Unmanned Aircraft Systems

Over the last 5 years, unmanned aircraft systems (UAS) have been experiencing healthy growth in the United States and around the world. UAS consists of the unmanned aircraft platform and its associated elements--including communication links, sensors, software and power supply-- that are required for the safe and efficient operation in the national airspace system (NAS). While the introduction of UAS in the NAS has opened up numerous possibilities, it has also brought operational challenges including safe integration into the NAS. Despite these challenges, the UAS sector holds enormous promise. Uses may include modelers experimenting with small UAS (sUAS), performing numerous functions including aerial photography and personal recreational flying. At the same time commercial operators may be experimenting with package and medical supply delivery and providing support for search and rescue missions.

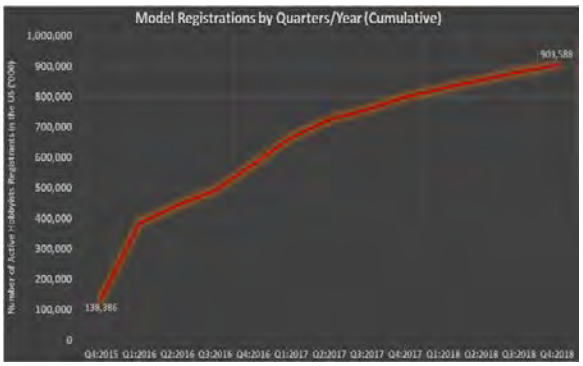
This section provides a broad landscape covering model and non-model aircraft[12] and their recent trends as gleaned from trends in registration, overall market and operational information. Using these trends and insights from industry, the FAA has produced several areas of forecasts for UAS. Forecasts reported in this section are driven primarily by the assumption of continuing evolution of the regulatory environment (i.e., unconstrained environment), the commercial ingenuity of manufacturers and operators and underlying demand, including business models. The FAA will continue to enable the thriving UAS industry, with the safe integration of UAS into the NAS.

Trends in Model Aircraft and Forecast

The FAA's online registration system went into effect on Dec. 21, 2015. This required all UAS weighing more than 0.55 pounds (250 grams) and less than 55 pounds to be registered using the on-line system (https://www.faa.gov/uas/getting_started/registration/) or by using the existing (paper-based) aircraft registry. In May, 2017, a U.S. Appeals Court Order caused a temporary halt in UAS registration. Subsequently, the registration requirement for all model aircraft owners was reinstated in December 2017 with the 2018 National Defense Authorization Act (NDAA). Despite the temporary halt, registration's pace continued beyond May, 2017. The latest FAA reauthorization codifies the requirement [see https://www.faa.gov/news/updates/?newsId=91844 for more details].

With the continuing registration, more than 900,000 owners had already registered with the FAA by Sept. 2018. Monthly owner registration averaged around 8,000-9,000 during Jan.-Dec., 2018, with some expected peaks during the holiday season and summer.

[12] These are also called, interchangeably, hobby and non-hobby UAS, respectively. In previous notes including other documents of the Agency, these terms are often interchanged.



The pace of registration in 2018 slowed considerably compared to 2016 and 2017. Monthly owner registration now stands at half of what was observed a year ago.

Model registration and thus ownership of sUAS is distributed throughout the country. Using the data as available in Sept 2018, a spatial distribution of ownership by zip code below demonstrates that sUAS continue to be distributed throughout the country with denser ownership mapping closely against the population centers of the country, as expected.

Unlike non-model counterparts, the registration rules do not require modelers to register each individual aircraft; only owners are registered. Each owner registers, and each owner might have multiple UAS. Exceptions may be registered modelers with no owned equipment. Notwithstanding these challenges, there is information available for both industry and academia, allowing us to understand aircraft ownership. Furthermore, under the sponsorship of the UAS Integration Research Plan, the Agency 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 model flying and safety implications for the UAS fleet from gradual integration into NAS. The forecasts presented use all available resources to analyze and forecast both model and non-model activities in the U.S.

With over 900,000 modelers registered as of December 31, 2018, we estimate that there are around 1.25 million drones distinctly identified as model aircraft. Comparing with industry sales and other data noted above, we conclude that model aircraft is almost 40 percent higher than ownership registration[13]. A comparison of last year's data with this year's (2018) shows that the annual growth rate to be around 13 percent. This continues to be substantial growth as anticipated from the introduction of drones as a recreation activity facilitated by falling equipment prices and improved technology, such as built-in cameras and relatively easy maneuvering.

[13] This calculation involves taking into account retirement, redundancy, and loss of craft corresponding to ownership registration. As craft becomes sturdier and operators situationally aware, we expect this rate to change dynamically over time.

However, like in all other technologies including hobby items, (e.g., cell phones and video game consoles; and prior to that, video cameras, and video players), the trend in model aircraft is likely to slow as the pace of falling prices diminishes and the early adopters begin to experience limits in their experiments or simply eagerness plateaus.

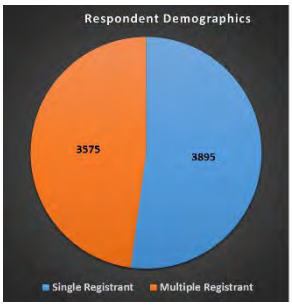
	Total Recreation/Model Fleet (Million sUAS Units)		
year	Low	Base	High
2018	1.25	1.25	1.25
2019	1.29	1.31	1.35
2020	1.31	1.35	1.44
2021	1.31	1.37	1.52
2022	1.32	1.38	1.59
2023	1.32	1.39	1.66

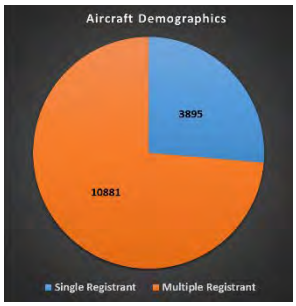
Given the trend in registration and market developments, we forecast that the model aircraft market will saturate at around 1.4 million units. However, there are still some upside uncertainties due to further changes in technology and the likely event of continuously falling prices. This yields to some upside uncertainty in the forecast. We do not anticipate similar symmetry in low side as it parallels to the growth in the base projection. Nevertheless, we provide a forecast base (i.e., likely) with high (or optimistic) and low (or pessimistic) scenarios, provided in the table above. The FAA projects, unlike in previous years, that this sector may have exhausted downside risks; i.e., decline in registration beyond saturation as captured by base forecast.

We use the trend observed in registrations, particularly over the past year, expert opinions collected in TRB annual workshops, review of available industry forecasts, market/industry research, and a time-series model on registration trends. Using these, we forecast that the model fleet will likely (i.e., base scenario) attain its peak over the next 5 years, climbing from the present 1.25 million units to around 1.39 million units by 2023. The high/optimistic scenario may be estimated at 1.66 million units over the next 5 years. As evident, the growth rates underlying these numbers are fairly steady in the initial years but are diminishing faster in the last 2-3 years. The gradual saturation that is projected in 5 years and beyond in the model aircraft fleet parallels other consumer technology products.

Survey of Non-Model Aircraft Owners

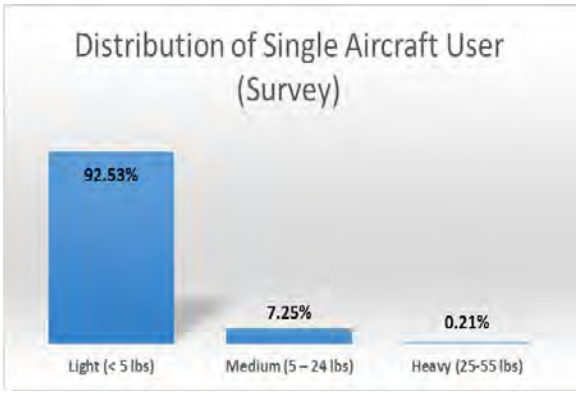
Before we describe non-model sUAS trends and forecasting in the next section, we provide a brief overview of results from a prototype survey that the FAA undertook during June-July, 2018. The results provide likely growth path in the near future. The survey, based on a well-tested questionnaire, was sent by the FAA to individuals registered by December 31, 2017 and conducting activities under Part 107 (i.e., non-model or commercial activities) in that year. The response rate to the survey was approximately 8 percent (7,400 responses from 89,000 contacted). The survey was designed primarily to get a snapshot of non-model/commercial mission characteristics including location, types of aircraft used, and altitude flown. In addition to providing the FAA key data in understanding operational characteristics of non-model activities throughout the country, these key metrics are also important for understanding trends in non-model activities and likely growth trajectory in the near future.



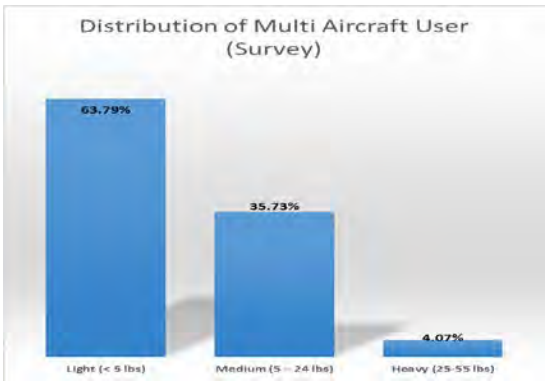


Registrants with one aircraft and those who owned/operated multiple aircraft responded almost equally as the figure above shows. The average number of aircraft among multiple registrants was around 3 with a margin of error of ± 0.2. Survey sample was representative when checked against the population from the Registry.

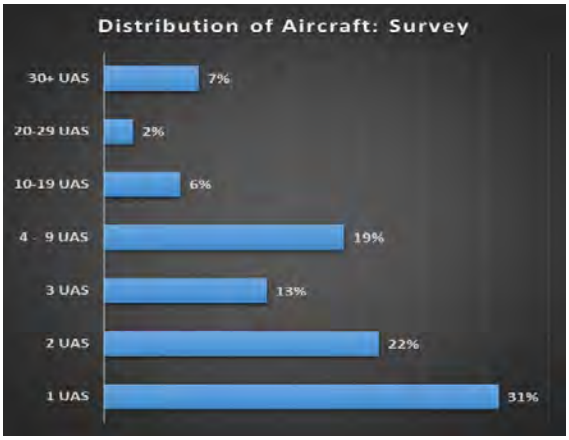
The survey reveals that most of the non-model UAS are light UAS, those weighing 5 lbs or less. This result was the same as in the Registry. The figure below shows the distribution among the responses from single sUAS users:



A similar distribution is reflected in responses from multiple aircraft owners, although the weight of the classes are skewed more towards the medium (5-24 lbs) and heavy (25-55 lbs):



Turning to distribution of ownership, we observe that almost 1 in 3 survey respondents used one sUAS compared to 55 percent from the population (i.e., the Registry). For those who operate multiple sUAS, a large group (54 percent) falls into the category of operating 2-9 sUAS, as compared to only 1 in 3 in that category from the Registry or population counts. For operators with over 10 sUAS, survey response (15 percent) were closer to what we observe in the Registry (12 percent). This distribution provides valuable information regarding the use intensity of sUAS by both single and multiple owners.



Bigger variations are observed between single and multiple sUAS when asked about in-

tensity of operations as captured by the number of missions[14] in 2017. It is apparent from the table below, the more one operates (i.e., multiple owners) sUAS, the more missions they fly during the year; i.e., over twice as many as the single operator. On average, while a single operator flies 32 missions/year, multiple owner/operators flew more than twice that number (82 missions, on average):

		# of Respondents	# of Aircraft	Total Missions	Average Missions per Aircraft
Single Registrant	1 UAS	2,575	2,575	81,827	32
	Total	2,575	2,575	81,827	32
Multiple Registrant	1 UAS	496	496	18,304	37
	2 UAS	1,148	2,296	128,312	56
	3 UAS	458	1,374	101,622	74
	4 - 9 UAS	391	1,961	237,843	121
	10-19 UAS	34	425	52,817	124
	20-29 UAS	9	207	16,183	78
	30+ UAS	9	510	41,336	81
	Total	2,545	7,269	596,417	82
Grand Total		**5,120**	**9,844**	**678,244**	**69**

Trends in Non-Model Aircraft and Forecast

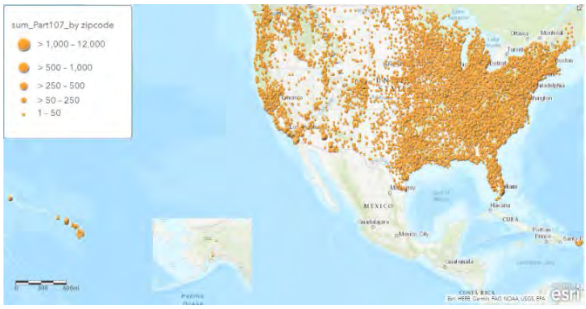
Unlike model ownership, rules for non-model registration require owners to register each sUAS, thus giving a one-to-one correspondence between registration and aircraft. For the calendar year 2018, more than 175,000 non-model owners/operators registered their equipment. The pace of monthly registration, almost 15,000, is nearly 3-times higher than the pace at which non-model aircraft owners registered their craft during the same time last year. While the pace of model registration ownership has slowed down considerably, interestingly, the pace of registration is accelerating for non-model counterparts. By the end of 2018, there were more than 277,000 non-model aircraft registered since registration opened.

Since the registration process has been available through Dec 2017, over 4,600 aircraft per month have been registered. This pace accelerated to 14,600 registrations a month during the last year (2018). The non-model sector is primarily commercial in nature. It is dynamic and appears to be at an inflexion point of demonstrating powerful stages of growth. Unlike the model sector, we anticipate that the growth rate in this sector will continue to accelerate over the next few years. Since initiation of Part 107, there has been proposed rule changes (see https://www.federalregister.gov/documents/2019/02/13/2019-00732/operation-of-small-unmanned-aircraft-systems-over-people. The requirements would address operations over people, operations at night without waivers and possibilities for waivers including enhancement of operational efficiencies. They would also address more commercial uses that will likely facilitate further growth. Notably, a single point for submission of all operational information, including

[14] Missions were described as a job or economic activity consisting of many take-offs/landings.

registration, authorization, and accident logging, helps facilitate this growth further [https://faadronezone.faa.gov/#/].

As in the case of model UAS ownership, non-model sUAS are distributed across the country. A spatial distribution of equipment registration (using data for September 2018) demonstrates that non-model sUAS are distributed throughout the country with denser activities mapping closely against the economic or commercial activities of the country.



Last year, we forecasted that the non-model sector would have around 229,400 sUAS in 2019, a growth rate exceeding 44 percent from the year before (2018). Actual data far exceeds that trend with over 277,000 aircraft already registered by the end of 2018. Our forecast of non-model sUAS last year thus fell short by almost 80 percent for 2018 (or 277,000 actual aircraft vs 158,900 that we projected last year). The significant growth in this sector over the past year demonstrates the uncertainty and potential of the market.

Given the trend observed in the registrations, information from the survey, review of available industry forecasts, and internal research, together with market/industry research, we project that the non-model fleet by 2023 will likely (i.e., base scenario) be three times larger than the current number of non-model aircraft[15]. As the present base (i.e. cumulative total) gets larger, we anticipate the growth rate of the sector will slow down over time. Nevertheless, the sector will be much larger than what we understood as recently as last year. Given the accelerated registration over the last year, we now project the non-model sUAS sector will have over 835,000 aircraft in 2023 (i.e., end of 5-year period). Important to note here is that last year's forecasted sUAS for 2022 (452,000 units) will be surpassed sometime towards the later part of 2019 or early 2020 if the present registration trend continues. This will shorten the forecast outcome period by almost 2-3 years.

In order to understand the growth trajectory of the sector better, we divide the non-model sector into two types of UAS aircraft: consumer grade and professional grade. The consumer grade non-model aircraft are priced in a wide range, somewhere below US

[15] Last year, this ratio (from base year of forecast to end-year of forecast) was 4-times; i.e., we projected forecast to be 4-times the base year's (2017) numbers in 5-year.

$10,000 with an average unit price of around $2,500. The professional grade is typically priced above US $10,000, with an average unit price assumed to be around $25,000[16]. For both consumer grade and professional grade aircraft, the average price has been falling over time, particularly over the last three years. Currently, the consumer grade dominates the non-model sector with a market share approaching 95 percent. However, as the sector matures and the industry begins to consolidate, the share of consumer grade non-model aircraft is likely to decline but will still be dominant. By 2023, FAA projects this sub-sector will have around 85 percent share of the overall non-model sUAS sector.

Starting from a low base of around 13,000 aircraft in 2018, professional grade non-model sUAS sub-sector stands to expand rapidly over time, especially as newer and more sophisticated uses are identified, designed, and operationally planned and flown. If, for example, professional grade sUAS meets feasibility criteria of operations, safety, regulations, and satisfies economics and business principles and enters into the logistics chain via delivering small packages, the growth in this sector will likely be phenomenal. This growth trajectory may even be further enhanced by, for example, the Low Altitude Authorization and Notification Capability (LAANC) system[17], which began authorization in May, 2018. LAANC is designed to allow considerable flexibility in sUAS operations and facilitate non-modelers' use of the NAS. While most of the near-term growth in non-model sUAS will continue to come from consumer grade (over 90 percent), we anticipate a significant part will come from professional grade non-model sUAS as well.

As non-model aircraft become operationally more efficient and safe, battery life expands and integration continues, 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, search-and-rescue operations, etc.) that are somewhat latent and at the experiment 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, an attempt has been made to capture the low-range to the projected demand. Hence, we provide the likely or base scenario together with the enormous potential embodied in the

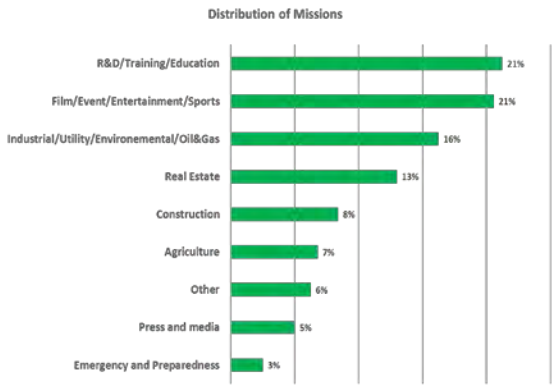
[16] Because of this wide range in prices between types of sUAS in commercial activities, start-up cost for a business may vary somewhere between $2,500 and $25,000.

[17] Low Altitude Authorization and Notification Capability [https://www.faa.gov/uas/programs_partnerships/uas_data_exchange/] or LAANC 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, 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.

"high" scenario, representing cumulative annual growth rates of 25 percent and 36 percent, respectively. In the event of unforeseen slowdown or obstacles, "low" scenario projects a cumulative growth rate of around 17 percent annually.

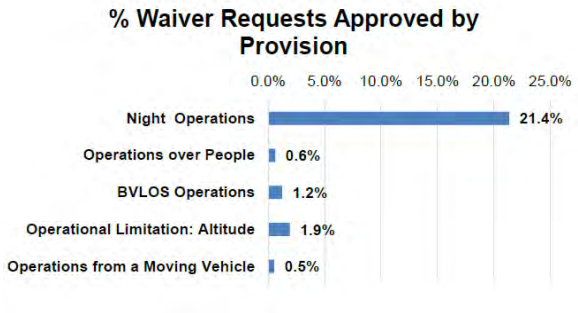
	Total non-Model Fleet (no. of '000 units)		
year	Low	Base	High
2018	277	277	277
2019	369	400	426
2020	460	545	638
2021	552	711	932
2022	588	789	1,112
2023	603	835	1,290

Non-model sUAS are presently used for numerous purposes. The survey of non-model sUAS aircraft owners reveals their present uses as follows:



Non-model sUAS are used extensively in carrying out research and development (R&D), and in training-education missions (21 percent), followed by filming events including weddings, entertainment and sports (21 percent), industrial/utility and in environmental projects such as aerial inspection (16 percent) followed by real estate (13 percent) and in construction activities (8 percent). Agriculture (7 percent) including crop inspection; and press and media (5 percent) come next. Increasingly, state and local governments are using sUAS for emergency services including search-and-rescue operations and presently employ around 3 percent of all non-model sUAS. As the sector grows, we anticipate there will be many more uses of non-model sUAS as they are increasingly evident from the participants' activities, for example, under the Integration Pilot Program (IPP). In May, 2018 the FAA awarded 10 communities, among a pool of 149 applications, [https://www.faa.gov/uas/programs_partnerships/uas_integration_pilot_program/awardees/] to participate in the IPP. IPP applications and preliminary data indicate that awardees overwhelmingly plan to undertake numerous commercial and public interest activities.

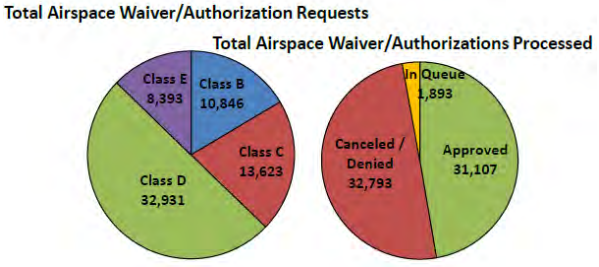
One way of identifying early trends of non-model sUAS uses is to analyze the waiver applications granted to non-model sUAS operators. Both the magnitude and relative composition of waiver types may indicate the direction of the non-model sUAS sector as a whole. A breakdown of the waiver requests granted in December 2018 is shown in the chart below:



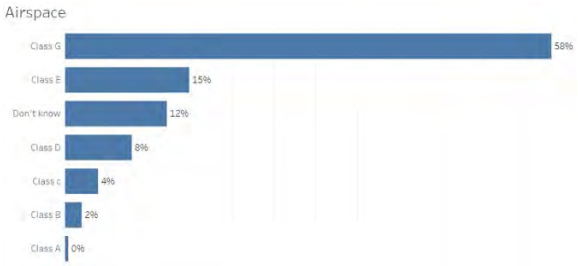
Beyond what is presently allowed under existing Part 107, expanding non-model applications further would require waivers, to a large extent, for night operations, (1 in 5 waivers) and operating limitations of altitude (1.9 percent). Many of these waivers are combined, and hence, total waivers granted

(over 2100 in December 2018) exceed 100 percent. The Agency issues these waivers to facilitate commercial activities by non-model sUAS while preparing for the next round of regulations. New regulations seek to amend the present waiver requirements. (See https://www.federalregister.gov/documents/2019/02/13/2019-00732/operation-of-small-unmanned-aircraft-systems-over-people for current notice of proposed rulemaking (NPRM) on operations of small unmanned aircraft over people in certain conditions and operations of small UAS at night without obtaining a waiver). Analysis of these waiver applications allows us to understand the industry trends, one of many metrics essential for understanding and projecting both the trajectory, course corrections, and growth trends of the sector.

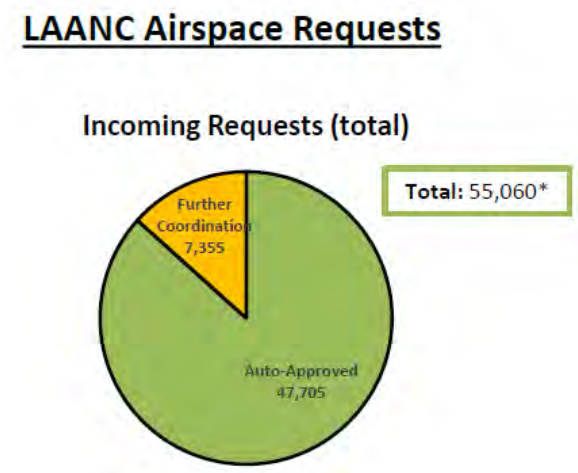
Almost 50 percent of airspace authorizations and waivers were approved for the controlled airspaces at the end of December, 2018. While over half of them were for class D airspace (i.e., smaller airports with control towers), other classes were also requested and regularly flown.



Survey responses show that while most of the respondents routinely fly in Class G airspace (almost 60 percent), there are quite a few users, who fly within controlled airspace facilitated by the airspace waivers.



Finally, LAANC continues to routinely provide auto-approval. It has provided, so far, over 47,000 auto-approvals for airspace access requests, while sending over 7,000 for further coordination. LAANC authorizations are facilitated by combining UAS facility maps (UASFM) [https://faa.maps.arcgis.com/apps/webappviewer/index.html?id=9c2e4406710048e19806ebf6a06754ad] that provide maximum allowed altitudes around airports where the FAA may authorize Part 107 UAS operations without additional safety analysis. The UASFMs are used to inform requests for Part 107 airspace authorizations and waivers in controlled airspace.

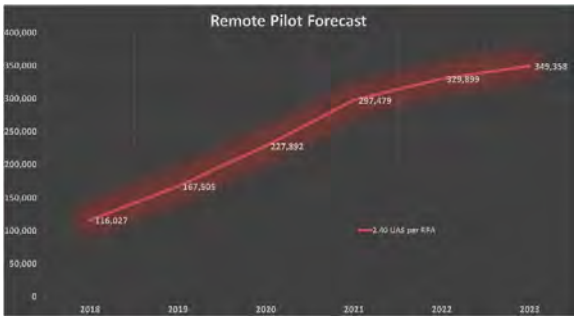


Remote Pilot Forecast

An important final metric in non-model sUAS is the trend in remote pilot (RP) certifications. RPs primarily facilitate non-model sUAS

flights for commercial activities. As of December 2018, more than 116,000 RP certifications have been issued[18]. Over 90 percent of those who took the exam passed and obtained RP certification. The RP forecasts presented below are based on using two data sources: (a) trends in total RPs; and (b) trends in non-model sUAS registration and forecasts of fleet. Given the trends in registration and our forecast of non-model fleet, we assume that one pilot is likely to handle 2.4 units of non-model sUAS.

Using these assumptions and combined with the base scenario of non-model sUAS forecast, we project RPs in the graph below. Last year, we projected RPs to be around 106,000 by the end of 2018; which fell short by 10,000 by the end of 2018. However, the registration of non-model sUAS far exceeded, as noted earlier, what we projected last year.



Given these, we made the adjustment to RPs per non-model aircraft, thus increasing it by one more unit than last year. Despite this adjustment, RPs are set to experience tremendous growth following the growth trends of the non-model sUAS sector. Starting from the base of 116,027 RPs in 2018, non-model activities may require almost 350,000 RPs in 5 years, a three-fold increase, providing tremendous opportunities for growth in employment associated with commercial activities of UAS. Potential for RPs may enhance even more if larger UAS are used in commercial activities and urban air mobility becomes a reality in the near future.

Urban Air Mobility

In Sept 2017, NASA launched a market study for a segment crossing over some functions of UAS discussed above. This segment of autonomous vehicles broadly called Urban Air Mobility (UAM) is defined as "a safe and efficient system for air passenger and cargo transportation within an urban area, inclusive of small package delivery and other urban unmanned aircraft systems (UAS) services, which supports a mix of onboard/ground-piloted and increasingly autonomous operations" (see https://www.nasa.gov/aero/nasa-embraces urban-air-mobility). Studies sponsored by NASA were undertaken by two consulting firms and are presently under review from expertise within the government and academia. Executive summaries of the two reports suggest (https://www.nasa.gov/uamgc), broadly speaking, the following: (a) UAS may play a significant role in transforming short-haul urban air transportation, e.g., airport shuttle, air taxi, air ambulance, last-mile parcel delivery, etc.; (b) substantial financial and business opportunities exist, but there are significant technological, operational, and regulatory challenges including issues involving public

[18] In our accounting of RPs, we take pilots who passed the initial knowledge test plus current manned pilots who took online training in lieu of the knowledge tests.

perceptions and acceptance; and (c) gradual integration of sUAS into the overall system may facilitate integration of UAM by around 2030.

In order to understand and address the challenges identified by the studies, the new Grand Challenge (GC) has been initiated, under which NASA will host UAM ecosystem-wide challenges in 2020. Under GC, participants will be required to execute system level safety and integration within operationally robust and relevant environments. The goal of the first GC (GC-1), from a series of GCs, will be to "promote public confidence in UAM safety and facilitate community-wide learning while capturing the public's imagination" (see https://www.nasa.gov/uamgc for more details).

As the sector grows and new initiatives are taken, the Agency is keeping a keen eye on understanding the overall trends.