Unmanned Aircraft System

Unmanned Aircraft Systems or Drones

Drones have been experiencing healthy growth in the United States and around the world over the past few years. The last two years have been no exception, despite the profound impact of COVID-19 on the overall economy.[12] A drone consists of a remotely-piloted aircraft and its associated elements—including the control station and the associated communication links—that are required for safe and efficient operation in the national airspace system (NAS). The introduction of drones in the NAS has opened up numerous possibilities, especially from a commercial perspective. That introduction has also brought operational challenges including drones' safe and secure integration into the NAS. Despite these challenges, the drone sector holds enormous promise; potential uses range from individuals flying solely for recreational purposes to large companies delivering commercial packages and delivering medical supplies. Public service uses, such as conducting search and rescue support missions following natural disasters, are proving promising as well.

This section provides a broad overview covering recreational and commercial (or part 107) unmanned aircraft and their recent trends, as gathered from trends in registration, surveys, overall market, and operational information.[13] Using these trends and insights from industry, the FAA produces a number of forecasts. Forecasts reported in the following sections are driven primarily by the assumptions of the continuing evolution of the regulatory environment, the commercial ingenuity of manufacturers and operators, persistent recreational uses, and underlying demand for drone services.

Trends in Recreational/Model Aircraft New Registration

The FAA's online registration system for recreational/model small drones went into effect on December 21, 2015. This required all drones weighing more than 0.55 pounds (or 250 grams) and fewer than 55 pounds (or 25 kilograms) to be registered using the on-line system [www.faa.gov/uas/getting_started/register_drone/] or the existing

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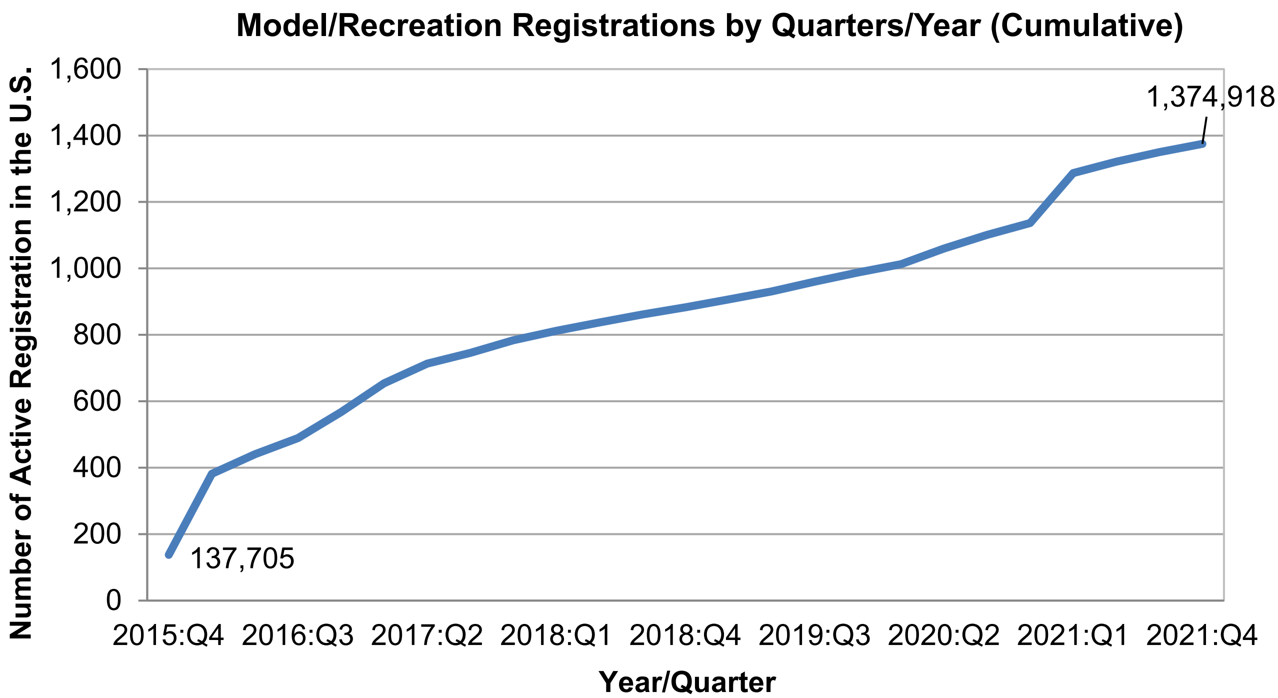
[12] Drone, model aircraft, and unmanned aircraft systems are often used interchangeably, both in common and legal terms. Although some communities differentiate between these terms, the three terms are used interchangeably in this document.

[13] Recreational and commercial drones are also called, interchangeably, hobby and non-hobby UAS, respectively. On October 5, 2018, the President signed the FAA Reauthorization Act of 2018 (Pub. L. 115-254). Section 349 of that Act repealed the Special Rule for Model Aircraft (section 336 of Pub. L. 112-95; Feb. 14, 2012) and replaced it with new conditions to operate recreational sUAS without requirements for FAA certification or operating authority. The Exception for Limited Recreational Operations of Unmanned Aircraft established by section 349 is codified at 49 U.S.C. 44809 [see www.federalregister.gov/documents/2019/05/17/2019-10169/exception-for-limited-recreational-operations-of-unmanned-aircraft for more details]. Recreational fliers, under Section 349, are referred to as "recreational fliers or modeler community-based organizations" [see www.faa.gov/uas/recreational_fliers/]. In previous notes including other documents of the Agency, these terms are often interchanged.

(paper-driven) aircraft registry. Registration was free for the first 30 days, and $5 thereafter. Following a temporary halt in registration due to an order from the US Appeals Court in Washington, DC in May, 2017 (*Taylor v. Huerta*), the registration requirement for all model aircraft was reinstated in December, 2017 with the National Defense Authorization Act (NDAA) [Pub. L. 115-91, Sec. 1092]. The NDAA extended the registration for three years for those registered prior to December, 2017. New registration resumed after the temporary halt was removed. On October 5, 2018, the President signed the FAA Reauthorization Act of 2018, which formalized new conditions for recreational use of drones. [See www.faa.gov/news/updates/?newsId=91844 for more details].

With the continuing registration, over 1.37 million (new) recreational drone owners had already registered with the FAA by end of December, 2021.[14] On average, new owner registration stood at around 10,300 per month during January – December 2021 with some expected peaks during the holiday seasons and summer.



The current pace of new registration has decreased compared to last year in the same period; average new monthly owner registration during 2021 stood at 2,500 less than the level observed in 2020.

[14] For our estimate and projections using the registration database, applying to recreational, commercial/part 107 and remote pilots, we use only those who are registered in the US and the territories for the period January – December, 2021. Furthermore, we draw a clear distinction between new registrations, cancellations, and renewals in this document.

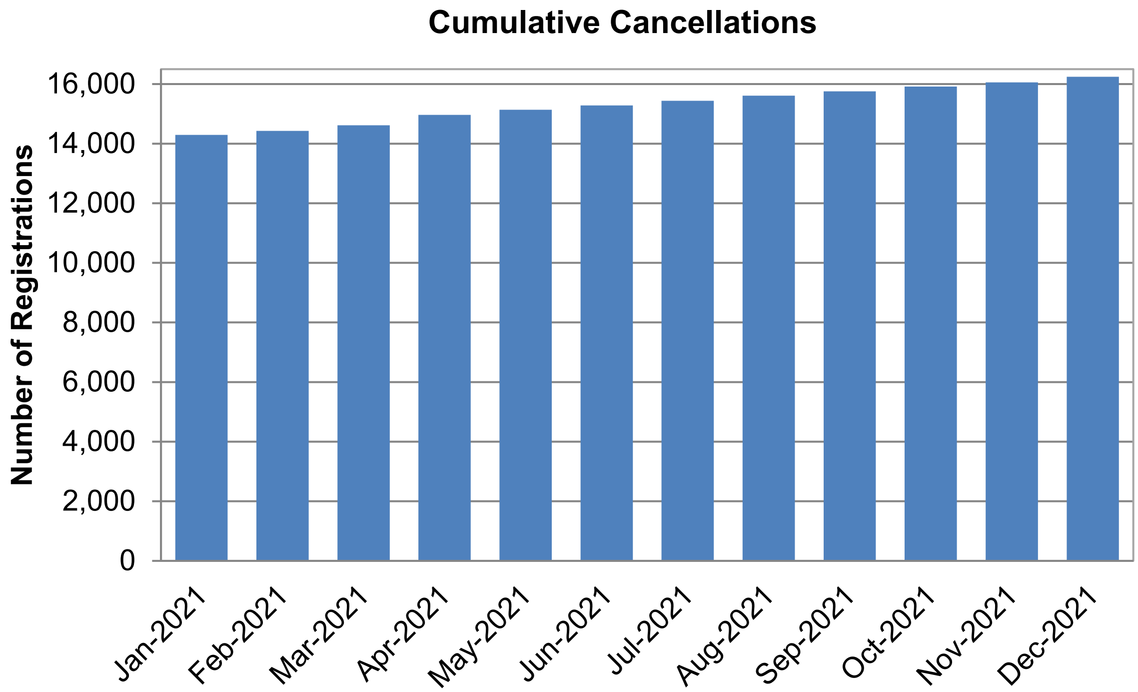
Forecasts Using New Registrations vs. Effective/Active Fleet

As noted in last year's Aerospace Forecast, small drones are registered for 3 years while remote pilot (RP) certifications are valid for 2 years. [See www.faa.gov/uas/getting_started/register_drone/ and www.faa.gov/uas/commercial_operators/become_a_drone_pilot/.] Following the *Taylor vs. Huerta* ruling and the FAA's authority over registration via NDAA, the Agency elected to extend the registration period, for all drones registered prior to December 12, 2017, for three years. Thus, December 12, 2020 marked the first effective renewal date. As a result of this sequence of events, as noted in last year's report, approximately 800,000 small drone registrations were due for renewal in December 2020.

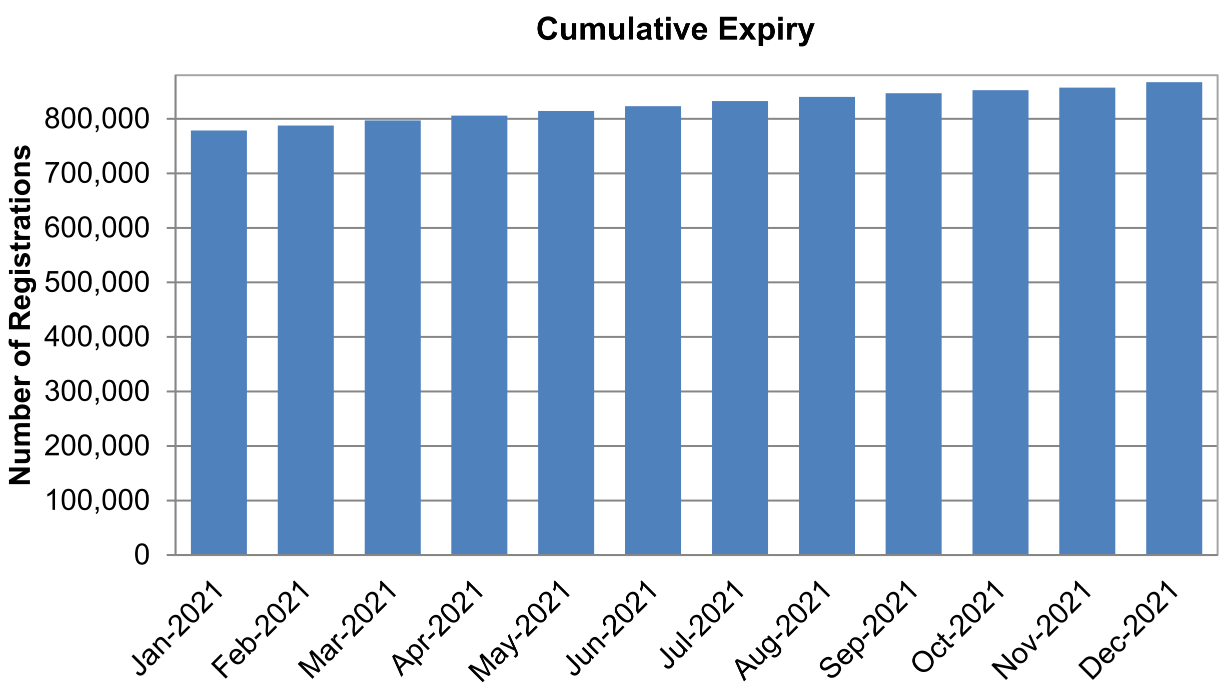
The beginning of the registration renewal afforded the FAA an opportunity to analyze the data, including duplicate and spurious registrations. Following this process, an examination of the data provided an opportunity for the FAA to discern the effective/active fleet more succinctly using the following five elements: *Cancellations*, defined as number of registrations canceled by user; *Expiry,* defined as the number of registrations expired; *New*, defined as the number of brand new registrations (i.e. new registration number) that are reported in the preceding section; *Renew*, defined as the number of registrations renewed prior to expiration; and *Renew+,* defined as the number of registrations renewed after expiration.

Cumulative cancellations were, on average, 15,313/month for the time period of January 2021 – December 2021 (or averaging around 179 new cancellations, or the average gaps between the two bars, for each month during the January – December 2021 timeframe):[15]

[15] We report cumulative numbers throughout this document for two reasons: first, cumulative numbers reflect the stability of the trend over time, taking into account past changes; and second, differences between the two numbers (i.e., bars) capture the changes between two particular time periods.

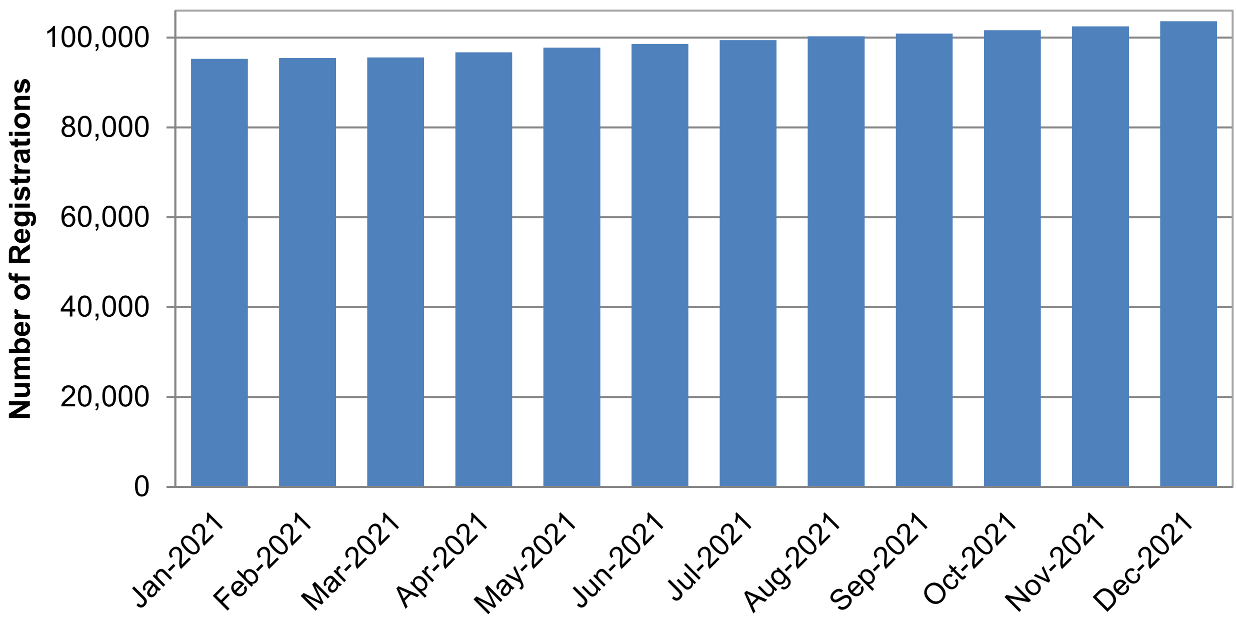


On average, cumulative registrations expired at a rate of more than 825,000/month following the substantial adjustment in December 2020, as noted above and as shown below. (This is equal to slightly more than 8,480 new average expiries for each month during January – December 2021):

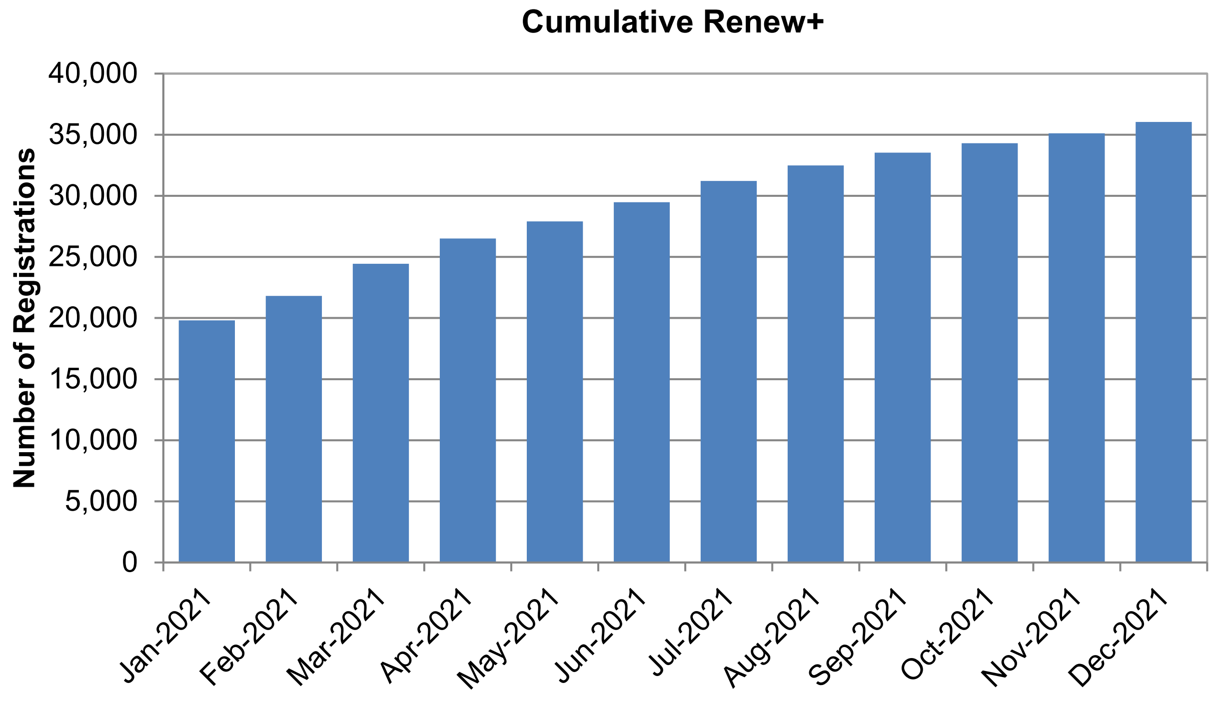


Renew or re-registrations prior to expiry date logged, on average, more than 98,984/month on a cumulative basis (or 712 new average renewals for each month during January – December 2021). This was almost four times higher than Renew+ on a cumulative basis, as reported below:

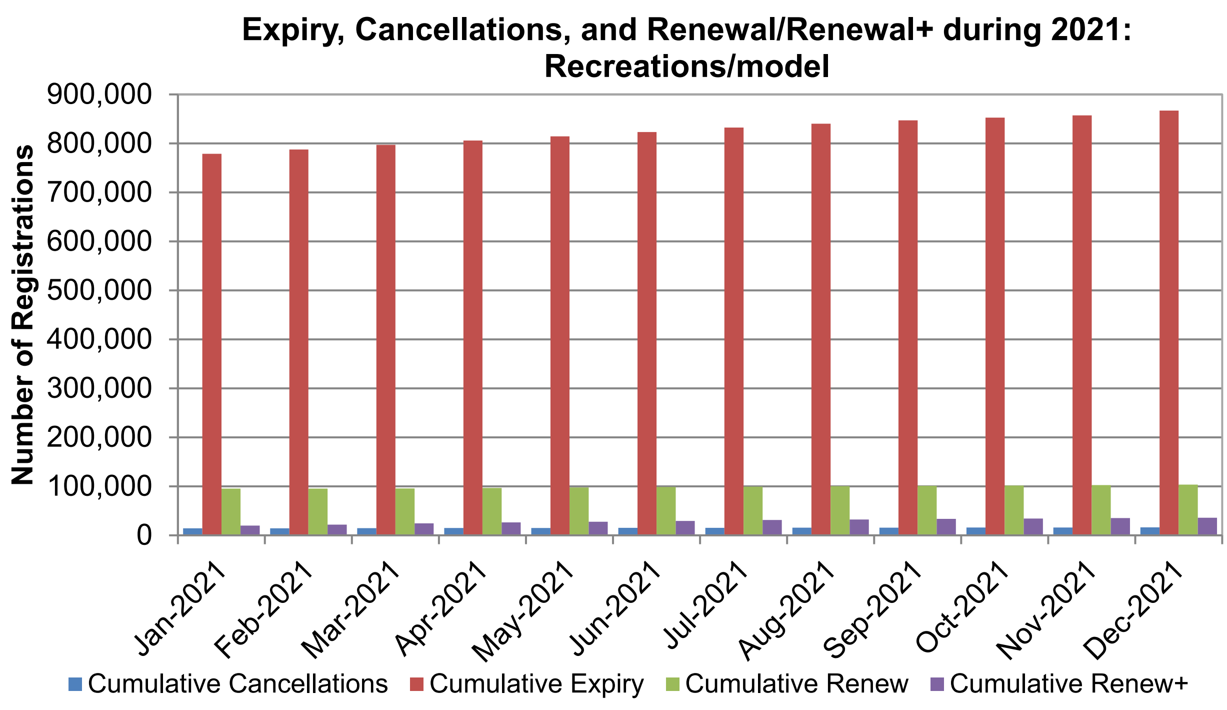
Cumulative Renew



Renew+ are re-registrations after expiry date logged, on cumulative average, at 28,254/month. This is equivalent to approximately 1,780 new average Renew+ registrations for each month during January – December 2021 and are reported in below:



A summary of the above 4 charts is provided in below to narrate the relative contributions of cancellations, expiry, renew and renew+:



Calculating active/effective registrations for a particular day requires calculating the "net gain/loss" of registrations for each preceding day and adding them together with the particular day (i.e. calculating the running sum).

The following are the contributions of each element to the day's net gain/loss:[16]

- Cancel: (-1 for each registration);
- Expire: (-1 for each registration);
- New: (+1 for each registration)
- Renew: (0); and
- Renew+: (+1 for each registration)[17]

An example of this calculation may be constructed as follows: calculating the net gain/loss for recreational registration for August 9, 2021, where Cancel = 11; Expiry = 263; New = 276; Renew = 20; and Renew+ = 46 had been reported for recreational operators/modelers.

Thus, Net Gain/Loss for August 9, 2021 =

11 X (-1) + 263 X (-1) +

276 X (1) + 20 X (0) +

46 X (+1) = 48

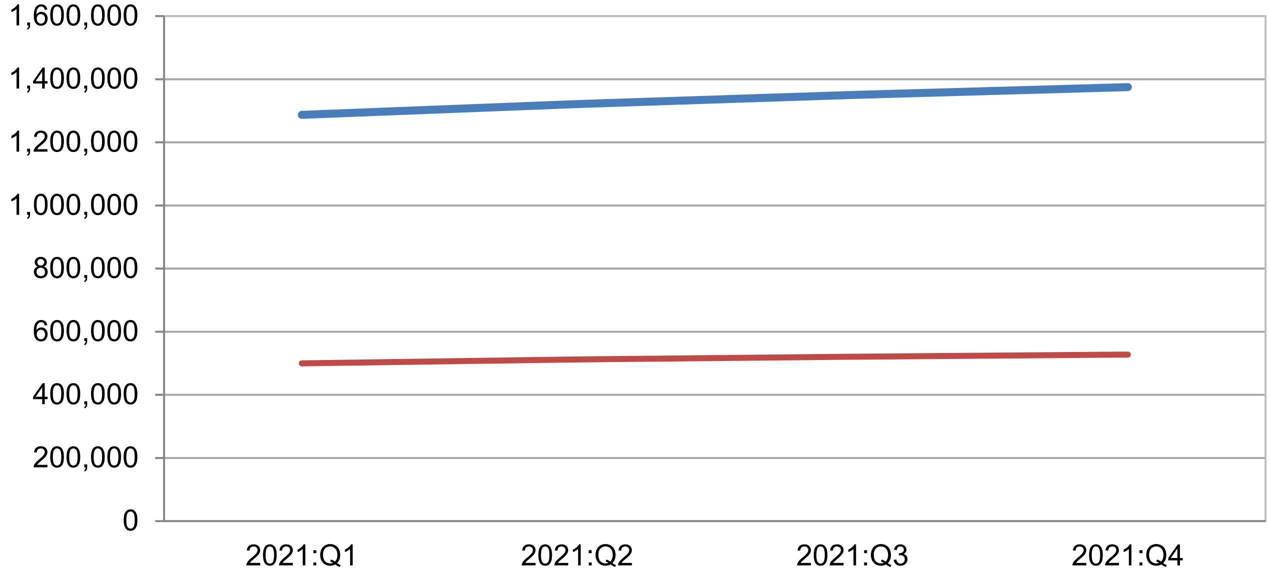
Finally, a comparison chart capturing the difference between cumulative new registrations and. effective/active registrations, using cumulative net gain/loss for recreational registrations, is provided below:[18]

[16] We attribute this methodology of calculations to the UAS Integration Office (AUS), provided internally to facilitate this year's forecasts. For cumulative new registration trends, see the final graph preceding this section.

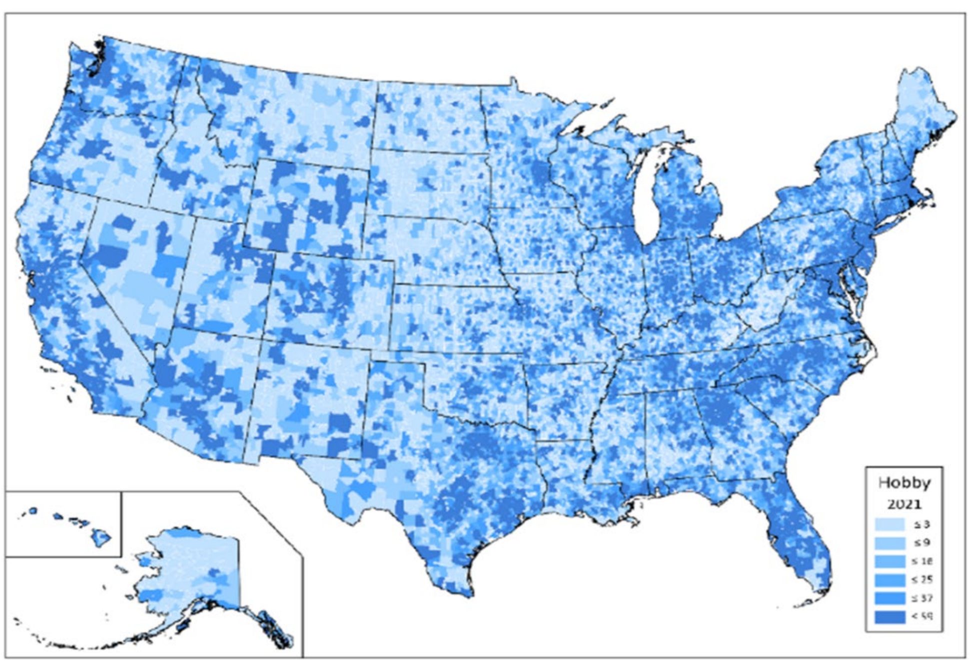
[17] It is important to note here that renew+ is a replacement for cancellation on a one-on-one basis.

[18] There are two important aspects making the difference: (a) the base; and (b) the rate of change in two lines. For cumulative net gain/loss, the base is highly influenced by substantial expiry and cancellations implemented in December 2020, as discussed above; the rates of change (or slope) of the cumulative net gain/loss line is influenced by these two elements plus new registrations and Renew+ re-registrations. In comparison, new registration counted cumulatively has a substantial base thus making the difference between the two lines while new monthly registrations is the primary factor driving the rate of change for cumulative new registrations line.

New Registrations versus Effective/Active Fleet: Model Recreation



Recreational registration, and thus ownership of small drones, is distributed throughout the country. Using the data available in December 2021, the spatial distribution of ownership by zip codes (shown below) demonstrates that small drones continue to be distributed throughout the US, with denser ownership mapping closely to the population centers of the zip codes, as expected.



At present, recreational ownership registration does not correspond one-to-one with aircraft. Unlike their commercial non-model counterparts, the registration rules for recreational operators do not require owners of recreational small drones to register each individual aircraft; only operators are registered. For each registration, therefore, one or more aircraft may be owned. In some instances, there is no equipment associated with registration. Free registration at the initial phase may have incentivized some to create a registration without any equipment to report. Notwithstanding these challenges, there is information available, both from industry and academia, allowing us to understand aircraft ownership. Furthermore, as a result of robust strategic drone research planning, the FAA has launched various research activities to understand the possible magnitude of the sector as well as implications for likely aircraft that may be used for recreational flying, as well as the safety impacts on the small drone fleet from gradual integration into the NAS. Finally, the Agency has incorporated outside analysis to aid forecasting efforts.

As noted in earlier annual reports, forecasts of small drones were based primarily on new registrations without considering the effective/active fleet for reasons described in the beginning of the section (e.g., lack of renewals required). However, now that data on elements for net gain/loss are available, more granular forecasts can be made, particularly the lower bound, using the effective or active fleet. With over 1.37 million new recreational operators cumulatively registered as of December 2021, the FAA estimates that there are approximately 1.58 million sUAS in the fleet distinctly identified as recreational aircraft. Comparing with industry sales and other data noted earlier, we conclude that the number of recreational aircraft is almost 15% higher than ownership registration.[19] Applying cumulative net gain/loss calculations from above, the effective/active fleet is estimated to be around 607,177 as of December 2021. This provides us the lower bound of effective/active fleet of recreational small drones in the NAS.

A comparison of last year's data (2020) with this year's (2021) shows the annual growth rate for new registration to be approximately 10.2%. This was possible due to the continuation of drones playing a dominant role in recreation, a continuation facilitated by decreasing equipment prices (e.g., average price of $750 or less), improved technology such as built-in cameras and higher capability sensors, and relatively easy maneuvering. Furthermore, it appears that COVID-19 had a positive impact on recreational registration during 2020, but a negative impact during 2021. (See below for more details.) Nevertheless, similar to all technologies fueling growth of hobby items, (e.g., cell phone and video game consoles, and prior to that, video cameras and video players), the trend in recreational small drone ownership registration has been slowing. It is likely to slow down further as the pace of falling prices diminishes

[19] This calculation involves taking into account retirement, redundancy, and loss of aircraft corresponding to ownership registration. As aircraft become sturdier and operators more situationally aware, this rate has been changing and we expect it to change dynamically over time. Assumptions tying ownership to aircraft holding and issues related to compliance have been discussed elsewhere. [See napawash.org/academy-studies/federal-aviation-administration-assessment-of-compliance-with-and-effective for a recent study by the National Academy of Public Administration on these issues.]

and the early adopters begin to experience limits in their experiments, or simply because recreational eagerness plateaus.

Given trends in registration and market developments, the FAA forecasts that the recreational small drone market will saturate at around 1.81 million units over the next five years.[20] However, there is still some upside uncertainty due to further changes in technology, including battery life, faster integration from a regulatory standpoint, and the likely event of continued decreasing prices. This leads to upside possibilities in the forecast of as many as 1.84 million units by 2026. In contrast, there are some low-side uncertainties; the primary among them is the lack of renewal (i.e., before and after expiry dates), followed by expiry and cancellations. The inertia, loss of interests, or lack of recreational opportunities may be key factors leading to the observed trends in renewal. Nevertheless, if renewals were kept up over time, effective/active fleet would likely converge to base forecasts, i.e., derived from cumulative new registrations combined with multiplicity of craft ownership. In the presence of slower renewal tendency, as data presently indicates, it is likely that the effective/active fleet will be lower than that derived from base forecasts. This provides the FAA with an opportunity to derive low-side forecasts using effective/active fleet calculations. Nevertheless, low-side uncertainty growth trajectory (i.e., annual growth rates) tracks closer to the base forecast. A forecast base (i.e., likely), together with high and low scenarios, is provided in the table below:[21]

Total Recreation/Model Fleet (Million sUAS Units)

Fiscal Year	Low*	Base**	High**
Historical			
2021	0.6072	1.5822	1.5822
Forecast			
2022	0.6509	1.6965	1.6981
2023	0.6848	1.7576	1.7645
2024	0.7096	1.7965	1.8182
2025	0.7262	1.8039	1.8272
2026	0.7378	1.8075	1.8360

*: Effective/Active fleet counts combined with multiplicity of craft ownership.

**: New registration counts combined with multiplicity of craft ownership.

[20] These forecasts have two dimensions worth emphasizing. When looked at from the cumulative base, "total" captures the number of drones that *are reported* to be in the system (i.e., base and high); while "effective/active fleet" refers to how many aircraft are *presently operating* in the system (i.e., low).

[21] As noted earlier, low scenario reports effective/active fleet using a net gain/loss calculation. By definition, low scenario differs from base and high scenarios, which are based on new registrations. Hence, a low scenario for the year 2021 is markedly different than the baseline and high scenario for the same year.

Last year, the FAA forecasted that the recreational small drone sector would have slightly more than 1.50 million drones in 2021, a growth rate exceeding 4.6% from the year before (2020). Actual data using new registration overshot the projection by a little over 80,000 registrations, with over 1.58 million small drones already accounted for by the end of 2021. Thus, our forecast of recreational small drones last year undershot by 5.06% for 2021, (or 1.5822 million actual aircraft vs 1.5022 million aircraft that were projected last year).

The FAA uses the trends observed in registrations, particularly over the past year; calculation of net gain/loss (described above) this year; information from the survey conducted in 2018; expert opinions distilled from Transportation Research Board annual workshops; review of available industry forecasts; market/industry research; and time-series models fitted on monthly data. These apply to all three elements reported above: low, base, and high forecasts. Using these, the FAA forecasts that the recreational small drone fleet will likely (i.e., base scenario) attain its peak over the next 5 years, from the present 1.58 million units to approximately 1.81 million units by 2026.

Following a similar growth trajectory as the base, there will be approximately 738,000 active/effective small drones over the next five years in 2026, which is now the low forecast for recreational/model small drones. Active/effective fleet count is derived and projected based on the net gain/loss calculation discussed above. The high scenario, on the other hand, may reach as high as 1.84 million units. High scenario projection is based on the base forecast.

Notice that eventual saturation at somewhat higher levels, in comparison to last year's projections, reflects relatively higher new registration by recreational flyers observed during 2021. The increased new registration trend, in part driven by COVID-19, may or may not continue in the longer run.[22] In comparison, low side forecasts assume the present trend in renewals followed by similar expiry and cancellations. Nevertheless, the growth rates underlying these numbers are fairly steady in the initial years, but fade faster in the last two to three years. The gradual saturation that is projected in five years and beyond in the recreational small drone fleet parallels other consumer technology products and the Agency's projections from last year, particularly with respect to base and high forecasts. However, both the numbers and the growth trajectory for the low scenario (i.e., effective/active fleet) are fundamentally different than the last year for reasons described above. Nevertheless, it provides a lower bound that is likely to be closer to reality in terms of small drones that are in use and effective in the NAS.

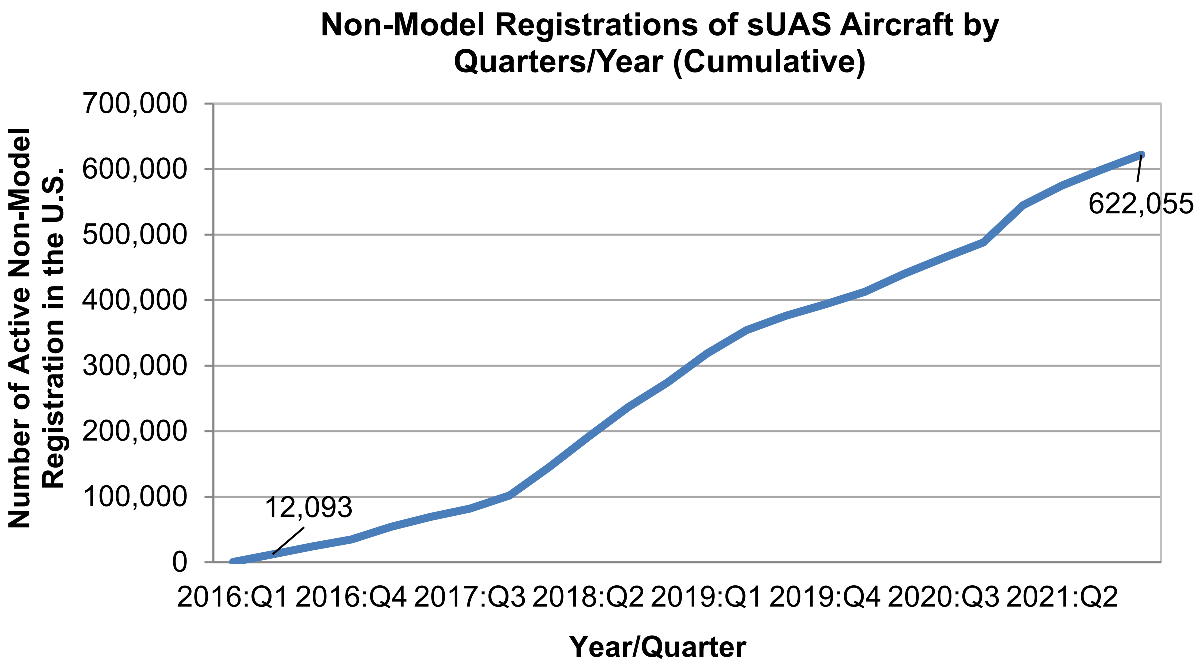
[22] It is quite likely that many users are buying and experimenting with recreational small drones given the COVID-19 public health emergency and the substantial portion of the workers presently working from home. This trend may or may not continue once regular work patterns are resumed.

The Recreational UAS Safety Test (TRUST)

Under the most recent (2018) reauthorization bill [see www.congress.gov/115/bills/hr302/BILLS-115hr302enr.pdf], new requirements for recreational pilots have been introduced. (See P.L. 115-254 – exception for limited recreational operations of unmanned aircraft.). TRUST is the safety test for recreational/model small drones. It provides education and testing for recreational flyers on important safety and regulatory information. All recreational flyers must pass an aeronautical knowledge and safety test and provide proof of test passage – the TRUST completion certificate — to the FAA or law enforcement upon request. [See www.faa.gov/uas/recreational_fliers/knowledge_test_updates/ for more details.] By December 2021, more than 175,000 recreational flyers completed TRUST certification subsequent to its inception in June 2021.

Trends in Commercial/Non-Model Aircraft and Forecasts Using Registrations vs. Effective/Active Fleet

Online registration for commercial/non-model small drones went into effect on April 1, 2016. Unlike recreational/model ownership, rules for commercial registration require owners to register each small drone, thus creating a one-to-one correspondence between registration and aircraft. During the period of January – December 2021, more than 100,000 commercial operators registered their new equipment. The pace of monthly registration, around 8,500, is higher than the same period in 2020, which was approximately 7,870. It appears that the pace of new registrations is picking up speed slightly in comparison with 2020 and prior years. (From April 2016 – December 2020 there were roughly 9,100 new registrations per month.) As the pace of recreational registration has increased somewhat, particularly last year, the pace of new registration for the commercial counterparts has followed suit, with more than 620,000 commercial drones registered since April 2016.



For each month the registration has been available, over 4,600 new aircraft per month were registered until December 2017. This pace accelerated to 14,600 new registrations per month during 2018. During 2019, average monthly new registrations stood at approximately 10,100. In the past year, 2020, average monthly registration dropped to 7,850, while during 2021, average monthly registrations jumped by 650 to around 8,500. The commercial small drone sector is dynamic and appears to be at an inflection point, demonstrating powerful stages of growth. Unlike the recreational small drone sector, the FAA anticipates that the growth rate in this sector will remain high over the next few years. This is primarily driven by the regulatory clarity that part 107 continues to provide to industry. In particular, the Operations Over People final rule, published on December 28, 2020, is the latest incremental step towards further integration of small drones into the NAS. This final rule allows routine operations over people and routine operations at night under certain circumstances, and eliminates the need for individual part 107 waivers. [See www.faa.gov/news/media/attachments/OOP_Executive_Summary.pdf for more details.]

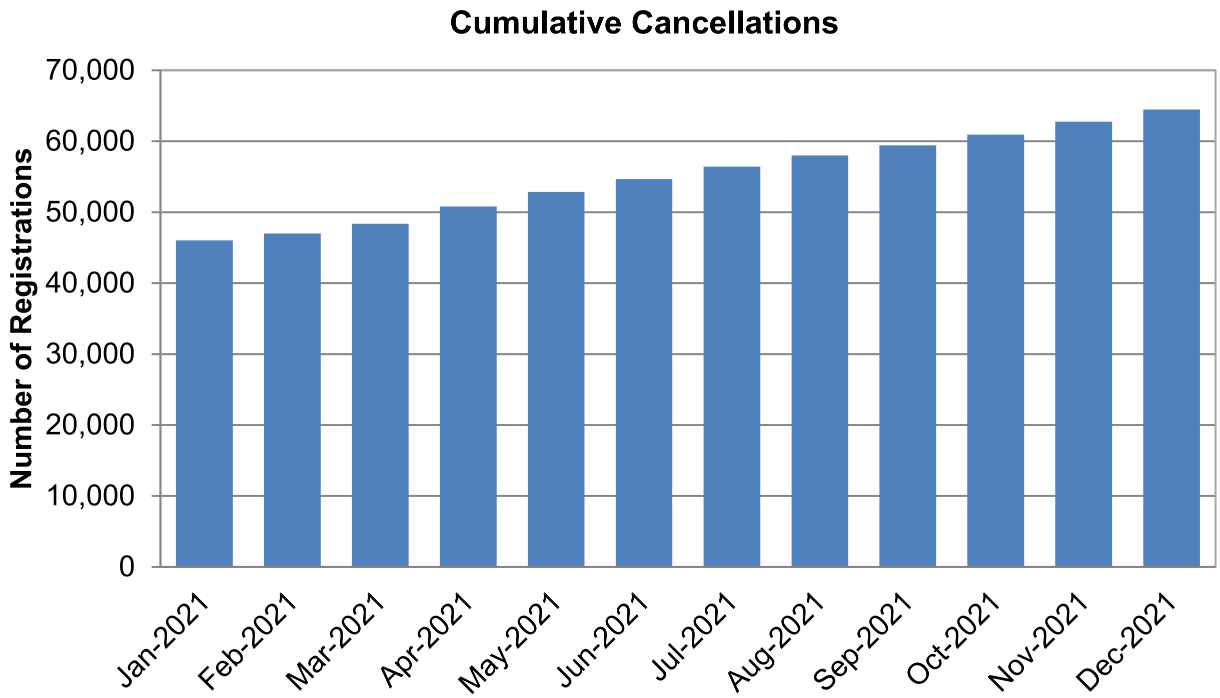
The Remote ID rule was announced on December 28, 2020 as well. [See www.faa.gov/news/media/attachments/RemoteID_Final_Rule.pdf] Upon adjudicating numerous comments from stakeholders, the final rule [See www.faa.gov/sites/faa.gov/files/2021-08/RemoteID_Final_Rule.pdf for more details] was published in the Federal Register on January 15, 2021 with an original effective date of March 16, 2021. Corrections made to the rule and published in the Federal Register on March 10, 2021 delayed the effective date to April 21, 2021. Remote ID (i.e., digital license-plate) of remotely piloted aircraft is necessary to ensure public safety and efficiency of US airspace. The rule applies to all operators of small drones that require FAA registration (i.e., both recreational and part 107). Remote ID provides airspace awareness to the FAA, national security agencies, law enforcement entities, and other government officials. In accordance with the requirements of the present rule, remotely piloted aircraft in flight are to provide, via broadcast, certain identification, location, and performance information that can be received by interested parties on the ground and by other airspace users.

There are three ways to comply with the remote ID rule: (a) operate a standard remote ID small drone broadcasting identification and location information of both the aircraft and control station; (b) operate a small drone with a remote ID broadcast module attached to it that broadcasts identification, location and take-off information; and (c) operate a small drone without remote ID at specific FAA-recognized identification areas (or FRIAs). As noted, almost all of the final rule on remote ID became effective on April 21, 2021. The subpart covering the process for FRIA applications from community-based organizations and educational institutions becomes effective September 16, 2022. Drone manufacturer compliance with the final rule's requirements becomes effective on September 16, 2022 as well. Finally, operator compliance with the remote ID rule and/or in an FAA designated FRIA is required by September 16, 2023. [See www.faa.gov/uas/getting_started/remote_id/ for more details]

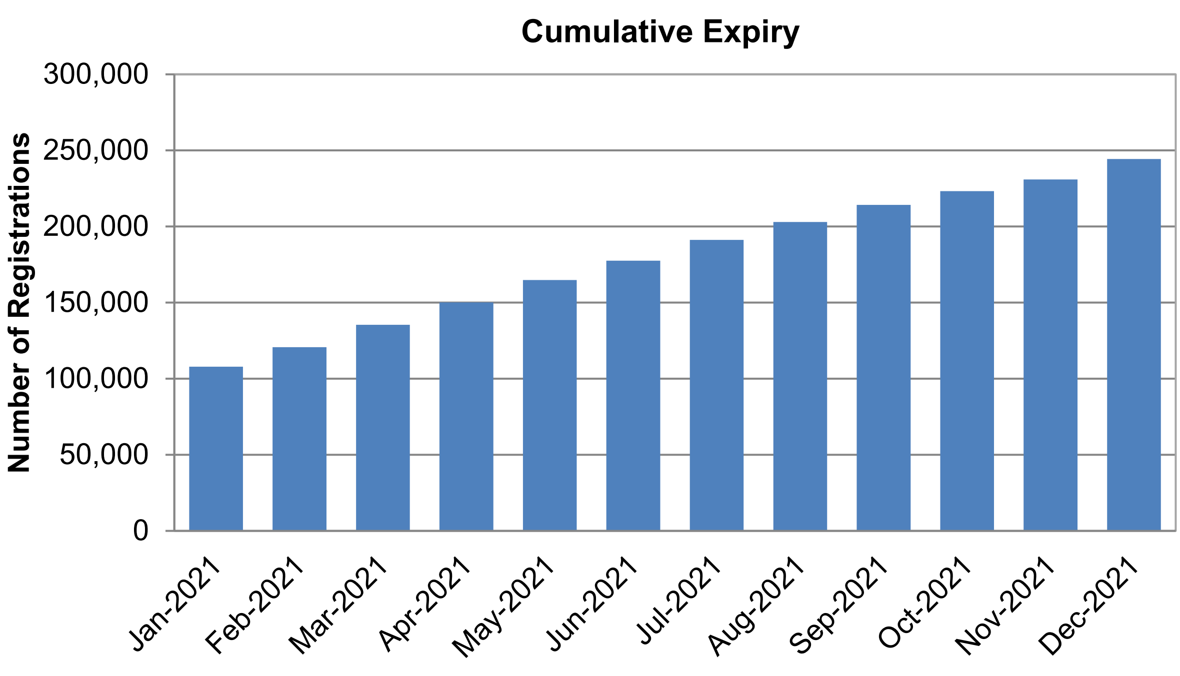
These two rules together provide much-needed regulatory clarity and reduce the need for waivers under part 107. With enhancement of operational efficiencies under increasingly well-defined concepts of operations (CONOPS)—which ensures safety and transparent information flow across the community—more and more commercial uses will become likely, fueling even further growth. Notably, as a central location for receiving all operational information, including registration, authorization, and accident report logs the DroneZone has helped further facilitate this growth. [faadronezone.faa.gov/#/].

As noted in the preceding section, the beginning of the registration renewal afforded the FAA an opportunity to review part 107 data; duplicates and unnecessary registrations were removed, and the registration database was made cleaner and more compact. As in the case of recreational/model aircraft, an examination of the data provides an opportunity to discern the effective/active fleet more accurately using the following five elements introduced earlier: Cancellations; Expiry; New; Renew; and Renew+. It is worth mentioning here that, prior to having access to these five elements, forecasts in the past were based only on new registration trends.

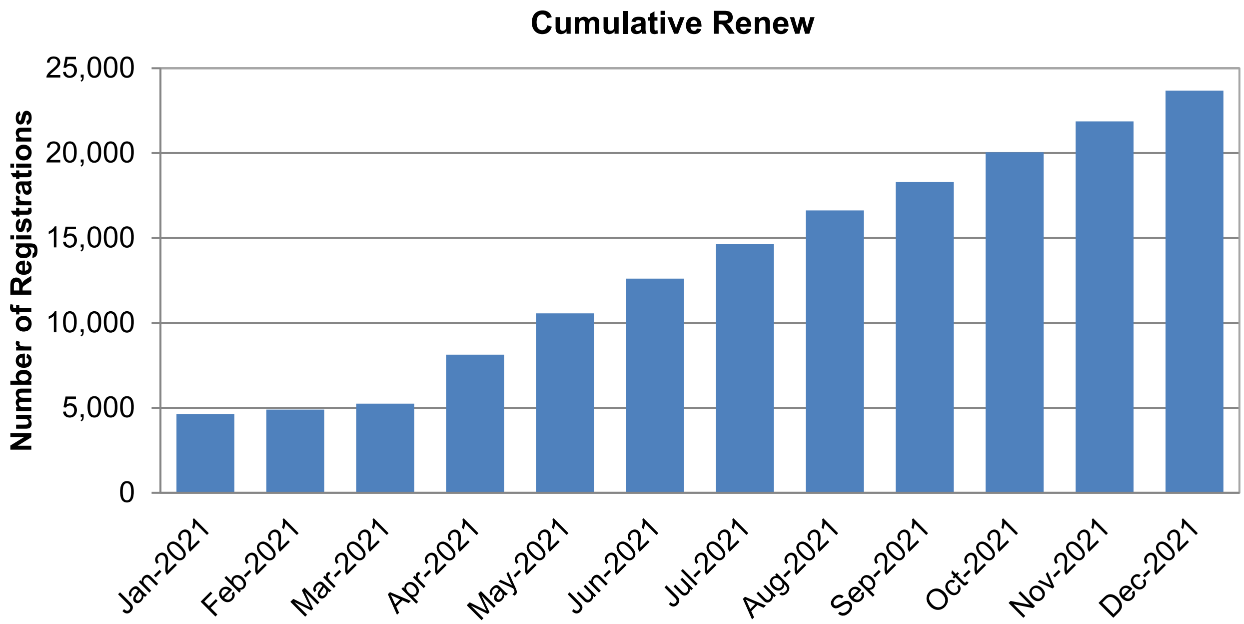
An average of 55,140 cancellations per month, on a cumulative basis, were reported between January – December 2021, as shown below. This is an average of approximately 1,650 new cancellations for each month of 2021.



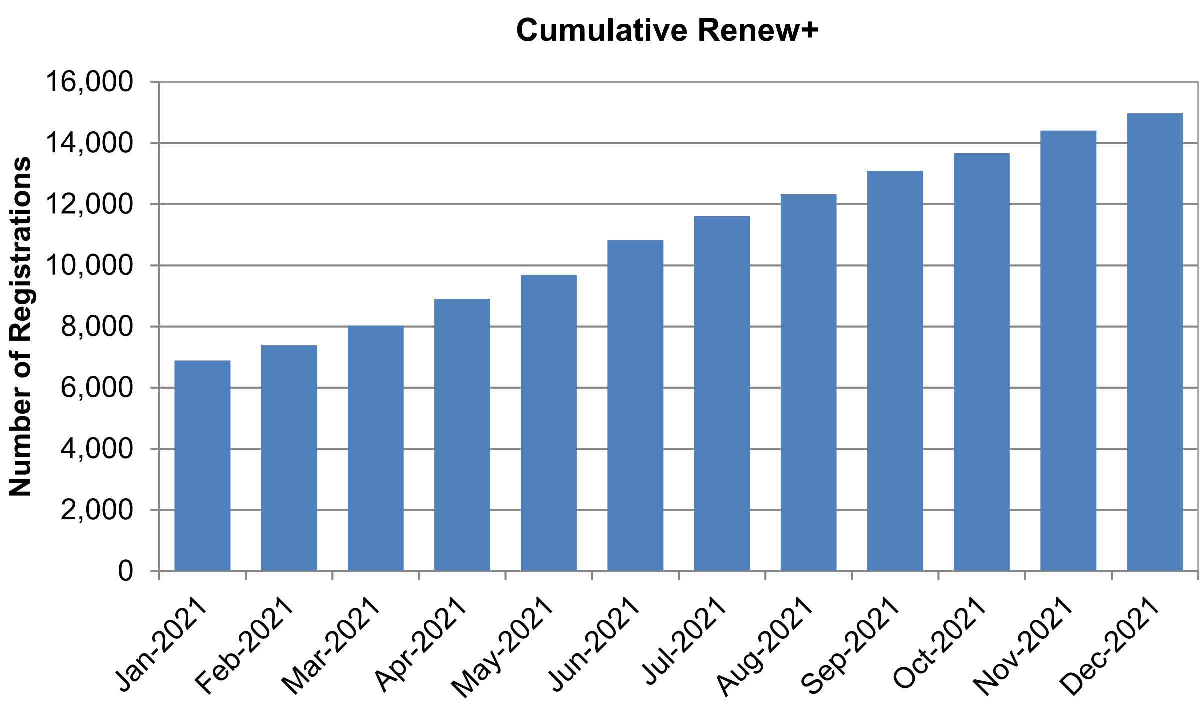
An average of 180,306 expirations per month was reported on a cumulative basis between January 2021 – December 2021 following the substantial adjustment noted above and as shown below. (This equals approximately 12,610 new average expiries for each month during January 2021 – December 2021):



Renew or re-registration prior to expiry date logged, on average, more than 13,440/month on a cumulative basis during January 2021 – December 2021 (or 1,610 new average renewals for each month during January – December 2021):



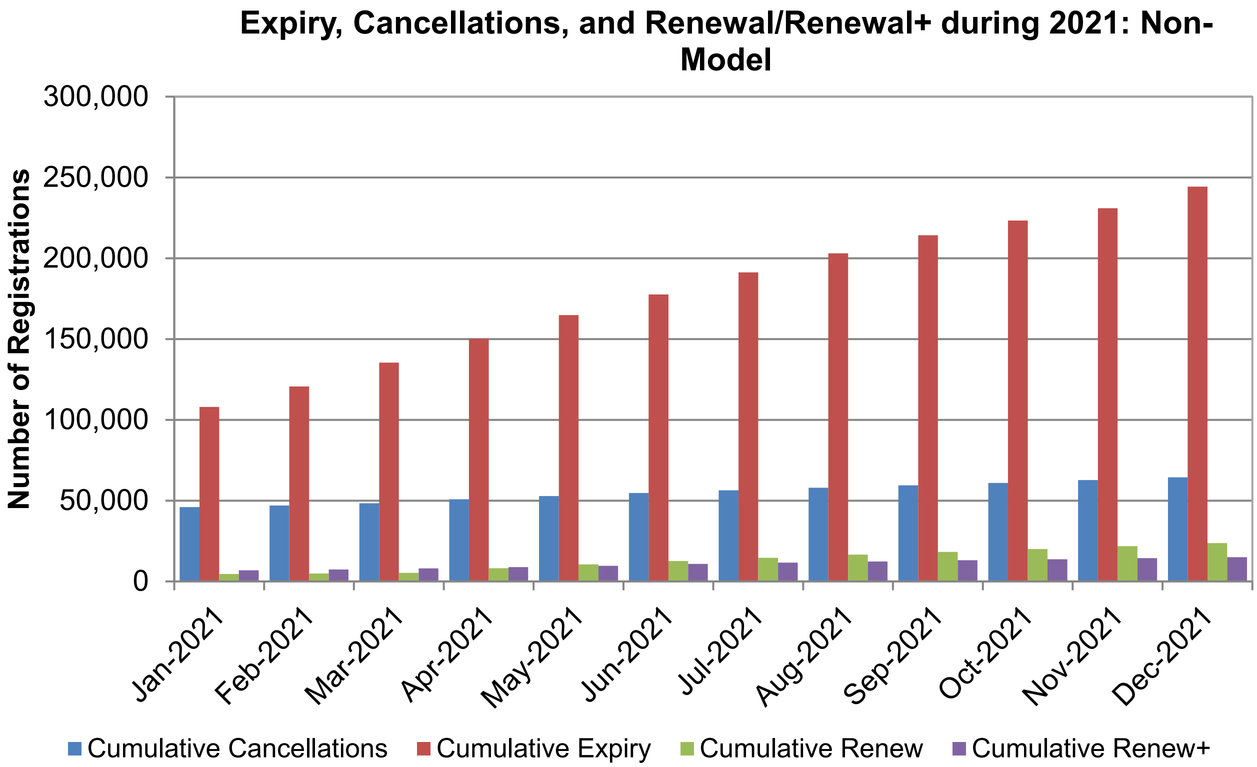
“Renew+” are re-registrations after expiry, and logged, on average, 10,986/month on a cumulative basis. This is an average of 718 new Renew+ each month between January 2021 – December 2021, as reported below:



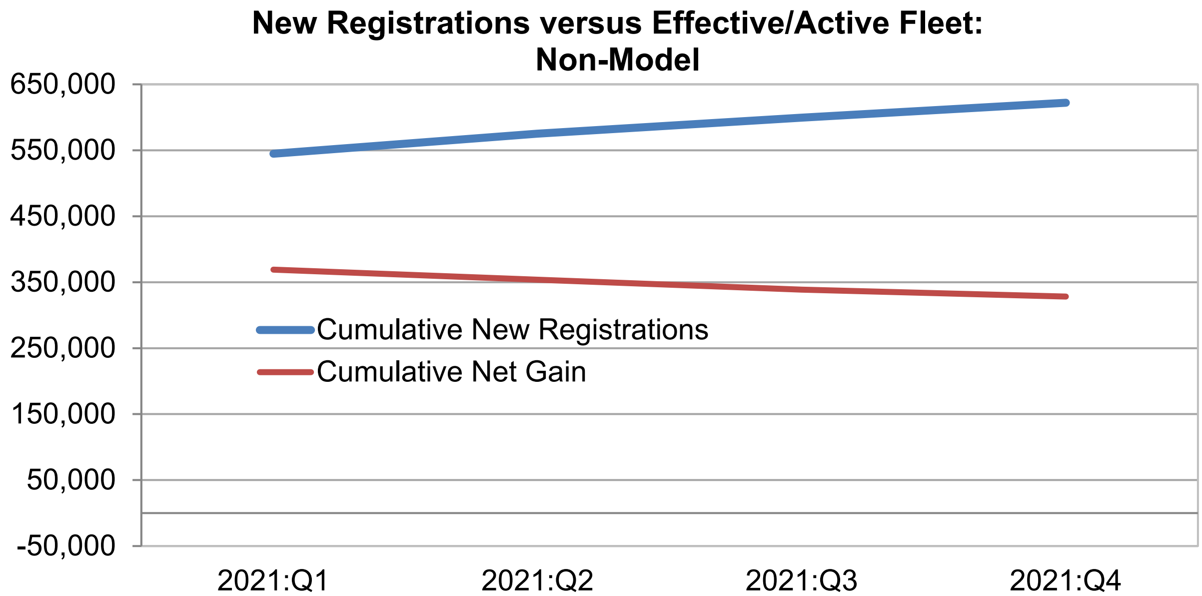
As in the case of recreational/model registrations, calculating active/effective registrations for a particular day requires calculating the "net gain/loss" of registrations for each preceding day and adding them with the particular day (i.e. calculating the running sum).

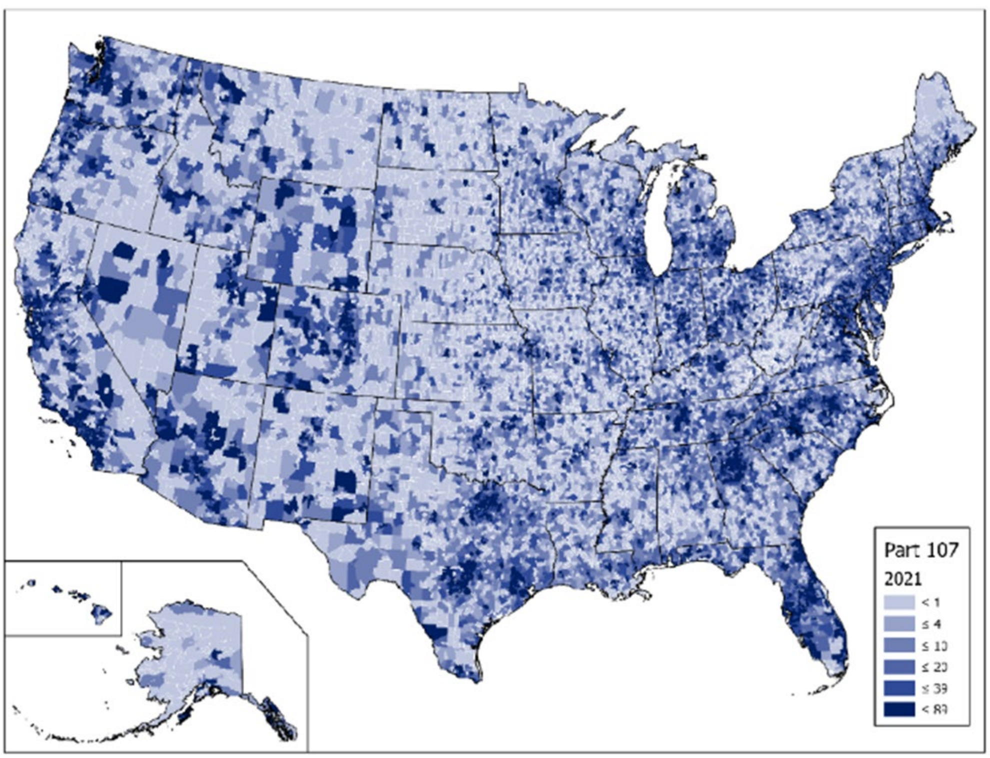
Using the formulation described in the example in the preceding section, we can derive the net gain/loss for part 107 data as well.

A summary of the above 4 charts is provided in below to relate the relative contributions of cancellations, expiry, renew and renew+:



A comparison chart capturing the difference between cumulative new registrations vs. effective/active registrations using net gain/loss for part 107 registration is provided below:





As in the case of recreational drone ownership, commercial small drones are distributed across the country. A spatial distribution of equipment registration by zip codes (using data for December 2021) demonstrates that commercial small drones are distributed throughout the country, with denser activity mapping closely against the economic or commercial activities of the geographical areas.

Last year, the FAA forecasted that the commercial drone sector would include approximately 589,000 small drones in 2021, a growth rate exceeding 21% over the year before (2020). Actual data came in slightly over 622,000 aircraft by the end of 2021. Our forecast of commercial small drones last year thus undershot by 5% for 2021 (or 622,055 actual aircraft vs 589,463 projected aircraft).

Forecasting in a time of tremendous uncertainty is indeed challenging, especially given the economic slowdown during COVID-19 and its impact on the drone sector. The commercial small drone sector's fast growth and adjustments during the pandemic demonstrate that fact. Nevertheless, our forecast errors for both recreation and commercial small drones appear to be within the bounds of reasonableness.

Total Commercial/Non-Model Fleet (Thousand sUAS Units)

Fiscal Year	Low*	Base**	High**
Historical			
2021	328	622	622
Forecast			
2022	292	699	729
2023	301	757	809
2024	320	801	869
2025	339	834	918
2026	355	858	968

*: Effective/Active fleet counts;

**: New registration counts based on fleet counts;

The FAA uses the trends observed in registration during previous years, calculation of net gain/loss, information from the survey conducted in 2018, a review of available industry forecasts/workshops and past FAA Drone Symposiums, and internal research together with market/industry research. Using these, the FAA forecasts that the commercial drone fleet will likely (i.e., base scenario) be at around 858,000 by 2026. This is 1.38 times larger than the current number of new commercial small drones.[23]

Using low or effective/active fleet, the FAA forecasts an expansion of the small drone fleet by 26,000, 1.08 times larger than the currently calculated effective/active fleet of

[23] Last year, the ratio of end-year forecast to base-year forecast was 1.7-times. (That is the FAA forecasted end-year to be 1.7 time base year's (2020) numbers in 5-year (2025)). Higher forecasts are often the result of improved regulatory environments, as noted below, and environments that are in the process of rule-making evaluation (See fn. #17-19).

328,000 units.[24] As the present base (i.e., the cumulative total) increases, the FAA anticipates the growth rate of the sector will slow down over time, and the effective/active fleet will likely catch up with the growth trajectory of new registrations. Nevertheless, the sector will be much larger than what was understood only a few years earlier.

In order to understand the growth trajectory of the sector better, this report divides the commercial drone sector into two types of small drone aircraft: consumer grade and professional grade. Consumer-grade, commercial drones have a wide range of prices, below US $10,000 with an average unit price of approximately $2,500. The professional grade, on the other hand, is typically priced above US $10,000 with an average unit price assumed to be around $25,000.[25] For both consumer-grade and professional-grade drones, the average price has fallen over time, particularly over the last few years. Currently, the consumer grade dominates the commercial drone sector, with a market share approaching 91%. However, as the sector matures and the industry begins to consolidate, the share of consumer grade commercial drones is likely to decline, though it will still be dominant. By 2026, the FAA projects this sub-sector will have approximately 86% of the overall commercial small drone sector.

Starting from a lower base of approximately 59,000 aircraft registered in 2021, the professional-grade commercial small drone subsector stands to expand rapidly over time, reaching 115,000 in 2026—especially as newer and more sophisticated uses are identified, designed, and operationally planned and flown. If, for example, professional-grade small drones meet criteria of operations, safety, and regulations, and if they satisfy economic and business principles and enter into the logistics chain via small package delivery, the growth in this sector will likely be phenomenal. On the other hand, starting from a registration base (and not active/effective fleet) of 563,000 in 2021, consumer grade small drones are likely to grow over 744,000 by 2026. These numbers will be somewhat smaller if we use the effective/active number of drones as the basis for calculation instead of new registration.

These growth trajectories could be even further enhanced by expanding operations in controlled airspaces, e.g., the LAANC system, which began authorization in May 2017.[26] LAANC is designed to facilitate small drone use of controlled airspace (i.e., Class B terminal airspace) in the NAS. While most of the near-term growth in commercial small drones will continue to come from consumer-grade units (over 90%), the FAA anticipates a significant part will come from professional-grade small drones as well.

[24] This is driven completely by the combined effects of projected underlying growth rates of cancellations, expiry, new registrations, and renewals.

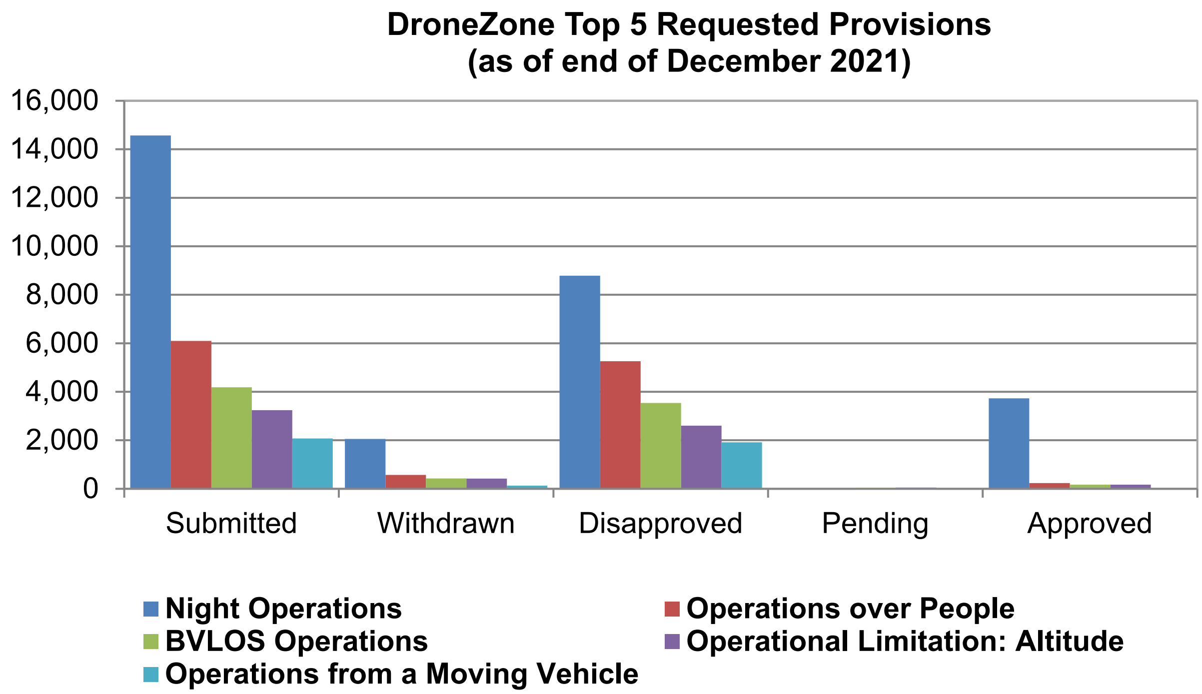
[25] Because of this wide range in prices between types of small drones in commercial activities, start-up costs for a business may vary between $2,500 and $25,000.

[26] Low Altitude Authorization and Notification Capability (LAANC) [https://www.faa.gov/uas/programs_partnerships/uas_data_exchange/] automated the application/approval process for airspace authorizations. Requests submitted via FAA-approved UAS Service Suppliers (USS) are checked against airspace data in the FAA UAS Data Exchange, such as temporary flight restrictions (TFRs), Notice to Airmen (NOTAMS), and the UAS Facility Maps (UASFM). Approved requests thus provide the FAA/ATO visibility into where and when planned drone operations will take place.

Unlike its recreational small drone counterpart, it is extremely difficult to put a floor on the growth of the commercial small drone sector due to its composition (i.e., consumer vs. professional grades) and the varying business opportunities and growth paths. As commercial small drones become operationally more efficient and safe, battery life expands, and integration continues (e.g., recent final rule involving operations over people; and remote ID), new business models will begin to develop, thus enhancing robust supply-side responses. These responses, in turn, will pull demand forces (e.g., consumer responses to receiving commercial packages, routine blood delivery to hospitals, and search-and-rescue operations) that are somewhat latent and in the experimental stage at present. Unlike a developed sector such as passenger air transportation, it is impossible to put a marker on "intrinsic demand" (or core demand) primarily driven by economic and demographic factors underlying this sector. Nevertheless, in this year's forecast the FAA makes a provisional attempt to provide a "low" side for now, essentially capturing the intrinsic demand and making use of the calculation of effective/active fleet. In addition, we provide the likely or base scenario, together with the enormous potential embodied in the "high" scenarios, representing cumulative annual growth rates of 7% and 9%, respectively. As noted earlier, low scenarios are driven by two positive factors (i.e., new registration and renew+) and two negative factors (i.e., cancellations and expiry). Average annual growth rate corresponding to the low scenario is determined by the combined effect of both positive and negative factors, and at present is calculated to be approximately 1.6%. This is much smaller than both base and high scenarios and this is because effective/active count is driven to catch up with the new registrations trend. [See fn. #7 for further explanation pertaining to effective/active count for recreational registration].

Commercial small drones are currently used for numerous purposes. As the sector grows, the FAA anticipates there will be many more uses for, and much more use of, commercial small drones. This is increasingly evident, for example, from the successful implementation of the UAS Integration Pilot Program (IPP). [See www.faa.gov/uas/programs_partnerships/integration_pilot_program/ for more details] and continuation in BEYOND [see Section later on].

One way of identifying early trends in commercial small drone use is to analyze the waiver applications granted to small drone operators. Both the magnitude and relative composition of waiver types may indicate the direction of the commercial small drone sector as a whole. A breakdown of the waiver requests granted in December 2021 is shown in the chart below:



Beyond the daytime operation that is presently allowed under existing part 107 rules, expanding applications further requires waivers, to a large extent, for night operations as distinct from daylight operations (around 9 of every 10 granted waivers), and operations over people (around 1 of every 20 granted waivers). As noted earlier, approved rules will now allow night operations and some operations over people as part of routine operations no longer requiring waivers. There are also beyond visual line-of-sight (BVLOS) waiver requests (around 14% of total requests) and limitations on altitude (around 11% of total requests), for which waiver approvals are granted at a rate of 3.9% in both cases. Many of these waivers are combined, and thus total waiver approvals (i.e., full + partial) granted (over 4,321 by December, 2021) exceed 100%.

Waivers are issued to facilitate business activities by small drones while preparing for the next round of regulations that will enable routine, more complex drone operations. Now that night operations and operations over people have been finalized,[27] amending Title 14 of the Code of Federal Regulations part 107 (14 CFR part 107) by permitting the routine operation of small drones at night[28] or over people under certain conditions,[29] the

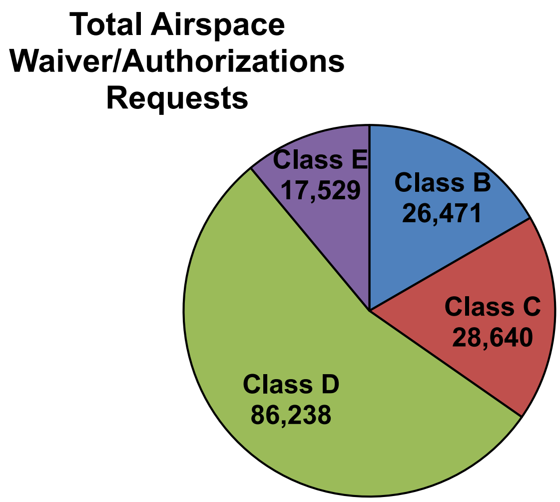
[27] The rule was published in the Federal Register on January 15, 2021. Corrections to the final rule were published in the Federal Register on March 10, 2021, delaying the effective date from March 16, 2021 to April 21, 2021 [See: www.faa.gov/uas/commercial_operators/operations_over_people/.].

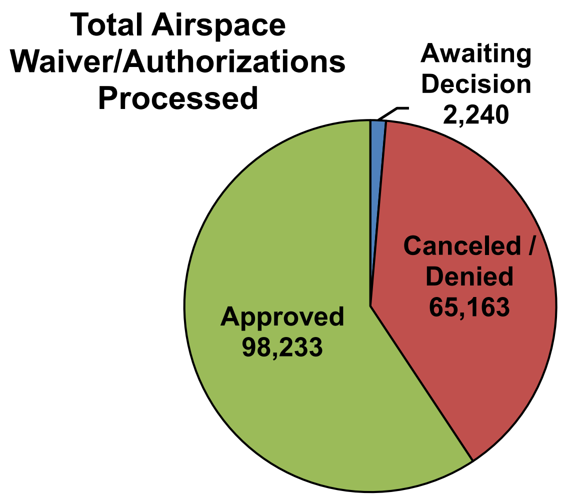
[28] *See* § 107.29. An operation at night was defined as an operation conducted between the end of evening civil twilight and the beginning of morning civil twilight, as published in the Air Almanac, converted to local time (*ibid*).

[29] *See* § 107.39. An operation over people was established as one in which a small remotely piloted aircraft passes over any part of any person

Agency is turning its focus to long term solutions that will eventually enable routine BVLOS fights without waivers.[30] Analysis of the waiver applications allows the FAA to understand industry trends, one of many metrics essential for understanding and projecting the growth trajectory, course corrections, and growth trends of the sector.

Nearly 60% of airspace authorizations and waiver requests were approved for controlled airspace at the end of December 2021. While over half were for Class D airspace (i.e., smaller airports with control towers), other classes were also requested and regularly flown.





Finally, LAANC has been routinely providing auto-approval since its inception in May 2017, and now covers 732 airports. It has provided over 1 million approvals: 545,074 auto-approvals for airspace access requests from part 107 users, and 352,775 requests from recreational operators as defined by 49 U.S.C. §44809[31] and sending 102,837 for further coordination. Approvals thus total more than 1 million, 570,000 more since this time last year. (See below.) LAANC authorizations are facilitated by the use of UAS Facility Maps (UASFM) that provide maximum allowed altitudes around airports where the FAA may authorize Part 107 UAS operations without additional safety analysis. [See faa.maps.arcgis.com/apps/webappviewer/index.html?id=9c2e4406710048e19806ebf6a06754ad.] The UAS facility maps are used to

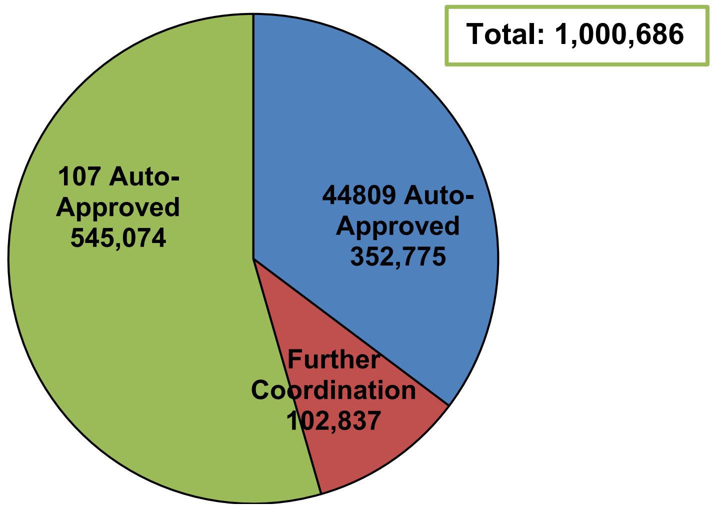
who is not directly participating in the operation and who is not located under a covered structure or inside a stationary vehicle.

[30] On June 9, 2021, the FAA initiated an Aviation Rulemaking Committee (ARC) to facilitate BVLOS in the NAS. [See www.faa.gov/regulations_policies/rulemaking/committees/documents/index.cfm/committee/browse/committeeID/837 for details.] Recently, UAS BVLOS ARC has provided recommendations to the FAA for performance-based regulatory requirements to normalize safe, scalable, economically viable, and environmentally advantageous BVLOS drone operations that are not under positive air traffic control (ATC) [see www.faa.gov/regulations_policies/rulemaking/committees/documents/media/UAS_BVLOS_ARC_FINAL_REPORT_03102022.pdf for the final report]

[31] §44809 is strictly for recreational uses. [See www.faa.gov/uas/recreational_fliers/new_changes_recreational_uas/media/44809_authorization.pdf.]

inform requests for part 107 airspace authorizations and waivers in controlled airspace.

LAANC Airspace Requests



Status of Survey

The FAA has initiated a comprehensive survey of drones, the "Survey of UAS Operators."[32] The survey targets commercial, public safety, and recreational small drone operators within the United States.[33] Recreational, commercial, and public safety UAS operators are identified via the aircraft registry and are randomly sent invitations to complete a questionnaire specific to their geographic location and operating type. Utilizing the part 107 (commercial and public safety) and section 44809 (recreational) registries, Survey of UAS Operators invites small UAS operator to participate in the survey by completing a questionnaire.[34] These invitation are randomly sent to operators within the two registries controlling for the U.S. County or the equivalent in which the registrant is registered and the type of operating: recreational, commercial, and public safety.[35] This

[32] The FAA has received OMB approval for a new information collection (OMB# 2120-0797). For additional information, see www.reginfo.gov/public/do/PRAViewDocument?ref_nbr=202008-2120-005.

[33] Survey respondents are all individuals or organizations who own and operate small drones within the United States. This does not include licensed remote pilots who pilot drones for other individuals or organizations.

[34] The section 44807 registry is used as the sample frame for sampling recreational operators. The part 107 (or Section 44809) registry is divided into two sample frames, commercial and public safety operators, by applying an algorithm to a registrant's data within the part 107 registry. These three frames serve as the bases for random sampling stratified by operator type. See following footnote for additional details in the survey design.

[35] The survey is designed as a stratified random sample with two strata: operator type and US county or the equivalent (such as parish or borough). Each cell, operator, and county pair is randomly sampled 30 times. If the cell has 30 or fewer registrants within it, the entire cell is sampled. See Supporting Statement B in the Information Collection Request (ICR) supporting doc-

survey method ensures a geographical representation of the operators and their behavior.

The survey aims to collect drone flight behavior, fleet characteristics, commercial activities, and features of public safety programs. To accomplish this, the questionnaire asks all operator types about typical flight activity such as average time of flight, operation over a week, and activity in specific months; and the composition of their fleet, such as number of aircraft, propulsion type, and operability.[36] Commercial and public safety operators who operate under part 107 are asked additional questions. Commercial operators are asked where they are operating, the industries in which they operate, and whether they intend to apply for a part 107 waiver. Public safety operators are asked about their drone program, if they share their program with other agencies or hire a commercial operator, and types of missions conducted.

The FAA is currently conducting pilot studies for the Survey of UAS Operators, and anticipates completion by summer 2022. These pilot studies are used to improve the survey design, clarify the questionnaire, and increase statistical validity.[37] The pilot studies are designed to reveal respondent activities during 2021. In late summer of 2022, the FAA plans to conduct a standardized survey regarding 2022 behavior. The FAA plans to publish the results of the 2022 standardized survey in the following year's Aerospace Forecast.[38] The Survey of UAS Operators is expected to be conducted annually, with the results published in the following year's Aerospace Forecast.

The FAA plans to use the information from the survey to paint a comprehensive picture of small drone activity throughout the NAS and how this activity is expected to change over time. This includes developing a geographical density estimate of small drone activity across the United States, and the change in activity over the course of a year. The annual survey is expected to become an additional data source for developing the small drone forecasts after multiple years of

uments at www.reginfo.gov/public/do/PRAViewDocument?ref_nbr=202008-2120-005 for additional information regarding the survey design.

[36] The survey questionnaire is administered through Survey Monkey, and invitations are sent to selected participants through an FAA email. Questionnaire completion time ranged from 5 to 10 minutes, depending on operator type. All three types were asked identical questions regarding flight behavior and fleet. Only commercial and public safety operators have additional question following the flight behavior and fleet questions.

[37] Pilot studies include several studies of sampling and nonresponse bias as well as testing several aspects of the questionnaire.

[38] The data from the 2022 Survey of UAS Operators is expected to appear in a supplement to the Aerospace Forecast 2023-2043.

survey data have been collected.[39] Moreover, the fleet data collected from the survey should support forecasting at the county level and thus increase the granularity of the small drone forecast. Overall, the Survey of UAS Operators is expected to increase the data available to FAA forecasters and the drone industry as it becomes a standard product of the FAA.

Remote Pilot Forecast

An important final metric in commercial small drones is the trend in remote pilot (RP) certifications. RPs are used primarily to facilitate commercial and public use small drone flights. As of December 2021, 254,850 RP certifications had been issued, an increase of approximately 52,000 from the same time last year (2020) and slightly higher than the year before (2019).[40]

Part 107 certifications require completing a multi-step process, beginning with obtaining an FAA tracking number via the creation of an Integrated Airman Certification and Rating Application (IACRA) profile prior to registering for a knowledge test. Following this initial step, scheduling and passing the initial aeronautical knowledge test at a Knowledge Testing Center is required. Provided that one has passed this test, the applicant is required to fill out FAA Form 8710-13 in IACRA. A confirmation email is sent when an applicant has completed the necessary Transportation Security Administration (TSA) security background check. This email contains instructions for printing a copy of the temporary remote pilot certificate from IACRA. A permanent remote pilot certificate is sent via mail once all other FAA-internal processing is complete. An RP certificate is valid for two years, and certificate holders must pass a recurrent knowledge test every two years at a Knowledge Testing Center. It is required that RPs carry their certificate whenever flying a small drone.

Certifications for part 61 operators, on the other hand, require an applicant to hold a pilot certificate issued under 14 CFR part 61, and to have completed a flight review within the previous 24 months. Since part 61 operators already have IACRA profiles established, they are required to complete, like part 107 operators, FAA Form 8710-13 in IACRA. Upon completion of this form, submission of proof of current flight review, and submission of proof of online course completion, part 61 operators are required to meet with FAA representatives at the FAA Flight Standards District Office (FSDO), or with an FAA-designated pilot examiner (DPE), or an airman certification representative (ACR) or an FAA-certificated flight instructor (CFI), who issues the RP certificate to the part 61 operator. Like their part 107 counterparts, certificates for part 61 operators are valid for 2 years and require renewal. [See

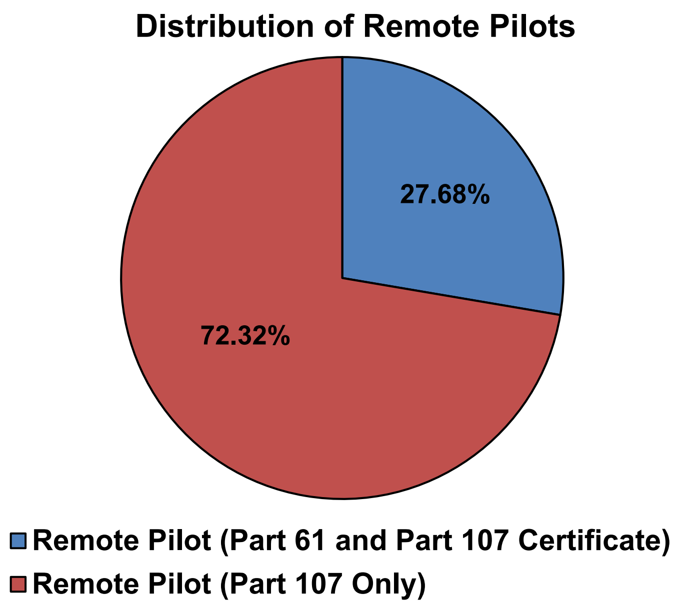
[39] The FAA has authorization to conduct the Survey of UAS Operators through 2023 under the current information collection authorization from OMB. The FAA anticipates the renewal of the survey in 2024 and to continue the survey annually in perpetuity.

[40] In our accounting of RPs, we take pilots who passed the initial knowledge test (or part 107), plus current traditional pilots who took online training in lieu of the knowledge test (or part 61).

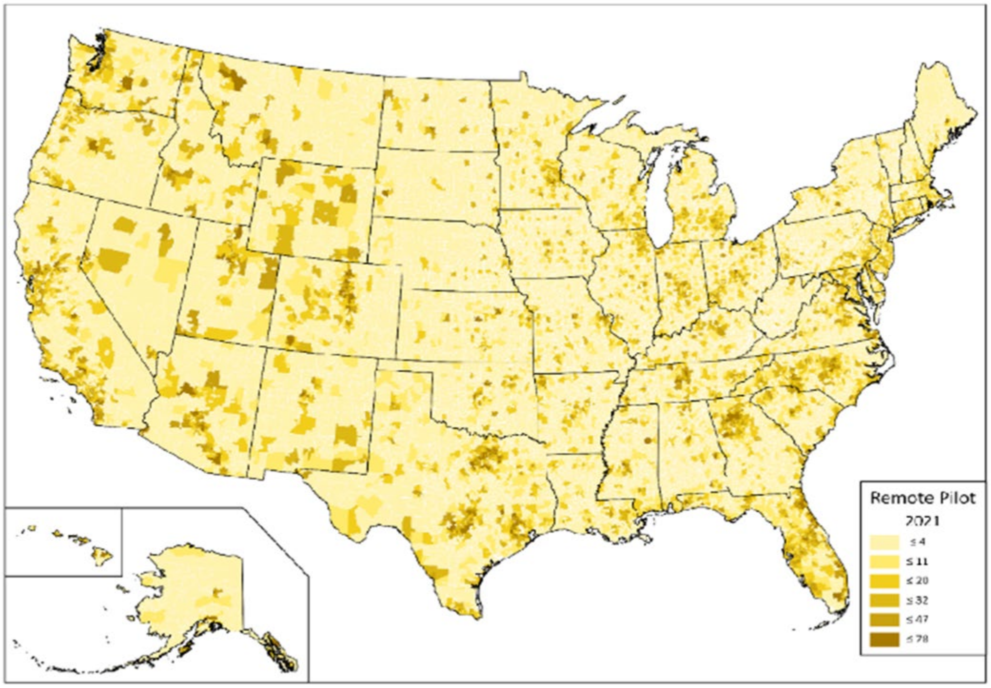
www.faa.gov/uas/commercial_operators/become_a_drone_pilot/ for more details.]

Following the process above, the FAA classifies RPs into two categories:

- those who do not hold any pilot certificate other than the part 107, or Remote Pilot Only; and
- those who hold a part 61 certificate and a part 107 certificate, or Part 61 and Remote Pilot.

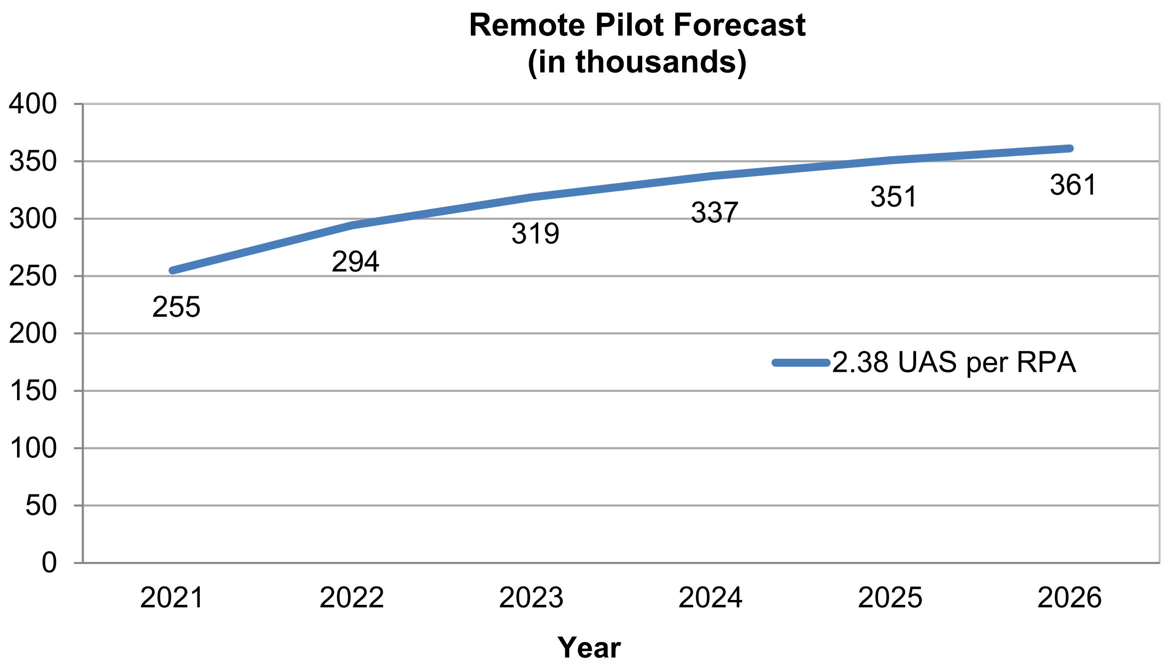


Over 70% of the RPs are part 107 RPs only. Over 90% of those who took the exam passed and obtained RP certification. A cumulative density distribution of remote pilots by zip codes in 2021 is provided in the map below.



The RP forecasts presented below are based on three primary data sources: (a) trends in total RPs; (b) renewal trends; and (c) trends in commercial small drone registration and forecasts of fleet. In this context, it is important to note that the empirical relationship between trends in RP and commercial/part 107 small drone registration, particularly new registration, appear to hold despite expiry, cancellations and renewal. Given the trends in registration and our forecast of the commercial small drone fleet (i.e., base forecasts), the FAA assumes that one pilot is likely to handle 2.38 units of commercial small drone aircraft, the same as the previous two years.

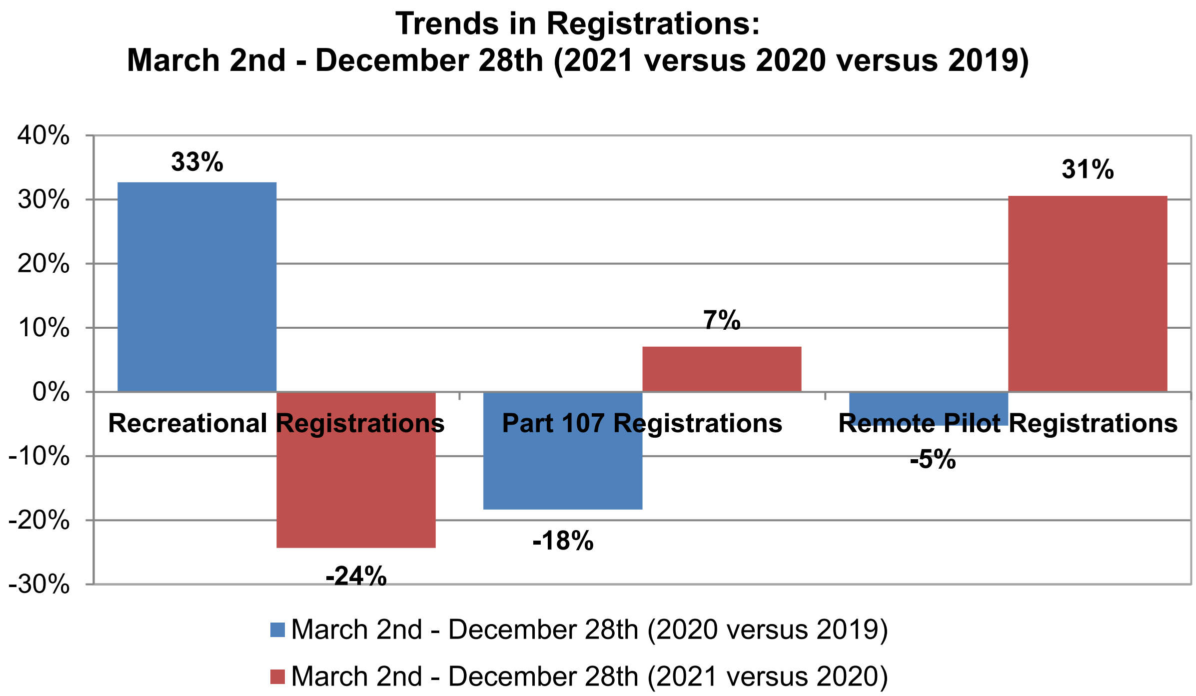
Using these assumptions and combined with the base scenario of the commercial small drone forecast, we project RPs in the graph below. Last year, the FAA projected RPs to be approximately 248,200 by the end of 2021. Actual registrations by the end of 2021 totaled 254,850 (or more than 6,800 from last year's projection) thus actual exceeding last year's projection by 2.68%.



Given the actual numbers at the end of 2021, RPs are set to experience tremendous growth following the growth trends of the commercial small drone sector. Starting from the base of 254,850 RPs in 2021, commercial activities may require over 361,000 RPs in five years, a 1.4-fold increase that may provide tremendous opportunities for growth in employment—over 100,000 new RP opportunities—associated with commercial and public use activities of small drones. Potential for RPs may enhance even more if larger drones are used in commercial activities and advanced air mobility (AAM) becomes a reality in the near future.

COVID-19 and Its Impact on sUAS

The chart below summarizes how COVID-19 may have impacted three areas of registration. During the prolonged and partial economic shut-downs during March – December 2020 and January – December 2021, respectively, it is clear that commercial facets of small drone operations, i.e., part 107 and RP registrations, were impacted negatively during 2020.



Part 107 registrations dropped by over 18% in 2020 compared to the prior year, but recovered in 2021 with an increase of 7%. RP registrations dropped by 5% in 2020, followed by a 31% increase in 2021. Interestingly, the registration of recreational users increased by almost 33% during the past year (2020) in comparison to the year before; however, recreational user registration went down by 24% in the second year of the pandemic, in comparison with the first year. While it is quite possible that these drops/increases were led by developments within the Part 107 community, we believe that at least some of the observed drops/increases were caused primarily by COVID-19. As the economy slowed down considerably, the use of commercial small drones (and, correspondingly, the use of RPs), may have decreased in the first year, followed by economic adjustments in the following year that allowed for increased commercial use. On the other hand, the economic slowdown may have afforded more time to people working from home to experiment with recreational use of small drones; this may have caused higher recreational registration in the first year of the pandemic in comparison to the prior year. The situation seems to have reversed during 2021, where recreational registrations dropped by 24%, while part 107 and RP registrations bounced back by 7% and 31%, respectively, in comparison to the prior year. The changing nature of registrations, and subsequently forecasts, offers challenges and opportunities for integration of small drones into the NAS.

IPP to BEYOND and PSP

One such integration challenge was addressed under the UAS Integration Pilot Program (IPP). Beginning in 2017, the IPP brought state, local, and tribal governments together with private sector entities, such as UAS operators or manufacturers, to test and evaluate the integration of civil and public drone operations into the NAS. The IPP program concluded on October 25, 2020 [See www.faa.gov/uas/programs_partnerships/integration_pilot_program/ for more details.] The FAA launched a new program called BEYOND to continue working on specific challenges of drone integration by:

- identifying ways to balance local and national interests related to drone integration;
- improving communications with local, state and tribal jurisdictions;
- addressing security and privacy risks; and
- accelerating the approval of operations that currently require special authorizations.

BEYOND started on October 26, 2020 to continue the partnership activities with eight of the nine IPP participants. [See www.faa.gov/uas/programs_partnerships/beyond/.]

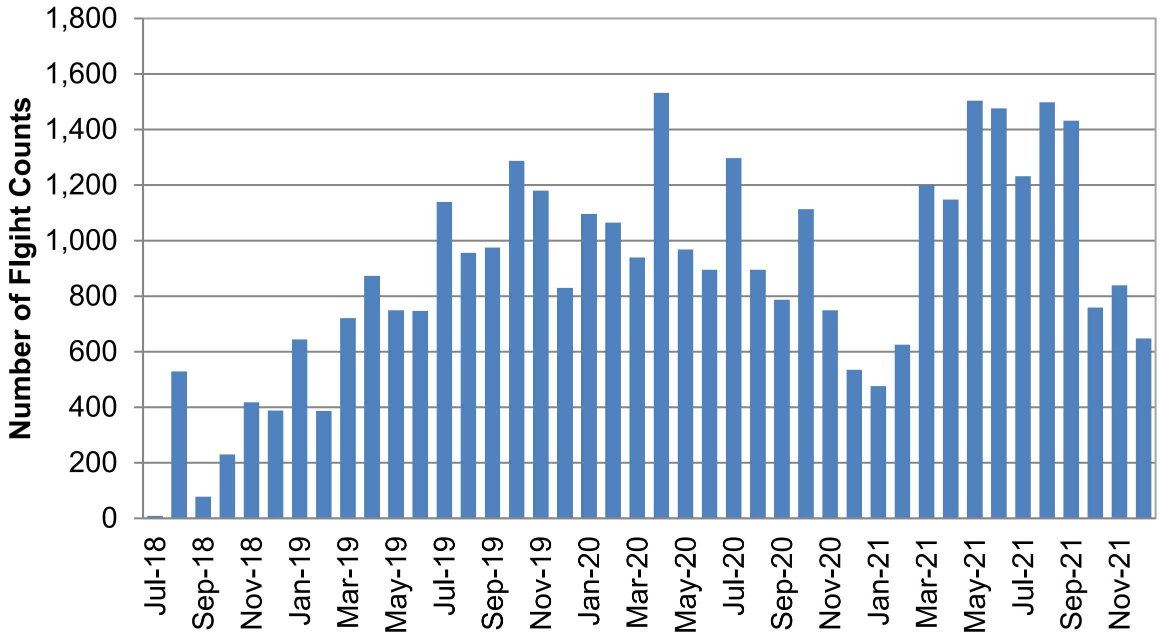
In addition to these programs, the FAA launched the UAS Partnership for Safety Plan (PSP) initiative in December 2016 to address and advance complex drone operational capabilities. The program establishes a working relationship between the FAA and industry to help facilitate the full integration of drones into the NAS. [See www.faa.gov/uas/programs_partnerships/psp/ for more details.][41]

Since their beginning, these programs have facilitated numerous activities by the participants. For example, under the programs, participants have logged over 36,800 flights using over 2,300 small drones, accumulating over 9,100 hours of flight time. Activities under both BEYOND and the PSP continue.

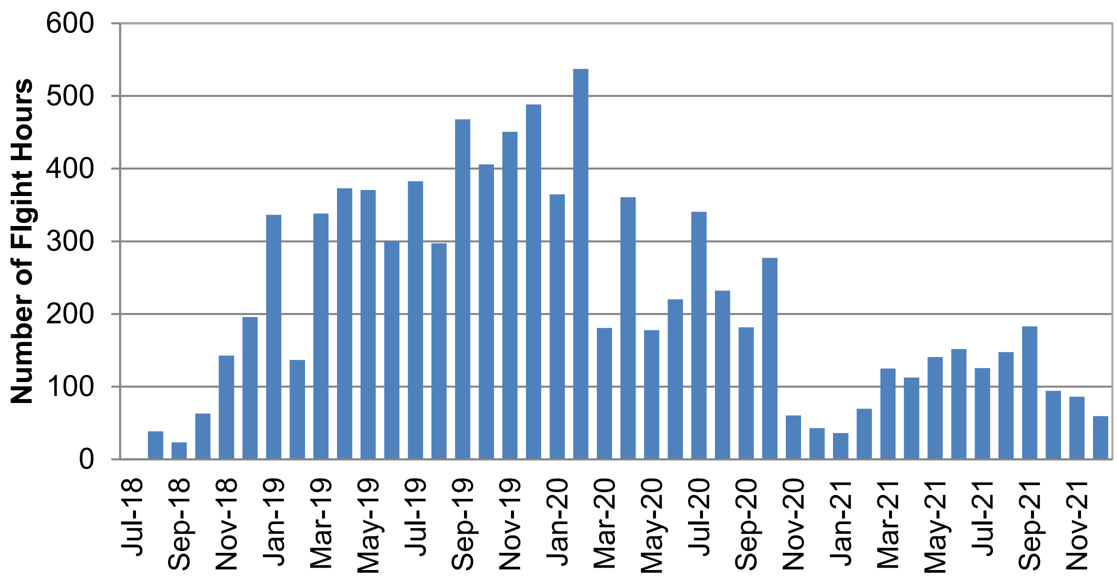
Distribution of the combined flight counts and corresponding total flight hours over time are given, respectively, in the following charts:

[41] In order to assist and accommodate other members outside these programs, the FAA has created a category called "voluntary reporting." Under this program, members outside BEYOND and PSP can volunteer their information which is then aggregated with IPP, BEYOND, and PSP information and presented in this section.

Flight Counts Aggregated Across All Programs



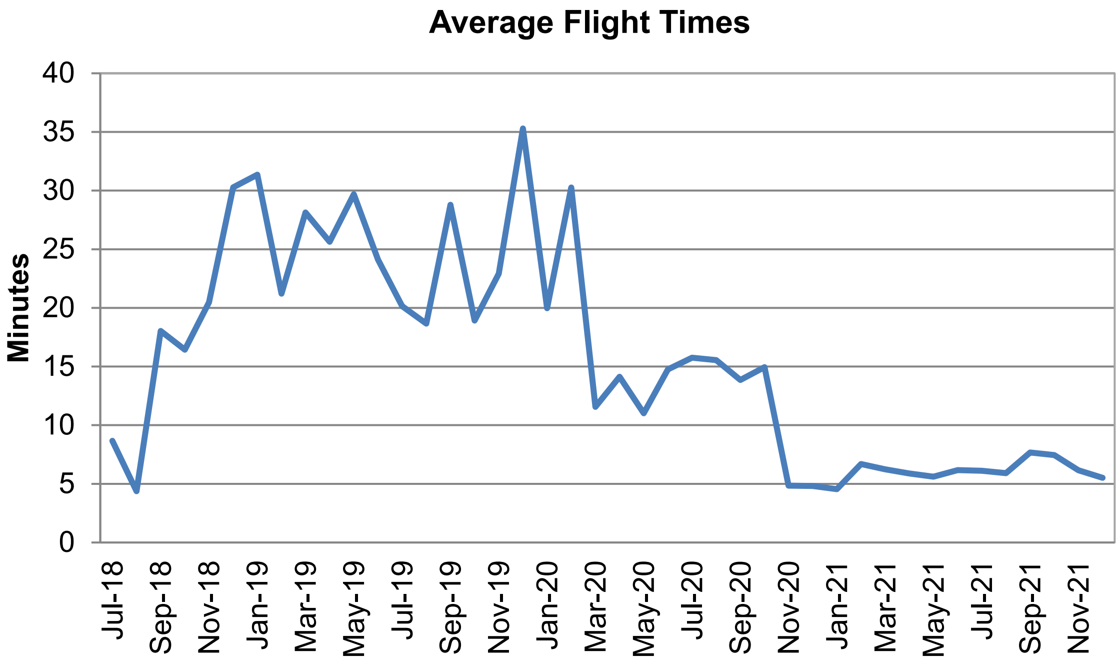
Flight Hours Aggregated Across All Programs



Based on the above information, average flight time over the years across all programs has stood at approximately 15 minutes.[42] Distribution of flight times during the period is provided in the graph below. Given that BE-

[42] This is an important metric to understand the scope of operational activities of drones across the NAS. When widely operational, i.e., outside BEYOND and PSP, this will have implications in terms of capital investment in infrastructure, planning for personnel, and unmanned traffic management (or UTM) in the future.

YOND and PSP programs are presently operational and active, average flight times are expected to increase over time.



Of around 36,850 total flights over the lives of these programs, a large majority of the flights have been geared towards package delivery (73%), thus signifying the commercial importance of this mission. Package delivery flights are followed by infrastructure inspection, both linear and non-linear, accounting together for over 14%; and other activities such as public safety (7.7%) and research/testing (4.4%). This composition provides some guidance in terms of likely forecasts and growth trajectory of the drone sector in the near future. The table below summarizes the types of missions and corresponding flight counts aggregated under all three programs.

Flight Counts by Mission Type

Mission Type	Flight Count
Agricultural Operations	125
Infrastructure Inspection (Linear)	2,047
Infrastructure Inspection (Non-Linear)	3,176
Media	11
Package Delivery	26,859
Public Safety	2,835
Research/Testing	1,613
Surveillance	183
Grand Total	**36,849**

All these activities take place in different types of airspace classes, thus signifying the importance of drone integration into the NAS. Furthermore, these classes of airspace intersect with different types of geographic locations, broadly captured under assembly, rural, suburban and urban.[43] The table below summarizes airspace usage by aggregated location within the NAS.

Total Flight Counts by Geographic Locations and Use of Airspaces

Airspace Classes	Assembly	Rural	Suburban	Urban	Grand Total
Class B	50	65		1,233	1,348
Class B, Class G		50			50
Class C, Class G		1		1	2
Class D	3	534	1,816	2	2,355
Class D, Class G				486	486
Class G	28	11,618	10,102	5,463	27,211
Class G, SUA				1	1
NA		1,867	3,529		5,396
Grand Total	**81**	**14,135**	**15,447**	**7,186**	**36,849**

*NA: Not Available or Reported

Clearly, the most used airspace is Class G (74%), and it is distributed primarily in rural (43%) and suburban (37%) areas, followed by urban areas (20%). Class D and B are increasingly used while intersections of other classes, (e.g., Class D/G, and Class B/G), are also observed.

Finally, participants under all three programs undertake the above activities using different operating rules. The table below summarizes flight counts under these rules:

[43] "Assembly" is short for "open-air assembly". An open-air assembly is generally understood as a dense gathering of people in the open, usually associated with concert venues, sporting events, parks, and beaches during certain events. Such assemblies are usually associated with public spaces. [See www.faa.gov/documentLibrary/media/Advisory_Circular/AC_107-2A.pdf for more details.]

Flight Counts by Operating Rules

Operating Rules	Flight Count
Airspace	931
BVLOS w/o VO	110
BVLOS w/VO	25,373
Multiple UA	57
Night Operations	101
OOP	3,365
OOP; OOMV	187
VLOS	2,223
UNK*	4,502
Grand Total	**36,849**

*UNK: Not documented/Not reported

As noted earlier, one of the primary focuses of the BEYOND program is to accelerate the approval of operations that currently require special authorizations (or waivers). On the other hand, advancing complex operations has been the key focus of the PSP program. Given these, it is quite natural that BVLOS is the predominant operating rule under all three programs, accounting for almost 70% of total flight counts. The previous table shows that the majority of flights are conducted with a visual observer (VO), while only 0.2% of flights are conducted without a VO. [44] For operations requiring waivers, i.e., multiple UA, night operations, operations over people (OOP), operations over moving vehicles (OOMV)), airspace and altitude are facilitated and observed across programs. Thus the table above demonstrates the underlying focus of these programs in facilitating different operating rules proposed and performed by the participating members. Finally, "UNK" (unknown) stands for flights that had not reported and/or where there was very little documentation to report.

Large UAS

Drones weighing 55 pounds or greater cannot be operated under part 107 or as recreational remotely piloted aircraft. These large drones must be registered using the existing aircraft registration process and operated under a section 49 U.S.C. § 44807 exemption or public aircraft operator (PAO) certification. [See www.faa.gov/uas/advanced_operations/certification/section_44807/ for more

[44] BVLOS with VO has numerous classifications within it; e.g., BVLOS w/VO for airspace; BVLOS for operating multiple drones; BVLOS w/VO for night operations; BVLOS w/VO for operations over people, moving vehicles, and visibility. These are combined under the broad category of "BVLOS w/VO" in the table. Following on BVLOS Final Report (see fn. #19) from the ARC, it is anticipated that regulatory environment will evolve in the near future.

details.][45] At present, many of these large drones are flown within the NAS by government entities, but commercial operators have steadily increased in 2021, with the majority of new large drone operators active in agricultural spraying markets. In order to calculate active large drones in the NAS, we employ a multitude of data from various sources:

- COA Online system and its successor CAPS or COA Application Processing System [see www.faa.gov/about/office_org/headquarters_offices/ato/service_units/systemops/aaim/organizations/uas/coa];
- MITRE's Threaded Track infusing data from different sources [see www.mitre.org/publications/technical-papers/threaded-track-geospatial-data-fusion-for-aircraft-flight-trajectories];
- FAA's Performance Data Analysis and Reporting Systems (PDARS) [see www.faa.gov/about/office_org/headquarters_offices/ato/service_units/systemops/perf_analysis/perf_tools];
- FAA's Aircraft Registry [see www.faa.gov/licenses_certificates/aircraft_certification/aircraft_registry/];
- Published decisions on 44807 exemption applications; and
- Notices to Airmen (NOTAM).

Combining these data sources, the FAA estimates that 285 IUAS or large drones were operating in 2021. However, these estimates are likely the lower bound since a growing number of agricultural large drones are operating in close proximity to the ground (i.e., likely below 400 feet above ground level (AGL)) and are not captured by this data. The exemptions and registration of these agricultural spraying large drones have increased significantly in 2021 and are likely to grow rapidly over the next five years. However, these agricultural spraying large drones will have little effect on air traffic in the NAS given their location away from busy traditionally-piloted air traffic and low altitude traffic.

Large drones operated by military and civilian agencies in the NAS are expected to grow at a steady pace over the next five years. Currently, military aircraft and military contractors constitute the majority of large drone activity in airspace above 400 feet AGL and are likely to remain the predominant operators over the forecast time horizon.

In 2021, 51 companies were granted FAA 49 U.S.C. § 44807 exemptions for commercial drones with weights above 55lbs, more than double the exemptions granted in 2020. Some of these companies were granted multiple exemptions. Over 92 percent of the new 44807 exemptions for large drones were granted for use in agricultural spraying.[46] This sharp increase in the number of new exemptions granted in 2021, as well as the vast majority granted to agricultural spraying

[45] Large drones operated by the military or a military contractor are operated under authority of the Department of Defense. Military large drones are not required to be registered in the public aircraft registry.

[46] Although 92 percent of the 44807 exemptions are for agricultural spraying, only 9 percent of the public aircraft registrations were linked to agricultural large drones in 2021. However, registered agricultural large drones more than doubled between 2020 and 2021, a trend that started in 2019. This suggests that registration of large drones could lag behind grants of 44807 exemptions.

companies, signals regulatory standardization around the use of large drones operating close to ground level and outside of populated areas, such as in the case of agricultural spraying.

The registration, in the public aircraft registry, of heavier-than-air, remotely piloted aircraft over 55lbs has increased by 56 percent, from 510 at the end of 2020 to 784 at the end of 2021. Three hundred and twenty-one (321) large drones were registered or renewed in 2021, up 52 percent from 2020, while the delisted and expired registrations fell by 39 percent from 128 in 2020 to 78 in 2021. This has led to a 50 percent increase in large drones registered in the public aircraft registry.

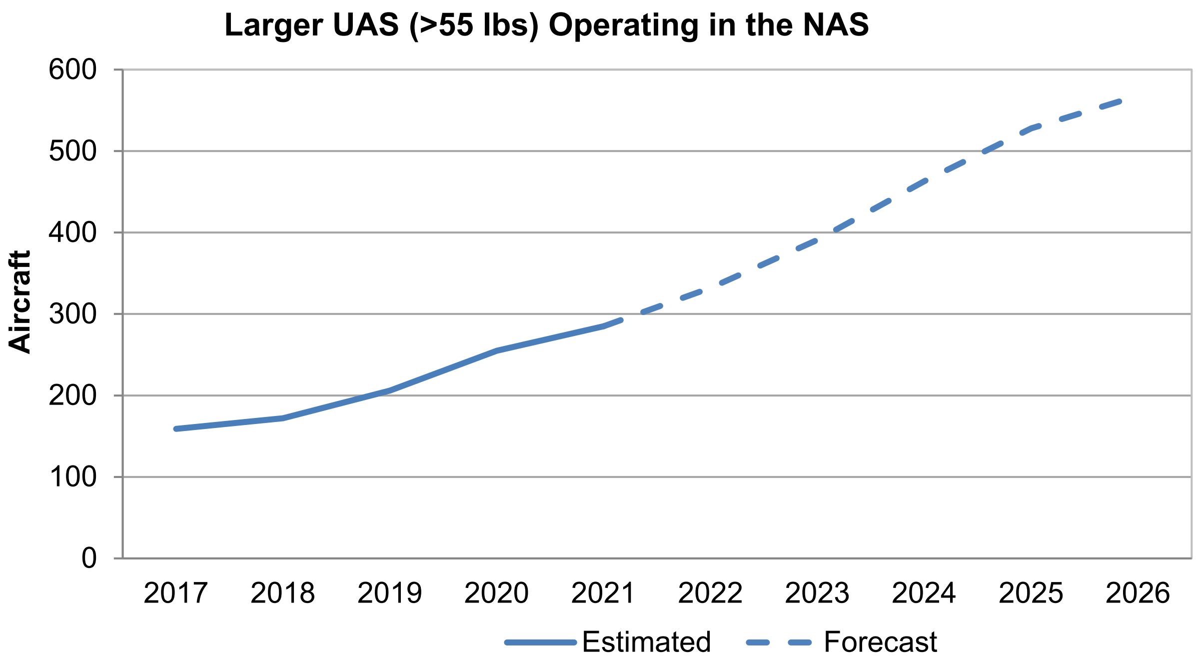
Although 784 large drones are registered in the public aircraft registry, only 12 percent of those registered large drones have been observed in flight.[47] As such, a sizable portion of large drone operators are not active in the NAS due to safety or regulatory concerns or because they only operate close to the ground or in private airfields. Thus, the vast majority of registered large drones are unlikely to come in contact with air traffic control (ATC). For the purposes of this forecast, the FAA limits the projected large drone activity to aircraft operating in airspace where contact with other large drones or traditionally-piloted aircraft is likely.

Larger UAS (>55 lbs) Forecast - 5 Years

Year	Active L-UAS	Number of Flights
Historical		
2017	159	7,066
2018	172	7,223
2019	206	7,360
2020	255	7,144
2021	285	7,519
Forecast		
2022	332	8,757
2023	391	10,325
2024	463	12,223
2025	528	13,930
2026	568	14,981

[47] The statistic is based on tail numbers from MITRE's thread tracking data and manufacturer/model characteristics from the public aircraft registry.

Combining the baseline from military and civilian agencies and projections of commercial exemptions from the FAA, large drones are estimated to have increased from 255 in 2020 to 285 in 2021; they are expected to continue increasing at a steady pace, through 2026, to 568 aircraft. This is due to an increase in the commercial and research applications of large drones. However, the sunset of drone exemptions under section 44807 in September of 2023 could create headwinds for further deployment of large drones. Operators are likely to scale back investment in new large drones as their ability to operate these aircraft beyond 2025, assuming they receive renewals in 2023, becomes uncertain. Extending or replacing the 44807 exemptions before 2025 would likely remove these obstacles to continued fleet expansion.



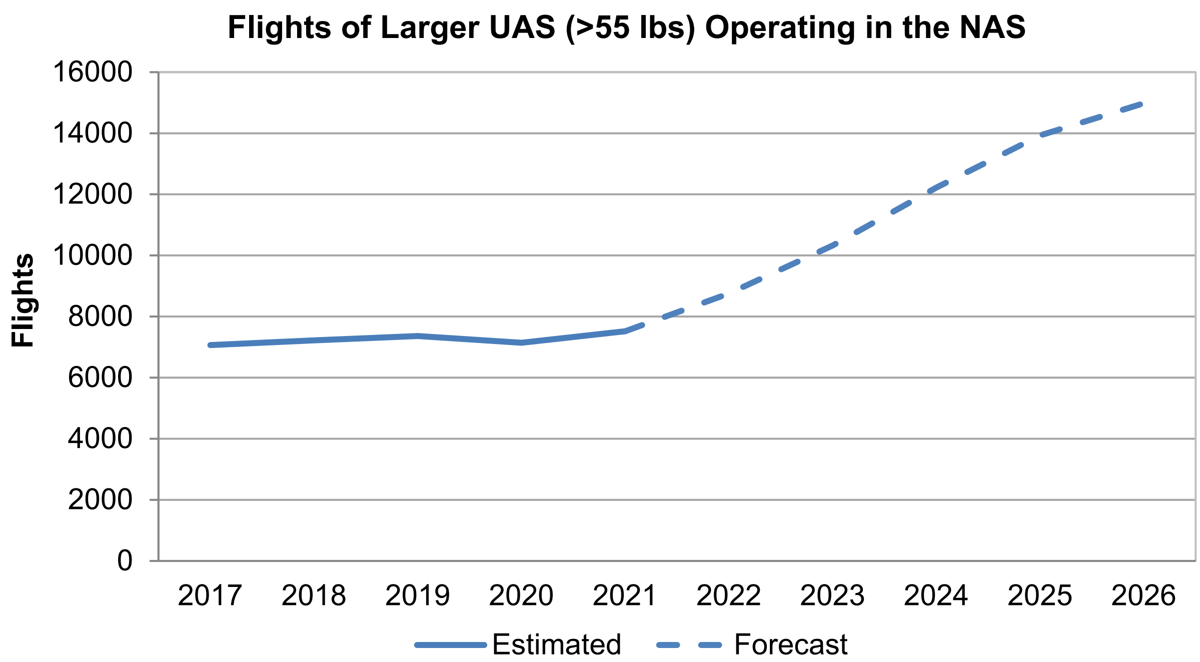
Corresponding to the active large drone fleet, the number of large drone flights increased from an estimated 7,144 in 2020 to 7,519 in 2021.[48] This indicates that the utilization of large drones is falling compared to previous years.[49] The increase in IUAS or the large drone fleet and decreasing aircraft utilization suggests that IUAS or large drones are still at an early stage of development.

However, the sharp increase in 44807 exemptions granted, and the healthy increase in registered large drones in the public aircraft registry suggest that large drone operators have shrugged off the uncertainty of the 2020 – 2021 recession, which should increase investment in new aircraft over the next five years. As such, the forecast has been adjusted upward to reflect the growth

[48] Estimates of 2021 large drone flights are based on new methodology. The new algorithm decreases the misidentification of traditionally-piloted aviation as large drones. . Over 70% of the observed flights are conducted by registered large drones operating under a variety of authorities: 44807 exemptions, public aircraft operators (PAO), or the Department of Defense.

[49] Utilization is calculated as IUAS flights divided by active IUAS or large drones.

path from before the pandemic-related recession, which is likely a more accurate reflection of future outcomes, barring an economic downturn in the near future.



Advanced Air Mobility

In September 2017, NASA launched a market study for a segment crossing over some functions of drones discussed above. This segment of piloted and autonomous vehicles, broadly called AAM, is defined as "a safe and efficient system for air passenger and cargo transportation, inclusive of small package delivery and other urban drone services, which supports a mix of onboard/ground-piloted and increasingly-autonomous operations."[50] [See www.nasa.gov/aero/nasa-embraces-urban-air-mobility.] Building on the UAM concept by incorporating use cases not specific to operations in an urban environment, the FAA defines the scope of AAM as follows [See www.faa.gov/uas/advanced_operations/urban_air_mobility/):

- Commercial Inter-city (Longer Range/Thin Haul);
- Cargo Delivery;
- Public Services; and
- Private / Recreational Vehicles

[50] The community is in the process of establishing nomenclature. Only recently, the community-at-large has moved on to coining earlier-used "urban air mobility" (UAM) as "advanced air mobility" (AAM) to broaden its operational scope, technical characteristics, economic opportunities, and regulatory framework. Under this broad characterization, UAM is considered a subset of AAM.

AAM technology presents considerable opportunities for economic growth over the coming decades. Markets for AAM services, such as package delivery by drone or larger autonomous or remotely piloted cargo delivery, airport shuttling (or services along the fixed routes between urban routes to airports), or traditionally-piloted, remotely-piloted, or autonomous passenger shuttles or air taxis (i.e., on-demand point-to-point services) have significant potential both in the United States and globally. For example, package or larger cargo delivery is the AAM service that is most likely to experience economic growth in the next decade. By 2030, package delivery is likely to be profitable at a price point of $4.20 per delivery, with a fleet of 40,000 vehicles completing 500 million deliveries per year.[51]

Passenger services, on the other hand, promise larger markets for AAM services, but safety challenges, infrastructure, public acceptance, and evolving technology leading to market uncertainties may slow the pace of AAM's penetration into this segment of the market. Nevertheless, flight testing continues to elucidate the performance dynamics of electric vertical take-off and landing (eVTOL). For example, Joby Aviation announced in July 2021 that it has completed a test flight which surpassed 150 miles on a single charge with its eVTOL aircraft. The flight was remotely piloted and completed 11 laps of a predefined circuit, covering a total distance of 154.6 statute miles with a total air time of 1 hour and 17 minutes.[52] Additionally, in fall 2021, under NASA's AAM National Campaign, Joby Aviation conducted further flight tests which produced data on its eVTOL aircraft performance and acoustic characteristics.[53] The data was shared with NASA to support its modeling and simulation and AAM research efforts. The flight tests also helped evaluate NASA's flight safety and airworthiness processes to approve flight testing participants and establish a baseline and protocols for future testing.

The increasing number of flight tests and data collection are paving the way for type certification of eVTOL aircraft. In 2020, Joby became the first eVTOL company to sign a G-1 issue paper to define a certification basis with the FAA, and in February 2022 Joby announced it started certification testing observed by an on-site FAA Designated Engineering Representative (DER). The test will evaluate the material strength of its eVTOL components, and is an important step in obtaining FAA aircraft type certification.[54] It is also worth noting that Joby has begun the process to obtain an FAA part 135 air carrier certificate, which it expects to receive in 2022, to formalize its status as an eVTOL airline.

There is also eVTOL type certification progress globally. In February 2022, Eve Urban Air Mobility, which plans to operate eVTOL flights in Brazil and in Latin America, formalized the process for obtaining type certification from the National Civil Aviation Agency – Brazil for its eVTOL aircraft (with deliveries

[51] Urban Air Mobility (UAM) Market Study, Nov. 2018, NASA. (See www.nasa.gov/uamgc)

[52] www.jobyaviation.com/news/joby-completes-flight-of-more-than-150-miles/

[53] NASA launched a National Campaign in March 2020 to promote public confidence and accelerate the realization of emerging aviation markets for passenger and cargo transportation in urban, suburban, rural, and regional environments. [See www.nasa.gov/aamnationalcampaign for more details.]

[54] www.jobyaviation.com/news/joby-begins-first-conformity-testing-enters-next-phase-certification-process/

expected to start in 2026).[55] German air taxi manufacturer, Volocopter, obtained a production organization approval (POA) from the European Union Aviation Safety Agency (EASA).[56] Recently, Volocopter laid out an urban transportation and mobility roadmap enabling tourist routes within the Marina Bay area and to nearby regional economic centers from Singapore in just 30 minutes.[57] In a similar vein, Joby Aviation, in collaboration with ST Telecom, signed a partnership on February 6, 2022 to introduce aerial ridesharing services to cities and communities in South Korea.[58] Airbus expects its UAM aircraft to meet EASA certification standards (EASA SC-VTOL Enhanced Category) and receive type certification around 2025.[59]

One of the major challenges of eVTOL entering into the marketplace is infrastructure. In order to increase accessibility of vertiports for AAM services, air taxi operators have been evaluating different approaches to expand the potential network of vertiports or takeoff and landing areas (TOLAs). In 2021, both Joby and Archer entered into partnerships with parking garage operator REEF Technology with the goal of running air taxi operations from the rooftops of redesigned parking garages.[60]

The infrastructure constraint—the availability of desirable TOLAs—will be a challenge for scaling AAM operations, as they require community acceptance and affect issues relating to social equity and noise and environmental impacts. NASA is leading research in these areas, and in 2021 it released a report with NUAIR (Northeast UAS Airspace Integration Research Alliance, Inc.) and industry describing a concept of operations for high density vertiport operations.[61] Recently, the FAA issued an engineering brief providing interim guidance to airport owner/operators and their support staff for the design of vertiports for vertical takeoff and landing operations [see www.faa.gov/airports/engineering/engineering_briefs/drafts/ for more details].

Other than eVTOL operators, some companies are focusing on developing the infrastructure needs which require partnering with local governments and property owners to locate and acquire sites for future vertiports. For example, Urban-Air Port, a UK-based startup, announced in January 2022 that it plans to develop 200 vertiports for eVTOL flights in 65 cities to accommodate the anticipated AAM demand.[62]

Due to uncertainties associated with numerous issues such as type certification and infrastructure, market estimation for the overall sector has been quite wide. The total available market for passenger services is estimated to be $500 billion in the United States, but AAM is unlikely to garner more than $2.5

[55] Eve Urban Air Mobility is an Embraer company planning to become public through a merger with a special purpose acquisition company (SPAC), as predecessors Joby, Archer, Lilium, and Vertical Aerospace have.

[56] www.aerospace-technology.com/news/volocopter-poa-easa-evtol/

[57] volocopter-statics.azureedge.net/content/uploads/220209_Volocopter_Singapore-Roadmap.pdf for more details.

[58] See ransportup.com/category/headlines-breaking-news/vehicles-manufactures/

[59] www.airbus.com/en/newsroom/press-releases/2021-09-airbus-reveals-the-next-generation-of-cityairbus

[60] www.jobyaviation.com/news/joby-aviation-announces-infrastructure-partnership/

[61] ntrs.nasa.gov/api/citations/20210016168/downloads/20210016168_MJohnson_VertiportAtmtnConOpsRprt_final_corrected.pdf

[62] dronedj.com/2022/01/26/urban-air-ports-to-create-200-evtol-vertiports-for-aam-service/

billion of this market in the near term, as one study estimates.[63] On the upside of the estimation, a recent study conducted by Deloitte and the Aerospace Industries Association (AIA) estimates the AAM market in the US to reach approximately US $115 billion by 2035, equivalent to 30% of the present US commercial air transportation market.[64] Of that total, US $57 billion is expected to originate in passenger air mobility, while an equivalent amount is expected to come from the cargo market.

Market dynamics underlying AAM are complex, numerous, and quickly evolving. Although COVID-19 has led to an increased adoption of virtual work versus commuting and business travel, persistence of this trend in the long-run is mired in uncertainty.[65] Socioeconomic changes such as population shifts from urban to suburban or rural areas (i.e., de-urbanization) could also affect the various AAM use cases differently. AAM services, both cargo and passenger, may appear to be unprofitable in the near future, like many other services in the beginning. The AAM passenger industry is likely to expand due to an inflow of venture capital and experimental services exploring market opportunities. For example, following the numerous SPAC mergers for AAM companies last year, which injected significant capital to further their development and commercialization efforts, Wisk Aero secured an additional $450 million investment from Boeing in January 2022. Volocopter has also recently entered into an agreement that may provide up to $1 billion in financing.[66] Furthermore, eVTOL operators like Joby are expanding partnerships to operate air taxis in international markets[67] and many companies are experiencing rising interest and increased orders of their eVTOL aircraft, both in the US and globally.[68]

Airport shuttles and other fixed-route passenger services are the AAM passenger services most likely to gain economic traction in the coming decade. Optimistic reports project the AAM passenger industry to have 23,000 aircraft with 740 million enplanements per year at a price of around $30 per trip by 2030.[69] However, several other studies have reported more conservative estimates, arguing that market penetration is likely to be limited to a handful of major metropolitan areas where geography and economic conditions are conducive to AAM market development. As such, estimates by KMPG predict 60.4 million enplanements by

[63] UAM Market Study – Technical Out Brief, Oct. 2018, Booz-Allen-Hamilton and NASA. [See ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20190001472.pdf.]

[64] www2.deloitte.com/us/en/insights/industry/aerospace-defense/advanced-air mobility.html?id=us:2el:3pr:4diER6839:5awa:012621:&pkid=1007244

[65] Road congestion and associated opportunity cost in commuting around metro areas provided the most powerful boon for economic and financial justifications for AAM passenger services. However, changed working pattern and working from home (WFH) location due to COVID19 put a damper on that earlier economic trade-off, at least in the near-term.

[66] www.flyingmag.com/volocopter-partners-with-acg-to-provide-1-billion-in-financing-solutions/

[67] www.forbes.com/sites/catherinewang/2022/02/09/heads-up-sk-telecom-joins-forces-with-joby-aviation-to-launch-flying-taxis-in-south-korea/?sh=41b6642615c8

[68] dronedj.com/2022/01/20/japanese-helicopter-service-provider-orders-50-air-taxis-from-ehang/ and https://eveairmobility.com/eve-and-bristow-enter-partnership-to-develop-uam-capabilities-with-an-order-of-up-to-100-evtols/

[69] Urban Air Mobility (UAM) Market Study, Nov. 2018, NASA. [See www.nasa.gov/uamgc.]

2030 and a much smaller industry size.[70] Similarly, Roland Berger estimates a fleet of only 12,000 passenger drones by 2030.[71] However, given the current safety and technology challenges, even these projections may be optimistic. Using airport shuttle and air taxi as the scope, a recent study concluded that AAM passenger services could have a daily demand of 82,000 passengers served by approximately 4,000 four to five-seater aircraft in the US. Baselining in the most conservative scenario, these services may yield an annual market valuation of $2.5 billion[72].

Given the enormous economic potential underlying the AAM sector, coordination led by the FAA, including collaborations with NASA and industry, is allowing numerous integration activities to take place presently. For example, under NASA's National Campaign (NC), working groups drawn from the FAA, NASA, and numerous stakeholders are focusing on understanding the four areas of AAM integration: aircraft, airspace, community integration, and cross-cutting areas. Complimenting this effort, the FAA created an internal AAM Integration Executive Council, and is actively working with internal and external stakeholders to understand the nature, scope, and likely evolutions of AAM. [See www.faa.gov/uas/advanced_operations/urban_air_mobility/.] The FAA also issued a concept of operations (CONOPS) in June 2020, and is likely to publish a strategic implementation framework in the near future.

All these activities are facilitating an operational framework for gradual integration of AAM into the NAS; e.g., flight testing of AAM vehicles [see www.nasa.gov/centers/armstrong/features/nasa-begins-air-mobility-campaign.html], regulatory coordination for safety, traffic management, and international harmonization with other agencies, e.g., European Union Aviation Safety Agency (EASA) leading to type certifications [e.g.,www.faa.gov/uas/advanced_operations/certification/].

These proactive steps are positioning the AAM industry positively towards realizing market opportunities. In December 2020, for example, Joby Aviation received the first airworthiness approval by the US Air Force (USAF) for an eVTOL aircraft under Agility Prime, and it recently reached an agreement with the FAA to certify its aircraft using the FAA's part 23 requirements along with special conditions for eVTOL aircraft.[73] Joby Aviation plans to launch air taxi services in the US by 2023. Lilium GMBH, a German company, is developing an eVTOL transport network centered on Lake Nona in Orlando, Florida. It has partnered with the City of Or-

[70] Getting Mobility Off the Ground, 2019, KPMG (see institutes.kpmg.us/manufacturing-institute/articles/2019/getting-mobility-off-the-ground.html).

[71] Urban Air Mobility: The rise of a new mode of transportation, Nov. 2018, Roland Berger. (See www.rolandberger.com/en/Publications/Passenger-drones-ready-for-take-off.html.)

[72] Advanced Air Mobility: Demand Analysis and Market Potential of the Airport Shuttle and Air Taxi Markets. [See escholarship.org/uc/item/4b3998tw for more details.]

[73]www.aviationtoday.com/2021/02/09/joby-agrees-evtol-certification-requirements-faa/

lando and a real estate development company to establish a vertiport hub in Lake Nona by 2025. It will be used for regional, inter-city air mobility services, with travel distances of up to 186 miles in 60 minutes by Lilium Jet aircraft currently under development.[74]

The trend is somewhat similar at the international level as well. For example, EHang, a Chinese manufacturer of autonomous aerial vehicles (AAVs), established a strategic partnership with UAM pilot cities in Spain, Austria, and China in 2020.[75] It also conducted demonstration flights in South Korea with its two-passenger autonomous aerial vehicle, the EHang 216. German AAM companies, Lilium and Volocopter, are also working to launch passenger air transport services within the next few years. Volocopter completed demonstration air taxi flights in Singapore in 2019 and began to sell tickets for commercial service, expected to start in Singapore by 2023.[76] Volocopter has also announced plans to introduce air taxi services in the US.

AAM services are likely to face stiff competition from technological advances in industries with close substitutes, such as ground transportation (i.e., emerging automated solutions on increasingly electric-powered vehicles). Furthermore, economic and financial tradeoffs underlying the emergence of AAM may have changed following COVID-19, changing travel patterns and perhaps long-term living arrangements. Finally, the high costs of urban infrastructure and potential community concerns pose challenges for AAM adoption. Future AAM operators must also prepare to comply with new operating requirements and other regulations yet to come.

Despite these challenges, state, local, and regional governments are aligning themselves with the manufacturers and likely operators. For example, the city of Los Angeles announced the creation of its Urban Air Mobility Partnership in December 2020. It is a public-private partnership, called Urban Movement Labs that will evaluate barriers and solutions now towards facilitating air taxi services in Los Angeles by 2023.[77] Other entities, including the Canadian AAM Consortium (CAAM,) have also studied the impacts of AAM on regional economies.[78]

In order to facilitate AAM entry into local transportation networks, numerous local and state entities have begun the process of preparing and self-identifying as early adopters. [See www.nasa.gov/aeroresearch/programs/iasp/aam/nasa-to-help-local-governments-plan-for-advanced-air-mobility.] Furthermore, targeting investments in regional air mobility (RAM) by utilizing the country's vast underutilized airport infrastructure may compliment and accelerate local and state initiatives on emerging markets, including those targeted by AAM, likely transforming the entire NAS in the future. [See sacd.larc.nasa.gov/ram/ for more details.]

As the sector grows and new initiatives are undertaken, the FAA, together with numerous stakeholders including NASA, is keeping

[74] lilium.com/newsroom-detail/lilium-partners-with-tavistock-and-orlando

[75] www.ehang.com/news/617.html

[76] www.bloomberg.com/news/articles/2020-12-09/first-electric-air-taxis-set-to-fly-in-singapore-by-2023

[77] www.lamayor.org/mayor-garcetti-announces-first-nation-urban-air-mobility-partnership; see also https://www.urbanmovementlabs.com/programs-projects/

[78] www.pnwer.org/uploads/2/3/2/9/23295822/economic_impact_assesment_-_caam_-_v1.0.pdf

a keen eye on understanding overall trends in AAM. It is likely that AAM services will become a reality in the US by 2025-2026 and will initially become incrementally available in certain urban and suburban areas. As more information becomes available, the FAA will likely provide emerging trends and forecasts for AAM in the near future.