people while completing their deliveries. It explores the nascent laws that govern ADV operation and points out areas for improving the safety, efficiency, and social benefits of last-mile delivery.

Many different robotic platforms can serve as ADVs including self-driving cars, autonomous delivery pods, unmanned aerial vehicles (UAVs or "drones"), and sidewalk delivery robots, which are also known as personal delivery robots (PDRs).[8] This article discusses all types of ADVs and the laws and administrative agencies that regulate them. However, it focuses primarily on sidewalk delivery robots because they are the newest and fastest growing type of ADV, and their operators currently face the fewest legal and regulatory hurdles. The article describes the laws governing them and how they differ from laws controlling other ADVs before making recommendations for improving the laws.

Last mile delivery is generally thought to be "the most expensive and time-consuming part of the shipping process" because it is the most personalized.[9] Driving a delivery truck on major

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[2] *See e.g.* Chaim Gartenberg, *The debut of a new ISS AI robot 'crew member' went exactly how you'd think,* VERGE (Dec. 2, 2018), https://www.theverge.com/tldr/2018/12/2/18119889/cimon-iss-ai-robot-crew-member-video-hal-9000-esa-space (describing a German autonomous robot name Cimon deployed on the International Space Station and making comparisons between its behavior and that of the H.A.L. 9000 computer from Arthur C. Clark's novel 2001: A Space Odyssey); *See* also Jonathan Amos, *Mars: Nasa lands InSight robot to study planet's interior,* BBC NEWS (Nov. 27, 2018), https://www.bbc.com/news/science-environment-46351114 (describing the deployment of NASA's Insight probe); *See* also Kenneth Change, *Follow NASA's New Horizons Mission as It Heads for New Year's Flyby With Ultima Thule,* NY TIMES (Dec. 31, 2018), https://www.nytimes.com/2018/12/31/science/ultima-thule-pictures-new-horizons.html (describing the flight of NASA's New Horizons probe past Pluto toward Ultima Thule).

[3] Most robots function in a commercial setting in factories, warehouses, etc.

[4] Rebecca J. Rosen, *Unimate: The Story of George Devol and the First Robotic Arm,* ATLANTIC (Aug. 16, 2011), https://www.theatlantic.com/technology/archive/2011/08/unimate-the-story-of-george-devol-and-the-first-robotic-arm/243716/.

[5] *See* Matt Simon, *The Wired Guide to Robots,* WIRED (May 17, 2018), https://www.wired.com/story/wired-guide-to-robots/.

[6] *See Id.*

[7] *See* Shelagh Dolan, *The challenges of last mile logistics & delivery technology solutions,* BUSINESS INSIDER (May 10, 2018), https://www.businessinsider.com/last-mile-delivery-shipping-explained.

[8]

[9] *Id.*

highways to the outskirts of a city or suburban neighborhood is relatively predictable and efficient. In contrast, last-mile delivery involves venturing into cities and neighborhoods and traveling on local roads that are often narrower and less predictable. Moreover, it requires multiple stops in which very few packages, or even individual packages, are delivered to unique addresses, which may be difficult to find, making it more complicated and less efficient.[10] In rural areas, individual recipients may be miles apart contributing to the inefficiency of last-mile delivery. In urban areas, drop-off points may be closer together, but traffic congestion can delay travel between them. Industry estimates suggest that last-mile delivery can account for up to 53 percent of total shipping costs.[11]

Some companies have experimented with crowdsourcing to decrease the cost of last-mile delivery.[12] The "Uber model" has worked for meal and grocery delivery companies such as GrubHub and Instacart, and Amazon is crowdsourcing package delivery by contracting with local non-professional drivers. ADVs are designed to further overcome the inefficiencies of last-mile delivery by eliminating the need for human drivers. A lobbyist for one ADV maker says its robots are "like an Uber for things" instead of people.[13] ADVs can function independently and inexpensively to deliver meals, groceries, packages, and other products directly to consumers, and they can do it quickly to help companies meet growing demand for same day deliveries.[14]

ADVs are now part of a global automated delivery industry that is too large to be considered a gimmick or a novelty. Companies have invested billions in the industry, and McKinsey & Company estimates that by 2025, ADVs will perform 85 percent of last-mile deliveries.[15] The delivery robot industry is currently valued at about $11.9 billion and is projected to grow to $34 billion by 2024.[16] Softbank recently invested $940 million in the autonomous delivery pod maker Nuro, which is testing automated grocery delivery in Arizona, and Honda has invested $2.75 billion in GM's autonomous vehicle subdivision Cruise Automation, which is testing automated food delivery in San Francisco.[17] In fact, ADVs from numerous tech start-ups and Fortune 500 companies are currently being tested across the United States from the suburban outskirts of Seattle to the urban streets of Miami.[18] They have also been deployed in a variety of settings in

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[10] Edwin Lopez, *Why is the last mile so inefficient?* SUPPLY CHAIN DRIVE (May 22, 2017), https://www.supplychaindive.com/news/last-mile-spotlight-inefficient-perfect-delivery/443089/.
[11] Shelagh Dolan, *How crowdsourcing shipping through technology will make last mile delivery cheaper,* Business Insider (Jun. 14, 2018), https://www.businessinsider.com/amazon-flex-hitch-deliv-crowdsource-shipping.
[12] *Id.*
[13] https://universe.byu.edu/2018/02/08/houses-passes-bill-that-would-allow-personal-delivery-robots-access-to-utah-streets1/ (quoting Starship lobbyist David Catania).
[14]
[15] Jonathan Shieber, *The race to build autonomous delivery robots rolls on,* TechCrunch (Jun. 4, 2018), https://techcrunch.com/2018/06/04/the-race-to-build-autonomous-delivery-robots-rolls-on/.
[16] https://www.prnewswire.com/news-releases/the-delivery-robots-market-projected-to-grow-at-a-cagr-of-19-15-300789270.html
[17] *See* https://techcrunch.com/2018/10/03/honda-commits-2-75-billion-in-partnership-with-gms-cruise/; *see* also http://www.thedrive.com/tech/25793/gms-cruise-automation-launches-autonomous-food-delivery-program.
[18] *See* Benjamin Romano, *Amazon tests delivery robots in Snohomish County,* SEATTLE TIMES (Jan. 23, 2019), https://www.seattletimes.com/business/amazon/amazon-tests-delivery-robots-in-snohomish-county/; *see* also Andrew J. Hawkins, *Ford is bringing its self-driving cars to Miami,* Verge (Feb. 27, 2018), https://www.theverge.com/2018/2/27/17055616/ford-self-driving-car-miami-test-av (describing the testing of Ford's autonomous delivery vehicles in Miami, which were previously deployed in Michigan to delivery for Domino's Pizza).

the UK, the EU, Australia, Africa, and Asia.[19] Though ADVs are increasingly common, at least so far, the laws governing how they travel through space and interact with people and property are limited and inconsistent, and they depend on the robots' form factor, their mode of locomotion, and where they are deployed.[20] Many states have passed or are currently drafting laws to regulate self-driving cars,[21] and the National Highway Traffic Safety Administration (NHTSA), a federal agency tasked with keeping people safe on America's roads, has issued federal guidance for automated vehicles.[22] Similarly, the Federal Aviation Administration (FAA), the agency that regulates civil aviation, has issued rules for operating UAVs,[23] and 42 states have passed laws to regulate them.[24] The laws governing self-driving cars and UAVs currently limit the use of these technologies for last-mile delivery and slow their adoption, at least in the short term.[25]

The public has raised concerns regarding the use of UAVs and self-driving cars. UAVs have been called a nuisance due to the chainsaw-like noise created by their rotors.[26] They have also been criticized for their potential to violate people's privacy given their sensors and bird's-eye view of their surroundings.[27] Safety concerns over self-driving cars have arisen following a series of highly publicized accidents and deaths.[28] The social resistance to adopting UAVs and self-driving cars, and growing state and federal regulation, is clearing the way for the rapid

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[19] Top Ten Autonomous Delivery Solutions of 2018, https://medium.com/eliport/the-top-ten-autonomous-delivery-solutions-of-2018-5cfe4e0c90a5

[20] *Delivery Robots Rolling Into Regulatory Thicket*, BLOOMBERG LAW (Jun. 19, 2017), https://www.bna.com/delivery-robots-rolling-n73014453559/ (reporting that sidewalk delivery robot laws are inconsistent)

[21] Jack Karsten and Darrell West, *The state of self-driving car laws across the U.S.*, Brookings (May 1, 2018), https://www.brookings.edu/blog/techtank/2018/05/01/the-state-of-self-driving-car-laws-across-the-u-s/ (reporting that "Twenty-two states and the District of Columbia have passed laws and an additional 10 state governors have issued executive orders regarding the operation of autonomous vehicles, while ten other state legislatures have considered legislation and the remaining eight state legislatures have not considered any.").

[22] *Automated Driving Systems*, U.S. Department of Transportation, https://www.nhtsa.gov/vehicle-manufacturers/automated-driving-systems (last visited Feb. 23, 2019).

[23] *See* Richard Korman, *What is 'safe enough' for drone deliveries?,* SEATTLE TIMES (Feb. 22, 2019), https://www.seattletimes.com/business/boeing-aerospace/what-is-safe-enough-for-drone-deliveries/.

[24] *Current Unmanned Aircraft State Law Landscape*, NAT'L CONF. ST. LEGIS. (Sep. 10, 2018), http://www.ncsl.org/research/transportation/current-unmanned-aircraft-state-law-landscape.aspx (reporting that 41 states have enacted laws addressing unmanned aerial vehicles and an additional three states have adopted resolutions).

[25] *See* Hilma Kazem, *Drone no-fly zone in California will stifle innovation, say industry advocates*, GUARDIAN (Aug. 24, 2015), https://www.theguardian.com/technology/2015/aug/25/drone-no-fly-zone-in-california-will-stifle-innovation-say-industry-advocates; *see* also Alan Ohnsman, *Arizona Governor Bans Self-Driving Ubers After Pedestrian Fatality*, FORBES (Mar. 26, 2018), https://www.forbes.com/sites/alanohnsman/2018/03/26/arizona-governor-bans-self-driving-ubers-after-pedestrian-fatality/#2fa51c3376ab.

[26] Kyle Wiggers, *Customers compare the noise from Alphabet spinout Wing's delivery drones to a chainsaw,* VENTUREBEAT (Dec. 27, 2018), https://venturebeat.com/2018/12/27/alphabet-spinout-wings-drones-are-too-noisy-customers-say/.

[27] *See e.g.* Matthew Stern, *Amazon's Drones May Collect Valuable Data On Their Fly-Overs*, FORBES (Aug. 28, 2017), https://www.forbes.com/sites/retailwire/2017/08/28/amazons-drones-may-collect-valuable-data-on-their-fly-overs/#6f01973d6cbe.

[28] *See e.g.* T.S., *Why Uber's self-driving car killed a pedestrian*, ECONOMIST (May 29, 2018), https://www.economist.com/the-economist-explains/2018/05/29/why-ubers-self-driving-car-killed-a-pedestrian; *see* also Alison Griswold, *People lash out at Waymo's self-driving cars*, QUARTZ (Dec. 31, 2018), https://qz.com/1512543/arizona-residents-lash-out-against-waymo-self-driving-cars/.

expansion of sidewalk delivery robots. Very few states currently regulate them, and the laws of those that do are generally favorable to robot manufacturers and operators. Cities, companies, and universities are welcoming sidewalk delivery robots to their walkways and campuses. As a result, companies are investing heavily in the technology, and the lack of regulation has allowed sidewalk delivery robots to proliferate rapidly.[29]

Because sidewalks are locally regulated by cities and counties, no federal agencies regulate sidewalk deliver robots. So far, seven states and the District of Columbia have implemented laws that regulate them, however, the laws are favorable to sidewalk robot operators in part because they were influenced by one of the leading manufactures of the robots.[30] In some jurisdictions, permits or licenses are required to operate sidewalk delivery robots. However, most states and cities have no regulations at all, and the relative lack of regulation has allowed sidewalk robots to proliferate at a rate that has far outpaced existing regulation. In this respect, the rapid growth of sidewalk delivery robots is comparable to the rapid expansion of electric scooters and dockless bicycles, which have spread quickly throughout US cities. Electric scooters made by companies such as Bird and Lime have provoked the ire of city residents, advocacy groups, and city and state officials because they are often strewn carelessly about the city obstructing sidewalks and angering pedestrians who sometimes revolt by throwing them into lakes, vandalizing them, or setting them on fire. [31] The makers of these scooters and bikes have been criticized for imposing their products on society without first gaining permission. Sidewalk delivery robots raise some of the same concerns as e-scooters and dockless bikes, and those similarities will be discussed below.

This article contains four parts. Part I explains the origins of ADVs in the early Twentieth Century automation of factories, the mid-Twentieth Century robotization of manufacturing, and the early Twenty-first Century introduction of autonomous robots to factories and warehouses. It explores how the migration of robots out of those private commercial factories and warehouses and into public streets, sidewalks, and airspace represents the increasing privatization of public space and the imposition of "warehouse logic" and values onto society at large. Part I concludes by describing the current state of the art of ADV technology and how the technology may evolve in the future.

Part II describes current local, state, and federal laws that govern ADV operation including the laws and federal agencies that regulate UAVs, self-driving cars, autonomous delivery pods, and sidewalk delivery robots. Part II concludes with a comparison between the laws that govern sidewalk delivery robots and other types of ADVs. Part III discusses the risks and benefits of deploying ADVs for last-mile delivery and compares the risks and benefits of operating sidewalk robots to the risks and benefits of other form factors. Part IV make suggestions for future regulation to minimize the risks of sidewalk delivery robots and limit the privatization of sidewalks and the creep of warehouse logic into public spaces and social norms.

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[30] https://www.recode.net/2017/4/22/15273698/robot-delivery-startup-starship-state-laws-lock-out-competitors

[31] Sam Levin, *San Francisco's scooter war: city hits back as 'unlawful' schemes flood streets,* Guardian (Apr. 17, 2018), https://www.theguardian.com/technology/2018/apr/17/san-francisco-electric-scooter-schemes-backlash-cease-desist.

I. ADV Origins and State of the Art

ADVs and other commercial robots have their roots in the automation of factories and warehouses. In 1913 Henry Ford introduced the mechanized assembly line to the US auto industry. A rope-and-pully system advanced each vehicle from one worker's station to the next along the length of the assembly line.[32] Commenting on his accomplishment, Ford reportedly said: "If I could save every one of my workers 50 steps a day then I could save miles by the end of the year."[33] Automation quickly increased the efficiency of factory workers, decreased the cost of production, and made automobiles and other products more affordable.[34] In 1961, the first robot was introduced to the auto assembly line.[35] This robot, the Unimate robotic arm, further increased efficiency on assembly lines.

Over half a century later, automation is transforming other supply chain industries such as warehousing, logistics, and delivery services. Companies automate distribution centers with AI and robotics to increase efficiency. Amazon is leading the charge. In 2012, the company acquired robot-maker Kiva Robotics for $775 million and subsequently rebranded it Amazon Robotics.[36] Like Ford's innovative assembly line and Unimate's robotic arm, Amazon's warehouse robots significantly reduce the daily steps workers must take. Instead of walking through aisles to stock warehouse shelves or retrieve products for distribution, workers remain stationary.[37] In a computer-choreographed ballet, stocked shelves travel to the workers on the backs of a swarm of autonomous robots.[38] The time saved gives Amazon an advantage that allows it to delivery products to consumers the same day or the following day. Amazon now operates at least 26 automated fulfillment centers internationally.[39] And at least 100,000 robots within its warehouses. To further automate its warehouse operations, Amazon recently acquired a portion of a French company called Balyo that makes self-driving forklifts.[40]

Autonomous robots are also changing the way warehouses take stock of their inventory. Walmart recently introduced UAVs that fly through warehouse aisles scanning product bar codes as they

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[32] Sheena McKenzie, *Rise of the robots: The evolution of Ford's assembly line,* CNN (Apr. 29, 2015), https://money.cnn.com/gallery/technology/2015/04/29/ford-factory-assembly-line-robots/index.html.
[33] *Id.*
[34] *Ford's assembly line turns 100: How it changed manufacturing and society,* NY DAILY NEWS (Oct. 7, 2013) https://www.nydailynews.com/autos/ford-assembly-line-turns-100-changed-society-article-1.1478331.
[35] Rebecca J. Rosen, *Unimate: The Story of George Devol and the First Robotic Arm,* ATLANTIC (Aug. 16, 2011), https://www.theatlantic.com/technology/archive/2011/08/unimate-the-story-of-george-devol-and-the-first-robotic-arm/243716/.
[36] Evelyn M. Rusli, *Amazon.com to Acquire Manufacturer of Robotics,* NY TIMES (Mar. 19, 2012), https://dealbook.nytimes.com/2012/03/19/amazon-com-buys-kiva-systems-for-775-million/.
[37] Nick Wingfield, *As Amazon Pushes Forward With Robots, Workers Find New Roles,* NY TIMES (Sep. 10, 2017), https://www.nytimes.com/2017/09/10/technology/amazon-robots-workers.html.
[38] *Id.*
[39] Andria Cheng, *Amazon's Robot-Filled New York Fulfillment Center Gives Rivals Another Reason to Worry,* FORBES (Dec. 10, 2018), https://www.forbes.com/sites/andriacheng/2018/12/10/amazons-first-new-york-fulfillment-center-should-give-rival-retailers-another-cause-for-worry/#66aae834614c.
[40] Tony Owusu, *Amazon Agrees to Deal with French Robotic Forklift Company Balyo,* THE STREET (Jan. 10, 2019), https://www.thestreet.com/investing/amazon-invests-in-french-robotic-forklift-company-balyo-14830203.

whiz past each item.[41] Warehouse UAVs can survey a company's inventory in a fraction of the time required by human workers. These types of innovation are not limited to warehouse operations. Autonomous robots are migrating out of warehouses and into communities where they occupy neighborhood skies, streets, and sidewalks.[42] "The same autonomous technologies (i.e., sensors, perception, prediction, planning) used to pack boxes in the warehouse are now being pressed into the service of delivering those packages that last mile to your door — the most complex and expensive leg of the supply chain."[43]

The goal is to automate the delivery process by employing aerial and terrestrial ADVs that use AI to navigate their surroundings. But problems arise because the companies that created factory and warehouse robots implemented them to increase efficiency, and they are now deploying similar robotic systems into public spaces where efficiency may not be the most important value. There are other values such as safety, personal freedom, wellness, and a sense of community that people value more highly than efficiency and that may be in tension with the "warehouse logic' that currently governs the operation of ADVs particularly in areas where there is no state or federal regulation. ADVs have been launched on sidewalks around the world, a space that has come to

Sidewalks have a long and fascinating history. They are thought to have first appeared around 2000 B.C. in central Anatolia (now modern Turkey).[44] The city of Corinth in Ancient Greece is said to have had sidewalks in the fourth century, but nobody knows when they were constructed.[45] Ancient Romans used sidewalks until they were destroyed when the city was "conquered from the north."[46] In Europe during the Middle Ages, pedestrians shared streets with horses and wagons.[47] Sidewalks resurfaced during the reconstruction of London after the great fire of 1666.[48] In 1751, the Westminster Paving Act created sidewalks on both sides of London roads to give pedestrians a hygienic place to walk, protected from the filth, muck, and manure of roadways.[49] Here they served a public health function, but in France, they were thought to give the masses a civilized place to walk.[50] Whereas the wealthy traveled the roadways in carriages, the rest of the population could enjoy the city by waking its sidewalks.[51] "By the late nineteenth century, sidewalks were commonly constructed in London, Paris, and most other European

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[41] Tom Jackson, *The flying drones that can scan packages night and day*, BBC NEWS (Oct. 27, 2017), https://www.bbc.com/news/business-41737300. (According to one consultant says two of these robots can do the work of 100 humans)

[42] *See* e.g. Ryan, Robots in American Law (2016). (reporting that "robots are leaving the factory and theatre of war and entering our roads, skies, offices, and homes").

[43] Jonathan Shieber, *The race to build autonomous delivery robots rolls on*, TechCrunch (Jun. 4, 2018), https://techcrunch.com/2018/06/04/the-race-to-build-autonomous-delivery-robots-rolls-on/. [change to supra]

[44] Sidewalk book

[45] *See Id; see* also Jennifer Palinkas and James A. Herbst, *A Roman Road Southeast of the Forum at Corinth*, 80 Hesperia 287 (2011).

[46] Sidewalk book

[47] *Id.*

[48] *Id.*

[49] *Id; see* also Edwin Heathcote, *Secrets of the sidewalk*, Financial Times (Sep. 9, 2016), https://www.ft.com/content/83bf6932-6f9c-11e6-a0c9-1365ce54b926.

[50] *Secrets of the sidewalk*, Financial Times (Sep. 9, 2016), https://www.ft.com/content/83bf6932-6f9c-11e6-a0c9-1365ce54b926

[51] *Id.*

cities."[52] Grand boulevards were built in cities such as Barcelona, Paris, and Vienna, which gave pedestrians wide walkways.[53]

[In San Francisco, advocacy groups voiced concerns that delivery robots would clog sidewalks making it difficult for pedestrians, people with disabilities, and seniors to navigate the city's walkways. Some cities have sold of their sidewalks to private companies.]

Some of the ADV technologies described in this article may be used in combination. For example, a self-driving delivery truck can be used as a platform to launch a swarm of smaller UAVs or sidewalk delivery robots. The truck could navigate autonomously to a neighborhood drop off spot where a swarm of smaller ADVs disembark to complete the last-mile of delivery.[54] After making their deliveries, the ADVs return to the mothership at a rendezvous point farther down the delivery route.

UPS and German automakers Daimler and Continental are testing these types of systems. The mothership can be completely automated or operated by a human driver. Daimler and Tesla are developing autonomous or semi-autonomous trucks that could serve as platforms to launch PDVs.[55] A sidewalk delivery robot maker Kiwi once used a human powered tricycle as a mothership to launch a small swarm of four sidewalk delivery robots. However, the Kiwi is now phasing this model out.

Some pieces of this automated delivery chain are reaching roadblocks in the form of regulation, government oversight, etc. The Federal Aviation Administration (FAA) regulates airspace over consumers homes and is regulating aerial drones. This has been an obstacle to full utilization of aerial PDVs. Similarly, the National Transportation Safety Board (NTSB) regulates highways and self-driving cars and trucks, which may affect the implementation of self-driving delivery trucks and motherships. Even warehouse robots are regulated by the Occupational Safety and Health Administration (OSHA). However, in contrast, there are no federal agencies or laws regulating sidewalk delivery robots. So companies are taking the path of least resistance and investing heavily in personal delivery vehicles because there are no federal laws or agencies obstructing their progress. OSHA regulates robots in warehouses. And states are rolling out the red carpet for them (hoping to attract companies and cash in on the tech boom). Seven states and Washington, DC have passed laws allowing ADVs to travel on sidewalks, and several others are contemplating similar laws. Lobbyists from the Estonian founded robot company Starship Technologies helped draft and implement the laws.

The following section describes the ADVs that are currently being manufactured and deployed around the world.

Part II: Companies Manufacturing and Operating Autonomous Delivery Vehicles

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[52] Sidewalk book
[53] *Id.*
[54] UPS, UPS Tests Residential Delivery Via Drone, YouTube (Aug. 25, 2017), https://www.youtube.com/watch?v=xx9_6OyjJrQ
[55] Sean O'kane, *Daimler is Beating Tesla to Making Semi-autonomous Big Rigs,* VERGE (Jan. 11, 2019), https://www.theverge.com/2019/1/11/18174275/daimler-tesla-self-driving-trucks-tusimple-ces-2019.

The following section describe the four primary types of ADVs that have been introduced. They are divided into UAVs, sidewalk delivery robots, self-driving cars, and autonomous delivery pods. Though their form factors differ, they all generally accomplish the same objective of completing last-mile delivery.

The autonomy of self-driving cars has been divided into six levels labeled zero through six. Level zero is no automation at all, and the car requires a driver. Level five is full vehicle automation requiring no driver. Due to safety concerns, there are currently no level five passenger vehicles on the road. However, autonomous delivery vehicles routinely operate autonomously at the equivalent of level five.

A. UAVs

The FAA estimates there will be 1.6 million commercial UAVs in operation in the US by 2021.[56] Most testing of UAVs for autonomous delivery has been conducted in relatively rural areas. It has been suggested that drones may be the ideal ADV for areas of low population density, for example, in areas with fewer than 50,000 inhabitants.[57] In underdeveloped regions, UAVs have an advantage over other ADVs because they do not require roads or sidewalks to operate, which allows them to function efficiently in areas that lack modern transportation infrastructure. Furthermore, whereas the speed of other ADVs is limited, UAVs can travel at high speed, which makes them useful for delivering medical supplies in emergency situations. For instance, UAVs have been used to fly perishable medical products such as blood to people in Rwanda, Ghana, and Tanzania.[58] In the US, UAVs are being tested to delivery human organs for transplantation. However, in Western nations, restrictions on UAVs may limit their utility for these purposes. UAV regulations are discussed further in part III.

UAVs come in a variety of shapes and sizes. They may take the form of a fixed-wing aircraft or a wingless quadcopter, and they may carry a single small parcel or a larger and more complex payload." However, all UAVs share several common features. They have components that provide lift and propulsion, compartments that carry their payload, sensors that collect information about their environments, and software and hardware that analyzes data collected by sensors and aids in navigation.

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[56] Kelly McSweeney, *FAA anticipates 1.6 million commercial drones by 2021,* ZDNet (Mar. 23, 2017), https://www.zdnet.com/article/faa-anticipates-1-6-million-commercial-drones-by-2021/.

[57] Martin Joerss et al., *How customer demands are reshaping last-mile delivery,* McKinsey & Company (Oct. 2016), https://www.mckinsey.com/industries/travel-transport-and-logistics/our-insights/how-customer-demands-are-reshaping-last-mile-delivery.

[58] *See* Paul Nuki, *Pointing the way: hoe medical drones are saving lives in Africa,* TELEGRAPH (Feb. 16, 2018), https://www.telegraph.co.uk/news/0/pointing-way-medical-drones-saving-lives-africa/; *see* also Sella Oneko and Isaac Kaledzi, *Medical Drones: Ghana to follow Rwanda's example,* DW (Nov. 12, 2018), https://www.dw.com/en/medical-drones-ghana-to-follow-rwandas-example/a-46690095; *see* also Esther Landhuis, *Tanzania Gears Up to Become A Nation of Medical Drones,* NPR (Aug. 24, 2017), https://www.npr.org/sections/goatsandsoda/2017/08/24/545589328/tanzania-gears-up-to-become-a-nation-of-medical-drones.

Drone delivery has been described as "a hodgepodge of pilot programs and promising proposals."[59] The following sections describe some of the most prominent programs and proposals. Because drones are heavily restricted by the FAA, many programs have been implemented outside the US. Federal and international drone regulation will be discussed further in Part II.

Dominos

On November 16, 2016, Domino's made its first pizza delivery by UAV to a select group of consumers in New Zealand.[60] The deliveries were part of Domino's Robotics Unit (DRU). An autonomous hexacopter with six exposed rotors carried a pizza for 2 – 3 minutes over a residential neighborhood near Auckland before hovering and lowering it into a customer's backyard with a retractable cable.[61] The hexacopter was designed by Australian UAV maker Flirtey.[62] On March 10, 2016, Flirtey completed the first FAA-sanctioned UAV delivery in an urban area when its hexacopter delivered emergency medical supplies to a house in Hawthorne, Nevada.[63] Flirtey previously made the first FAA-sanctioned UAV delivery in a rural area on July 17, 2015 in Wise County, Virginia.[64]

Alphabet

Google's parent company Alphabet has been using a UAV to delivery burritos to residents of Canberra Australia.[65] The program, called Project Wing, started as a subsidiary of Alphabet and is now a standalone entity called "Wing." Project's Wing's original design was a dodecacopter with twelve exposed rotors for vertical flight and two fixed wings each with a propeller enabling it to fly horizontally at speeds of up to 75 miles per hour.[66] Like Flirty's UAV, Wing's unit delivered its payload with a retractable capable so that it need not land. After the program was implemented in Canberra, numerous residents complained about the loud chainsaw-like noise of the UAVs, which they claimed interfered with their quiet enjoyment of their homes and disturbed their pets. Residents also complained the UAVs invaded people's privacy, and disturbed local wildlife, particularly birds.[67] To address those concerns, Alphabet announced it would reduce the Wing's flight speed and periodically alter its flight paths so that it won't

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[59] Greg Nichols, *$7.5 million to push last-mile drone delivery closer to reality,* ZDNet (Jan. 15, 2019), https://www.zdnet.com/article/7-5-million-to-push-last-mile-drone-delivery-closer-to-reality/.
[60] Sean Buckley, *Domino's starts delivering pizza by drone, but only in New Zealand,* ENGADGET (Nov. 16, 2016), https://www.engadget.com/2016/11/16/dominos-starts-delivering-pizza-by-drone-but-only-in-new-zeala/.
[61] CNBC, *Domino's First Company to Delivery Pizza by Drone,* YouTube (Nov. 16, 2016), https://www.youtube.com/watch?v=JoP1lvgGLys.
[62] *See* Sean Buckley, *Domino's starts delivery pizza by drone, but only in New Zealand,* Engadget (Nov. 16, 2016), https://www.engadget.com/2016/11/16/dominos-starts-delivering-pizza-by-drone-but-only-in-new-zeala/.
[63] Mariella Moon, *Nevada gets first FAA-approved urban drone delivery,* Engadget (Mar. 25, 2016), https://www.engadget.com/2016/03/25/nevada-gets-first-faa-approved-urban-drone-drone-delivery/.
[64] Andrew Tarantola, *Rural pop-up hospital gets America's first drone delivery,* Engadget (July 17, 2015), https://www.engadget.com/2015/07/17/rural-pop-up-hospital-gets-americas-first-drone-delivery/.
[65] *See* TechCrunch, *Alphabet's Project Wing delivers burritos by drone in Australia,* YouTube (Oct. 18, 2017), https://www.youtube.com/watch?v=L_zoJfkElmw.
[66] *Id.*
[67] Niki Burnside and Tahlia Roy, *Whining drones bringing burritos and coffee are bitterly dividing Canberra residents,* ABC NEWS (Nov. 9, 2018), https://www.abc.net.au/news/2018-11-09/noise-from-drone-delivery-service-divides-canberra-residents/10484044.

continuously pass over the same houses.[68] The design changes should be implemented before Alphabet rolls out a new delivery pilot-program in Finland.[69] The Helsinki based program will launch in Spring of 2019 and deliver packages of up to 3.3 pounds over distances of up to 6.2 miles.[70]

Wing previously formed partnerships with Chipotle and Starbucks in the US. However, neither arrangement developed beyond initial stages.[71] Wing CEO James Ryan Burgess said the company is still working on projects in the US, "but the regulatory environment is more complicated."[72] During the Finnish trial, customers will not be charged for UAV deliveries, but Wing envisions a charge in the single digits in the future.

Amazon

On December 7, 2016, Amazon made its first autonomous UAV delivery to a customer in the countryside of Cambridgeshire, England.[73] Its quadcopter UAVs were launched from a nearby "Amazon Prime Air" fulfillment center.[74] The program started with a beta test involving two customers.[75] The tests were made possible by an agreement between amazon and the British government that allowed Amazon to fly UAVs beyond the visual line-of-sight (BVLOS).[76] Flying BLOS is essential for UAV delivery services to be viable. Partly due to its agreement with the British government, Amazon built an office in Cambridge England focused on developing Prime Air UAV deliveries.[77]

In 2016, Amazon filed a patent application for a UAV that self-destructs into fragments if it encounters problems while in flight.[78] In 2018, the company filed a patent application for a UAV that can respond to human speech and gestures such as waving and pointing.[79] Though these features have not yet been incorporated into Amazon's UAV, they illustrate where the technology may be headed in the future.

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[68] Feilidh Dwyer, *Alphabet to build quieter delivery drones following widespread noise complaints,* We Talk UAV (Dec. 31, 2018), https://www.wetalkuav.com/alphabet-try-to-make-quieter-delivery-drones/.
[69] *Id.*
[70] Ingrid Lunden, *Wing, Alphabet's drone delivery business, to begin a pilot in Finland in Spring 2019*, TechCrunch (Dec. 4, 2019), https://techcrunch.com/2018/12/04/wing-takes-flight-in-finland/.
[71] *Id.*
[72] *Id.*
[73] Amazon, *Amazon Prime Air's First Customer Delivery,* YOUTUBE (Dec. 14, 2016), https://www.youtube.com/watch?v=vNySOrI2Ny8.
[74] *Id.*
[75] *Id.*
[76] Mike Murphy, *The UK countryside's opposition to Amazon's drone tests is just so quintessentially British,* Quartz (Aug. 3, 2016), https://qz.com/748701/the-uk-countrysides-opposition-to-amazons-drone-tests-is-just-so-quintessentially-british/.
[77] Samuel Gibbs, *Amazon makes Cambridge heart of Alexa and drone innovation with new offices,* Guardian (Nov. 11, 2017), https://www.theguardian.com/technology/2017/nov/11/amazon-uk-development-centre-cambridge-new-offices-alexa-prime-air-drone-deliveries.
[78] *See* U.S. Patent Application No. 9828097 (Directed fragmentation for unmanned airborne vehicles); *see* also James Vincent, *Amazon patents self-destructing drone that falls apart in an emergency*, Verge (Dec. 1, 2017), https://www.theverge.com/2017/12/1/16723190/amazon-self-destructing-drone-falls-apart-midair-patent.
[79] *See* Thuy Ong, *Amazon's latest patent is a delivery drone that understands when you shout at it,* Verge (Mar. 22, 2018), https://www.theverge.com/2018/3/22/17150868/amazon-drone-patent-delivery-wave-speech-recognition.

In 2019, Amazon announced a collaboration with NASA and Single European Sky ATM Research (SESAR) "to solve the problem of how small unmanned aircraft systems (UAS) performing a wide variety of commercial applications can fly safely in the same low-altitude airspace."[80]

Though the British government has allowed Amazon to test its UAVs beyond the visual line-of-sight since 2016, the has not allowed BVLOS flight until recently. In 2019, US insurance company State Farm acquired the first waiver from the FAA to conduct operations over people (OOP) and to fly BVLOS.[81] State Farm uses its drones to assess property damage during insurance inspections.[82] It had previously been granted geography-specific, limited duration waivers by the FAA to assess for damage following natural disasters.[83] FAA waivers will be discussed further in Part II.

UPS

Amazon is testing a UAV delivery service in which drones are launched from mothership built from a modified UPS truck.[84] As the UAV makes its deliveries, a UPS employee can make deliveries using the truck before meeting the UAV farther along the delivery route.[85]

The system is based on the HorseFly UAV system developed by Workhorse.[86] "It is a high-efficiency, octocopter delivery drone that is fully integrated with Workhorse's line of electric/hybrid delivery trucks. The drone docks on the roof of the delivery truck. A cage suspended beneath the drone, extends through a hatch into the truck. A UPS driver inside loads a package into the cage and presses a button on a touch screen, sending the drone on a preset autonomous route to an address. The battery-powered HorseFly drone recharges while it's docked. It has a 30-minute flight time and can carry a package weighing up to 10 pounds. For this test, Workhorse preset the route for the drone. But in the future, routes could be determined by UPS's On-Road Integrated Optimization and Navigation (ORION), which is the company's proprietary routing software."[87]

DHL

Deutsche Post/DHL operates a UAV called Parcelcopter 4, a quadcopter with four exposed rotors and two horizontal wings each with a propeller for horizontal flight.[88]

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[80] Patrick C. Miller, *Amazon testing commercial UAS traffic management system,* UAS Magazine (Jan. 29, 2019), http://www.uasmagazine.com/articles/1979/amazon-testing-commercial-uas-traffic-management-system.

[81] https://www.ainonline.com/aviation-news/general-aviation/2019-01-08/state-farm-obtains-first-national-drone-bvlos-waiver

[82] *Id.*

[83] *Id.*

[84] https://www.youtube.com/watch?v=xx9_6OyjJrQ

[85] https://www.youtube.com/watch?v=xx9_6OyjJrQ

[86] https://pressroom.ups.com/pressroom/ContentDetailsViewer.page?ConceptType=PressReleases&id=1487687844847-162

[87] https://pressroom.ups.com/pressroom/ContentDetailsViewer.page?ConceptType=PressReleases&id=1487687844847-162

[88] https://www.youtube.com/watch?v=id00S4L0P5A

DHL is testing a drone called Paketkopter to make deliveries of medicine from a pharmacy in Bonn, Germany.[89]

Flytrex
In 2018, Israeli UAV company Flytrex started delivering food in Reykjavik, Iceland with an autonomous.[90] Also in 2018, Flytrex performed the first UAV food delivery to golfers on a US golf course in North Dakota.[91] The North Dakota Department of Transportation in Bismarck is one of ten initial selectees authorized by the FAA to serve as test sites for the UAS Integration Pilot Program (IPP)."[92] The IPP is partnership between the FAA, the selectees made up of local, state, and tribal governments, and private sector companies. Launched in 2017, its purpose is to test drones for a variety of applications including last-mile delivery. It will be discussed further in Part II.

JD.com
Chinese e-commerce company JD.com, the largest rival of Alibaba, has introduced a hexacopter UAV for last-mile delivery. In 2017, "the Civil Aviation Administration of China (CAAC) gave the go-ahead for JD.com and SF Holding Co., the country's biggest express-delivery company, to start sending packages by drone in certain rural areas."[93] In 2019, JD.com started testing UAVs for delivering items between islands in Indonesia.[94]

Zipline
Zipline uses UAVs to delivery blood and medical supplies in Rwanda.[95]

B. Sidewalk Delivery Robots

The design of sidewalk delivery robots varies. Some are about the size of a golden retriever. Others are as large as washing machines. They usually travel on four or six wheels, but some travel on legs or tank treads.[96] The features they have in common are a chassis, a cargo container that sits atop the chassis, navigations systems, communication systems, and antitheft systems. Some sidewalk delivery robots resemblance the androids of science fiction such as R2-D2. They are about the same size, and like their fictional counterparts, they are designed to be cute, endearing, and helpful.[97] However, like the robots of science fiction, they can also be a clumsy,

[89] https://consumerist.com/2013/12/09/dhl-uses-drone-to-deliver-medicine-in-germany/
[90] Shoshanna Solomon, *Israel's Flytrex set to supply half of Reykjavik with food by drone,* Times Israel (Aug. 7, 2018), https://www.timesofisrael.com/israels-flytrex-set-to-supply-half-of-reykjavik-with-food-by-drone/.
[91] https://venturebeat.com/2018/09/05/flytrex-golf-delivers-food-and-beverages-to-hungry-golfers-via-drone/
[92] http://www.thedrive.com/tech/23405/flytrex-launches-aerial-food-delivery-at-kings-walk-golf-course-in-north-dakota
[93] https://www.bloomberg.com/news/features/2018-07-03/china-s-on-the-fast-track-to-making-uav-drone-deliveries
[94] https://techcrunch.com/2019/01/22/jd-drone-indonesia/; https://www.popsci.com/china-drone-deliveries
[95] https://www.bbc.com/news/av/technology-43886039/drones-deliver-blood-and-medical-supplies-in-rwanda
[96] https://www.oregonbusiness.com/article/tech/item/18242-small-town-robot
[97] Cute, endearing, helpful…

somewhat unpredictable, and a bit bumbling.[98] When they malfunction, they can cause property damage, human injury, and potentially even death.[99]

Sidewalk delivery robot manufacturers claim they reduce delivery time, cut costs, improve the user experience, decrease traffic congestion, reduce carbon emissions, assist people with disabilities who may have difficulty leaving home, democratize access to logistics and delivery resources for small businesses allowing them to compete with large corporations, and create unique opportunities to use logistics for charitable purposes.[100]

Critics claim sidewalk PDRs may negatively impact public health by encouraging inactivity, obstructing sidewalks and crosswalks, impairing the mobility of seniors and people with disabilities, endangering safety due to their potential to collide with people who are not agile enough to get out of the way. PDRs may also reduce the need for human delivery workers and represent the increasing privatization of sidewalks, which is generally considered a public space that should be reserved for pedestrians.[101]

Pedestrians' responses to these robots have been mixed. People have been observed kicking the robots[102], vandalizing them (police robots), children have been found to obstruct their movement or kick, hit, and throw objects at them. Advocacy groups have voiced concerns. Talks about response of the people from the San Francisco organization (the walking group).

To engender empathy from consumers, robot manufacturers design their robots to have human-like features and expressions. Robby robots painted eyes on their robot, Kiwi robots have eyes that can change expression and make heart shaped eyes at a pedestrian that steps into its path, Nuro designed the front fascia of its robot to resemble the eyes of a motorcycle rider peering out from a helmet so that it would appear familiar to drivers.

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[98] *See* e.g. Jeremey Hsu, *Out of the Way, Human! Delivery Robots Want a Share of Your Sidewalk,* SCI. AMER. (Feb. 19, 2019), https://www.scientificamerican.com/article/out-of-the-way-human-delivery-robots-want-a-share-of-your-sidewalk/ (describing how a delivery robot became stranded after children covered its sensors with snow); *see* also Jon Porter, *Delivery robot spontaneously bursts into flames in California,* Verge (Dec. 17, 2018), https://www.theverge.com/2018/12/17/18144304/kiwibot-fire-berkeley-california-thermal-runaway-faulty-battery ; *see* also Guardian News, *Hapless Boston Dynamics robot in shelf-stacking fail,* YouTube (Aug. 15, 2017), https://www.youtube.com/watch?v=JzlsvFN_5HI.

[99] *See e.g.* Laurel Wamsley, *Robot Punctures Can of Bear Repellent at Amazon Warehouse, Sickening Workers,* NPR (Dec. 6, 2018), https://www.npr.org/2018/12/06/674201649/robot-punctures-can-of-bear-repellent-at-amazon-warehouse-sickening-workers; *see* also Guardian News, *Russian postal drone crashes into wall on maiden flight,* YOUTUBE (Apr. 3, 2018), https://www.youtube.com/watch?v=QfSMyHCm4d8; *see* also Daisuke Wakabayashi, *Self-driving Uber Car Kills Pedestrian in Arizona, Where Robots Roam,* NY TIMES (Mar. 19, 2918), https://www.nytimes.com/2018/03/19/technology/uber-driverless-fatality.html; *see* also Steve Miletich, *Pilot of drone that struck woman at Pride Parade gets 30 days in jail,* SEATTLE TIMES (Feb. 24, 2017), https://www.seattletimes.com/seattle-news/crime/pilot-of-drone-that-struck-woman-at-pride-parade-sentenced-to-30-days-in-jail/.

[100] London Assembly Transport Committee Site Visit to Starship Technologies, (Nov. 1, 2017) https://www.businessinsider.com/last-mile-delivery-shipping-explained [cite properly]

[101] Cite the organization in San Francisco and reach out to them.

[102] https://www.sfgate.com/technology/businessinsider/article/People-kicking-these-food-delivery-robots-is-an-12980712.php

Starship technologies

Starship Technologies ("Starship") arguably makes the most widely recognized sidewalk delivery robot.[103] The Starship unit is about the size of a large picnic cooler and has been described as an autonomous box on wheels.[104] It uses six wheels to accelerate and steer, and it avoids obstacles using machine learning, nine external cameras, ultrasound sensors, a global positioning system (GPS), and a radar system.[105] According to a Starship, "the robot has nine cameras – front, back and sides – and they can be recording as well. So an incident could be placed on YouTube immediately.[106] It also has two-way audio, which means that we can listen and talk to people around the robot. We can have human interaction and engage with people, which is quite interesting."[107]

Starship was founded in Tallinn, Estonia in 2014 by two Skype co-founders, and it now has working delivery robots around the world.[108] In 2017, German automaker Daimler invested $17.2 million in the company.[109] By the end of 2018, Starship raised $42 million from multiple investors. The company now has over 200 hundred employees and offices in the Estonia, Hamburg, London, and San Francisco, and Washington, DC.[110]

Starship completed its first official delivery on November 28, 2016, when one of its robots delivered takeout to a customer in London's Greenwich neighborhood.[111]Since then, it has launched trials in over 100 cities around the world, and as of as of January 22, 2019, the company had logged over 150,000 miles and completed over 25,000 deliveries.[112]

Starship has tested and deployed its robots in a variety of settings from corporate office parks and college campuses to dense urban areas and rural neighborhoods. It had previously tested the robots on London streets by allowing them to roam freely to map and learn the area.[113] A little

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[103] [Starship most widely recognized delivery robot]

[104] *See* Lora Kolodny, *Postmates and DoorDash are testing delivery by robot with Starship Technologies,* TechCrunch (Jan. 18, 2017), https://techcrunch.com/2017/01/18/postmates-and-doordash-are-testing-delivery-by-robot-with-starship-technologies/.

[105] *See* Tanel Parnamaa, *How Neural Networks Power Robots at Starship,* Medium (Nov. 28, 2018), https://medium.com/starshiptechnologies/how-neural-networks-power-robots-at-starship-3262cd317ec0; *see* also *Robot company Starship Technologies start Milton Keynes deliveries,* BBC NEWS (Oct. 31, 2019), https://www.bbc.com/news/uk-england-beds-bucks-herts-46045365.

[106] https://www.theengineer.co.uk/autonomous-delivery-robots-hit-london/

[107] *Id*.

[108] Mike Butcher, *Skype Co-Founders Launch The Starship 'Ground Drone' For Deliveries,* TechCrunch (Nov. 5, 2015), https://techcrunch.com/2015/11/05/skype-co-founders-launch-the-starship-ground-drone-for-deliveries/.

[109] *See* Cat Zakrzewski, *Daimler Invests In 'Last Mile' Robotic Delivery Startup,* WALL ST. J. (Jan. 12, 2017), https://www.wsj.com/articles/daimler-invests-in-last-mile-robotic-delivery-startup-1484224207; *see* also Darrell Etherington, *Daimler leads $17.2M round in rolling delivery drone startup Starship Technologies,* TECHCRUNCH (Jan. 12, 2017), https://techcrunch.com/2017/01/12/daimler-leads-17-2m-round-in-rolling-delivery-drone-startup-starship-technologies/.

[110] Khari Johnson, *Starship Technologies raises $25 million to expand robot delivery services,* VENTUREBEAT (Jun. 7, 2018), https://venturebeat.com/2018/06/07/starship-technologies-raises-25-million-to-expand-robot-delivery-services/.

[111] Stu Robarts, *Autonomous droid makes first fast-food delivery*, NEW ATLAS (Dec. 1, 2016), https://newatlas.com/just-eat-starship-technologies-first-robot-food-delivery/46735/.

[112] Kyle Wiggers, *Starship Technologies' robots begin delivering food to college kids,* VENTURE BEAT (Jan. 22, 2019), https://venturebeat.com/2019/01/22/starship-technologies-robots-begin-delivering-food-to-college-kids/.

[113] [Free-roaming to map and learn the area]

over one year later, the company had "amassed a global fleet of 150 robots carrying out daily drop-offs in eight cities in the US, UK, Estonia, and Germany."[114] One of its early test sites was the Mountain View campus of Intuit, a Silicon Valley-based accounting software firm.[115] Employees and visitors across Intuit's 12-building campus can order meals and coffee through a smartphone app and have it delivered from the staff cafeteria to the building or outdoor location of their choice.[116] Starship also started delivering industrial materials between campus buildings of German auto-maker Mercedes-Benz.[117]

Daimler, the parent company of Mercedes-Benz, has partnered with Starship to create a "mothership" van concept that will carry a "swarm" of eight Starship robots to a neighborhood before releasing the swarm.[118] The drones then disperse throughout the neighborhood to complete last-mile delivery.[119] "Deliveries would be co-ordinated by an algorithm that determines the best route for the van to take. This algorithm would pick out the best location for the van to stop and release the army of delivery bots and also collect those that have completed their routes."[120] The mothership concept is also being tested by other companies including German auto-maker Continental for use with sidewalk PDRs and by UPS and for use with UAVs.[121]

In late 2018, hundreds of Starship's robots started delivering packages throughout the British town of Milton Keynes.[122] After signing up for the service, town residents can list Starships receiving center as their home address, which allows the cent to receive a customer's packages when the consumer is not home. Recipients can then schedule delivery from the receiving center to their homes through Starship's smartphone app. Residents can also order grocery delivery from stores including Tesco and Co-op, and Starship claims it can make deliveries within 15 minutes.[123] The company plans to expand its delivery services beyond Milton Keynes in the near future.[124]

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[114] *See* Alex Hern, *First robot delivery drivers start work at Silicon Valley campus,* GUARDIAN (Apr. 30, 2018), https://www.theguardian.com/cities/2018/apr/30/robot-delivery-drivers-coming-to-a-campus-near-you-starship-technologies.
[115] *Id.*
[116] *Id., see also* Starship Technologies, Starship Campus Delivery Service with Robots, YOUTUBE (Apr. 30, 2018), https://www.youtube.com/watch?v=P_zRwq9c8LY.
[117] Carolyn Said, *Robots from Starship to carry food on corporate, college campuses,* SF CHRONICLE (Apr. 30, 2018), https://www.sfchronicle.com/business/article/Robots-from-Starship-to-carry-food-on-corporate-12870950.php.
[118] *See* Matt Burgess, *Mercedes vans filled with swarming delivery bots could be heading to your hometown,* WIRED (Sep. 7, 2016), https://www.wired.co.uk/article/mercedes-starship-drones-delivery-van.
[119] *Id.*
[120] *Id.*
[121] *See e.g.* James Vincent, *Robot dogs are the weirdest package delivery system we've seen,* VERGE (Jan. 10, 2019), https://www.theverge.com/2019/1/10/18176856/robot-dog-package-delivery-continental-demo-ces-2019; *see* also UPS, *UPS Tests Residential Delivery Via Drone,* YOUTUBE (Feb. 21, 2017), https://www.youtube.com/watch?v=xx9_6OyjJrQ; *see* also , DHL
[122] *Robot company Starship Technologies start Milton Keynes Delivery*, BBC NEWS (Oct. 31, 2018), https://www.bbc.com/news/uk-england-beds-bucks-herts-46045365.
[123] Sean Poulter, *Food shopping delivered by a ROBOT,* Daily Mail (Jan. 8, 2019), https://www.dailymail.co.uk/sciencetech/article-6569647/Now-food-shopping-delivered-ROBOT.html.
[124]

Starship has also launched its robots on college campuses. In 2018, it provided a fleet of 25 robots to George Mason University's campus in Fairfax, Virginia. Students, faculty, and staff can order food and drinks from Starbucks, Dunkin', and Blaze Pizza using Starship's smartphone app for a $1.99 delivery fee.[125] GMU is the first university to incorporate delivery robots into its campus dining plan.[126] That means students no longer need to leave the dorm to utilize their meal plans. Starship's choice of a Virginia university for its first campus deliveries should come as no surprise because Virginia was the first US state to pass a law legalizing sidewalk delivery robots.[127] Moreover, Starship was instrumental in drafting the law.[128] The company deploys lobbyists who have provided model legislation to lawmakers in several states. As a result, the sidewalk delivery robot laws of many states have striking similarities, but there are subtle differences (in weight, speed, etc.) that may affect safety, etc. These laws will be discussed further in part III.

The response from GMU students and staff has been mixed. According to students and staff, student behavior changed almost immediately after the robots were introduced. One employee was concerned the robots might replace human workers. A professor suggested that the robots will cause students to interact less with each other. One staff member reported that the Starship system collects data about students' food consumption. In 2018, Starship said it planned to launch about 1,000 robots on about 20 college campuses in the US, UK, and Germany.[129]

Starship has partnered with other companies around the world including Postmates, Door Dash, and Domino's Pizza.[130] [in Europe].

Amazon Robotics

Amazon is starting its own autonomous parcel delivery platform to reduce its reliance on other carriers such as UPS and the US Postal Service. On January 25, 2019, the US Patent and Trademark Office published Amazon's patent application for "autonomous ground vehicles based at delivery locations."[131] The application includes device and method claims related to

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[125] Peter Holley, *George Mason students have a new dining option: Food delivered by robots,* Wash. Post (Jan. 22, 2019), https://www.washingtonpost.com/technology/2019/01/22/george-mason-students-have-new-dining-option-food-delivered-by-robots/?noredirect=on&utm_term=.4d6fafbd6915.

[126] Peter Holley, *How one university changed overnight when it let 25 semiautonomous robots roam its campus,* Wash. Post (Jan. 25, 2019), https://www.washingtonpost.com/technology/2019/01/25/how-one-university-changed-overnight-when-it-let-semi-autonomous-robots-roam-its-campus/?utm_term=.f22390b289a2.

[127] Tom Regan, *Virginia is the first state to legalize delivery robots,* ENGADGET (Mar. 2, 2017), https://www.engadget.com/2017/03/02/virginia-is-the-first-state-to-legalize-delivery-robots/.

[128] Will Yakowicz, *Robot Delivery Company Influencing Laws That Favor Its Autonomous Bots*, INC. (Apr. 24, 2017), https://www.inc.com/will-yakowicz/starship-technologies-virginia-idaho-florida-wisconsin.html.

[129] Paul Sawers, *Starship Technologies launches autonomous robot delivery services for campuses,* VENTUREBEAT (Apr. 30, 2018), https://venturebeat.com/2018/04/30/starship-technologies-launches-autonomous-robot-delivery-services-for-campuses/; Melanie Abbott, *Robot company Starship Technologies plans 1,000 delivery bots,* BBC News (May 1, 2018), https://www.bbc.com/news/technology-43949554.

[130] Lora Kolodny, *Domino's and Starship Technologies will deliver pizza by robot in Europe this summer,* TECHCRUNCH (Mar. 29, 2017), https://techcrunch.com/2017/03/29/dominos-and-starship-technologies-will-deliver-pizza-by-robot-in-europe-this-summer/.

[131] Parmy Olson, *Amazon Just Sparked A Race To Bring Robots To Our Doors,* FORBES (Jan 31, 2018), https://www.forbes.com/sites/parmyolson/2018/01/31/amazon-just-sparked-a-race-to-bring-robots-to-our-doors/#24e40c62b3a2.

autonomous delivery vehicles.[132] Claim 1 describes a transport system comprising an autonomous ground vehicle that is based at a user's residence and a computing system that instructs the vehicle to meet and retrieve an item from a transport vehicle before returning to the user's residence.[133] Claim 7 describes an autonomous ground vehicle comprising a propulsion system, a storage compartment with a locking mechanism, and a computing system.[134] Claim 14 describes a method for transporting items comprising determining a location at which a transport vehicle meets two autonomous ground vehicles and instructing the vehicles to receive items from the vehicle before delivering them.[135]

One year after the patent application was published, on January 23, 2019, Amazon unveiled a six-wheeled sidewalk delivery robot called Scout.[136] That day, the company started delivering packages to residents of Snohomish County, Washington.[137] Amazon reportedly acquired robotics start-up Dispatch in 2017 to help build Scout.[138] At first glance, the unit resembles Starship's robots. Scout is about the same size and looks like a cooler on six wheels. Amazon has not discussed the technical specifications of Scout such as how many onboard cameras and other sensors it contains.

Amazon is starting out with six Scout robots for pilot testing in Washington.[139] As the system evolves, it may eventually be compatible with Amazon Key, which allows Amazon to deliver packages inside customer's homes or garages.[140] However, as a latecomer to the PDR market, Scout may face several challenges. For instance, Amazon has some catching up to do. While Amazon has only six delivery robots operating in one US community, Starship has hundreds in operation around the world, and numerous other companies have entered the market. However, Amazon has years of experience developing autonomous robots.

Kiwi

Unlike Starship and Amazon's PDRs, Kiwi's robots ('KiwiBots") have four wheels, and they are smaller than the units of their competitors. Kiwi's first delivery occurred in March of 2017.[141] Today, more than 100 KiwiBots deliver food to students and staff on the campus of UC Berkeley.[142]

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[132] U.S. Patent Application No. 20180024554.
[133] *Id.*
[134] *Id.*
[135] *Id.*
[136] Brian Heater, *Amazon is piloting its own delivery robot,* TECHCRUNCH (Jan. 23, 2019), https://techcrunch.com/2019/01/23/amazon-is-piloting-its-own-delivery-robot/.
[137] Kris Holt, *Amazon starts testing its 'Scout' delivery robot,* ENGADGET (Jan. 23, 2019), https://www.engadget.com/2019/01/23/amazon-scout-delivery-robot/.
[138] Mark Harris, *Amazon quietly acquired robotics company Dispatch to build Scout,* TECHCRUNCH (Feb. 7, 2019), https://techcrunch.com/2019/02/07/meet-the-tiny-startup-that-helped-build-amazons-scout-robot/.
[139] Sean Scott, *Meet Scout,* About Amazon (Jan. 23, 2019), https://blog.aboutamazon.com/transportation/meet-scout.
[140] *See* Rachel England, *Amazon Key opens your home for indoor deliveries,* Engadget (Oct. 25, 2017), https://www.engadget.com/2017/10/25/amazon-key-service-delivery-access-unlock-door/; *see also* Shannon Liao, *After trying your front door, Amazon wants to let people deliver packages inside your garage,* Verge (Jan. 7, 2019), https://www.theverge.com/2019/1/7/18167425/amazon-key-garage-business-home-deliveries-prime-ces-2019.
[141] https://www.kiwicampus.com/technology
[142] Sophia Brown-Heidenreich, *KiwiBot catches fire outside Martin Luther King Jr. Student Union,* DAILY CALIFORNIAN (Dec. 14, 2018), http://www.dailycal.org/2018/12/14/kiwibot-catches-fire-outside-mlk-student-union/.

Kiwi's Head of Product told me the KiwiBot rides on a custom-built "glorified RC car chassis." The unit has five forward facing cameras and one rear-view camera. The HD Cameras give the KiwiBot a 250-degree view of its surroundings.[143] It also has three solid state lidars sensors that allow it to detect nearby obstacles. According to the company's website, "At Kiwi, we use Deep Learning to teach the Kiwi Bot the correct way to interpret data gathered from its sensors and to make intelligent decisions that ensure a fast, safe and cost-efficient delivery."

In late 2018, Kiwi expanded its operations into the Westwood neighborhood of Los Angeles, which is home of the UCLA campus.[144] For now the robots delivery food to students off campus because Kiwi has not yet acquired the permits necessary to travel on campus.[145]Students can choose food from 15 area restaurants.[146] Kiwi reportedly completed about 200 deliveries within its first two weeks of operation in Westwood.[147] The company aims to launch 500 more robots in 2019 and expand its operations to other UC campuses."[148] And up to 50 campuses total . The company targets the student demographic and has found students and university campuses to be very receptive to the technology (interview)

Kiwi initially used an electric tricycle unit as a mothership to launch three KiwiBots. A Kiwi employee would pedal the tricycle to the general area of the delivery and deploy a trio of robots. However, the company is phasing out its mothership platform and experimenting with other systems.[149] Currently using bikes and people walking around on the sidewalk to launch each delivery.[150]

KiwiBots often operate autonomously. However, human drivers monitor their progress from a control center in Colombia.[151] Kiwi's Head of Product Sasha Iatsenia compares the operation of KiwiBots to the autopilot system in an airplane. Though the units can function independently, a human pilot can take control if necessary, for example, if the robot enters a crowded area or crosses a very busy street.[152] The robots recently started operating at night, and they currently make deliveries from 10am to 10pm.[153]

Continental

German automotive company Continental unveiled a four-legged robot delivery "dog" at the 2019 Consumer Electronic Show in Las Vegas.[154] The robot, called ANYmal, was designed and

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[143] Kiwi website
[144] Chris Albrecht, *Kiwi Delivery Robots Expand into Los Angeles,* SPOON (Oct. 24, 2018), https://thespoon.tech/kiwi-delivery-robots-expand-into-los-angeles/.
[145] *Id.*
[146] David Gray, *Kiwi Bots roll into the Westwood area's food delivery scene,* Daily Bruin (Oct. 24, 2018), http://dailybruin.com/2018/10/24/kiwi-bots-roll-into-the-westwood-areas-food-delivery-scene/.
[147] *Id.* .
[148] *Id.*
[149] Personal interview with Kiwi Head of Product Sasha Iatsenia.
[150] *Id.*
[151] *Id.*
[152] *Id.*
[153] *Id.*
[154] *Supra note* https://www.theverge.com/2019/1/10/18176856/robot-dog-package-delivery-continental-demo-ces-2019

built with help from robotics company ANYbotics.[155] In a live demo, the ANYmal navigated a fake suburban sidewalk after disembarking from an autonomous vehicle called "the Cube" that served as its mothership.[156] Continental calls its system "cascaded robot delivery" that "leverages a driverless vehicle to carry delivery robots, creating an efficient transport team."[157] In the demonstration, the ANYmal walked down a faux sidewalk carrying a package on its back.[158] Continental demonstrated the robot's ability to avoid obstacles by having it step over an overturned electric scooter that obstructed the sidewalk.[159] The ANYmal then walked up the front porch of a fake home, extended its front leg to ring the fake doorbell, and tilted its body sideways, tipping the package off its back and onto the porch.[160]

Though Continental's cascaded robot delivery system is unique, currently it is only a proof-of-concept and is not in commercial use.[161]

Marble

Marble is a San Francisco based startup founded by three graduates of Carnegie Mellon University.[162] In 2017, Marble began testing its robots on the sidewalks of San Francisco's Mission and Potrero Hill Districts.[163] On April 12, 2017, the company announced it had raised $4 million in seed funding and formed a partnership with Yelp's Eat24 food delivery brand.[164] One year later, it announced it had raised a total of $15 million and had plans to move beyond food delivery to last-mile logistics in general.[165] According to Marble's CEO Matthew Delaney: "It's a lot more than just food delivery. It's about rearchitecting the urban supply chain of the future, to open up these services that everyone can afford and bring that next level conveyance to everyone. The at-home parent with six kids or the homebound, elderly or disabled. They don't have this option. Nobody can afford these services."

According to Marble's website: "We improve access to goods and connect companies to their customers with electric vehicles built on sustainability, safety and neighborly manners."[166] However, when Marble tested its robots on the streets of San Francisco, it faced considerable backlash from neighbors and city legislators.[167] The backlash was likely triggered in part by the size of Marble's delivery bots. Unlike Kiwi and Starship's relatively compact robots, Marble's

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[155] *Id.*
[156] *Id.*
[157] *See* Megan Rose Dickey, *Robot delivery dogs deployed by self-driving cars are coming,* TECHCRUNCH (Jan. 7, 2019), https://techcrunch.com/2019/01/07/robot-delivery-dogs-deployed-by-self-driving-cars-are-coming/.
[158] ANYbotics, *Last-Meter Robotic Package Delivery with ANYmal (CES 2019), ANYbotics & Continental),* YOUTUBE (Jan. 30, 2019), https://www.youtube.com/watch?v=v3g5xp5Kr2g.
[159] *Id.*
[160] *Id.*
[161] *Id.*
[162]
[163] April Glaser, *New robots are hitting the streets of San Francisco to deliver food to your doorstep,* Recode (Apr. 12, 2017), https://www.recode.net/2017/4/12/15266142/robots-delivery-san-francisco-marble-yelp.
[164] *Id.*
[165] Brian Heater, *Delivery robotics company Marble raises $10 million, with plans to move beyond food,* TechCrunch (Apr. 24, 2018), https://techcrunch.com/2018/04/24/delivery-robotics-company-marble-raises-10-million-with-plans-to-move-beyond-food/
[166]
[167]

unit appears to come in two sizes: large and extra-large depending on the size of the cargo bay attached to the robot's chassis.[168] In fact, Marble makes the largest sidewalk delivery robot currently in use, which has been described by some critics as a filing cabinet or washing machine on wheels or a "kitchen appliance crossed with a Mars rover."[169] Whereas Starship's robots are about knee high to a human, Marble's are more than waist high.[170] By comparison, KiwiBots have the smallest form factor.[171]

Like KiwiBots, Marble's unit has four wheels instead of six. It senses its environment using cameras. Marble is testing its robots in Concord, California. It has begun mapping streets in Arlington and is discussing a pilot with a city in Nevada, Erickson said. Last year, it ran a meal delivery pilot in San Francisco with Yelp 324, a food delivery business that the online review company acquired."

C. Self-Driving Delivery Pods

Self-driving delivery pods are smaller, lighter, and narrower versions of self-driving cars that are used for autonomous delivery. Though they resemble sidewalk delivery robots in some ways, self-driving delivery pods are too large to travel on sidewalks. Instead, they drive exclusively on roads like their larger cousins. However, they typically travel at lower speeds and are limited to local roads instead of busier highways. They can bring an entire produce aisle to the curb of a consumer's home.[172]

Nuro

Nuro was founded in 2016. Its robots currently operate and Arizona, and it recently received $940 million in investment from Softbank.[173] The company is taking a different approach to food delivery. Instead of traveling on the sidewalk, its larger robot travels on the street. "Nuro is one of the few companies to be operating fully driverless vehicles on public roads today"[174] "The 1,500-pound pod is battery powered, putters at low speeds and has a customizable interior that can carry about 250 pounds of cargo."[175] At least for now, a manned chased vehicle follows the robot to ensure that it operates safely.[176]

There may be some downsides compared to sidewalk delivery robots. "The big difference, of course, is that Nuro's delivery service won't include a human being who will bring your delivery right to your door. In other words, Nuro's self-driving vehicle meets customers at the curb. This could prove difficult for customers who live in apartment buildings, have children, or are elderly or disabled."

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172 https://www.theverge.com/2018/9/17/17859112/self-driving-cars-shuttle-pods-delivery-services

173 https://www.wired.com/story/softbank-nuro-self-driving-investment/

174 https://www.theverge.com/2019/2/11/18220287/nuro-robot-delivery-softbank-investment

175 http://fortune.com/2018/03/13/self-driving-delivery-vehicles-pizza/

176 https://sacramento.cbslocal.com/2018/12/18/grocery-delivery-with-autonomous-vehicles-is-underway/

Nuro is one of four autonomous delivery vehicle manufacturers to voluntarily release a safety report.[177] In the safety report, Nuro claims outlines for safety features of the R1: low speed operation; lighter, narrower, and more nimble vehicle, ability to self-sacrifice; and a safety-enhanced vehicle front-end. Nuro's R1 operates "exclusively at or below 25 miles per hour." Nuro claims the slower speeds increase reaction time allowing the vehicle to more effectively avoid collisions. According to Nuro, the lighter and narrower form factor give the R1 additional space to navigate around obstacles compared to other self-driving cars. Nuro says the reduced weight reduces the vehicles stopping distance. It claims the R1 "fully addresses all 12 safety elements that the Department of Transportation's National Highway Traffic Safety Administration has outlined as critical areas of focus for self-driving vehicles."[178]

D. Self-Driving Cars

Self-driving cars can serve as "mother ships" for UAVs or sidewalk delivery robots, or they can function as autonomous deliver vehicles in their own right and deliver products directly to a customer's door. However, unlike UAVs that travel in the sky and sidewalk delivery robots that share sidewalks with pedestrians, self-driving cars and trucks share roads with motorists and other self-driving vehicles. [to be expanded]

II. Federal Laws and Administrative Agencies Governing ADVs

A. Federal Laws Governing UAVs

"The Federal Aviation Administration published new rules, which took effect in late August. The new FAA rules replaced the temporary restrictions on drone use by companies, which had previously required companies to apply for a special permit in order to use a drone for their business. The rules allow companies to use drones, but include the requirement that the drone be kept within the line of sight of the operator during use. Another major restriction is that drones are prohibited from being over individuals not involved with the drone operation. These restrictions directly effect the way in which Amazon had intended to use their Prime Air service, thus they have moved their testing to the UK where there are currently no such restrictions."

The FAA implemented new rules (formally known as Part 107) in 2016 to regulate the commercial operation of UAVs.[179] The rules prohibit the operation of commercial UAVs at night, over populated areas, or out of the visual line of site of a drone pilot unless the operator

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[177] Andrew J. Hawkins, *Self-driving delivery startup Nuro releases its voluntary safety report*, Verge (Sep. 13, 2018), https://www.theverge.com/2018/9/13/17855136/nuro-self-driving-car-safety-report.

[178] *Delivering Safety: Nuro's Approach* https://static1.squarespace.com/static/57bcb0e02994ca36c2ee746c/t/5b9a00848a922d8eaecf65a2/1536819358607/delivering_safety_nuros_approach.pdf

[179] https://www.faa.gov/news/updates/?newsId=86305; https://www.pcworld.com/article/3086790/new-faa-rules-mean-you-wont-get-amazon-drone-delivery-anytime-soon.html

obtains a waiver from the agency.[180] The FAA aims to grant waivers with 90 days of submission, however, successfully obtaining a Part 107 waiver can be challenging. These restrictions have limited the implementation of UAV delivery. However, on January 14, 2019, the FAA proposed new rules to allow UAVs to operate over populated areas and to fly at night without a waiver.[181] According to the agency, through 2017, it granted 1,233 waivers and no reports of nighttime UAV accidents.[182] Under the new rules, UAVs could be flown at night, but they would be required to undergo testing and training and have an anti-collision light visible from a distance of three miles.[183] Operators could fly UAVs weighing 0.55 pounds or less over populated areas without a waiver.[184] However, to fly UAVs over 0.55 pounds over people, their manufacturers would have to show that a collision would result in injuries "below a certain severity threshold."[185]

The FAA has also implemented a program to test UAV applications through partnerships with state agencies and private companies. On May 9, 2018, it announced ten selectees for its unmanned aircraft systems Integration Pilot Program (IPP).[186] "The three-year program aims to test practical applications of drones by partnering local governments with private sector companies to learn more about how this emerging technology can be safely and usefully integrated into day-to-day activities."[187] "It allows for governments and private sector entities to examine ways to accelerate safe UAS integration and to enable things such as package delivery and passenger transportation down the road."[188] Participants in the program "are evaluating a host of operational concepts, including night operations, flights over people and beyond the pilot's line of sight, package delivery, detect-and-avoid technologies and the reliability and security of data links between pilot and aircraft."[189]

The IPP selectees included cities and universities from across the country, three state departments of transportation, a county mosquito control district in Fort Myers, a county airport authority in Memphis, and the Choctaw Nation of Oklahoma.[190] Each selectee partnered with private companies to increase drone use and evaluate potential safety, security, and privacy

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[180] 14 C.F.R. §107.29 (UAV daylight operations); §107.39 (UAV operations over people); §107.31 (UAV visual line of sight aircraft operations); *see* also Part 107 waivers: https://www.faa.gov/uas/commercial_operators/part_107_waivers/

[181] https://www.reuters.com/article/us-usa-drones/u-s-proposes-to-allow-drone-operation-at-night-over-people-idUSKCN1P828W

[182] *Id.*

[183] *Id.*

[184] *Id.*

[185] *Id.*

[186] *See* Will Yakowicz, *Apple, Uber Among Companies Approved for Federal Drone Pilot Program*, Inc. (May 10, 2018), https://www.inc.com/will-yakowicz/faa-approves-us-drone-pilot-program.html; *see* also https://www.transportation.gov/briefing-room/dot3419

[187] https://www.ncdot.gov/news/press-releases/Pages/2018/2018-08-29-drone-program-partnership.aspx

[188] https://thenextweb.com/contributors/2019/02/24/jeff-bezos-promised-drone-deliveries-by-2019-but-3-things-are-missing/

[189] https://www.faa.gov/uas/programs_partnerships/integration_pilot_program/

[190] https://www.transportation.gov/briefing-room/dot3419

risks.[191] Corporate partners include tech, transportation, and logistics titans such as Alphabet, Apple, Airbus, FedEx, Intel, Microsoft, and Uber.[192] Smaller UAV startups such as Flirty and Zipline also made the cut.[193] The program focuses on evaluating package delivery, flying at night, operating over people (OPP), and flying beyond the visual line of sight (BVLOS).[194] Each company is working on a unique local pilot program. For example, Flirtey has partnered with an ambulance service in Reno, Nevada to test UAVs that deliver defibrillators to people experiencing heart attacks.[195] Swiss company Matternet has partnered with the North Carolina Department of Transportation to use UAVs to delivery medical supplies between hospitals.[196] Uber is working with the California Department of Transportation to use UAVs to deliver food to San Diego residents.[197] However, there are have been roadblocks that caught IPP participants off guard.[198] In San Diego, Uber discovered that its food delivery drones are subject to some of the same FAA regulations as passenger aircraft such as Part 135, which contains operating requirements for commuter planes such as crew flight time, duty period limitations, and rest requirements.[199]

B. Federal Laws Governing Sidewalk Delivery Robots

There are currently no federal laws that directly regulate sidewalk delivery robots. However, there are some federal laws that could be relevant and will be discussed further below (e.g. the Americans with Disabilities Act). [to be expanded]

C. Federal Laws Governing Self-Driving Cars and Autonomous Delivery Pods

[under development]

IV. State and Local Laws Governing ADVs

A. State and Local Laws Governing UAVs

[under development]

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[191] *See* John Bonazzo, *Feds Approve Drone Delivery Pilot Programs From Uber, Intel, Alphabet- But Not Amazon,* Observer (May 10, 2018), https://observer.com/2018/05/drone-delivery-pilot-program-faa-dot-amazon-uber-intel-alphabet/.
[192] *See* Yakowicz *supra* note 160.
[193] *Id*.
[194] *Id.*
[195] Jason Hidalgo, *Flirtey eyes Reno deliveries by 2020 after first multi-drone test milestones,* Reno Gazette J. (Sep. 12, 2018), https://www.rgj.com/story/money/business/2018/09/12/flirtey-eyes-reno-deliveries-2020-after-multi-drone-test-milestone/1284923002/.
[196] Shaun Courtney, *Dinner Delayed: Uber Delivery Drones Face Rules for Planes,* Bloomberg Gov. (Jan. 31, 2019), https://about.bgov.com/news/dinner-delayed-uber-delivery-drones-face-rules-for-planes/.
[197] http://www.thedrive.com/tech/24359/ubereats-wants-to-deliver-your-meal-via-drone-by-2021
[198] https://about.bgov.com/news/dinner-delayed-uber-delivery-drones-face-rules-for-planes/
[199] 14 C.F.R. 135; https://about.bgov.com/news/dinner-delayed-uber-delivery-drones-face-rules-for-planes/

B. State and Local Laws Governing Sidewalk Delivery Robots

At least seven states and the District of Columbia have passed laws that legalize sidewalk delivery robots. Virginia was the first.[200] Its law was drafted with the help of Starship's lobbyists, signed by the governor on Feb 24, 2017, and went into effect on July 1, 2017.[201] It defines sidewalk delivery robots as "electric personal delivery devices" and limits their weight to 50 pounds excluding cargo and caps their speed at 10 miles per hour.[202] Their operation is restricted to sidewalks, crosswalks, and shared-use paths, which may also be used by pedestrians, bicyclists, wheelchair users, and skateboarders.[203] Subsequent laws are generally patterned after the Virginia law with mostly subtle differences between them. Starship lobbyists also helped pass the laws in Florida, Wisconsin, Idaho, Utah, and Ohio.[204]

State laws generally have the following features:

- Limit the weight of the robots
    - Idaho was the second state to legalize the robots, and it permits a higher maximum weight than Virginia of 80 pounds (10 miles per hour). Florida was the fourth state to legalize the robots, and it also raised the weight to 80 pounds (10 miles per hour)
    - Ohio limit of 90 pounds.
    - The weight limits of several states may prohibit certain companies that operate heavier robots, such as Marble, from operating in those states.
    - Starship's chief operating officer Alan Martinson has said the weight limits are "not random but based on safety estimates."[205]
    - "The 50-pound limit came about in discussion about what would be the most approachable and safest route that a pedestrian would feel safe with this robot traveling next to them," said Rep. Ron Villanueva from Virginia, one of the lawmakers who championed the state's new robot policy.[206]
    - "A spokesperson for state Sen. Chris Kapenga, one of the sponsors of the Wisconsin bill that's making its way through the state legislature, said that they arrived at the 80-pound weight limit by doubling the weight of Starship's robot."[207]
    - A proposed Washington State bill limits the weight to 120 pounds.[208]
- Limit the speed of the robots
    - Idaho has same speed of 10 miles per hour.

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204 April Glaser, *Ohio is now the fifth U.S. state to permit delivery robots on sidewalks*, Recode (Jul. 5, 2017), https://www.recode.net/2017/7/5/15916688/ohio-fifth-state-delivery-food-robots-starship-law; *see* also Kate Harris, *House passes bill that would allow personal delivery robots access to Utah streets*, Daily Universe (Feb. 8, 2018), https://universe.byu.edu/2018/02/08/houses-passes-bill-that-would-allow-personal-delivery-robots-access-to-utah-streets1/.

205 April Glaser, *A robot-delivery startup helped write state laws that are locking out competition*, Recode (Apr. 22, 2017), https://www.recode.net/2017/4/22/15273698/robot-delivery-startup-starship-state-laws-lock-out-competitors.

206 *Id.*

207 *Id.*

208 *Id.*

    - Florida has same speed of 10 miles per hour.
- Give robots the same rights and duties as pedestrians. However, they must yield to pedestrians and must not unreasonably interfere with their movement.
- Require robot operators to carry liability insurance and specify the minimum required coverage. (often at least $100,000 [Florida]).
- Prohibit sidewalk delivery robots from operating on roads and highways except when navigating crosswalks (do states differ on whether you can use shared use paths???)
    - [Florida] A personal delivery device may not be operated on the Florida Shared-Use Nonmotorized Trail Network.
- Require robots to carry an identification tag or plate.
- Require the robots to have a specified number of external lights for low-light visibility.
- They must also be equipped with technology that permits them to be operated with or without active human control.
- Must be actively controlled or monitored by a human operator.
    - The laws don't go into much detail on what it means to be monitored. In other words, one operator could be responsible for monitoring 100 robots and meet the requirements of state statutes.
- Require that sidewalk robots be electrically powered.
- Wisconsin law creates a duty of care for device operators: "device shall be operated with due care" (346.807).
- "None of the states that have so far passed laws permitting the use of autonomous robots are major population centers."[209]

Areas of difference:
One important area where some state laws differ is whether the law functions as a floor or a ceiling. Under most state statutes, including Florida, Ohio, Arizona, and Utah, local jurisdictions are permitted to impose stricter laws for sidewalk delivery robots. However, in Virginia and Wisconsin, local jurisdictions are not permitted to implement stricter laws. These differences raise an important question: How important is local control of sidewalk delivery robots and are there situations in which state or federal law should reign supreme?

Whether the robots can use shared use paths, which are also used by bicyclists, pedestrians, and other users.

"A smattering of differing regulations in different jurisdictions would make it hard for businesses to figure out what the laws are in the areas they intend to operate, Jonathon Hauenschild, director of the conservative American Legislative Exchange Council's Task Force on Communications and Technology, said. A company opening in Virginia will need to find out not only state regulations but also the rules of Falls Church, Richmond, and any other city they might end up in, he said."[210] "To be sure, not everyone thinks a raft of differing regulations would be a burden. Varying city laws could present "new opportunities for competition and diversification," Michael B. Baylous, a shareholder and transportation attorney at Lane Powell in Anchorage, Alaska, said."

[209] April Glaser
[210] https://www.bna.com/delivery-robots-rolling-n73014453559/

A few things the laws don't regulate:

- Width of the robot
- Communication between the robot and pedestrians
- How data collected by robots is used and shared
- Interactions with vulnerable populations such as disabled people and children
- Collision avoidance and mitigation systems

The Idaho law expressly permits counties and cities to adopt additional regulations for the safe operation of delivery robots, as would the Florida measure. "We didn't want to have a 'top down' approach," Idaho Republican Rep. Jason A. Monks (R), who sponsored the Idaho measure, said. "Cities and counties could have specific and unique situations that would require additional regulations."[211] However, under the Virginia law, cities may prohibit the use of delivery robots but may not adopt additional regulations. The Wisconsin measure would do the same.

""It's quite possible there will be a patchwork across the country," Katie Matison, a shareholder and transportation attorney at Lane Powell in Seattle, said. If there is a matter of local public interest, municipalities can prevent delivery robots from operating at certain speeds, in certain areas, or otherwise restrict what they are doing, she said."[212]

"Wisconsin lawmakers attempted to avoid a jumble of disparate city laws by banning localities from further restricting the operation of robots beyond what the state law stipulates.
"We wanted to make sure we didn't have that problem," Wisconsin Senator Chris Kapenga (R), sponsor of his state's bill, said. "Any time you get a patchwork, it makes it hard from a business perspective.""[213]

Wisconsin's approach ensures delivery robot operators are treated equally throughout the state, Garrett J. Huffman, research assistant to Wisconsin Rep. Mike Kuglitsch (R), a sponsor of the Wisconsin bill, said. In addition, Huffman said, the "take it or leave it approach, as opposed to adding regulations per individual community, provides greater likelihood the technology will be introduced into more local communities."[214]

Benefits of ADVs and Sidewalk Delivery Robots

PDR manufacturers claim their robots and delivery services provide a variety of social, economic, and environmental benefits, which can be broken down into the following categories: Increased Delivery Efficiency, Decreased Delivery Cost, Increased Convenience for Consumers, Democratization of Access to Logistics Technology, Increased Access to Deliveries for Seniors and People with Disabilities, Improved Delivery Safety, and Protecting the Environment.

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[211] https://www.bna.com/delivery-robots-rolling-n73014453559/
[212] *Id.*
[213] *Id.*
[214] https://www.bna.com/delivery-robots-rolling-n73014453559/

Increased Efficiency and Decreased Cost of Last-Mile Delivery

As described above, the last-mile of the delivery process is the most expensive portion of the delivery process.[215] However, following the popularity of Amazon Prime, consumers expect to receive online purchases quickly, oftentimes the same day they are ordered or the following day. PDR manufacturers claim their robots can increase the efficiency of last-mile delivery to help retailers meet consumers' expectations.

Customers can "get delivery cheaper and faster than ever before. Traditional last-mile delivery costs about five to thirteen dollars in California. The delivery person has car and has to find parking." With personal delivery robots, "We don't need to find parking."[216]

Convenience

In addition to speedy delivery, consumers also want convenience. Robotic last mile delivery allows consumers to schedule delivery times that are convenient to them. Through traditional delivery using carriers such as UPS or FedEx, the customer has no choice when the item is delivered. If the consumer is not home at the time of delivery, the item may be left on a doorstep, stoop, or other are where it could be stolen.

Robotic last mile delivery offers an alternative. For example, Starship allows residents of Milton Keynes to provide its reception facility as their home address when ordering items online.[217] Consumers receive notifications when their packages arrive at the facility.[218] They can then schedule robot delivery of their purchases at their convenience. Eventually, robotic delivery may be compatible with Amazon key.[219]

PDR operators can also provide consumers with convenience by allowing them to track deliveries through smart phone apps.[220] GPS tracking can follow the robots progress as it makes its way to the consumer's home.[221] Tracking a delivery robot in real time is an advancement over the relatively clunky notifications provided by companies like UPS.[222]

Democratize Access to Logistics

Make logistics available to smaller business. They have a subscription plan.[223]
Companies can offer a subscription plan to small businesses. Compares it to a Netlix subscription.[224] For a flat rate, you can get an unlimited number of robot deliveries.[225] Instead of

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[215] Citation from above about how last mile delivery is the most expensive part of the delivery process.
[216] Personal interview with Kiwi Robotics.
[217] Kevin J. Ryan, *Lots of Companies Are Trying to Deliver Packages More Efficiently. This Startup Is Betting Its Tiny, 4-MPH Robots Will Win*, INC. (Oct. 31, 2018), https://www.inc.com/kevin-j-ryan/starship-technologies-rolling-bot-mail-delivery.html.
[218] *Id.*
[219] *Id;* https://www.inc.com/kevin-j-ryan/starship-technologies-rolling-bot-mail-delivery.html
[220]
[221]
[222]
[223] Personal interview with Kiwi.
[224] *Id.*
[225] *Id.*

a restaurant having to purchase its own delivery robot, it can rent the robots through a company like Kiwi or Starship.[226]

Access

Increase access for people with disabilities and people with decreased mobility such as seniors. People with disabilities will have to deal with increased obstacles on the sidewalk. Could be a violation of the ADA (cite to current ADA lawsuit and consider contacting the attorney). Delivery medicines to people who are homebound or who have mobility impairments.

Safety

Warehouse and fulfillment robots can potentially decrease work-related injuries. Robots may decrease repetitive strain injuries of delivery workers by taking over some repetitive tasks and they may decrease the need for workers to carry heavy loads. For instance, Amazon's robotic shelves eliminate the need for workers to operate heavy machinery to move pallets of products. However, may lead to new types of repetitive motions. For instance, instead of walking down aisles to pull products from shelves, workers at Amazon's automated fulfilment centers now remain stationary and may be at risks for new types of repetitive injuries. Further study is needed to evaluate these risks, which will be discussed further in the following section.

Amazon purchased a portion of French maker of autonomous forklifts that could decrease warehouse and fulfillment center accidents. Autonomous delivery vehicles may bring some of those safety benefits to delivery workers. Robots may allow delivery workers to carry fewer and lighter loads. Self-driving delivery trucks and motherships may decrease traffic accidents.

Autonomous delivery vehicles may also provide safety benefits to pedestrians and motorists. If pedestrians trip and fall on the sidewalk, or if they have medical emergencies such as stroke, seizure, or heart attack, sidewalk delivery robots could potentially signal emergency services for help. ADVs could also monitor the condition of roads and sidewalks, and their auto and foot traffic patterns, and provide that information to local governments to help them prioritize public works projects. There may be other benefits such as reporting crimes and motor vehicle accidents.

Sidewalk delivery robots are essentially mobile surveillance platforms. Human drivers monitor the video feed and are prepared to take over control if necessary. If they witness an accident or crime, they can contact police, the fire department, or paramedics. The risks of this ongoing surveillance will be discussed in the following section.

Environmental

Delivery robots may reduce carbon emissions by reducing the number of fossil fuel burning delivery trucks. ADV companies claim they are taking trucks off the road and putting the burden of delivery onto last mile delivery robots. Can ADVs really benefit the environment?[227]

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[226] *See Id.*

[227] Joshuah K. Stolaroff et al., *Energy use and life cycle greenhouse gas emissions of drones for commercial package delivery*, 9 Nature Communications (2018); https://www.smithsonianmag.com/innovation/drone-delivery-good-for-environment-180968157/; Oliver Milman, *Express delivery: use drones not trucks to cut carbon emissions, experts say*, Guardian (Feb. 13, 2018), https://www.theguardian.com/environment/2018/feb/13/drones-trucks-

Charitable Benefits (opportunities for social responsibility/decrease waste)
Some companies have proposed social responsibility programs that leverage their technologies. For example, robots could pick up food that would be wasted otherwise. There is currently no inexpensive and easy way to distribute wasted food, and delivery robots could provide a solution.[228]

Drones deliver blood and medical supplies in Rawanda.[229] In the U.S. drones are being tested for delivering organs for transplant.[230]

Economic Argument
Is it more economical to use last-mile delivery? "It's a market that has yet to be validated," says Brian Gerkey, CEO of Open Robotics. "You've seen a lot of startups working on this, but I think there's always been this question of whether it's going to make economic sense. It's tough to beat the capabilities of a person who goes around doing that last-mile delivery."[231] "A robot never tires, but humans are still far more capable at virtually everything. A delivery robot can't open gates without hands, and it can't climb steps to get right to your door. And if the robot requires the customer to enter a PIN to get the package out, how can the robot leave the package if you're not home? "Also, to be able to react to unexpected situations," Gerkey says. "People are just going to be fantastic at that."[232]

Risks of ADVs and Sidewalk Delivery Robots

Surveillance and risks to privacy
ADVs pose a variety of privacy risks for consumers who utilize them for last-mile delivery and for society at large. Because ADVs continuously collect data from their environments using sensors such as cameras, microphones, and lidar, they can serve as mobile surveillance platforms. Concerns have previously been raised over static surveillance systems such as cameras on the streets of New York City.[233] However, in contrast to static cameras and sensors, which cover only limited areas, ADVs can cover large areas and effectively blanket the streets with surveillance. UAVs can access areas that are not typically accessible to humans. As Ryan Calo puts it: "Robots of all shapes and sizes, equipped with an array of sophisticated sensors and processors, greatly magnify the human capacity to observe . . . they introduce new points of access to historically protected spaces."

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climate-change-carbon-emissions; Prachi Patel, *Drone Delivery, If Done Right, Could Cut Emissions,* IEEE Spectrum (Feb. 13, 2018), https://spectrum.ieee.org/energywise/energy/environment/drone-delivery-if-done-right-could-cut-emissions.

[228] Personal interview with Kiwi.

[229] https://www.bbc.com/news/av/technology-43886039/drones-deliver-blood-and-medical-supplies-in-rwanda

[230] https://spectrum.ieee.org/the-human-os/robotics/drones/test-run-confirms-that-drones-can-safely-deliver-organs-for-transplant

[231] https://www.wired.com/story/amazon-new-delivery-robot-scout/

[232] *Id.*

[233] LinkNYC privacy concerns: https://www.huffingtonpost.com/entry/privacy-battle-brewing-are-linknyc-kiosks-surveillance_us_5a284856e4b0650db4d40caf

To leverage this ability for data analytics purposes, Amazon patented a UAV that collects data about people's homes as it passes overhead. The information gained from UAV surveillance could be used for a variety of purposes from targeted advertising to law enforcement. If a UAV determines that a home has a backyard pool, that information could be used to stream targeted ads for pool furniture to the homeowner. Alternatively, if the UAV detects marijuana plants in the backyard, that information could be sent to law enforcement and used to prosecute the homeowner.

Though sidewalk robots travel in areas that can be reached by pedestrians, they raise similar concerns. The information collected by their sensors could be used for a variety of purposes including targeted advertising and law enforcement. As sidewalk delivery robots pass by a home, they can collect information about cars in the driveway (including license plates of those vehicles). If we anthropomorphize the robot as an intellectual exercise, and imagine that it is thinking as it travels along its delivery route, we can imagine how it might think "Mr. Jones at number 10 drives a Lexus, and Ms. Smith at number 12 drives a Jeep." The ADV might notice whether the lights are on or off to infer people's daily habits and observe whether the yard is well maintained or has fallen into disrepair. Perhaps the state of one's yard might be used as a proxy for credit worthiness. If the homeowners are users of Amazon Prime, then Amazon might claim it collects this information to "improve the user experience."

UAVs also have potential to collect information about people and their behavior. Unlike surveillance cameras, the purposes of which are self-evident to those who notice them, the cameras and sensors of ADVs are not immediately obvious to consumers and people who have incidental contact with the robots, even when they are in plain sight. The average pedestrian will likely be unaware that a sidewalk delivery robot contains up to ten cameras, microphones, and other sophisticated sensors. Thus, ADVs may collect information about people without their knowledge.

According to Nuro's privacy policy, its ADVs "use sensing systems, including cameras and microphones, to perceive objects and environmental conditions, enabling safe operation. The vehicles "see" and "hear" their environment in much the same manner as the driver of a regular, passenger vehicle would, and so these sensing systems may incidentally capture images or sounds that include users of the service. The data collected by these sensing systems is logged, and used to operate the vehicle and provide customer support, and to improve driving performance and customer experience."[234] This statement suggests that Nuro's ADV may collect and store images of people's faces, behavior, and property while recording audio of their conversations. According to the statement, the data may be used for any purpose that improves the ADVs performance or the customer experience, which could include many uses including targeted advertising. "Improving the customer experience" is a common (and vague) phrase that broad enough to encompass many services such as user profiling and targeted advertising. A Nuro representative spoke with me about Nuro's vision for autonomous delivery but declined to comment on privacy issues.

If ADVs record conversations, they might violate state and federal wiretapping laws, which could expose them to criminal and civil liability. "Federal law permits recording telephone calls

[234] Nuro privacy policy: https://nuro.ai/privacy

and in-person conversations with the consent of at least one of the parties. See 18 U.S.C. 2511(2)(d). This is called a "one-party consent" law. Under a one-party consent law, you can record a phone call or conversation so long as you are a party to the conversation. Furthermore, if you are not a party to the conversation, a "one-party consent" law will allow you to record the conversation or phone call so long as your source consents and has full knowledge that the communication will be recorded."[235]

"In addition to federal law, thirty-eight states and the District of Columbia have adopted "one-party consent" laws and permit individuals to record phone calls and conversations to which they are a party or when one party to the communication consents.[236] "Eleven states require the consent of every party to a phone call or conversation in order to make the recording lawful."[237]

In addition to collecting large amounts of data from their environments, ADVs use sophisticated machine learning software to analyze the data and make intelligent decisions about how to interact with people and objects in the environment. For example, using AI and data collected from their sensors, ADVs construct detailed 3D maps of their surroundings.[238] Those 3D maps and how they change over time could be extremely valuable to government actors and private companies.

According to Kiwi, its robots don't record video while traveling on the sidewalk. They do contain a black box that records a small loop of video that is saved locally to the device and continuously taped over. It would be retrievable in the event of an accident. However, the video is not uploaded to servers in the cloud. He acknowledged that continuously recording and retaining video would be technically feasible, but is not something Kiwi is interested in doing. "People are afraid," he said.[239]

Starship's privacy policy describes a black box system that may retain video data for up to four hours. It says that only 0.5 – 2 percent of video data is retained.[240] However, the policy also says medium resolution video clips of up to 20 seconds are retained "to improve robot safety and behavior."[241] Moreover, "During driving, low-resolution images are transmitted to the robot operator for the purposes of safe operation.[242] These images have low quality and they are obfuscated above the horizon during sidewalk driving, making people unidentifiable. During

[235] Temporary citation: http://www.dmlp.org/legal-guide/recording-phone-calls-and-conversations
[236] *Id.*
[237] *Id.*
[238] http://www.govtech.com/fs/Robots-May-Deliver-Central-Ohioans-Pizzas-in-the-Next-Year-or-Two.html?utm_content=bufferba0a3 (Postmates' new delivery robot turns burritos into valuable 3D maps); https://www.theengineer.co.uk/autonomous-delivery-robots-hit-london/ ("It uses computer vision to do that, meaning it analyses straight lines from its nine cameras, and it's analysing thousands of lines every second, which builds a 3D map of the environment around it. After it's built that map it can then operate autonomously in that neighborhood.")
[239] Phone interview with Kiwi Head of Product.
[240] Starship privacy policy: https://www.starship.xyz/data-privacy/
[241] *Id.*
[242] *Id.*

road crossings, obfuscation is disabled for added safety."[243]"They send information to Starship's database each time they make a journey, helping continually refine the company's maps."[244]

The ADV permitting schemes of some cities may require ADV operators to share data with the city government.[245] For example, under San Francisco's sidewalk delivery policy, manufacturers must share data with the city's Department of Public Works.[246]

Many ADV manufacturers say their goals to reduce the cost of last-mile delivery to zero. However, in todays surveillance capitalism, where data is harvested in exchange for free services, we must question the motives of these companies. Can delivery really be provided for free? Are consumers paying for the service in some other way. It has been reported that electric scooters manufacturers cannot recoup their costs through rental fees alone.

On college campuses, ADVs may be used to track the behavior of students. "The robots will also provide campus officials with valuable data showing what time students are eating, where that food is coming from and how meal plans are being used. Though that information won't be monetized by the school," a school official said, "it could lead to changes in how the university serves students." Tracking student eating habits raises privacy concerns.[247]

Like eScooters, ADVs can serve as a trojan horse for smart city technology as governments may be willing to pay private companies for the information that their ADVs generate.[248] ADVs map the neighborhoods and use AI to determine the fastest route. In Los Angeles, "City officials want granular location information on thousands of dockless scooters that are proliferating in the sprawling southern California metropolis. They say it's critical to know what's happening in their streets and ensure people are being served equitably."[249] "This sort of combination of private data in public hands is going to be a bigger and bigger issue, and when it's geolocation there are some particular questions . . . when government agencies create public databases, "law enforcement has the ability to access it, and they will."[250] "Last December, a collection of chief data officers of American cities signed an open letter heralding the launch of dockless vehicles and arguing that cities getting their raw data was "essential for internal urban planning."[251]

"Scooter- and bike-share operators Lime and Spin form an agreement with transportation technology company Remix to share loads of real-time data with the Los Angeles Department of

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[243] *Id.*
[244] https://www.inc.com/kevin-j-ryan/starship-technologies-rolling-bot-mail-delivery.html
[245]
[246]
[247] Starship on GMU campus article
[248] *See https://www.pcmag.com/news/364492/how-scooters-and-the-data-they-collect-can-transform-citie*
[249] https://www.politico.com/states/california/story/2019/03/01/this-is-creepy-in-la-scooters-become-the-next-data-privacy-fight-883121
[250] *Id.*
[251] *Id.*

Transportation."[252] "City officials want to use location data from Uber-owned Jump's dockless scooters to inform public transit policies."[253]

A first step of training the robots and their AI is to allow them to roam free throughout the city or neighborhood, which allows the companies to create a detailed map of the environment. How much of this data will be shared for business, government, and law enforcement purposes? Intersection with law enforcement? The units contain systems for contacting police if they are tampered with.

Decreasing Access

ADV manufacturers claim their robots increase access to essential services for seniors and people with disabilities. However, there is little evidence to support that claim, and ADVs may decrease access that these populations have to sidewalks, a vital means of transportation for many people, particularly in cities. Sidewalks serve as a vital artery of transportation for commuters, people with disabilities, seniors. They must be maintained to allow easy navigation by pedestrians, wheelchairs, walkers, canes, and other assistive devices.

People with disabilities in Atlanta have filed a class action lawsuit against the city arguing that its uneven and crumbling sidewalks violate the Americans with Disabilities Act (ADA).[254] If sidewalk delivery robots become so commonplace that they obstruct the movement of people with disabilities on the sidewalk, then the cities that permit them to operate could become liable for violating the ADA. The city of Los Angeles settled a similar lawsuit in 2015, and agreed to pay $1.3 billion to fix its sidewalks and make other improvements.[255]

Disability advocates in San Diego have filed a suit against electric scooter makers Lime and Bird claiming that their scooters violate the ADA by impeding access to sidewalks and crosswalks.[256] ""Without full use of the sidewalk and curb ramps at street intersections, persons with mobility and/or visual impairments have significant barriers in crossing from a pedestrian walkway to a street," the suit alleges. "This is exacerbated when the sidewalk itself is full of obstructions and no longer able to be fully and freely used by people with disabilities.""[257] "The lawsuit also alleges the scooter companies have been allowed to "appropriate the public commons for their own profit.""[258]

Unlike the lanes of roads and highways, which are relatively standardized and of uniform width, most sidewalks are not uniform. They vary in width, smoothness, and uniformity. Unlike traffic lanes in a roadway, foot and robot traffic on a sidewalk may flow in multiple directions. Some sidewalks are little wider than a pedestrian, a wheelchair, or a sidewalk delivery robot. Putting

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[252] Skip Descant, *Lime and Spin to Share Detailed Use Data with LADOT*, GOV. TECH. (Nov. 9, 2018), http://www.govtech.com/fs/Lime-and-Spin-to-Share-Detailed-Use-Data-with-LADOT.html.
[253] https://www.engadget.com/2019/03/07/los-angeles-uber-jump-scooter-data/; https://www.engadget.com/2018/08/31/uber-jump-own-electric-scooter-san-francisco/
[254] https://www.npr.org/2018/08/14/638629421/legal-battle-over-crumbling-sidewalks-unfolds-in-atlanta
[255] https://www.latimes.com/local/lanow/la-me-ln-lawsuit-broken-sidewalks-20150331-story.html
[256] https://www.latimes.com/local/lanow/la-me-ln-ada-suit-scooters-san-diego-20190112-story.html
[257] *Id*.
[258] *Id.*

sidewalk delivery robots onto sidewalks without any standardization or rules can result in chaos and an unpredictable environment for pedestrians.

For some populations, walking on the sidewalk is their primary mode of transportation. For some people with disabilities, venturing out on the sidewalk and navigating past people can be frightening and intimidating. Introducing robots with which

Safety Risks

"According to Starship, the goal is to achieve 99 per cent autonomy, with one human overseeing 100 bots. If a robot gets into a situation where intervention is required, the operator can step in and take control remotely."[259] However, one human observer for every 100 robots may be insufficient to ensure pedestrian safety. Moreover, Starship claims to partially obfuscate the images, and it uses medium to low resolution images to monitor the sidewalk, which may impair ADV operators' ability to navigate safely.

Though sidewalk delivery robots travel slowly compared to self-driving cars, if a sidewalk robot hits a pedestrian, the robot can impart a large force to that person's body. The robots can be very heavy even when unloaded. Some people may not be agile enough to get out of the way. The impact or a resulting fall could result in serious injury or death.

In 2018, Kiwi made national news when one of its robots spontaneously combusted on a Berkeley, California street.[260]

Health Risks

By crowding the sidewalks, delivery robots may disincentivize the use of public walkways encouraging the use of cars.

Delivery robots on college campuses may ecrease physical activity by making it unnecessary and inexpensive to leave the house or dorm. "One student says he no longer has to make a 10 to 15 minute trip to get his food."[261]

The robots also raise food safety issues: "Other than not running over a student or exploding, the number one rule for a food delivery robot is food safety, according to Candess Zona-Mendola, the editor of MakeFoodSafe.com, an advocacy site."[262]

"Stephen Joseph, chief executive of the Campaign for Better Transport, cited Pixar's animated science-fiction film 'WALL-E', about a robot in a world denuded of human beings, as he detailed his fear of a future "where there are no pavements and businessmen will be ferried around even short distances". He said the Milton Keynes scheme would mean "people will sit in these little vehicles which push people off pavements and they will get fatter and fatter rather

[259] https://www.theengineer.co.uk/autonomous-delivery-robots-hit-london/
[260] *Supra* note from Daily Californian.
[261] [starship on GMU campus article]
[262] https://www.forbes.com/sites/christopherelliott/2019/02/03/what-are-the-rules-for-robots-delivering-food/#f6e88d83bc6d

than walking", adding, "If this is what autonomous vehicles are going to be like, it takes us in the wrong direction.""[263]

CONCLUSION

[work in progress]

[263] https://eandt.theiet.org/content/articles/2017/07/pedestrians-rage-at-autonomous-pods-and-delivery-bots-on-pavements/