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AUCTIONING AIRSPACE

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The commercialization of air taxis and autonomous passenger drones will one day congest urban airspace. Operators expect that, once flights are autonomous and the cost of service falls, high-traffic urban "vertiports" could see hundreds of air taxi takeoffs and landings per hour. Low-altitude airspace—between 200 feet and 5,000 feet above ground level—offers a relatively blank slate to explore new regulatory models for air traffic management and avoid command-and-control mistakes made in the past in aviation. Regulators' current proposals would centralize air taxi traffic management into a single system to coordinate air taxi traffic, but this approach likely creates technology lock-in and unduly benefits the initial operators at the expense of later innovators. To facilitate the development of the air taxi market, regulators should consider demarcating aerial travel corridors and auctioning exclusive-use licenses to operators for use of those corridors, much like regulators auction radio spectrum licenses and offshore wind energy sites. Exclusive rights to routes would allow transfer and sale to more efficient operators and would also give operators the certainty they need to finance the substantial capital investments.

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With advancements in aviation technology, low-altitude airspace presents a vast new resource for automated transportation and delivery services. Vertical takeoff and landing aircraft, also called VTOLs or air taxis, are a new aerial transportation service currently in development. VTOL aircraft and drone companies expect that with computation advancements, autonomous VTOLs will bring down the price of flights and make mass air transit possible. Travelers in the future might routinely fly from downtown Washington, D.C. to Dulles International Airport in under ten minutes and Chicago families could escape the city heat and shuttle high above Lake Michigan to Indiana dunes and beaches in under twenty minutes. To prevent "route-squatting" and to facilitate the development of this market the Federal Aviation Administration (FAA) should consider demarcating aerial travel corridors and auctioning exclusive-use licenses to VTOL operators for use of those corridors.[1]

[1] Aerospace firms and vendors are identifying low-altitude aerial routes in anticipation of urban air mobility services. *See*, *e.g.*, *Nexa Capital Partners launches Urban Air Mobility Geomatics*, EVTOL MAGAZINE (Sept. 11, 2019), https://evtol.com/news/nexa-capital-partners-launches-urban-air-mobility-geomatics/ [https://perma.cc/6L24-UKQU] (providing an example of a company offering aerospace industry customers "capabilities such as identifying simple

Perhaps the primary obstacle to urban air mobility is integration of thousands of VTOL aircraft into regulated federal airspace. The U.S. aviation industry has a commendable safety record and regulators are cautious. However, the technological shock—the commercialization of air taxis—will create novel urban airspace scarcity and collective action conflicts. The overwhelmed U.S. air traffic control system handles about 5,000 aircraft in the sky at a given time.[2] U.S. regulators acknowledge that traditional air traffic management will not be able to handle drones and VTOLs.[3] When intended uses conflict, how should low-altitude airspace be allocated? This is an old problem for a resource: the transformation of a common pool resource in the face of intensive, new uses.[4] *Ad hoc* regulatory interventions won't suffice, nor will traditional air traffic control, as aviation authorities in the U.S. appear to be preparing to largely delegate day-to-day low-altitude airspace management of drones and VTOLs to commercial operators.[5]

'verti-pairs' (flights between two vertiports) that can support profitable eVTOL operations").

[2] FED. AVIATION ADMIN., *Air Traffic By The Numbers,* https://www.faa.gov/air_traffic/by_the_numbers/ [https://perma.cc/ZRS7-3ZDB] (last modified June 6, 2019). VTOLs and drones could plausibly exceed that number in a single city. Uber, *Uber Elevate Summit 2018: Live Stream Day 1 (Part 2) at 3:55:20*, YOUTUBE (May 8, 2018), https://www.youtube.com/watch?v=rWvQuk0_xjs [https://perma.cc/UKT8-XYGK] ("If you ask: Can we add thousands of aircraft and control them in the traditional way? The answer is: Absolutely not.").

[3] NASA, UNMANNED AIRCRAFT SYSTEMS (UAS) TRAFFIC MANAGEMENT (UTM) CONCEPT OF OPERATIONS VERSION 1.0 2 (May 18, 2018), https://utm.arc.nasa.gov/docs/2018-UTM-ConOps-v1.0.pdf [https://perma.cc/MD38-FAYS] ("Given the number and type of UAS operations envisioned, it is clear that the existing Air Traffic Management (ATM) System cannot cost-effectively scale to deliver services for UAS. Further, the nature of most of these operations does not require direct interaction with the ATM System.").

[4] *See* Richard A. Epstein, *Property Rights and Governance Strategies: How Best to Deal with Land, Water, Intellectual Property, and Spectrum*, 14 COLO. TECH. L.J. 181, 188–89 (2016).

[5] *See* Press release, NASA, *NASA Completes its Latest Drone Traffic Management Flight Campaign*, (June 8, 2017) https://www.nasa.gov/aero/nasa-completes-latest-drone-traffic-management-flight-campaign [https://perma.cc/5NGT-6CWA].

Private management of low-altitude airspace to accommodate VTOLs is still at a nascent stage. Theorists, regulators, and lawmakers have the daunting task of ascertaining which legal institutions for airspace optimize public use, safety, and benefit.[6] Since a side-by-side comparison of legal institutions for airspace is infeasible at present, this article looks to property theory and draws on how the government disposes of other public assets to private management.

For traditional aviation, air traffic management is centralized and relies on complex collaboration between airlines, the general aviation industry, air traffic controllers, and regulators. Safe separation between aircraft,[7] routes,[8] and slot fees[9] are highly regulated in this interconnected system. Economic distortions result from the regulated rationing of airspace and terminal access.[10] Low-

[6] Richard A. Epstein, *The Public Trust Doctrine*, 7 CATO J. 411, 412 (1987) ("The task of justification has been to show what general set of legal institutions will advance the welfare of the public at large, when measured against the next best alternative."). *See also* RONALD H. COASE, THE FIRM, THE MARKET, AND THE LAW 153–154 (1990) (urging theorists to use an opportunity-cost approach "when dealing with questions of economic policy and to compare the total product yielded by alternative social arrangements").

[7] Radar separation standards typically require air traffic controllers to maintain at least three nautical miles between aircraft near airports. FED. AVIATION ADMIN., *Final Report 7, Research, Engineering and Development Advisory Committee, Separation Standards Working Group* (2006), https://www.faa.gov/about/office_org/headquarters_offices/ang/offices/tc/about/campus/faa_host/RDM/media/pdf/Report-SepStandardsWorkingGroup.pdf [https://perma.cc/6FLQ-KDNP]. *See* North Atlantic Operations – Airspace, SKYBRARY, https://www.skybrary.aero/index.php/North_Atlantic_Operations_-_Airspace [https://perma.cc/N7QY-DLKU] (explaining that aircraft flying over the North Atlantic have prescribed vertical and horizontal minimum separation).

[8] Fed. Aviation Admin., Instrument Procedures Handbook 2–2 (2017) ("Airways can be thought of as three-dimensional highways for aircraft. In most land areas of the world, aircraft are required to fly airways between the departure and destination airports. The rules governing airway routing, Standard Instrument Departures (SID) and Standard Terminal Arrival (STAR), are published flight procedures that cover altitude, airspeed, and requirements for entering and leaving the airway.").

[9] 49 U.S.C. § 41714 (2012) (defining "slot" as "a reservation for an instrument flight rule takeoff or landing by an air carrier of an aircraft in air transportation.").

[10] *Trump Wants to Privatize Air Traffic Control; Canada and Europe Prove It Will Work*, INVESTOR'S BUSINESS DAILY (June 5, 2017),

altitude airspace—used here to mean between 200 feet and 5,000 feet above ground level[11]—offers a relatively blank slate to explore new models for air transport and avoid command-and-control mistakes made in the past in aviation.

This paper proceeds as follows: Part I briefly covers the commercial VTOL industry, the history of airspace regulation, and public property theory. Part II describes U.S. regulators' tentative plans for VTOL aircraft management and the "regulated commons" model, which resembles today's air traffic control, whereby routes and terminal access are shared and managed within a single unmanned traffic management (UTM) system or database. Part III describes likely competitive and technical problems with this regulated commons and UTM approach. Part IV introduces a different idea: that the FAA instead delimit geographic tracts of low-altitude airspace and assign exclusive-use licenses to those aerial routes via auction for a term of years. Flight path, speed, terminal

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https://www.investors.com/politics/editorials/trumps-plan-to-privatize-air-traffic-control-would-follow-canadas-and-europes-lead/ [https://perma.cc/6LN2-MBV8] ("The Federal Aviation Administration-run ATC system in the U.S., in contrast, has been a monument to mismanagement and waste."). DJ Gribbin et al., *Toward a More Efficient Use of Airspace*, 76 J. TRANSP. L., LOGISTICS & POL'Y 20, 92 (2009) ("Slots are a valuable public resource; yet they have been underutilized for decades as a result of a failure to clearly define property rights to slots and to provide appropriate incentives for slots to be used in a manner of greatest benefit to the traveling public."). *See also* Marvin S. Soroos, *The Commons in the Sky: The Radio Spectrum and Geosynchronous Orbit as Issues in Global Policy*, 36 INT'L ORG. 665, 673–74 (1982) (describing the hoarding of geosynchronous orbital slots when assigned via regulation).

[11] VTOL use today appears to be contemplated up to 5000 feet. Margaret Brown, *New York Drone Corridor Enables Testing of UAS Platforms and UTM Technologies in Real-World Settings*, THE NEW AIRSPACE (June 5, 2018), https://thenewairspace.com/2018/06/05/new-york-drone-corridor-enables-testing-of-uas-platforms-and-utm-technologies-in-real-world-settings/ [https://perma.cc/RFF8-2DU8]. Airspace use below 200 feet raises fraught questions about the property rights of landowners and is outside the purview of this paper. *See* Kevin Gray, *Property in Thin Air*, 50 CAMBRIDGE L.J. 252, 254 (1991) ("Courts are notoriously unwilling to quantify the extent of the airspace which falls within the dominion of the landowner . . . ."); Colin Cahoon, *Low Altitude Airspace: A Property Rights No-Man's Land*, 56 J. AIR L. & COM. 157, 191 (1990) ("[C]ourts have yet to adopt a uniform theory of airspace property ownership.").

locations, aircraft size, UTM technologies, and pricing choices would largely be delegated to the tract licensees. Finally, Part V explains why this approach, which draws on real-world examples from spectrum auctions and other federal asset markets, may offer more competitive UTMs and dynamic efficiencies for low-altitude air transit. This auction approach also allows aviation regulators to focus less on scientific management of airspace and UTM interoperability and more on aircraft safety, dangerous weather, and inspections.

This article assumes that navigable airspace will remain publicly owned and *does not* propose the introduction of fee simple property in this airspace.[12] James Buchanan's work on club goods[13] initiated a rich literature that shuns the private property-public property dichotomy in favor of nuanced analysis of various categories on the "property spectrum."[14] In that vein, this article analyzes a common category on the spectrum, "licensed property": publicly-owned resources that are used or processed by private operators for commerce and public benefit.[15]

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[12] This paper proposes for airspace what Prof. Raymond dubbed "licensed property." *See* LEIGH RAYMOND, PRIVATE RIGHTS IN PUBLIC RESOURCES: EQUITY AND PROPERTY ALLOCATION IN MARKET-BASED ENVIRONMENTAL POLICY 14 (Routledge 2003).

[13] James M. Buchanan, *An Economic Theory of Clubs*, 32 ECONOMICA 1, 1 (1965) (noting there is "a whole spectrum of ownership-consumption possibilities, ranging from the purely private or individualized activity on the one hand to purely public or collectivized activity on the other.").

[14] *See, e.g.*, Aleksandar D. Slaev & Marcus Collier, *Managing Natural Resources: Coasean Bargaining versus Ostromian Rules of Common Governance*, 85 ENVTL. SCI. & POL'Y 47 (2018); ELINOR OSTROM, GOVERNING THE COMMONS: THE EVOLUTION OF INSTITUTIONS FOR COLLECTIVE ACTION (2011).

[15] *See* RAYMOND, *supra* note 12. Licensed property means "a private legal right that provides a significant degree of security and exclusivity to resource users but remains unprotected from future government adjustment or cancellation without compensation." *Id*. at 15. Other types of licensed property in the United States include unpatented mining claims, federal grazing permits, and individual transferable quotas for fisheries. *Id*. at 18-23. *See, e.g.*, Vernon L. Smith, *On Divestiture and the Creation of Property Rights in Public Lands*, 2 CATO J. 663 (1982); Walter J. Mead, *Natural Resource Disposal Policy—Oral Auction Versus Sealed Bids*, 7 NAT. RESOURCES J. 194 (1967).

Aviation regulators should assess the feasibility of airspace auctions promptly because, as described below, it is very difficult to introduce such market-based assignment later, even after the drawbacks of a regulated commons regime are obvious. The FAA's Drone Advisory Committee included this proposal in its 2018 report.[16] Subsequently, in the FAA's 2018 reauthorization law, Congress instructed the Government Accountability Office to study this airspace auction proposal as a financing mechanism.[17] VTOL companies would like to start testing commercial service as early as 2023 in the U.S.,[18] and timely resolution of airspace deconfliction is essential for the industry to thrive.

I. BACKGROUND

Before discussing VTOL traffic management approaches, a description of the VTOL industry, airspace regulation, and underlying property theory is required to familiarize readers with the technology and regulatory tradeoffs.

A. VTOL Transportation Industry

Though designs vary, VTOLs tend to be multi-rotor, one- to six-passenger aircraft that land and take off like helicopters and fly at

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[16] *See* DRONE ADVISORY COMMITTEE, FED. AVIATION ADMIN., DRONE INTEGRATION FUNDING FINAL REPORT 21–22, (Mar. 2018), https://www.rtca.org/sites/default/files/dac_tg3_funding_report_long_term_final.pdf [https://perma.cc/B49F-5BGN] (discussing the "Auction or Lease of Airspace"). The author was invited to present the idea of airspace auctions to Task Group 3 in 2017.

[17] FAA Reauthorization Act of 2018, Pub. L. No. 115-254, § 360(b) (instructing the Comptroller Generalto study "any recommendations of Task Group 3 of the Drone Advisory Committee"). Task Group 3 of the FAA's Drone Advisory Committee included airspace auctions as a possible mechanism for funding drone regulation. *See also* DRONE ADVISORY COMMITTEE, *supra* note 16, at 21-22 (discussing the "Auction or Lease of Airspace").

[18] Marcy de Luna, *Uber's flying taxis are coming to one Texas city in 2023*, HOUSTON CHRON. (June 19, 2019), https://www.houstonchronicle.com/news/transportation/article/Uber-Air-Skyports-launch-Dallas-Texas-2023-14015577.php [https://perma.cc/K9X5-5Q6D].

several hundred feet above the ground.[19] Electric VTOL (eVTOL) companies are designing battery-powered aircraft for commuter and intra-metropolitan transportation, that is, a range up to sixty miles.[20] Other companies are designing hybrid (fuel-electric) VTOLs, which will have a range of a few hundred miles and serve inter-city routes.[21] VTOLs in urban areas would land at helipads and, one day, "vertiports"—specially-designed helipad-like landing structures for VTOL operations.[22]

Improvements in manufacturing, battery technology, sensors, autonomous systems, and networking have spurred a global race to commercialize autonomous air taxi flight, and companies have completed test flights.[23] VTOL companies are planning to test (piloted, at first) VTOL flights in the U.S. in the next few years and

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[19] See Electric VTOL News, *eVTOL Aircraft Directory*, https://evtol.news/aircraft/ [https://perma.cc/MKK5-5M44] (last visited Sep. 9, 2019), for examples of eVTOL and hybrid VTOL designs.

[20] *See* Jerry Siebenmark, *Uber Elevate Summit Lays Out 2023 Flight Plan*, AIN ONLINE (June 28, 2019), https://www.ainonline.com/aviation-news/business-aviation/2019-06-28/uber-elevate-summit-lays-out-2023-flight-plan [https://perma.cc/2LHQ-AYLV].

[21] *See, e.g.*, Talia Avakian, *Flying Taxi Company Wants to Get You From New York City to Boston in 36 Minutes*, TRAVEL + LEISURE (Oct. 2, 2018), https://www.travelandleisure.com/airlines-airports/transcend-air-corporation-flying-taxis [https://perma.cc/ZU8N-4T3F]; Loz Blain, *Joby's wild 16-rotor convertible aircraft for long-range, high-speed, electric VTOL commuting*, NEW ATLAS (Dec. 2, 2015), https://newatlas.com/joby-s2-tilt-rotor-vtol-multirotor-aircraft-concept/40662/ [https://perma.cc/4NKP-TA5N].

[22] *See* Joe Pappalardo, *The "Mega Skyport" Is a Fanciful Future Landing Spot for Uber's Flying Taxis*, POPULAR MECHANICS (July 19, 2018), https://www.popularmechanics.com/flight/a22454961/mega-skyport-uber-flying-taxi-vertiport/ [https://perma.cc/Y92G-P3EB].

[23] In early 2018, Chinese drone maker Ehang flew an autonomous VTOL on a 15-kilometer (9.3 mile) route. Andrew J. Hawkins, *Ehang's passenger-carrying drones look insanely impressive in first test flights*, THE VERGE (Feb. 5, 2018), https://www.theverge.com/2018/2/5/16974310/ehang-passenger-carrying-drone-first-test-flight [https://perma.cc/BA59-VZ42]; Matthew Campbell, Jie Ma, & Kiyotaka Matsuda, *Japan is Getting Serious About Flying Cars*, BLOOMBERG BUSINESSWEEK (Jan. 22, 2019), https://www.bloomberg.com/news/features/2019-01-22/the-birthplace-of-the-walkman-wants-to-be-first-in-flying-cars [https://perma.cc/4RCS-NA3U].

to scale up operations as technology and regulation allow.[24] Already in 2019, a Chinese eVTOL company, Ehang, began flying tourists in a two-passenger, autonomous eVTOL aircraft,[25] and many companies are testing aircraft around the world.

If regulators allow this form of transportation, and the costs of flight fall with the introduction of autonomous systems and UTM, the busiest VTOL vertiports would see hundreds of takeoffs and landings per hour.[26] At scale, there will be a need to manage flights landing or taking off every few seconds from each high-traffic vertiport, and each VTOL will have to be charged, cleaned, and turned over for a new flight in minutes.[27] Many VTOL (and perhaps large drone) operations may depend on these tight turnarounds, and vertiports require substantial investments in terminals, operations, and infrastructure.

The nascent vertical takeoff and landing aircraft industry could stimulate substantial consumer demand for millions of low-altitude passenger flights in the U.S. annually. Regulators are likely to see several UTM and VTOL operators in urban areas.[28] It's possible to

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[24] *See* Emily Chang & Thomas Black, *Boeing CEO Says Air-Taxi Prototype Will Be Ready for Takeoff Next Year*, BLOOMBERG (Oct. 3, 2018), https://www.bloomberg.com/news/articles/2018-10-03/boeing-ceo-sees-air-taxi-prototype-ready-for-takeoff-next-year [https://perma.cc/7AX6-7DDX].

[25] Chen Chuanren, *China Abuzz with eVTOL Action*, AIN ONLINE (Apr. 17, 2019), https://www.ainonline.com/aviation-news/business-aviation/2019-04-17/china-abuzz-evtol-action [https://perma.cc/TW6S-P65E].

[26] At a 2018 conference devoted to the nascent industry, for instance, Uber representatives estimated, based on Uber trip data, that if prices fall according to their models there is demand for hundreds of thousands of daily air taxi trips and the potential need for 40 vertiports the Los Angeles area alone. Uber, *Uber Elevate Summit 2018: Live Stream Day 1 (Part 1)*, YOUTUBE (May 8, 2018), https://www.youtube.com/watch?v=hnceMcSnjQ0 [https://perma.cc/H9EV-QSHA].

[27] *Id*. "In this 40-node network [in the Los Angeles region], about 80% of the nodes require a throughput of about 400 to 800 landings per hour."

[28] Uber, Amazon, Google, Skyward, Airmap, Thales, Rockwell Collins, and others all anticipate being in the UTM space. Some plan to manage drones, some plan to manage VTOLs, and some plan to manage both types of services. *See, e.g.*, Press Release, NASA, *supra* note 5; Luke Geiver, *Global airspace group headed to NY for UAS UTM work*, UAS MAGAZINE (Apr. 7, 2018), http://www.uasmagazine.com/articles/1842/global-airspace-group-headed-to-ny-for-uas-utm-work [https://perma.cc/A334-QQYK]; Mike Ball, *Rockwell Collins*

make out the shape of competing business models and use cases—and sources—of airspace conflicts. Should urban VTOL corridors be for rapid commuting or for slower freight? Should regular, scheduled flights receive takeoff and landing precedence over episodic, recreational flights? How should landing, takeoff, and maintenance fees be priced? Who funds vertiport creation and upgrades? These and other questions depend on what institutions regulators choose to use to manage airspace and flight management.[29]

B. History of Airspace Regulation

Navigable airspace—which includes the VTOL airspace contemplated here[30]—in the U.S. is quasi-public property and the federal government regulates access.[31] Some natural resources—like navigable waters, airspace, and beaches—are customarily held in common but, once use increases, require specialized rules from the state, and even state control, to improve productive use.[32]

Demonstrates UAS Command & Control Datalink for NASA UTM, UNMANNED SYSTEMS NEWS (Apr. 30, 2018), http://www.unmannedsystemstechnology.com/2018/04/rockwell-collins-demonstrates-uas-command-control-datalink-for-nasa-utm/ [https://perma.cc/AB8W-AVWX]; Tiernan Ray, *LiDAR! Flying Taxis! Your Brain! The Changing Landscapes of CES*, BARRON'S (Jan. 16, 2018), http://www.barrons.com/amp/articles/lidar-flying-taxis-your-brain-the-changing-landscape-of-ces-1516145041 [https://perma.cc/Y4BS-SSJA] (describing Bell Helicopter plans to deploy "air taxis" by 2025 in cities); Monica Alleven, *Skyward aims to be the Verizon of drone services*, Fierce Wireless (July 6, 2017), https://www.fiercewireless.com/wireless/skyward-aims-to-be-verizon-drone-services [https://perma.cc/JLG2-N3KH].

[29] *See* E. Tazewell Ellett & Matthew J. Clark, *Passengers Without Pilots: Toward a Brave New World of Drones*, 45 VA. B. ASS'N J. 18, 21 (2018).

[30] 49 U.S.C. § 40102(a)(32) (2012) ("'Navigable airspace' means airspace above the minimum altitudes of flight prescribed by regulations . . . , including airspace needed to ensure safety in the takeoff and landing of aircraft.").

[31] Air Pegasus of D.C., Inc. v. United States, 424 F.3d 1206, 1217 (Fed. Cir. 2005) (stating "it is well established under federal law that the navigable airspace is public property not subject to private ownership.") (citing 49 U.S.C. § 40103(a)(2) (2000)).

[32] Richard A. Epstein, *How Spontaneous? How Regulated?: The Evolution of Property Rights Systems*, 100 IOWA L. REV. 2341 (2015). For a discussion of nineteenth century doctrines for "inherently public property," see Carol Rose, *The*

Richard Epstein points out, as an illustration, that by the eighteenth century heavily-trafficked river systems in England had developed elements of state ownership and control, which increased commerce and kept waters navigable.[33] For some resources, particularly with property necessary for extensive transportation networks, government control is necessary to enhance commerce because the holdout problems associated with bargaining with innumerable property owners tend to prove intractable.[34]

As with rivers, airspace developed elements of state control and then formal public ownership once aviation made airspace "navigable." The development of hot-air balloons, zeppelins, and early flying machines put stress on the *ad coelum* doctrine[35]—the historic notion that landowners had title to an indefinite height above their land—and by 1910 common law courts recognized that airspace was not, strictly speaking, private property.[36] Courts and legislatures found that a navigation servitude was necessary to prevent landowners from excluding flights that harmlessly took place hundreds or thousands of feet above their property.[37] It wasn't

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Comedy of the Commons: Custom, Commerce, and Inherently Public Property, 53 U. CHI. L. REV. 711 (1986).

[33] Epstein, *supra* note 32, at 2356–57 (As river traffic grows heavier, "the water system transforms itself from a *res commune* to one that has strong elements of government ownership and control."); Epstein, *supra* note 6, at 416 ("It is therefore possible to have a system of public ownership without an extensive government to administer it. The recognition of the public's navigation servitude in the original position ironically serves to *reduce* the size of government while recognizing the customary public ownership of public goods . . . .") (italics in original).

[34] Epstein, *supra* note 6, at 415 ("The risk is that the owner of one segment will hold out against all the others, so that bargaining breakdown will prevent any use of the river at all for navigation.").

[35] BERKELEY REYNOLDS DAVIDS, THE LAW OF MOTOR VEHICLES 292 (1911).

[36] *See* Arthur K. Kuhn, *The Beginnings of an Aërial Law*, 4 AM. J. INTERNAT'L L. 109 (1910). The Supreme Court later repudiated the *ad coelum* doctrine, stating that it "has no place in the modern world." United States v. Causby, 328 U.S. 256, 261 (1946).

[37] DAVIDS, *supra* note 35, at 292 ("The air domain of a proprietor may be utilized by him to any extent, but in so far as he has not appropriated it, it must be deemed to be subject to a servitude of passage by aviators. The case is analogous to that of the highway upon which the public have a right of passage, while the fee remains in the owner of the abutting land.") (citation omitted).

a large legal leap, then, for some courts to declare navigable airspace public property.[38]

C. *Creation of Property Institutions in the Face of Technology Shocks*

To date, low-altitude airspace use is relatively infrequent and highly dependent on norms and relatively simple rules of operation.[39] Episodic use of low-altitude airspace includes helicopter trips for tourists, traffic reports, and hospitals in many urban areas, as well as general aviation and model airplane flights for recreation and hobbyists. As Elinor Ostrom showed, small, homogeneous groups like these with regular interaction can create enduring, self-governing common pool resource institutions,[40] especially when uses are light.

Customary arrangements like this, however, are not sustainable in the face of a large demand shock for the resource and the presence

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[38] Air Pegasus of D.C., Inc. v. United States, 424 F.3d 1206, 1217 (Fed. Cir. 2005) (stating "it is well established under federal law that the navigable airspace is public property not subject to private ownership.") (citing 49 U.S.C. § 40103(a)(2) (2000)); 49 U.S.C. § 40102(a)(32) (2012) ("'Navigable airspace' means airspace above the minimum altitudes of flight prescribed by regulations . . . , including airspace needed to ensure safety in the takeoff and landing of aircraft.").

[39] This is particularly for airspace up to 1200 feet above ground level, which is Class G (uncontrolled) airspace in much of the country. *See, e.g.*, Press Release, NASA, *supra* note 5, at 3 ("ATC has no responsibility to provide separation services in Class G airspace, rather, manned aircraft cooperatively manage their operations based on specified principles of operations."); Pia Bergqvist, *The Freedom and Flexibility of Flying VFR*, FLYING MAG (Mar. 28, 2016), https://www.flyingmag.com/flying-vfr-offers-greater-freedom-and-flexibility **[**https://perma.cc/V677-M5ZT**]** (discussing the "unstructured nature" of low-altitude visual flight rules). The FAA has "helicopter highway" routes mapped for pilots. FEDERAL AVIATION ADMIN., VFR Raster Charts, https://www.faa.gov/air_traffic/flight_info/aeronav/digital_products/vfr/ **[**https://perma.cc/AG8G-N8N9**]** (last modified July 19, 2019). Joe Pappalardo, *Dallas Flyers Club: What Uber's Flying Taxi Future Feels like*, POPULAR MECHANICS (May 2, 2018), https://www.popularmechanics.com/flight/a20122610/uber-elevate-flying-taxi-dallas-bell-helicopter/ **[**https://perma.cc/P2VT-NJSV] (But "[i]n many places, using these routes is optional . . . .").

[40] Ostrom, *supra* note 14, at 58–89.

of many new claimants.[41] For land and chattels, as Harold Demsetz illustrated, "property rights arise when it becomes economic for those affected by externalities to internalize benefits and costs."[42] Often an exogenous event—like a technology improvement[43] or a new settlement[44]—occurs and then property institutions emerge to define and parcel out previously common pool resources.

There are several examples in North American history where property rights emerged to coordinate increased use of natural resources that were once common pool resources. Native Americans around Quebec divided their hunting land around 1700 because of increased demand for animal fur.[45] Cattlemen fenced off the Great Plains as land value increased and the cost of defining property rights decreased from 1860 to 1900.[46] Property rights in radio frequencies developed in the 1920s because of the emergence of broadcast radio technology.[47] The transformation from common pool resource to exclusive use can be costly, but the rise in

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[41] Epstein, *supra* note 4, at 188-89 ("And it follows that intense use creates the risk of collision, congestion, confusion, or worse. So eventually somebody says, and everyone recognizes, the need to control the commons . . . .") (citiation omitted). Gary D. Libecap, *State Regulation of Open-Access, Common-Pool Resources*, *in* HANDBOOK OF NEW INSTITUTIONAL ECON. 545, 547 (Claude Menard & Mary M. Shirley, eds., Springer 2008) ("When transaction costs rise due to larger numbers of heterogeneous competitors, perhaps attracted by exogenous forces, such as price increases or technological changes, that raise the value of the asset or that lower the costs of entry, then local, informal arrangements, such as community norms may no longer be effective in combating the wastes of open access.").

[42] Harold Demsetz, *Toward a Theory of Property Rights*, 57 AM. ECON. REV. 347, 354 (1967).

[43] *See* Svetozar Pejovich, *Towards an Economic Theory of the Creation and Specification of Property Rights*, 30 REV. SOC. ECON. 309, 310 (1972).

[44] *See* Terry L. Anderson & P.J. Hill, *The Evolution of Property Rights: A Study of the American West*, 18 J.L. & ECON. 163, 170–72 (1975).

[45] Demsetz, *supra* note 42, at 351–53.

[46] Anderson & Hill, *supra* note 44, at 170–172.

[47] *See, e.g.*, Thomas W. Hazlett, *The Rationality of U.S. Regulation of the Broadcast Spectrum*, 33 J.L. & ECON. 133, 143–44 (1990) ("There existed a very lively market in broadcast properties, sold with frequency rights attached, early in the development of the industry (that is, pre-1927)."); Howard A. Shelanski & Peter W. Huber, *Administrative Creation of Property Rights to Radio Spectrum*, 41 J.L. & ECON. 581 (1998).

productivity increases the value of the underlying resource and offsets the costs of defining and enforcing use rights.[48]

Airspace, like spectrum, navigable rivers, certain oil reserves, and timber lands, is a valuable resource managed on behalf of the public by the State. Property institutions cannot develop via custom or natural law for rationing public resources and the state must introduce property institutions to ensure productive use.[49] There are two basic paradigms for use of publicly-owned resource use: open access and exclusive use.[50] Open access means anyone can use the resource without limit.[51] Public sidewalks for pedestrians and open access publications are examples.[52] Exclusive use means legal control or ownership by a sole party. Real estate and licensed spectrum are examples.[53]

Publicly-controlled resources vary immensely in their character—taxi medallions, public parks, navigable waters, radio spectrum, game animals—and a resource use paradigm, once selected *de jure*, requires iteration and modification to ensure productive use.[54] Elinor Ostrom's work on resource management suggests that "getting the institutions right" is a "difficult, time-consuming, conflict-invoking process."[55] "The trick" for the state,

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[48] Demsetz, *supra* note 42, at 354 ("I have argued that property rights arise when it becomes economic for those affected by externalities to internalize the benefits and costs.").

[49] Epstein, *supra* note 32, at 2356–57 (As river traffic grows heavier, "the water system transforms itself from a *res commune* to one that has strong elements of government ownership and control.").

[50] Richard Epstein, *Property Rights in Water, Spectrum, and Minerals*, 86 U. COLO. L. REV. 389, 392 (2015).

[51] James A. Swaney, *Common Property, Reciprocity, and Community*, 24 J. OF ECON. ISSUES 451, 451–53 (1990).

[52] *See, e.g.*, *Licenses and Open Access*, CORNELL COPYRIGHT INFORMATION CENTER, https://copyright.cornell.edu/license_OA [https://perma.cc/X4GN-KA57] (stating open access "refers to freely available, digital, online information").

[53] *See* Thomas W. Hazlett & Matthew L. Spitzer, *Advanced Wireless Technologies and Public Policy*, 79 S. CAL. L. REV. 595, 603–04 (2006) (describing licensed spectrum).

[54] Epstein, *supra* note 50.

[55] Ostrom, *supra* note 14, at 14.

Epstein notes, "is to pick the right initial point to reduce the stress on making these further adjustments."[56]

II. AIRSPACE AS A REGULATED COMMONS

It is common, as explained below, for the government to de-conflict a valuable public resource by auctioning geographic, exclusive assignments. An alternative way to ration and de-conflict a federally-controlled resource is for the government to try to preserve a semblance of open access. To prevent a tragedy of the commons,[57] rationing and de-confliction is achieved via regulation of equipment, technologies, and business models—a regulated commons.[58]

This regulated commons model for VTOL and drone airspace is currently being explored in the U.S.[59] A regulated commons regime is seen in certain bands of spectrum[60] and for traditional aviation. A central administrator, which can be public or private, assigns access to the resource, often in response to real time demands. Regulators

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[56] Epstein, *supra* note 50.

[57] *See* Garrett Hardin, *The Tragedy of the Commons*, 162 SCIENCE 1243 (1968).

[58] More precisely, a regulated common pool resource. Fisheries are another example of a regulated common pool resource. *See* Carsten L. Jensen, *Reduction of the fishing capacity in 'common pool' fisheries*, 26 MARINE POL'Y 155 (2002).

[59] *See* NASA, *supra* note 3. The NASA UTM plans focus on management of drone operations, but experts expect that UTM will be incorporate VTOLs as the industry develops. *See* Ellett & Clark, *supra* note 29. Lilium, a VTOL aircraft company, similarly "is advocating an open system of VTOL landing pads, similar to public roads or airports today." Elan Head, *Lilium bets on regional mobility*, EVTOL MAGAZINE (Sept. 11, 2019), https://evtol.com/features/lilium-bets-on-regional-mobility/ [https://perma.cc/E4SX-2TUM].

[60] In many ways, the regulated commons approach for VTOL resembles the "spectrum commons" movement that was in vogue over a decade ago. *See, e.g.*, LAWRENCE LESSIG, THE FUTURE OF IDEAS 76 (2002). The regulated sharing of valuable "unlicensed" spectrum appears to have stalled because of the difficulty and inefficiency, anticipated by scholars like Jerry Brito and Thomas Hazlett. Jerry Brito, *The Spectrum Commons in Theory and Practice*, 2007 STAN. TECH. L. REV. 1, 1 (2007); Thomas W. Hazlett, *The Wireless Craze, the Unlimited Bandwidth Myth, The Spectrum Auction Faux Pas, and the Punchline to Ronald Coase's "Big Joke": An Essay on Airwave Allocation Policy*, 14 HARV. J.L. & TECH. 335, 495 (2001) ("'Open access' is not truly open under the FCC's unlicensed rules. Equipment regulation is used to prevent over-grazing.").

envision that VTOL (and drone) airspace management should resemble traditional airspace management in several key ways.[61] Namely, there will be a single UTM system (or a few systems that interoperate on regulated terms).[62] As NASA has said, "[UTM] is a community-based traffic management system, where . . . [o]perators share their flight intent with each other and coordinate to de-conflict and safely separate trajectories."[63]

With a regulated commons model, airspace and terminal management and de-confliction would take place, as with traditional air transportation, on an inter-firm basis.[64] Routes and vertiports, as with the commercial airline industry, will not be exclusive, they will be shared regularly every day.[65] In this scenario, VTOL and drone operators will input prospective flights into the UTM system and regulator-approved UTM system operators will use inputted data in real time to share the skies and schedule VTOL flights.[66] Experts anticipate that, with this model, because inter-firm sharing of the airspace is required, VTOLs and drones will need mandated and interoperable technologies like reliance on detect-and-avoid capabilities, ADS-B, airborne radar, or ground-based radar.[67]

III. PROBLEMS WITH A REGULATED COMMONS

This regulated commons regime—withholding geographic exclusivity and delegating VTOL (and drone) traffic management

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[61] *See* NASA, *supra* note 3, at 4.

[62] *Id*. ("The term 'UTM' refers to a set of federated services and an all-encompassing framework for managing multiple UAS operations.").

[63] *Id*. at 4–5.

[64] *Id*. at 5.

[65] *Id*. at 12.

[66] One possibility is that low-altitude airspace is "parcel-ized" by private UTM systems. Uber has proposed a "dynamic skylane network" for VTOL traffic. Uber, *supra* note 2, at 3:56:30. Dynamic skylane networks are virtual lanes in the sky that are dynamically adjusted. *Id.* These can be monitored to measure conformance within the lane. *Id.* The difference with the earlier auction and exclusive-use proposal is that there would be inter-firm sharing of the dynamic skylane parcels.

[67] THE ASPEN INST., RETHINKING INSTITUTIONS OF SPECTRUM MANAGEMENT 14 (2018).

to a single, interconnected UTM system—has foreseeable challenges.

A. Over-regulation and Underutilization of Airspace

The primary problem with the regulated commons approach is that innovators might deliver on their promise of mass air taxi service and the planned UTM system cannot handle the traffic. As NASA points out in one of its UTM reports, its regulated commons approach may suffice with modest levels of low-altitude air traffic: "[i]n airspace with *moderate airspace demand*, equitable access is achieved through Operator collaboration, efficient airspace design, and FAA rules."[68] However, the report adds, "if demand for a volume of airspace becomes too great to maintain safety of flight, or support all types of operations, *the FAA may be required to provide demand management of access*, but only for that purpose."[69]

The latter sentence raises alarm bells because, should the industry develop into a mass market, regulators will be forced to regularly referee competition for the most valuable urban airspace. Recall that companies are anticipating that many VTOL vertiports will be serving hundreds of landings per hour.[70] Consider the nature of transportation networks, which tend to cluster into a hierarchy of congested hubs,[71] the "lumpy" nature of urban travel (with peaks during commutes and special events), and the inevitability of bad weather, which requires re-scheduling. Almost certainly, under the current UTM plans, regulators will regularly be "providing demand management for airspace access" for valuable urban aerial corridors.

In spectrum[72] and aviation policy, a regulated commons with a private administrator requires intensive certification regulations and

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[68] NASA, *supra* note 3, at 25 (emphasis added).

[69] *Id*.

[70] "In this 40-node network [in the Los Angeles region], about 80% of the nodes require a throughput of about 400 to 800 landings per hour." Uber, *supra* note 2, at 59:57.

[71] Liang Zhao et al., *Onset of traffic congestion in complex networks*, 71 PHYSICAL REV. 1, 1 (2005).

[72] Where the regulators have a regulated commons for spectrum resources, they create very strict limits in order to prevent overuse or congestion. See, for instance, power limits and equipment rules on Part 15 and "unlicensed" devices.

often suffers from the same problems as command-and-control, including economic distortions and the endless refereeing of commercial disputes. This need to intervene, to set ad hoc rules, and proscribe certain business models in a regulated commons can create endemic underuse of the resource.[73]

For example, in 1968, nearly one-third of peak-time New York City air traffic—the busiest region in the US—was general aviation (that is, small, personal) aircraft.[74] To combat severe congestion, local authorities raised minimum landing fees by a mere $25 (1968 dollars) on sub 25-seat aircraft.[75] General aviation traffic at peak times immediately fell over 30%[76]—suggesting that a massive amount of pre-July 1968 air traffic in the region was low-value. The share of aircraft delayed by 30 or more minutes fell by half, from 17% of flights to about 8%.[77]

Even if regulators could determine the "best" UTM vendors, urban airspace will tend towards underutilization. Regulators are the only party that can prevent the tragedy of the commons; the asymmetry towards underutilization arises because aviation regulators have acute incentive to prevent overuse, since overuse creates safety hazards. However, as the 1960s experience with New York airports shows, regulators have a relatively weak incentive to

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See, *e.g.*, Thomas W. Hazlett, *Spectrum Tragedies*, 22 YALE J. ON REG. 242, 262 (2005); Brito, *supra* note 60 (noting that "[i]f government is to assure that technologies are 'properly certified' it must first establish what is proper certification. It will do this using the tools at its disposal—through a political regulatory process and without the benefit of the dynamic feedback a market could provide."); Thomas W. Hazlett & Brent Skorup, *Tragedy of the Regulatory Commons: LightSquared and the Missing Spectrum Rights*, 13 DUKE L. & TECH. REV. 1, 15 (2014) ("The "unlicensed spectrum" is governed by technical and behavioral rules (including power limits) established by regulators.").

[73] *See* Hazlett & Skorup, *supra* note 72, at 13–15.

[74] FEDERAL AVIATION ADMIN., AIRPORT QUOTAS AND PEAK HOUR PRICING: THEORY AND PRACTICE, REP. NO. FAA-AVP-775 55-56 Table 9, (1976).

[75] Similarly, before being overturned, Logan Airport raised fees on small aircraft in the 1980s in order to lessen congestion. Daniel R. Polsby, *Airport Pricing of Takeoff and Landing Slots: An Economic Critique of Federal Regulatory Policy*, 89 CAL. L. REV. 779, 809 (2001). The scheme worked and general aviation traffic fell by about one-third. *Id.* At 809.

[76] FEDERAL AVIATION ADMIN., *supra* note 74, at 55 Table 8.

[77] *Id.* at 57 Table 10.

maximize productive use of urban airspace. As explained next, the tools regulators are considering to promote efficient use of low-altitude airspace have significant tradeoffs.

B. Mandated Interoperability Creates Technology Lock-in

A centralized UTM system, even if privately operated, will require significant regulatory oversight to protect competition, regulate pricing, and ensure interoperability between UTM components.[78] A unified UTM system cannot have competing operators, so UTM will either be managed by a sole operator or will need to interoperate on regulated terms with other service providers. As a Wired magazine story put it, "flying cars aren't like smartphones; you can't let competing tech and protocols coexist while the market figures it out. Flying cars would require a single operating system—and therefore either a whole lot of cooperation between competing companies or a firm grip by the iron hand of regulators."[79]

There are substantial technical obstacles to a unified, interoperable UTM system.[80] "Interoperability" in technology has no agreed-upon meaning, carries immense tradeoffs and it can be quite complex to define and enforce compliance.[81] A major risk of mandated UTM interoperability is technology lock-in—the

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[78] In many ways, the regulated commons approach for VTOL resembles the "spectrum commons" movement that was in vogue over a decade ago. *See* LESSIG, *supra* note 60.

[79] Alex Davies, *Kitty Hawk, Flying Cars, and the Challenges of 'Going 3d'*, WIRED (Apr. 22, 2019), https://www.wired.com/story/future-of-transportation-kitty-hawk-self-flying-cars/ [https://perma.cc/7AHV-C7XH].

[80] *Behind the Scenes of Drone Integration: Managing Traffic in the Sky*, VA. TECH. NEWS (May 21, 2018), https://vtnews.vt.edu/articles/2018/05/ictas-nasautm2018.html [https://perma.cc/UEG6-FKPC] ("Balancing the requirements of different aircraft, on different missions, using different software, and doing as much of it as possible automatically, is a complicated equation.") (quoting a chief engineer working on a UTM system).

[81] As two scholars noted on the subject, "[t]he problems of too much interconnectivity present enormous challenges both for organizations and for society at large." JOHN PALFREY & URS GASSER, INTEROP: THE PROMISE AND PERILS OF HIGHLY INTERCONNECTED SYSTEMS 2 (2012). Therefore, "most of the specifics of how to bring interop about [must] be determined on a case-by-case basis." *Id*. at 17.

dominance of an established, but inferior, technology because of reliance interests long after improved replacement technologies have developed.[82] John Palfrey and Urs Gasser have studied interoperability and note, "[t]his problem of lock-in is one of the core puzzles of interoperability . . . ."[83] As a result, the list of failed or inordinately costly regulator choices—typically made after years of fact-finding and research—for interoperable technology elements is long.[84]

UTM interoperability also creates large systematic risk should the UTM operator encounter technical obsolescence or financial troubles. For Palfrey and Gasser, air traffic control stands out for its drawbacks, and UTM carries much of the same inherent rigidity as traditional air traffic management. Researchers note how difficult it is to integrate "plainly superior, technologies" like GPS into air

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[82] W. Brian Arthur, *Competing Technologies, Increasing Returns, and Lock-In by Historical Events*, 99 ECON. J. 116, 126 (1989) (describing examples "where an early-established technology becomes dominant, so that later, superior alternatives cannot gain a footing").

[83] PALFREY & GASSER, *supra* note 81, at 107.

[84] *See, e.g.*, SOCIETY OF CABLE TELECOMMUNICATIONS ENGINEERS, ANSI/SCTE 28 2007 (2007), https://law.resource.org/pub/us/cfr/ibr/005/scte.28.2007.pdf [https://perma.cc/CJ63-U8CV]; *see also*, Todd Spangler, *FCC Douses FireWire Requirement for Set-Tops With IP*, MULTICHANNEL NEWS (June 21, 2010) http://www.multichannel.com/news/news/fcc-douses-firewire-requirement-set-tops-ip/378067 [https://perma.cc/ZV7R-R2VL] (explaining that this mandated technology, marketed as "FireWire," became a costly "technological bridge to nowhere" as the industry moved to Internet Protocol-based standards); *see generally*, Nate Anderson, *FCC admits CableCARD a failure, vows to try something else*, ARS TECHNICA (Dec. 4, 2009) https://arstechnica.com/tech-policy/2009/12/fcc-admits-cablecard-a-failure-vows-to-try-something-else/ [https://perma.cc/YVH8-542L] (discussing that the Institute of Electrical and Electronics Engineers (IEEE) established IEEE 1394 interfaces for media cables. This standard, marketed as CableCARD, failed commercially despite government mandates); *see also* National Highway and Transportation Administration, Brent Skorup Comment on the Proposed Vehicle-to-Vehicle Technology Federal Motor Vehicle Safety Standards, Dkt. No. NHTSA-2016-0126 (Apr. 12, 2017) https://www.mercatus.org/system/files/skorup-v2v-technologies-pic-v1.pdf [https://perma.cc/FA7B-5K65] (commenting that the IEEE 802.11p communications standard for vehicle-to-anything (V2X) communications has also failed to gain traction despite two decades of government support).

traffic management.[85] This difficulty to improve traditional air traffic management is because of "the deeply rooted interoperability of the current system."[86] Palfrey and Gasser's conclusion has sobering implications for UTM plans: "it is very hard to envision what a successful interoperability strategy for the next generation of air traffic control systems will or should look like, because there are so many stakeholders around the world and so many different technologies involved." [87]

A centralized, shared UTM system that many parties rely on makes later modifications very difficult since it increases the number of parties who have veto power over changes to the system.[88]

C. Competitive Entry Problems and an Unwarranted First-Mover Advantage

A regulated commons model offers a large first-mover advantage that is difficult to reverse. As mentioned, several companies anticipate providing UTM or UTM components.[89] Presumably every prospective UTM operator likewise desires to be the exclusive UTM operator approved by regulators and needs extensive control of all VTOL aircraft. As one UTM contender has said, "[w]e must have direct operational control over every active element in our network," have authority to schedule in real-time every aircraft, and be the primary liaison with the FAA.[90] It's

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[85] PALFREY & GASSER, *supra* note 81, at 43–44. (explaining that technology exists to reduce separation times, but because of the free-rider problem, airlines have declined to make the necessary equipment installations); *see also*, MICHAEL BALL ET AL., AUCTIONS FOR THE SAFE, EFFICIENT AND EQUITABLE ALLOCATION OF AIRSPACE SYSTEM RESOURCES, 960 (Peter Cramton et al., eds, MIT Press 2006).

[86] PALFREY & GASSER, *supra* note 81, at 107.

[87] *Id*. at 261.

[88] *Id*. at 107.

[89] *See* Press Release, NASA, *supra* note 5 (reporting that some plan to manage drones, some plan to manage VTOLs, and some plan to manage both types of services); *see also*, Geiver, *supra* note 28; Ball, *supra* note 28.

[90] Uber, *supra* note 2 (referring to Uber Elevate Cloud Services).

unclear, at present, which company or companies will manage low-altitude airspace and on what terms.[91]

New users to shared, congested airspace and terminals will be under immense pressure to operate on a no-interference basis, if permitted to operate at all, even if they offer more efficient operations or better technology.[92] VTOL aircraft manufacturers like Bell anticipate that service will be predetermined routes between vertiports,[93] which means that first-movers will have an incentive to capture the popular, high-revenue routes as early as is feasible.[94]

The history of airport slot allocation and spectrum access is instructive.[95] The lesson from aviation history is that once the

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[91] ELLETT & CLARK, *supra* note 29.

[92] So, for instance, when new services are deployed in a regulated commons, "unlicensed spectrum," existing operators strenuously object to and lobby against newcomers. FCC rules stating that existing users in unlicensed bands "shall not be deemed to have any vested or recognizable right to continued use of any given frequency" are worth little if politically powerful incumbents resist. 47 C.F.R. § 18.111. *See* Brent Skorup, *Spectrum NIMBYs and the Return of FCC Beauty Contests?*, TECHNOLOGY LIBERATION FRONT (July 23, 2015), https://techliberation.com/2015/07/23/spectrum-nimbys-and-the-return-of-fcc-beauty-contests/ [https://perma.cc/429W-WQFE]; Brito, *supra* note 60 ("Predictably, Cisco, 3Com, Apple, and other Wi-Fi backers waged a contentious regulatory war against the rule change claiming that the new HomeRF technology would interfere with Wi-Fi transmissions.").

[93] Urban Air Mobility Conference, *CEO Mitch Snyder Keynote,* YOUTUBE (Apr. 9, 2019), https://www.youtube.com/watch?v=ZojkpfHF0Fw [https://perma.cc/TZ43-PFBR] ("As far as the flight control system goes we will use predetermined paths to move from vertiport to vertiport.").

[94] Analysts at McKinsey have noted the first-mover advantage phenomenon in this market. Robin Riedel & Shivika Sahdev, *Taxiing for takeoff: The flying cab in your future*, MCKINSEY & CO. (Jan. 2019), https://web.archive.org/web/20190109164929/https://www.mckinsey.com/industries/travel-transport-and-logistics/our-insights/taxiing-for-takeoff-the-flying-cab-in-your-future [https://perma.cc/UX4K-TLZD] ("It is likely that first movers will have an advantage by securing the most attractive sites along high-traffic routes.").

[95] It's recognized today in traditional aviation that "arrival and departure slots at certain critical airports [are] commodities that have substantial intrinsic value." COMBINATORIAL AUCTIONS 2 (Peter Cramton, Yoav Shaham & Richard Steinberg, eds., 2006). BALL ET AL., *supra* note 85, at 995. The Bush DOT proposed to auction a few slots at congested New York-area airports. *See* Justin Baer, *US presses on with NY airport slot sales*, FINANCIAL TIMES, Oct. 10, 2008. The proposal faced immense legal and political resistance and was dropped when

centralized allocation apparatus is in place it is very difficult to dislodge in order to permit market allocation of a federal resource.[96] Incumbents and interested parties resist later additions of exclusive use because of status quo inertia or because they believe (often sensibly) they can gain cheaper rights to public assets via manipulation of the administrative assignment of rights.[97]

IV. PROPOSAL: AUCTION AIRSPACE

To avoid the anticompetitive effects and technology lock-in that would come from common pool airspace management and government-selected UTM systems, the federal government should consider airspace auctions. The auction of low-altitude airspace should be explored promptly because it is very difficult to reverse policy once VTOL operators squat on high-revenue routes and are accustomed to regulated commons access. These auctions would require the FAA to define geographic tracts of low-altitude airspace

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the Obama administration took over. Michael E. Levine, *Airport Congestion: When Theory Meets Reality*, 26 YALE J. ON REG. 37, 68 (2009). New York Senator Chuck Schumer called it a "goofy, harebrained scheme." Matthew L. Wald, *Democrats Vow to Block Airport-Slot Sale*, N.Y. TIMES (June 18, 2008) https://www.nytimes.com/2008/06/19/nyregion/19airports.html [https://perma.cc/B4UH-W9R6]. For spectrum history, see Thomas W. Hazlett, *Assigning Property Rights to Radio Spectrum Users: Why Did FCC License Auctions Take 67 Years?*, 41 J.L. & ECON. 529 (1998).

[96] *See* DJ Gribbin et al., *supra* note 10, at 22–23, 47. The slot rules "limit[ed] competition and new entrants, [had] an inability to ensure efficient utilization of slots, and [] encouraged hoarding of slots."; U.S. GEN. ACCOUNTABILITY OFFICE, Airline Competition: Industry Operating and Marketing Practices Limit Market Entry, GAO/RCED-90-147 (Aug. 29, 1990) https://www.gao.gov/assets/150/149541.pdf [https://perma.cc/L7U4-3974].

[97] *See* Valeen Afualo & John McMillan, *Auctions of Rights to Public Property, in* THE NEW PALGRAVE DICTIONARY OF ECONOMICS AND THE LAW (Peter Newman ed., 1996). *See also* FEDERAL AVIATION ADMIN., Airport Quotas and Peak Hour Pricing: Theory and Practice 83, Rep. No. FAA-AVP-775 (May 1976), https://dspace.mit.edu/bitstream/handle/1721.1/67990/FTL_R_1976_01.pdf?sequence=1 [https://perma.cc/2Z7S-LBKA].

and to auction off exclusive usufruct rights[98] to use that airspace.[99] To promote competition in local markets, airspace tracts could be divided not simply by geography, but by altitude, like a layer cake.[100]

Within the designated airspace tracts and corridors purchased and combined, private operators would have freedom to select flight paths, terminal locations, flight speed, and business model. The federal government might regulate factors like separation minimums and emergency capabilities but could delegate most technology and operational choices to the licensees.

The number of financially viable vertiports in a metropolitan area will be limited. Zoning, noise regulations, prevailing wind direction, population density, and existing transportation infrastructure will all be considerations for vertiport placement. Given this scarcity, aerial corridors connecting likely vertiport locations—central business district to major airport, for instance—are a sensible airspace tract configuration.

Aerial corridors are not unheard of in traditional aviation, though they are typically shared between airlines and they are not auctioned. "Victor" airways in the U.S., for instance, are aerial corridors crisscrossing the U.S. about three miles tall and nine miles wide, further subdivided horizontally.[101] The air traffic system

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[98] "Usufruct" derives from Roman law and literally means the right to use land and collect the fruits of the land. The basic rule for usufruct is that the possessor of the right may use her interest as she pleases so long as she does not damage the owner's—here, the public—reversionary interest. The possessor is not allowed to sell the usufruct right without consent of the owner. *See* Epstein, *supra* note 50, at 396.

[99] Some effort might be made to compensate "displaced" air users, like helicopter tourism businesses and general aircraft airports. Resistance is to be expected but displacement will likely occur whatever regulatory system for VTOL is chosen.

[100] Airspace below 200 feet—and airspace subjacent to high-rise buildings—is needed for terminal access. Terminal access would require real property acquisitions and compliance with local laws and is outside the purposes of this paper.

[101] *See* FED. AVIATION ADMIN, Instrument Procedures Handbook, Ch. 2 2–2, FAA-H-8083-16B (2017), https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/instrument_procedures_handbook/media/faa-h-8083-16b.pdf [https://perma.cc/LWP3-Y84W] ("Airways can be thought of as

operator in the U.K. similarly has an aerial highway system connecting commercial airports within the country.[102] These airways are typically three and a half miles tall and ten miles wide with horizontal subdivisions.[103]

It is impossible to determine *a priori* what the precise, "proper" VTOL airspace tract size or corridor size but a few principles can be deduced to guide regulators in determining appropriate size. A single airspace tract license, or only a handful, in a metropolitan area creates a monopolization problem and should be avoided. On the other extreme, a tract size following the borders of a Census block—there are over eleven million in the U.S.—would likely overwhelm the government with a massive auction and create inefficient fragmentation for operators to recombine.

Given the local nature of urban eVTOL transportation, areas somewhat larger than Census tracts—there are about 66,000 Census tracts across the U.S. and are about neighborhood size in urban areas—is a good starting point. Highly-trafficked urban airspace parcels should probably be smaller sizes, similar to how offshore oil leases[104] and spectrum licenses[105] are sized, where more valuable areas have smaller sizes. In other contexts, regulators consult with

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three-dimensional highways for aircraft. In most land areas of the world, aircraft are required to fly airways between the departure and destination airports.").

[102] NAT'L AIR TRAFFIC SERVICES, *What We Do*, https://www.nats.aero/about-us/what-we-do/atc-explained/ [https://perma.cc/QYG9-FK2W].

[103] *Id*.

[104] PETER CRAMTON, HOW BEST TO AUCTION NATURAL RESOURCES 4 (May 21, 2009), http://www.cramton.umd.edu/papers2005-2009/cramton-auctioning-natural-resources.pdf [https://perma.cc/C6FL-CAQK]. *See* BUREAU OF OCEAN ENERGY MGM'T, COMBINED LEASING REPORT AS OF MAY 1, 2018, 5 (2018) https://www.boem.gov/2018-annual-lease-stats/ [https://perma.cc/JRM7-BCT7]. The DOI's Bureau of Ocean Energy Management offers nearly 60,000 lease blocks covering over 300 million acres in the Pacific Ocean and the Gulf of Mexico. Block size varies but are generally 9 square miles. *Id.*

[105] FED. COMMUNICATION COMM'N, CELLULAR MARKET AREAS (CMAS), https://www.fcc.gov/sites/default/files/wireless/auctions/data/maps/CMA.pdf [https://perma.cc/67Z3-S6JF]. *See* Thomas W. Hazlett, David Porter, & Vernon Smith, *Radio Spectrum and the Disruptive Clarity of Ronald Coase*, 54 J.L. & ECON. S125, S158–60 Appendix (2011). The FCC has auctioned licenses for cellular services for twenty years and license size tends to hover between 400 and 1000 license areas nationwide. *Id.*

industry and experts about what geographic tract size is practicable and output-maximizing.[106]

New legislation would be useful to signal the change in national policy but the FAA may not require new legislation to auction VTOL airspace. The FAA has broad statutory authority to "assign . . . the use of the navigable airspace under such terms, conditions, and limitations as [it] may deem necessary in order to insure the safety of aircraft and the efficient utilization of such airspace."[107] Further, the FAA has authority to lease any interest in property, including airspace, for "adequate compensation"[108] and the Secretary of Transportation is instructed by statute to "plac[e] maximum reliance on competitive market forces."[109] While exclusive rights to air navigation facilities are prohibited when the facility has received federal funds,[110] privately-funded facilities can be exclusively assigned.

Revenue generation from public assets should not dominate airspace auction priorities but it is a relevant factor because public trustees like the FAA have a duty to recover fair value.[111] Revenues from auction or leasing of public assets can be substantial. For instance, offshore oil auctions have raised over $280 billion from bonus bids and over $220 billion in government royalties (2015 dollars).[112] Government receipts from spectrum auctions have

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[106] CRAMTON, *supra* note 104. I leave it to other commentators to determine how revenue is optimally collected, whether royalties, profit-share, or other mechanism, as well as the auction format.

[107] 49 U.S.C. § 40103 (2006) (originally enacted as Pub, L, No, 85-726, 72 Stat, 731 (1958)).

[108] Air Traffic Management System Performance Improvement Act, 49 U.S.C. § 40110(a)(3) (Supp.V 2017) (giving the FAA express authority to lease property to others. FAA Final Rule, Congestion and Delay Reduction at Chicago O'Hare International Airport, 71 Fed. Reg. at 51, 360, 51, 362–63.

[109] 49 U.S.C. § 40101(a)(6) (2012).

[110] 49 U.S.C. § 40103(e) (2012).

[111] *See* discussion *infra* Section IV.A.

[112] CRAMTON, *supra* note 104, at 9. Winning bids from all federal lease sales for oil and gas extraction from 1954 to 2008 was around $75 billion. *See also* DAVID PAUL NORDT, A STUDY OF STRATEGIES FOR OIL AND GAS AUCTIONS 2, (August 2000) (dissertation, Office of Graduate Studies of Texas A&M University).

grossed over $100 billion (2015 dollars) since 1994.[113] These values are likely dwarfed by the consumer surplus derived from the commercial operations.[114]

A. VTOL Airspace Resembles Other Federal Assets that are Auctioned

Low-altitude airspace is like many valuable, publicly-owned natural resources where the federal government stands in as a public trustee.[115] Public trusteeship generally means government disposition and leasing to private actors to process is permitted so long as fair value is received in exchange.[116] Accordingly, under public trustee theory, there is a presumption that the state should not grant access to a publicly-owned resource like navigable airspace for free.

For federal resources where widespread public access and use cannot feasibly occur, long-term leases for geographic-based tracts works well.[117] The federal government operates as a public trustee for several types of natural resources and for decades—in order to

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[113] BRENT SKORUP, MERCATUS CTR. AT GEORGE MASON UNIVERSITY, THE IMPORTANCE OF SPECTRUM ACCESS TO THE FUTURE OF INNOVATION 1 (Dec. 2016), https://www.mercatus.org/system/files/skorup-spectrum-access-future-innovation-mop-v2.pdf [https://perma.cc/DZ3F-6CJ6].

[114] Hazlett, *supra* note 72, at 251 ("The capitalized social value of [cellular] bandwidth [in 2004] likely exceeds $1.6 trillion . . . .").

[115] For a discussion of the public trust doctrine, see Epstein, *supra* note 6. "The public trust doctrine is the mirror image of the eminent domain clause. Both are designed to place limitations upon the power of legislature to divert property, whether held privately or in common . . . ." *Id*. at 426. Joseph Sax, *The Public Trust Doctrine in Natural Resources Law: Effective Judicial Intervention*, 68 MICH. L. REV. 471, 556 (1970) ("It is clear that the judicial techniques developed in public trust cases need not be limited either to these few conventional interests [e.g. rivers, streams or parklands] or to questions of disposition of public properties.").

[116] *See* Walter J. Mead, *Natural Resource Disposal Policy—Oral Auction Versus Sealed Bids*, 7 NAT. RESOURCES J. 194 (1967); *see also* Epstein, *supra* note 32, at 2358.

[117] Geographic-based tracts, it might be said, are an effective market boundary for these federal resources. For a discussion of effective and ineffective market boundaries, see Gerald Faulhaber, *Policy-induced competition: the telecommunications experiments*, 15 INFO. ECON. & POL'Y 73 (2003).

de-conflict competing demands for resources—has delimited geographic parcels and auctioned usufruct rights and licenses to those assets.[118] This includes the sale and auction of grazing rights and "stumpage" rights on public lands,[119] the right to construct radio frequency transmitters like cellular facilities,[120] offshore wind energy collection locations,[121] coal extraction on federal lands,[122] oil retrieval rights in petroleum basins,[123] and mineral extraction rights.[124]

VTOL airspace resembles assets like radio spectrum and offshore energy locations—where tract auctions work well—more than it does a common pool resource like rivers or public roads—where tract auctions do not work well. At a glance, VTOL airspace appears to resemble public roadways and navigable rivers—transportation networks with ancient open access or regulated commons rules. Public roads and navigable waters, after all, allow significant economic activity and are not auctioned by tracts.

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[118] *See* Vernon L. Smith, *On Divestiture and the Creation of Property Rights in Public Lands*, 2 CATO J. 663 (1982); Mead, *supra* note 116.

[119] About 76% of state timber volume offered for sale is sold via auction. Ross Brown et al., *Assessing State Timber Sale Policies, Programs and Stumpage Price Drivers*, Staff Paper Series No. 209, Department of Forest Resources, U. Minn. (May 2010), https://pdfs.semanticscholar.org/d71a/622f1af685ec5792a13db6c23c98b9391599.pdf [https://perma.cc/96TB-J4R4].

[120] Shelanski & Huber, *supra* note 47.

[121] Adam Johnston, *US Atlantic Offshore Wind Energy Bidding Proposal Announced by Obama Administration*, CLEANTECHNICA (Dec. 3, 2012), https://cleantechnica.com/2012/12/03/us-atlantic-offshore-wind-farms-open-business/ [https://perma.cc/23AQ-CW6E].

[122] Obama White House, THE ECONOMICS OF COAL LEASING ON FEDERAL LANDS: ENSURING A FAIR RETURN TO TAXPAYERS 6, https://obamawhitehouse.archives.gov/sites/default/files/page/files/20160622_cea_coal_leasing.pdf%22%22 [https://perma.cc/Q9WH-7UZ7] ("In 2015, roughly 40 percent of coal produced in the United States was extracted from Federal lands . . . .").

[123] A market for petroleum basins, divided into geographic parcels, developed because of increased demand for oil. *See* S. Scott Gaille, *Allocation of International Petroleum Licenses to National Oil Companies: Insights from the Coase Theorem*, 31 ENERGY L.J. 111, 116 (2010).

[124] Afualo & McMillan, *supra* note 97.

However, airspace above 200 feet differs from roadways and navigable rivers in crucial ways.[125]

First, VTOL airspace more closely resembles spectrum rights or oil drilling rights in that "the resource cannot exist until the technology is created."[126] Use of road and river travel "rights," in contrast, do not require the technology or large investments that airspace use or drilling require. This fact relates to the second difference: roads and rivers have been *actually accessed* by the public for centuries—"propertization" of roads and rivers would be socially disruptive and nearly impossible to enforce.[127] VTOL airspace, on the other hand, is fairly "clean" and therefore enforcing exclusivity is much less socially disruptive than, say, introducing route exclusivity as a default rule for road or river travel.

The airspace discussed here, then, has access properties more closely resembling spectrum and offshore oil basins, resources which are typically demarcated via geographic tracts and auctioned, not allocated on open access principles like sidewalks, rivers, and roadways. There is not a longstanding custom of the public accessing any of these "licensed property" resources because it requires significant technological know-how and investment to build and operate a VTOL, an offshore drilling site, or a cellular or broadcast transmission tower.

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[125] Airspace below 200 feet is more easily accessed by the public and open access regimes might be more appropriate for drones below 200 feet.

[126] Epstein, *supra* note 4, at 212.

[127] Epstein, *supra* note 6, at 417 ("[I]t is hardly conceivable to think of effective ways to prevent persons on the river from using it for these purposes [like fishing and bathing] . . . . It is very difficult to exclude persons from using navigable waters when they cannot be excluded from gaining access to it."). This reasoning suggests that "drone airspace," below 200 feet or so, might not be amenable to exclusive use and auction. This is particularly true once you factor in the difficult problems surrounding where "navigable airspace" ends and "real estate"—the height to where landowners can build—begins.

B. For a New Resource, Regulators Need to Introduce Auctions Early

One lesson from public resources management literature is that auctions work best for new or relatively unused resources.[128] First, it's difficult for regulators to embrace auctions later when asset values are higher because auctions empower market processes, often at the cost of regulator and insiders' preferences, to determine the assignment of valuable public property.[129] Second, it is far easier to introduce property institutions at the start, when the resource is lightly used, than to create a regulated commons and then reverse policy.

Economist Gary D. Libecap evaluated natural resources that were once regulated as a common pool resource but, later, regulators attempted and only somewhat successfully introduced exclusive use.[130] For many common pool resources, he concluded, lawmakers attempt to inject property rights institutions only after conditions have deteriorated from overuse.[131] At that point, it was often too late for effective use of exclusive-use property institutions.[132] Aviation provides a good example of the difficulty of reforming pricing rules once services are being supplied. Airport congestion fees—which have been proposed for decades and have theoretical support—are

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[128] Gary D. Libecap, *Assigning Property Rights in the Common Pool: Implications for the Prevalence of First-Possession Rules for ITQs in Fisheries*, 22 MARINE RESOURCE ECON. 407, 408–413 (2007) (noting that "[w]hen there are no incumbents and rights are distributed by the state to a new, valuable resource and transaction costs of subsequent exchange are high, then auction is optimal. It directs the resource to those who will maximize its value and the resource rents can be secured by the state . . . ."). It was also very difficult to introduce markets in airline terminals. Levine, *supra* note 95.

[129] Afualo & McMillan, *supra* note 97. It is routine today to auction spectrum but there was tremendous FCC resistance for decades, in part because regulators had long tied spectrum assignment to the regulators' social goals, like local broadcast news and children's programming. *See* Hazlett, *supra* note 95.

[130] Libecap, *supra* note 128.

[131] *Id.* at 411 (noting that "formal property rights often are not implemented [by the state] until either resource values are very high (the rental losses of open access or central regulation are very large) or until late in the use of a resource when the open-access losses have largely been borne and the stock is close to depletion. At that time, the benefits of property rights become clearer.").

[132] *Id*.

strongly resisted by air transport operators and thus have gained little traction.[133]

V. THE BENEFITS OF AIRSPACE AUCTIONS OVER REGULATED COMMONS AIRSPACE

Exclusive-use auction assignment and flexible-use rules fill several important needs.[134] For the following reasons, exclusive use—intra-firm optimization within auctioned tracts—may generate more VTOL and delivery services more quickly than inter-firm sharing of airspace and terminals. In particular, an exclusive-use regime for airspace allocation may, relative to regulated commons access to airspace and terminals, reduce costly conflicts over resource use and allow for more dynamic efficiencies.

First, auctions and flexible-use rules allow operator autonomy within a distributed system. A federated system offers significant dynamic efficiency upside. The current regulatory proposals for an interoperable network like UTM would likely provide system uniformity at a large cost to innovation and the introduction of better aircraft and component systems.[135] As Palfrey and Gasser noted in their research on the subject, the "deeply rooted interoperability" of the traditional airspace system accounts for the difficulty in updating the system, "even when there are good reasons for doing so."[136] Airspace tract licenses, similar to spectrum licenses and unlike the regulated commons management, preserves option value, allows modularity, and allows combination of routes. In short, operators

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[133] *See*, *e.g.*, Steven A. Morrison & Clifford Winston, *Another Look at Airport Congestion Pricing*, 97 AM. ECON. REV. 1970 (2007).

[134] David C. Parkes & Lyle H. Ungar, *An Auction-Based Method for Decentralized Train Scheduling*, PROC. OF THE FIFTH INTERNATIONAL CONFERENCE ON AUTONOMOUS AGENTS, 43, 43–50 (2001).

[135] PALFREY & GASSER, *supra* note 81, at 149 (indicating that providers have an incentive to privately negotiate interoperability: "[m]ore and more firms, especially in the information business, are shedding their proprietary approaches in favor of interoperability at multiple levels. The goal is not to be charitable to competitors or customers, of course, but to maximize returns over time by building an ecosystem with others that holds greater promise than the go-it-alone approach.").

[136] *Id*. at 107.

would have more freedom to expand routes and recombine routes in response to business opportunities.

Exclusive-use rights also free companies from possible equipment mandates to operate on a regulated commons system. Exclusive use limits the need, for instance, for mandated high-precision, interoperable, and expensive (regulated) sensor systems. Firms can optimize their own systems without concerning themselves with the capabilities and technologies of competing systems since airspace assignment would physically separate VTOL flight corridors. Sensor systems require a significant amount of computational and battery overhead and add weight to aircraft. Exclusive use means the assurance of clear airspace and should allow VTOL operators more freedom to reduce the number and complexity of sensors.

Spectrum illustrates how important these dynamic efficiencies are, because there are "huge variations in the intensity of use of different portions of the spectrum" based on the underlying rules.[137] Spectrum auctions have been a tremendous policy success largely because spectrum uses are delegated to several companies on a geographically exclusive basis.[138] Exclusive-use airspace tracts give companies more freedom to iterate on their private UTM systems—similar to how cellular companies iterate upon and upgrade their radio access network technologies—and find operational

[137] Epstein, *supra* note 4, at 213.

[138] Aside from the substantial government revenues, the private investment in directly ancillary products and services (mobile devices, apps, nationwide fiber and mobile networks) and consumer welfare gains have been massive. Thomas Hazlett noted in 2005 when exclusively assigned by the FCC:

[Spectrum] is intensively shared. Common access among millions of subscribers is organized by network operators which, with broad rights to control the use of specific frequencies, invest heavily to provide opportunities for consumers to communicate via wireless networks. This investment can be summarized in both physical capital-for instance, the creation of 174,368 cellular base stations-and financial capital-the expenditure of $156 billion in aggregate capital investment (book value through June 2004).

Hazlett, *supra* note 72, at 249.

efficiencies that would not be possible with a shared, interoperable UTM system.[139]

Second, the transferability and subleasing of airspace tracts means first-movers and existing technologies are not unduly favored in initial allocation. It is self-evident that the UTM systems and VTOL aircraft of today will improve, if permitted, since they involve emerging technologies. A unified UTM and regulator-assigned routes and vertiports injects rigidity into the system since the community-based traffic management system that regulators envision would require new operators who wish to enter the market or introduce new routes, more frequent flights, or new vertiports to receive buy-in from competitors and regulators.[140] The ability to transfer and lease airspace tracts means that incumbent users have a financial incentive to transfer the resource to its highest-valued use and to new entrants. At present, there is no mechanism in the UTM plans for incentivizing incumbent VTOL operators to transfer routes to new, innovative entrants.

Third, competitive bidding and a secondary market in airspace tracts compels operators to reveal truthful information about their value for the resource. Once a UTM system is designed and selected, regulators and their approved UTM operators cannot expect VTOL operators "with private information about its time constraints, value, and costs" to report accurate access valuations to a centralized

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[139] Preliminary evidence from drone flights suggest the benefit of a single operator. Medical drones in Rwanda "fly[] in the exact same path. This is how we ensure that the system operates in a predictable, reliable, ultimately boring way. Logistics should be boring. There shouldn't be any surprises." Owning "the full stack" is important because "when one small team of hardworking engineers can own the entire system from scratch you can move fast." Alice Lloyd George, *Using drones to build the ambulance fleet of the future*, TECHCRUNCH (Dec. 25, 2017), https://techcrunch.com/2017/12/25/using-drones-to-build-the-ambulance-fleet-of-the-future/ [https://perma.cc/R545-VNDY]. Similarly, drone deliveries in Iceland are operating with exclusive, fixed routes. Phillip E. Ross, *Are Delivery Drones Commercially Viable? Iceland Is About to Find Out*, IEEE SPECTRUM (Sept. 26, 2018), https://spectrum.ieee.org/robotics/drones/are-delivery-drones-commercially-viable-iceland-is-about-to-find-out [https://perma.cc/NP2C-2XK8].

[140] NASA, *supra* note 3, at 4–5.

allocator.[141] Operators will misrepresent or omit information when "it will improve its own schedule in the system-wide solution."[142] This is the experience of traditional airlines, for instance, which hoard allocated slots and fly unprofitable flights in order to maintain the valuable routes.[143] Further, shared routes and terminals encourage overscheduling since the gains from a reduction in use cannot be internalized by the innovative or efficient company.[144] Overscheduling, therefore, can be a tactic to raise rivals' costs,[145] and should be anticipated with a shared UTM system.

Fourth, exclusive, geographic rights to airspace tracts give licensees stability of possession that induces the significant investment necessary for mass air taxi operations. Long-term licenses give companies the assurance they need to make high-fixed costs for permitting, vertiports, electrical grid upgrades, concessions, and related infrastructure construction. With a regulated commons and sharing of routes and terminals, investments are more precarious because continued operations depend on regulators' *ad hoc* decisions at who receives airspace and terminal access during times of congestion.[146] In contrast, when a single party exclusively controls routes and terminals, delays, congestion, and cancellations are internalized.[147] This internalization of costs should

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[141] Parkes & Ungar, *supra* note 134, at 43.

[142] *Id*.

[143] DJ Gribbin et al., *supra* note 10; Levine, *supra* note 95, at 58–59.

[144] Traditional airlines overschedule operations and "generat[e] excessive flight delays, cancellations, and loss-of-separation violations" because if an airline acts responsibly and doesn't overschedule at a busy airport, it has simply given a competitor opportunities to schedule more flights. BALL ET AL., *supra* note 85, at 954.

[145] BALL ET AL., *supra* note 85, at 954–55.

[146] NASA, *supra* note 3, at 4–5.

[147] There's some evidence for this in the aviation literature. *See* Jan K. Brueckner, *Airport Congestion When Carriers Have Market Power*, 92 AM. ECON. REV. 1357, 1357–58 (2002) (finding that a monopoly airline "*internalizes the congestion each flight imposes on the other flights it operates*") (emphasis in original). Further, using empirical evidence of the 25 most delayed US airports, "delays fall as airline market power rises." *Id*. at 1371; *see also* C. Mayer & T. Sinai, *Network Effects, Congestion Externalities, and Air Traffic Delays: Or Why Not All Delays Are Evil*, 93 AM. ECON. REV. 1194, 1206 (2003) ("We also find evidence that airports with low concentration have higher delays, possibly

operate as a powerful incentive to maintain infrastructure and systems.

Finally, a system for auctioning geographic aerial tracts for VTOL service reduces the number of dimensions with which aviation regulators need to concern themselves. Geographic partition and auction of airspace would allow for the competitive development of UTM and reduce contests over airspace and vertiport access. With no need to prescribe technology standards, referee conflicts over congested urban airspace, and select amongst many UTM operators, the FAA could focus on its core mission of safety. This includes developing separation standards, testing new VTOLs for airworthiness, identifying emergency landing areas in urban areas, and developing standards for vertiport construction.

VI. CONCLUSION

Technology improvements have made the prospect for mass air transit plausible, and regulators and manufacturers globally are racing towards autonomous flight. However, technology shocks can create resource conflicts and the need for a dramatic shift in legal institutions. U.S. regulators are public trustees of federal airspace and should study long-standing practices towards the disposition of assets. In particular, the identification and auction of geographic tracts of airspace could give VTOL and aviation startups the possession stability they need to maximize investment in autonomous technology and ground-based facilities. The lessons from the auction of other federal assets like spectrum, oil fields, and wind energy leases are not dispositive, but they provide evidence that auctioning airspace tracts could allow for the rapid and safe deployment of an air taxi industry in the U.S.

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because carriers do not fully internalize the costs their flights impose on other carriers.").