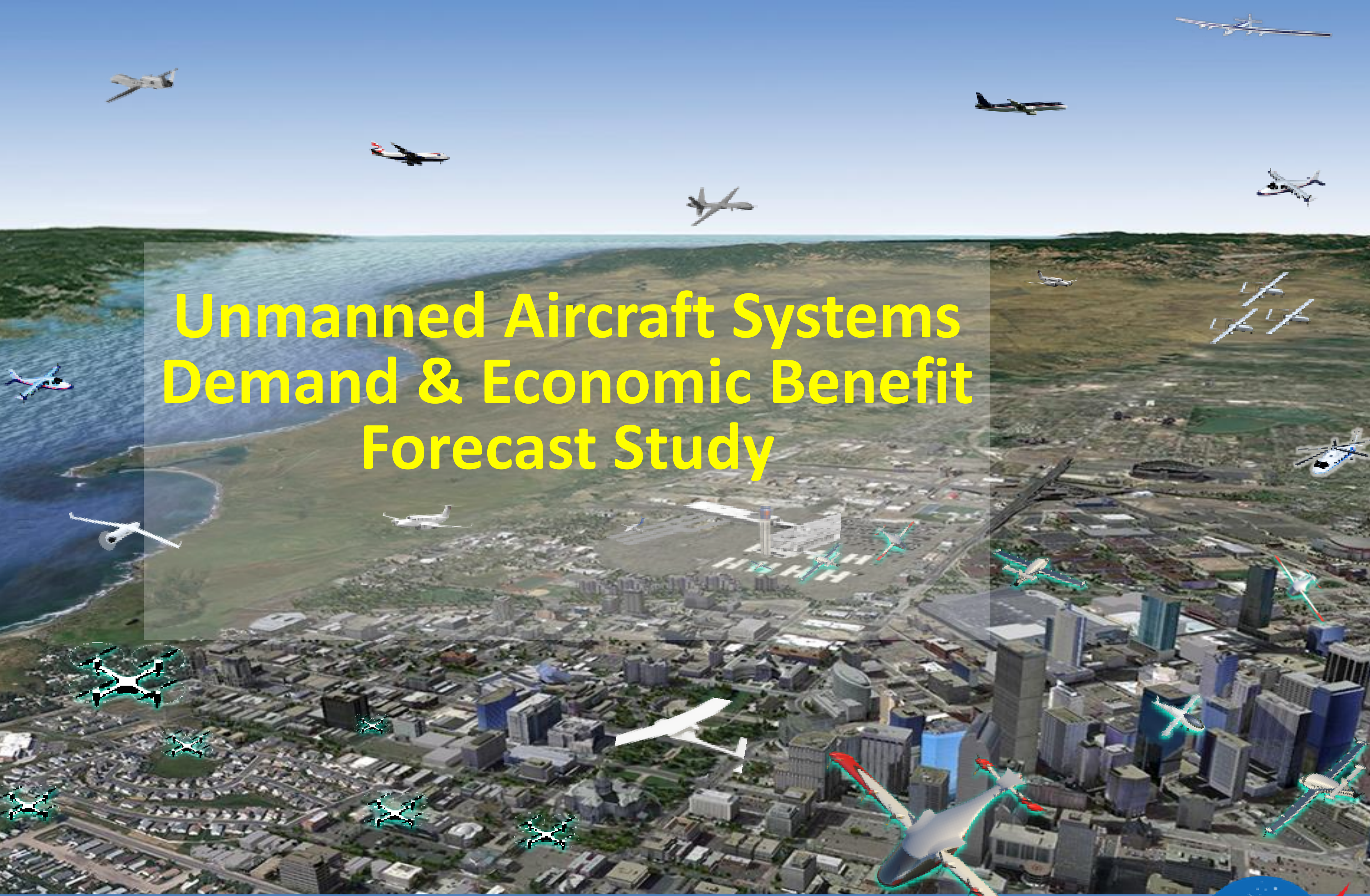
Unmanned Aircraft Systems Demand & Economic Benefit Forecast Study



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Acknowledgements

This study is being performed on behalf of the NASA Aeronautics Research Mission Directorate (ARMD). The team assembled to conduct this effort includes various representatives from government and industry; National Aeronautics and Space Administration (NASA), Modern Technology Solutions, Inc. (MTSI), and Aerospace Corporation.

Overview

- Purpose / Scope / Assumptions
- Research & Analytical Framework
- Aviation Market Categories
- Developed Forecasting Tools
- Future Demand Results
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  - Individual Use Case Details
- Economic Benefit Analysis
  - Package Delivery
  - HALE
  - Cargo
  - Firefighting
  - Unmanned Air Mobility
- Summary

Purpose / Scope / Assumptions

Purpose

- The development of an analytical tool that calculates projections for the demand and economic benefit from operating civil and commercial unmanned aircraft systems (UAS) within the National Airspace System (NAS).
- ***Demand speculation is based entirely on bounding potential market capacities, then adding assumptive UAS capability factors***

Scope

- ***Region***: US-based Markets only
- ***Airspace***: All Airspace Classes
- ***Use Cases***: Commercial and civil (excludes military and hobbyist)
- ***Duration***: Projections should look out far enough to observe forecast stabilization

Overarching Assumptions

- Federal, State and local authorities won't establish unfriendly laws preventing the adoption of UAS (assumes Federal Pre-emption)
- The FAA will continue to move forward with the creation of UAS Policies & Regulations
- The necessary standards needed to certify UAS will be developed in a timely manner
- Government and Industry will continue to make progress on the enabling technologies

Research & Analytical Framework

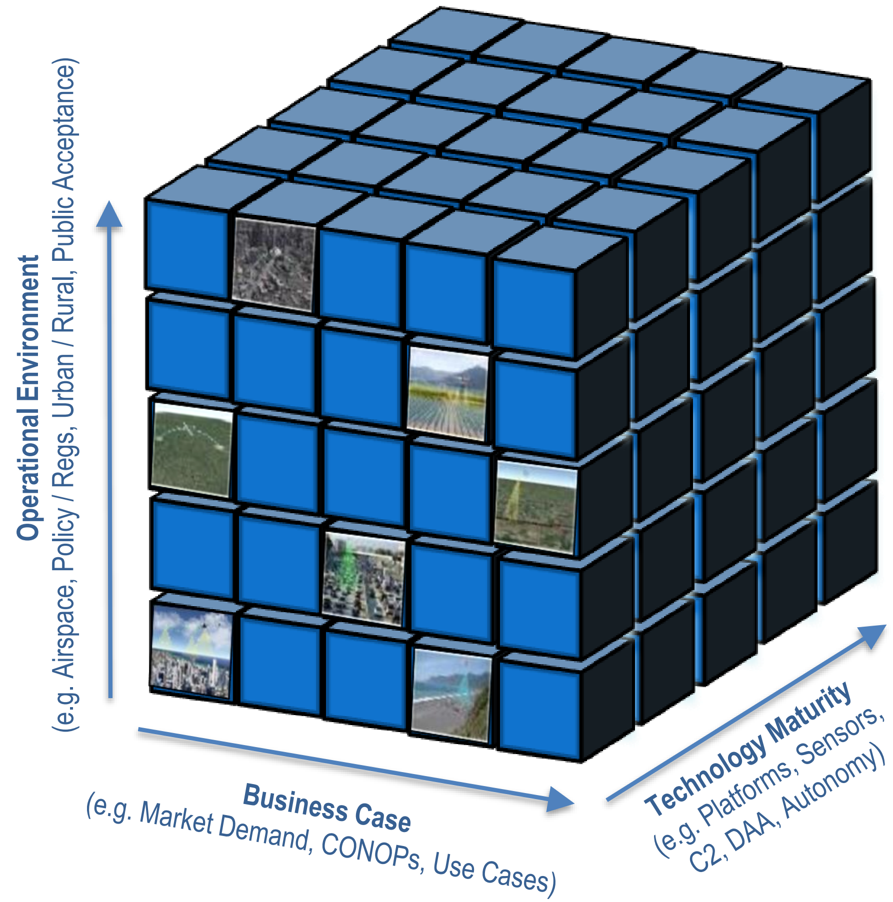
Objective: To gain an appreciation for the vast array of UAS business cases and key drivers that will impact demand and market adoption.

Approach:

- Extensive literature search
- Reviewed existing UAS Forecasts
- Solicited inputs from Government and Industry stakeholders

Results:

- Feasible UAS business cases identified
- Key drivers impacting adoption timeframe (e.g. Public Acceptance, Technology Maturity, Levels of Automation, Regulatory Timeframe)
- Established baseline common measurement (Missions per Day)
- Meaningful metrics used to quantify UAS demand & economic benefit



Aviation Market Categories

	Category	Definition
Traditional Markets*	**General Aviation**	General Aviation Aircraft owned and operated by individuals or corporations (e.g. Cessna, Piper Cub, Learjet), to include aircraft that is rented (e.g. sightseeing helicopter, NetJets)
Traditional Markets*	**Airlines**	Commercial air carriers that offer a service to transport people to and from airports across the country and internationally (e.g. United, American, Delta, SouthWest)
Traditional Markets*	**Cargo**	Aircraft used to transport freight to and from airports across the country and internationally (e.g. FedEx, DHL, UPS)
New UAS Enabled Markets**	**HALE**	Expanding unmanned aircraft market that operates over both rural and urban settings, well above traditional manned aircraft at high altitudes (>60K ft), for very long endurance (days/weeks/months) missions.
New UAS Enabled Markets**	**IFR-Like**	Expanding UAS market that increases traditional densities of the NAS, performs long distance and/or long endurance missions at a higher altitudes (18K ft - 60K ft); integrating exclusively with cooperative aircraft.
New UAS Enabled Markets**	**VFR-Like**	Early UAS market that will operate BVLOS over rural and populated areas at altitudes below critical NAS infrastructure (10K ft – 18K ft); routinely integrating with cooperative and non-cooperative general aviation aircraft.
New UAS Enabled Markets**	**Urban Passenger Transport**	Newly emerging market that requires high density VTOL operations for on demand, affordable, quiet, fast, transportation of people in a scalable and conveniently accessible verti-port network .
New UAS Enabled Markets**	**Low Altitude Urban**	Rapidly expanding market that uses fixed wing and VTOL UAS operating below 400 ft and BVLOS to deliver packages and offer a wide range of services to high density urban settings.
New UAS Enabled Markets**	**Low Altitude Rural**	Emerging market that includes fixed wing and VTOL UAS, ranging in size and capability, that operate beyond visual line of sight (BVLOS) in Class G airspace and above low-risk rural locations.
New UAS Enabled Markets**	**VLOS**	Growing existing market, partially enabled by Far Part 107, that includes visual line-of-sight (VLOS) fixed wing and VTOL UAS (<55 lb) operating below 400 ft.

**Traditional Markets are the categories the FAA has historically tracked for manned aviation.*

*** UAS Enabled Market Categories are based largely on the teams projected policy / regulatory releases*

UAS-Enabled Market Categories

Forecasting Tools

Objective: Analytical tools that facilitate the forecasting of UAS demand and economic benefit across various UAS market categories.

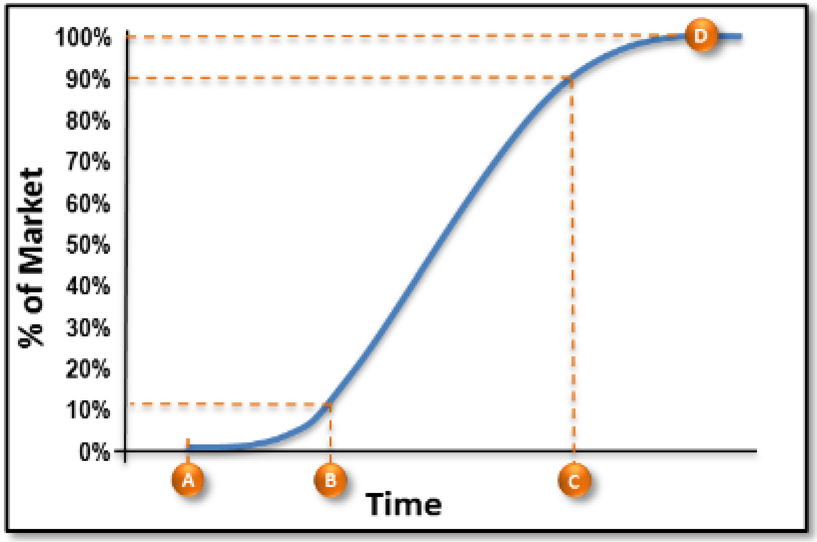
Approach:

- ***Future UAS Demand Growth***: Utilize a standard S-curve technology adoption calculation reliant on 4 variables
  - A Estimated start year of new technology
  - B Estimated fast-growth year (~10% of market)
  - C Estimated takeover year (~90% of market)
  - D Estimated total market saturation level (Either as a percentage of the existing market or estimated total of a new market)
- ***Economic Benefit***: Modify and collaborate existing Aerospace Corporation-developed estimating tools into a Cumulative UAS Benefit to the Economy (CUBE) Tool

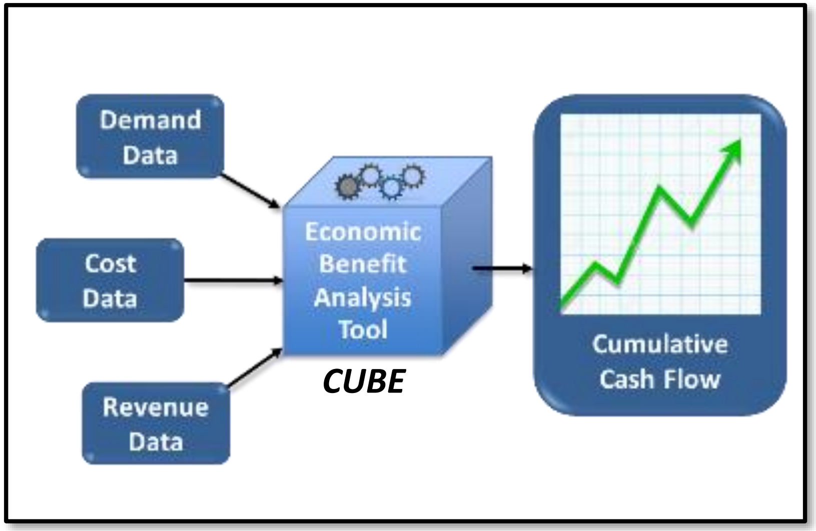
Results / Benefits:

- Demand Tool allows for quick prediction adjustments by simply adjusting the input variables
  - Input values can be based upon subject matter expert (SME) input or from rigorous business-case analysis
- CUBE tool requires extensive inputs, specific representative use cases were selected and analyzed.

UAS Demand



Economic Benefit



UAS Demand Forecast
Overall Summary Findings- Market Categories

- Within each major market category, the individual use cases showed similar growth timelines.
  - Category timeline averages and resultant cumulative max missions per day (variable D):

Market	10% Year Av.	90% Year Av.	Future Max Missions/Day*
Traditional	2033	2057	63,603
HALE	2023	2033	2,346
IFR-Like	2027	2039	86,624
VFR-Like	2022	2028	3,341
Rural Low Altitude	2020	2025	5,894,553
VLOS	2018	2022	2,102,359
Urban Passenger	2030	2045	4,046,890
Urban Low Altitude	2023	2031	4,534,006

*Definition of "Missions" varies slightly by use case. These reflect US-wide cumulative estimates.

UAS Demand Forecast
Overall Summary Findings by Use Case

Use Case	10% Year	90% Year	Missions/Day
TRADITIONAL MARKETS			
Cargo (Augmented)	2023	2030	2,016
Cargo (Unmanned)	2031	2056	2,016
General Aviation	2031	2056	40,204
Airlines	2036	2059	21,383
HALE			
ISP/Comm	2023	2033	2,346
Science Monitoring	2023	2033	>1
IFR- LIKE			
Thin/Short Haul	2030	2045	81,931
sUAS Monitoring	2023	2033	4,693
VFR-LIKE			
Border Patrol	2023	2028	179
Search and Rescue	2023	2028	81
Disaster/Forest Fire	2023	2028	563
Waterways	2023	2028	941
Sea Ice	2023	2028	7
Hurricane	2019	2028	13
Traffic	2022	2028	935
Weather	2022	2030	622

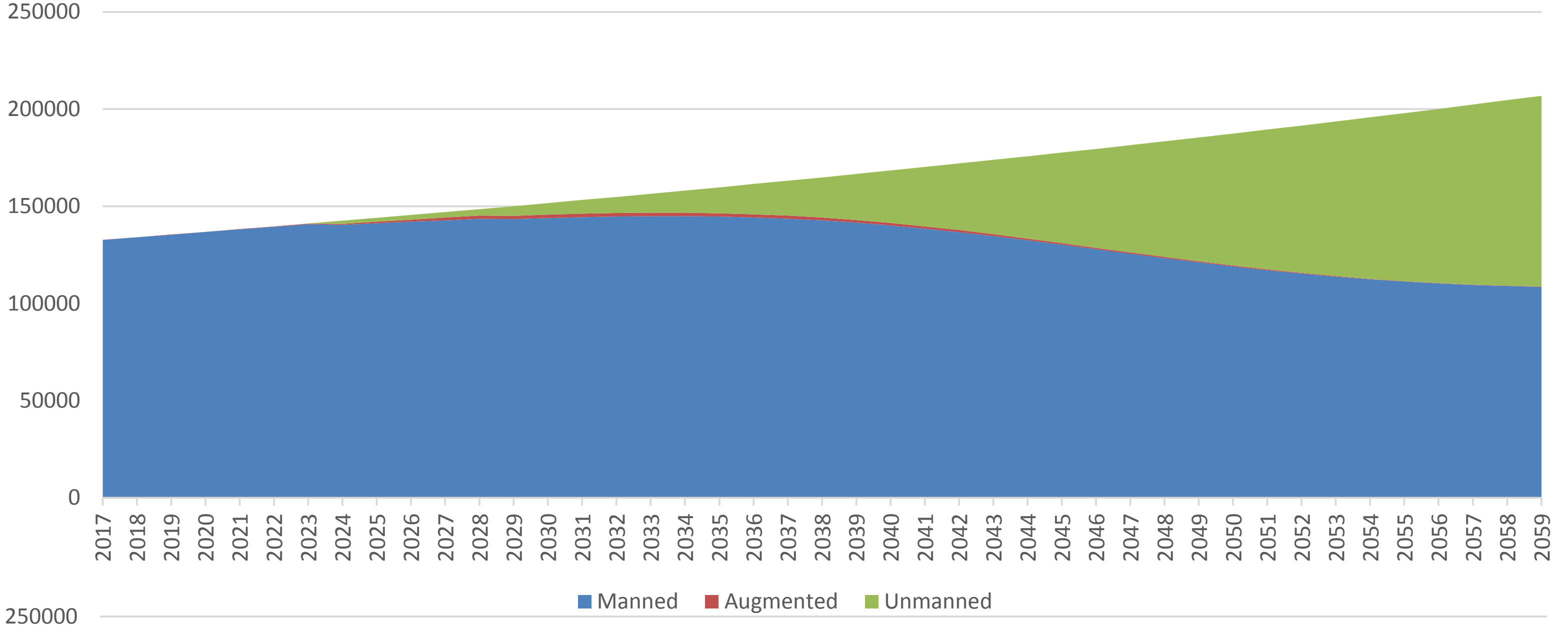
Use Case	10% Year	90% Year	Missions/Day
RURAL LOW ALTITUDE			
Rural Package Delivery	2024	2032	5,853,970
Pipeline	2019	2022	3,861
Road/Bridge	2020	2026	318
Rail	2020	2025	1,532
Power Line	2018	2022	271
Post Disaster/Insurance	2018	2023	13,808
Photogammetry	2019	2022	15,862
Search and Rescue	2018	2020	2,166
sUAS Border Patrol	2020	2024	300
Forest Fires	2020	2025	454
Science Monitoring	2020	2026	1,930
Advertising	2020	2027	81

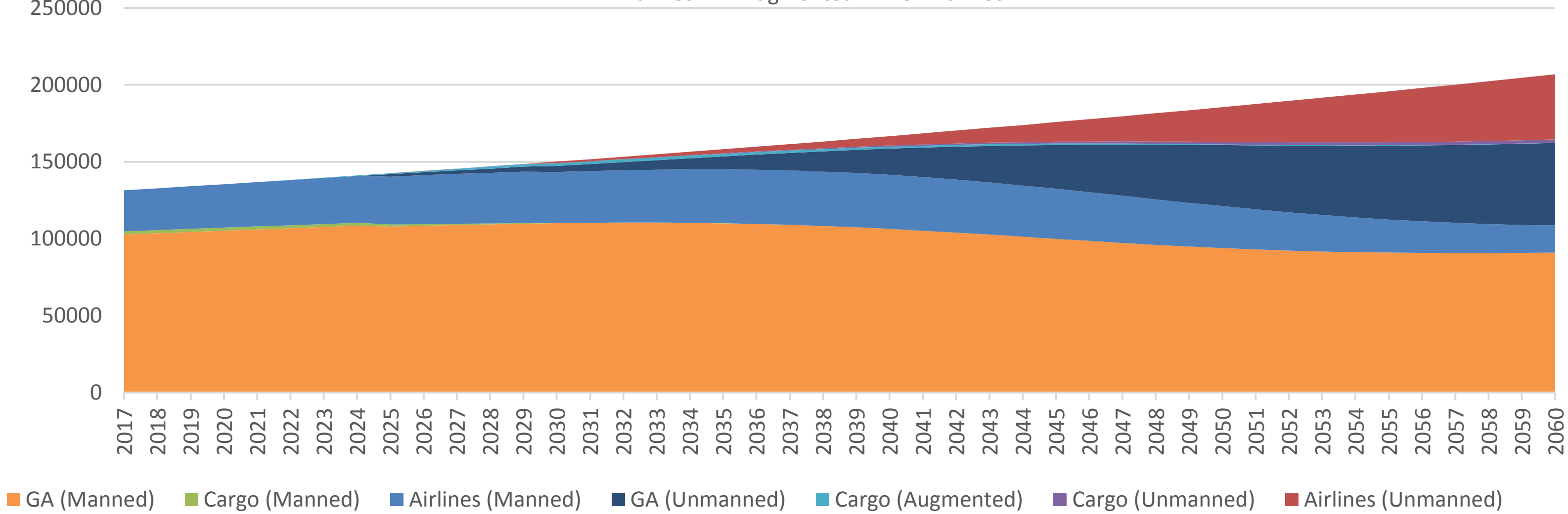
UAS Demand Forecast
Overall Summary Findings by Use Case (cont.)

Use Case	10% Year	90% Year	Missions/Day
VLOS			
Wildlife	2017	2022	22
Movie/Filming	2014	2016	207
Agriculture	2019	2022	1,997,706
Construction	2017	2020	47,237
Wind Turbine	2017	2025	142
Mining	2017	2020	642
Tower/Bridge	2019	2022	1,380
Forensice/Accidents	2019	2024	249
Property Security	2019	2025	30,300
Event Security	2020	2023	3,531
Rapid Comms	2020	2024	792
Sport Event Advertising	2020	2024	3,086
Light Show Swarms	2018	2022	134
VR Experiences/Training	2020	2024	16,917
Racing	2017	2020	14

Use Case	10% Year	90% Year	Missions/Day
URBAN PASSENGER			
Air Taxi	2030	2045	1,949,926
Urban Commuter	2030	2045	2,057,664
Medical Evacuation	2030	2045	39,300
URBAN LOW ALTITUDE			
Urban Package Delivery	2026	2040	4,510,218
Infrastructure	2022	2026	12,853
News/Traffic	2020	2026	4,679
First Responders	2025	2035	3,972
Fire Department	2022	2028	2,284

UAS Demand Forecast: Traditional Market Use Cases





CG-1 Cargo – Augmented/Unmanned Cockpit

Hub-to-Hub Cargo Transport

Key Assumptions:

- MISSION: 1 TO/Land with upgraded augmented/unmanned-capable cockpit
- Cargo acft readily available to augment near term
- Numbers are based on a rough analysis of UPS data in the western mountainous states and included Texas
- FedEx and USPS will have similar numbers (along with additional smaller carriers)
- Multiply by a factor of 1.9 to consider return flights to get UAS back to starting terminal
- Assume aircraft are flown for 35 years

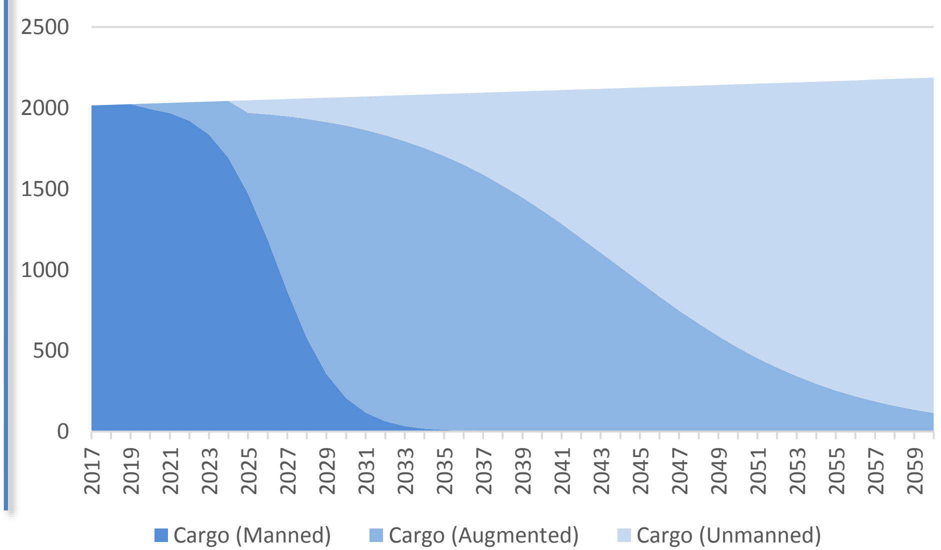
Cumulative Future Total per Day: D

Sub Use Cases	Calculated Estimates
UPS Air	300
FedEx Air	476
Additional Carriers	285
Total missions/day	**2,016 (plus growth)**

Date Projections:

Start year A	2020 (Augmented flight begins)	2025 (Technology safety advances)
10% Growth Year B	2023 (Modifications to aircraft increase)	2031 (Regulations and public view are in welcoming)
90% Growth Year C	2030 (Augmented procedure advances)	2056 (Complete cycle of purchasing / mod to aircraft)
Total Saturation D	100% of market	

UAS Demand:



GA-1 General Aviation

Key Assumptions:

- MISSION: 1 TO/Land with upgraded augmented/unmanned-capable cockpit
- GA aircraft augmentation investment not predicted due to cost, replacement only
- Personal use, instructional and sight seeing/air tours not impacted. (~61% of market)
- Business and charters set to match eventual Airline estimates (80%)
- Certain markets set to 100% based on value (Aerial observations, agriculture application, air medical)

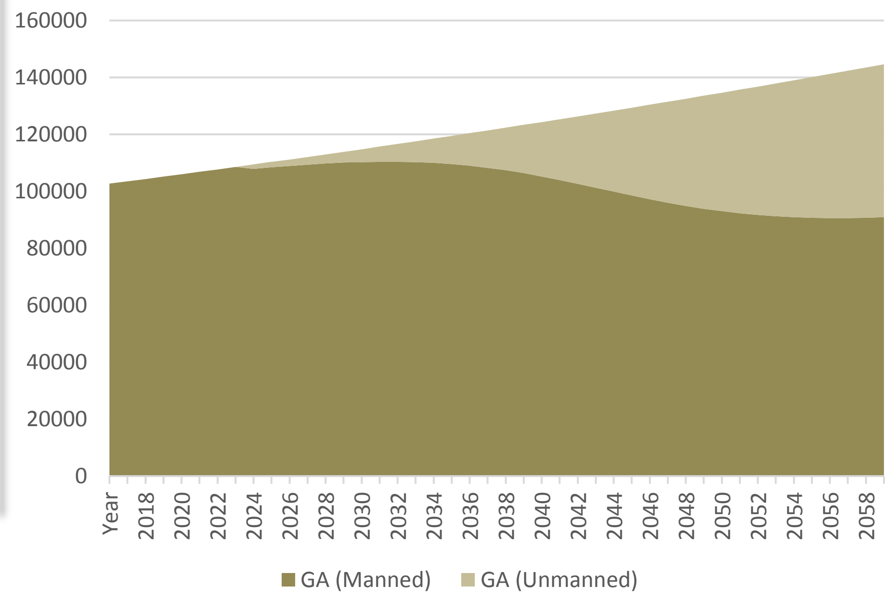
Cumulative Future Total per Day: D

Sub Use Cases	Calculated Estimates
Unaffected GA	(62,461)
Partial Market Takeover	24,116
Total Market Takeover	16,089
Total missions/day	**40,204 (plus growth)**

Date Projections:

Start year (A)	2025 (Testing and initial flights)
10% Growth Year (B)	2031 (General replacement of aircraft increase)
90% Growth Year (C)	2056 (25 year replacement of existing manned aircraft)
Total Saturation (D)	39% of market

UAS Demand:



AL-1 Airlines
Hub-to-Hub Passenger Transport

Key Assumptions:

- MISSION: 1 TO/Land with upgraded augmented/unmanned-capable cockpit
- Normal expected growth of the market
- Converted aircraft are "able" to be unmanned by technology, can support 2, 1, or 0 pilots
- Airlines begin conversion 5 years beyond lessons learned from cargo/smaller GA
- No augmentation/upgrades of existing aircraft, only conversion by attrition
- If only the top 5 airlines convert to unmanned capable, then over 80% of the market is covered

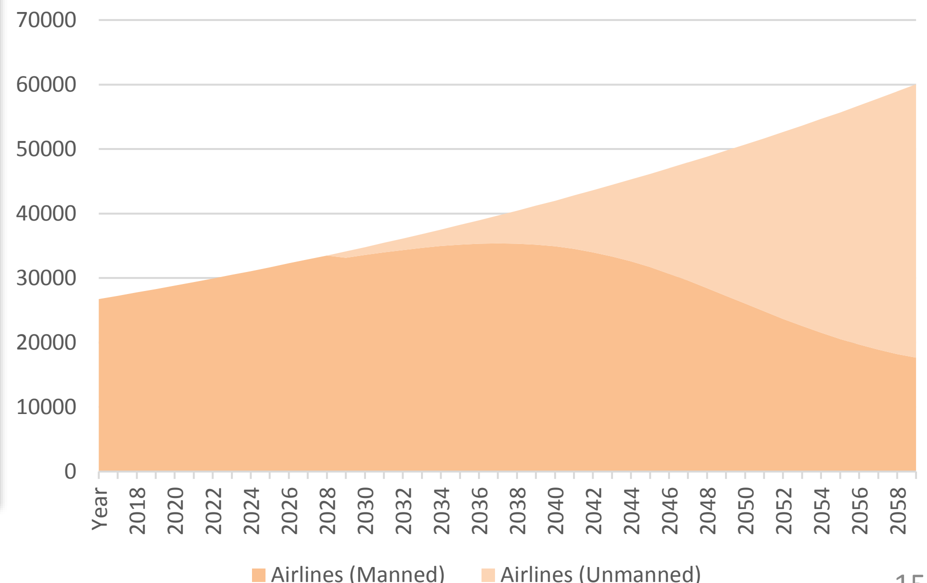
Cumulative Future Total per Day: D

Sub Use Cases	Calculated Estimates
Total Flights 2017	9,755,800
Av. Flights/day	26,728
Projected Growth/year	1.9%
% of market	80%
Total missions/day	**21,383 (plus growth)**

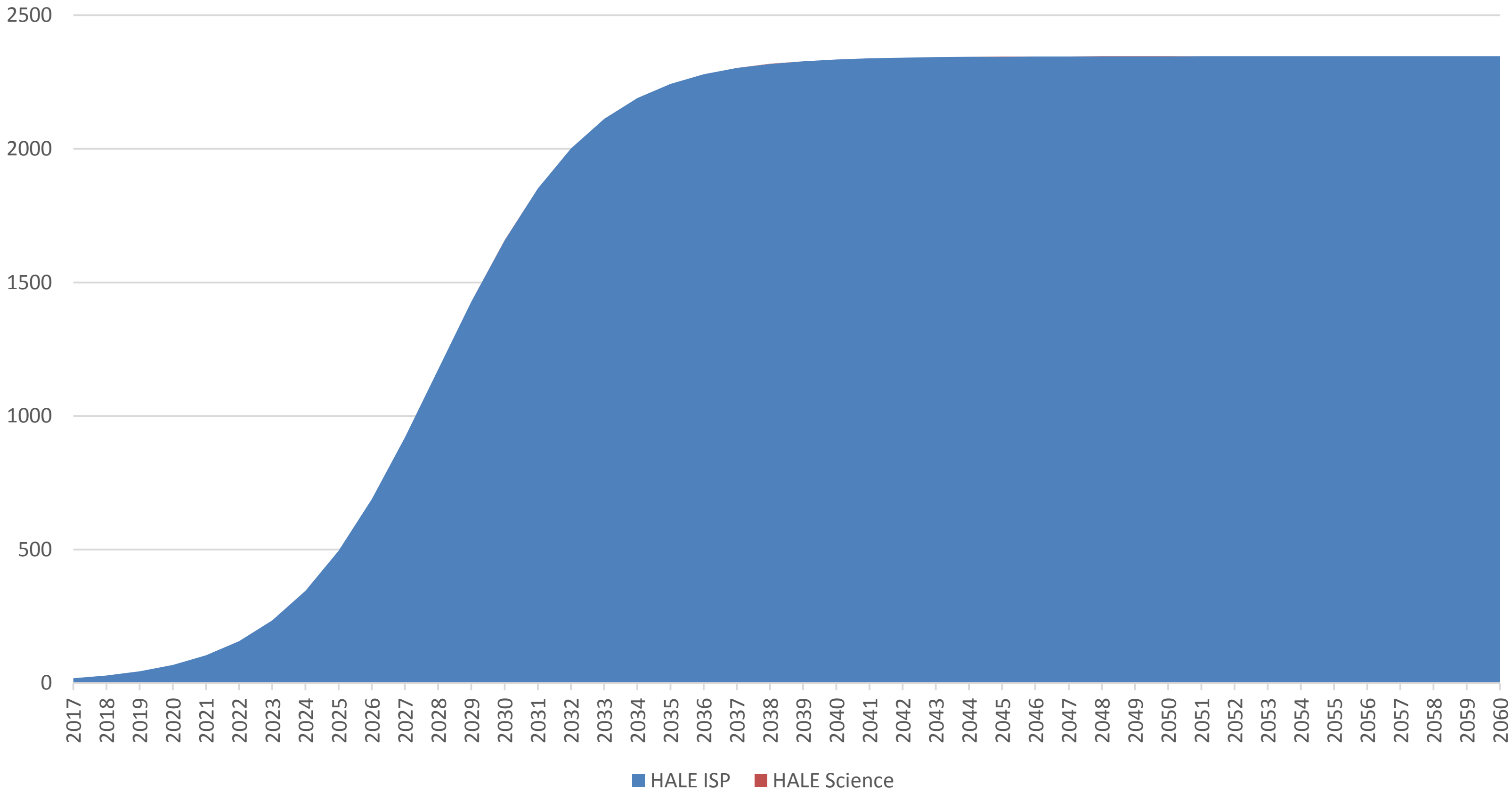
Date Projections:

Start year A	2030 (Testing and flights begin, 5 years beyond Cargo and smaller GA)
10% Growth Year B	2036 (General replacement of aircraft increases)
90% Growth Year C	2061 (25 year replacement cycle of existing aircraft)
Total Saturation D	80% of market

UAS Demand:



UAS Demand Forecast: HALE Use Cases



HA-1 High Altitude ISP/Communications
Multi-City Service Provider

Key Assumptions:

- MISSION: 1 TO and/or Land, or 1 if aircraft is aloft during entire day (for 24+ hour ops)
- Does not include lighter-than-air aircraft
- Assume two major providers will coexist to provide communication service to the same area (e.g. Verizon, AT&T)
- Will be used to provide communication services to cities with population <100k
- Very high populated areas (e.g. New York City) will need 2.5x UAS to service

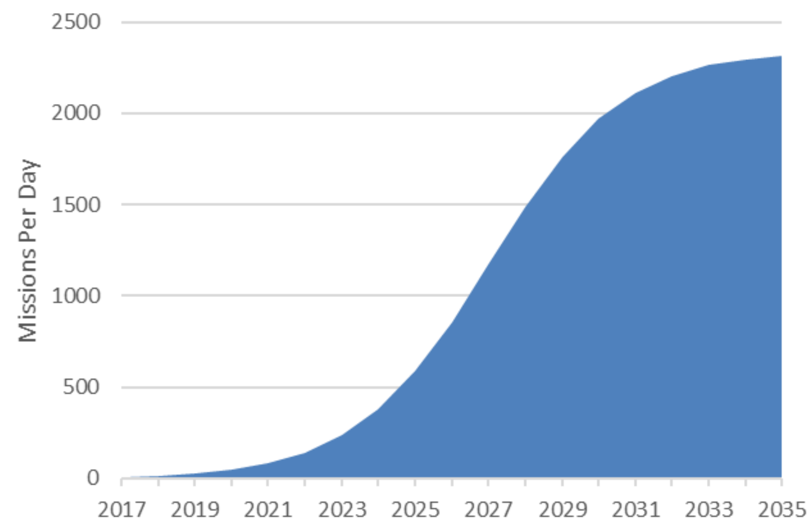
Cumulative Future Total: D

Description	Estimates
Sq. mi of >100k pop. cities	29,096
Sq. mi HALE UAS mission area coverage	62
UAS needed to provide service to major cities for 1 day	469
Total missions per day	**2,346**

Date Projections:

Start year A	2017 (demo flights)
10% Growth B	2023 (ramp up for testing and production)
90% Growth C	2033
Total Saturation D	2,346

UAS Demand:



HA-2 High Altitude Science Monitoring
Ozone Assessments, Cloud Seeding

Key Assumptions:

- MISSION: 1 TO and/or Land, or 1 if aircraft is aloft during entire day (for 24+ hour ops)
- Does not include lighter-than-air aircraft
- There will not be enough demand for a strictly science monitoring high altitude UAS. Combined with other payloads with different missions could allow for viable UAS but not as a standalone system.

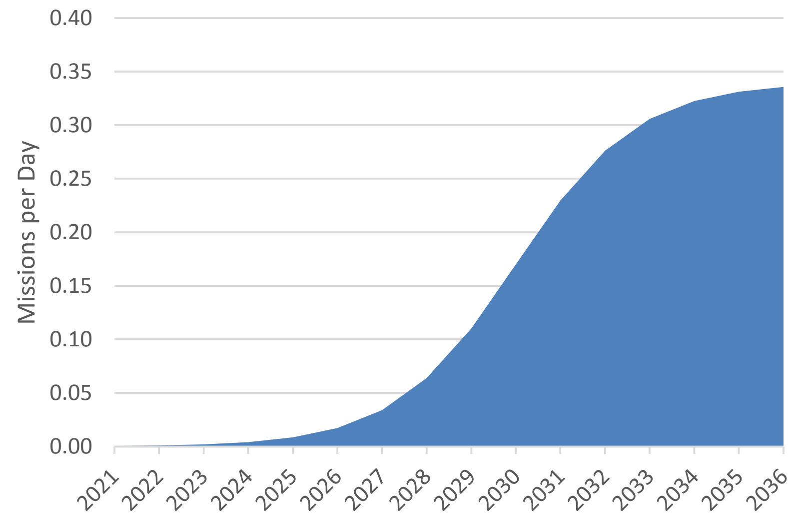
Cumulative Future Total: D

Sub Use Cases	Calculated Estimates
NOAA missions per year	12
NASA missions per year	112
Total missions per day	**0.34**

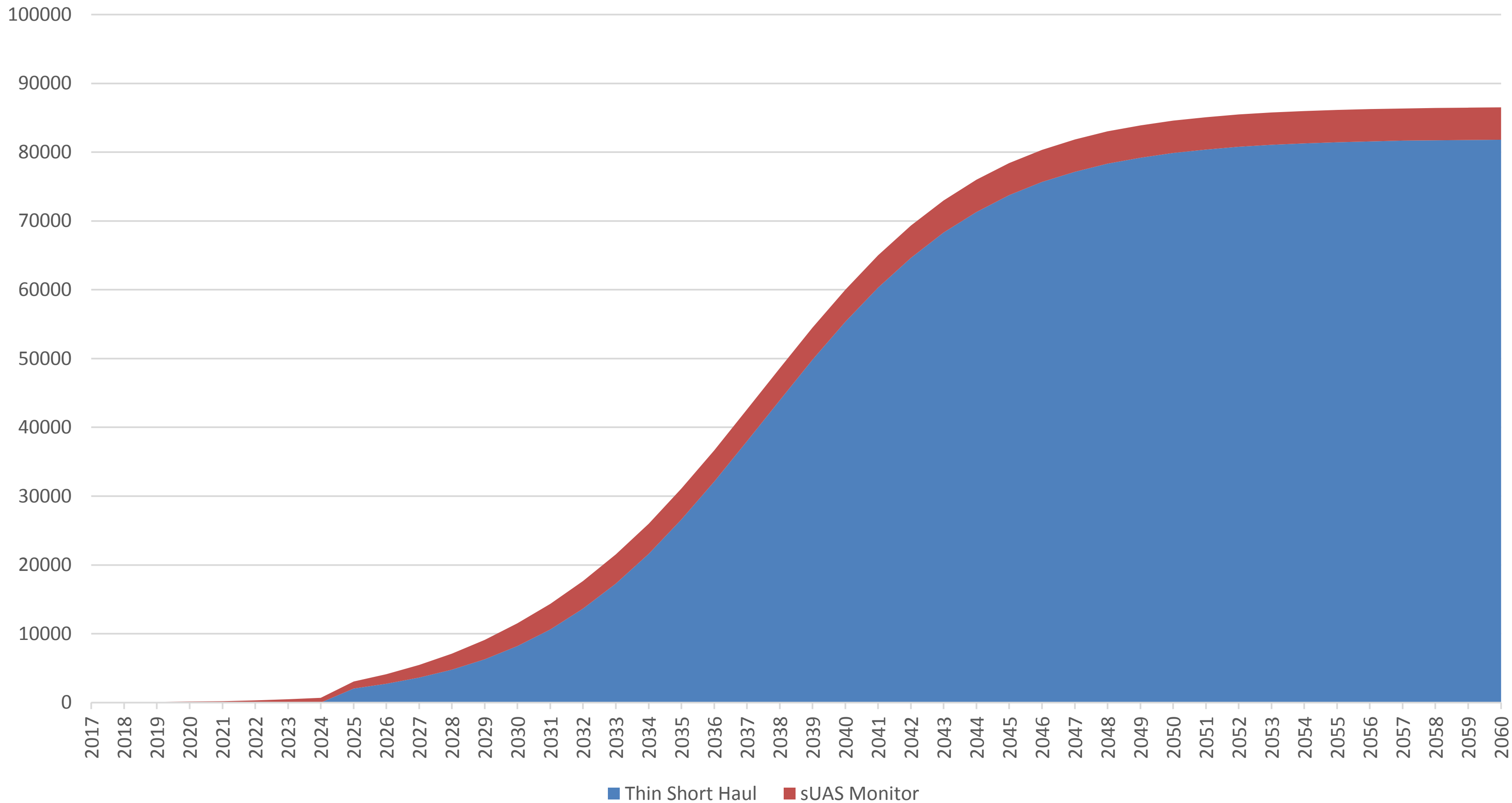
Date Projections:

Start year A	2017 (demo flights)
10% Growth B	2023 (ramp up for testing and production)
90% Growth C	2033
Total Saturation D	0.34

UAS Demand:



UAS Demand Forecast: IFR-Like Use Cases



IF-1 Thin/Short Haul Passenger Routes
Small Airport Commuter Service, Long Distance Travel

Key Assumptions:
- MISSION: 1 TO/Land with upgraded augmented/ unmanned-capable/pilotless cockpit
- New direct routes between non-hub airports (eliminate need for connections)
- Assuming 6 passengers/flight
- Assume to replace: .1% of large hub, 3% of medium hub, 15% of small hub, 35% of non-primary airports, 75% of non-primary airports
- Due to affordability/availability, assume to transition 1% of all existing long-distance travel

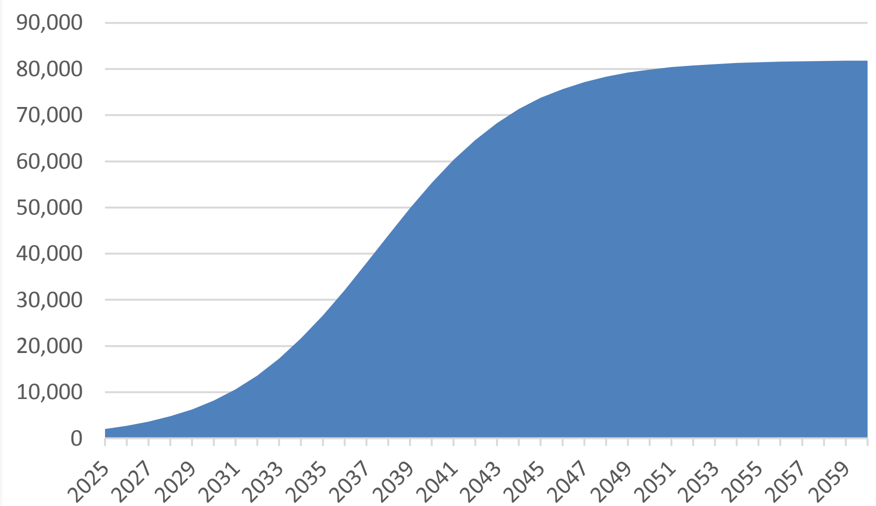
Cumulative Future Total: D

Sub Use Cases	Calculated Estimates
Converted missions/year	3,787,512
Converted missions/day	10,337
Total long distance trips	2,611.7 million
% of LD trips convert to T/SH	1%
New mission/day	71,554
Total missions/day	**81,931**

Date Projections:

Start year A	2025
10% Growth B	2030
90% Growth C	2045 (Regulations, technology, public acceptance)
Total Saturation D	81,931

UAS Demand:



IF-2 sUAS Monitoring
Situational Awareness

Key Assumptions:

- MISSION: 1 TO/Land
- Will be used to monitor/support sUAS services to cities with population <100k
- Very high populated areas (e.g. New York City) will need 2.5x UAS to service

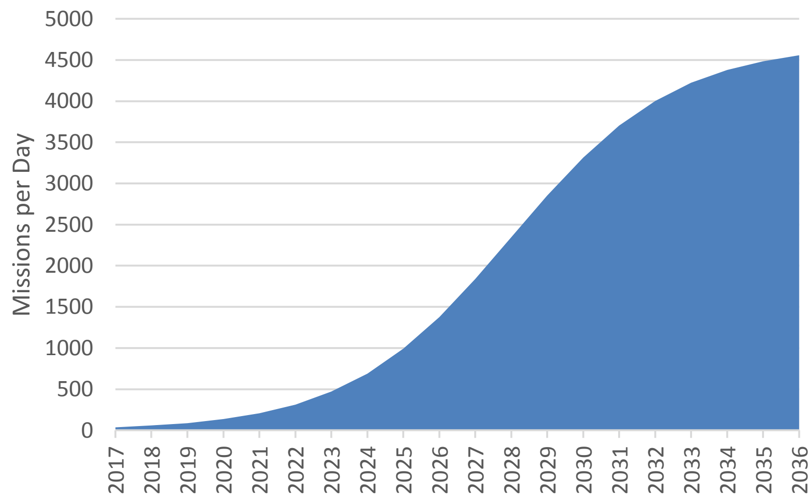
Cumulative Future Total: D

Description	Estimates
Sq. mi of >100k pop. cities	29,096
Sq. mi UAS mission area coverage	16
UAS needed to provide service to major cities for 1 day	1,877
Total missions/day	**4,693**

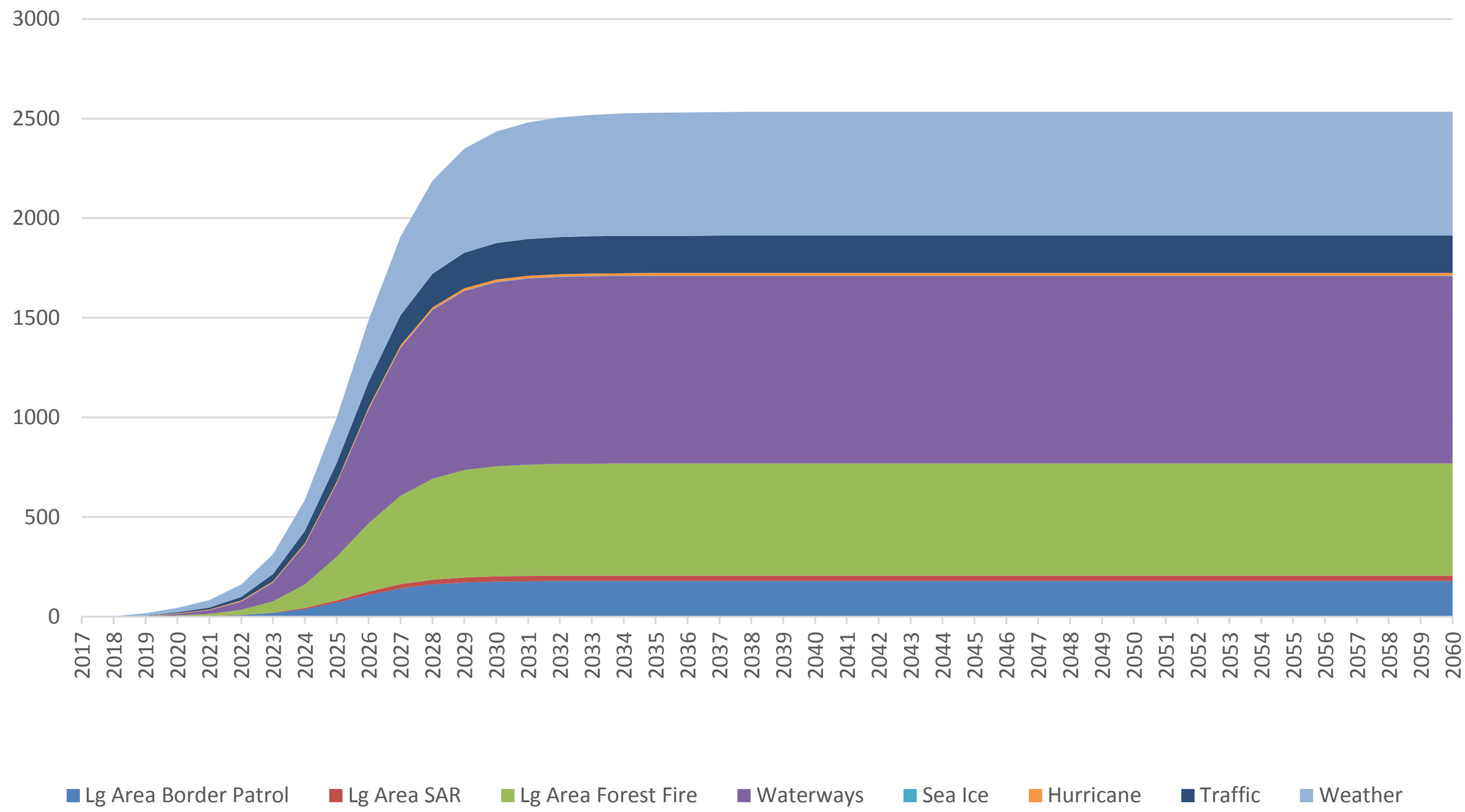
Date Projections:

Start year A	2017 (demo flights)
10% Growth B	2023 (ramp up for testing and production)
90% Growth C	2033
Total Saturation D	4,693

UAS Demand:



UAS Demand Forecast: VFR-Like Use Cases



VF-1 Large Area First Responder
Border Patrol

Key Assumptions:

- MISSION: 1 TO/Land
- Assume 3 missions per day for 24/7 surveillance
- 1 mission covers 100 miles
- Assume 24/7 surveillance
- Assume operations 365 days a year

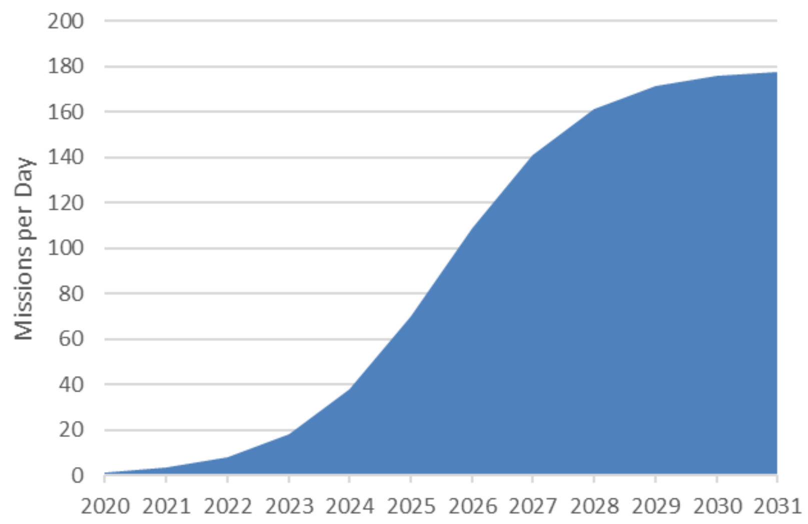
Cumulative Future Total: D

Description	Calculated Estimates
Miles of border miles	5,971
Total missions/day	**179**

Date Projections:

Start year (A)	2020
10% Growth (B)	2023
90% Growth (C)	2028
Total Saturation (D)	179

UAS Demand:



VF-2 Large Area First Responder
Search and Rescue

Key Assumptions:

- MISSION: 1 TO/Land
- SAR hours are derived from Coast Guard resource hour data. Apply an order of magnitude of 3 to account for other agencies for entire US coverage (See RL-8)
- 8% of SAR missions extend beyond 24 hours, assume that these missions would require larger coverage UAS.

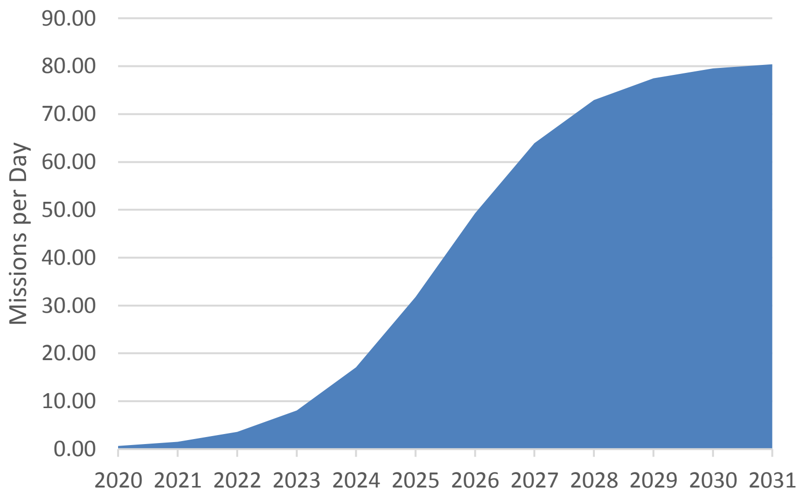
Cumulative Future Total: D

Description	Estimates
Total SAR Missions	1,013
Percent >24 Hours	8%
Total missions/day	**81**

Date Projections:

Start year (A)	2020 (Early adopters begin operations)
10% Growth (B)	2023 (Training and safety increases)
90% Growth (C)	2028 (Standard for forest fighting)
Total Saturation (D)	81

UAS Demand:



VF-3 Large Area First Responder
Disaster Response/Forest Fire

Key Assumptions:

- MISSION: 1 TO/Land
- UAS would be used for day and night operations depending upon role
- Need a UAS fleet size of 40% of the current manned fleet number wise to provide sufficient coverage
- 1 flight day = 2 flights /day
- Assume a firefighting season of 270 days

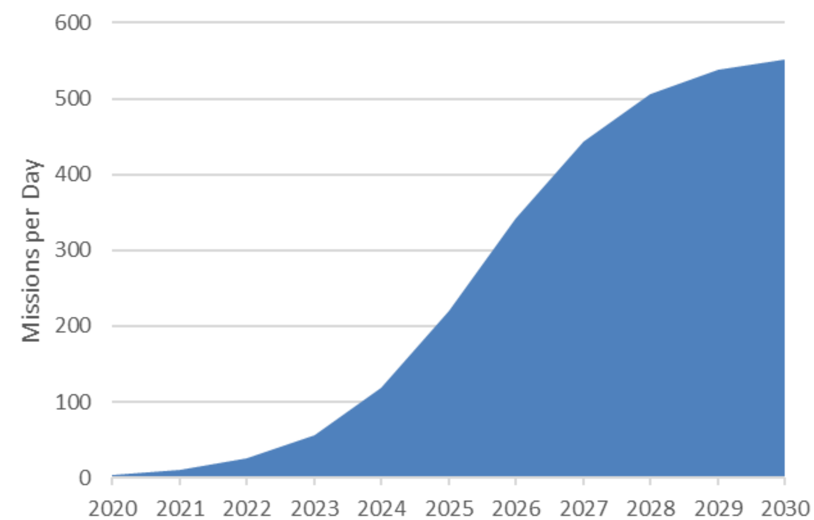
Cumulative Future Total: D

Description	Estimates
Total missions (local and large)	1017
Local area missions	454
Total missions/day	**563**

Date Projections:

Start year A	2020 (Early adopters begin operations)
10% Growth B	2023 (Training and safety increases)
90% Growth C	2028 (Standard for forest fighting)
Total Saturation D	563

UAS Demand:



VF-4 Large Area Surveillance
Waterways/Shipping

Key Assumptions:

- MISSION: 1 TO/Land
- Assume 1 mission per day
- 1 mission covers 100 miles
- Assume operations 365 days a year

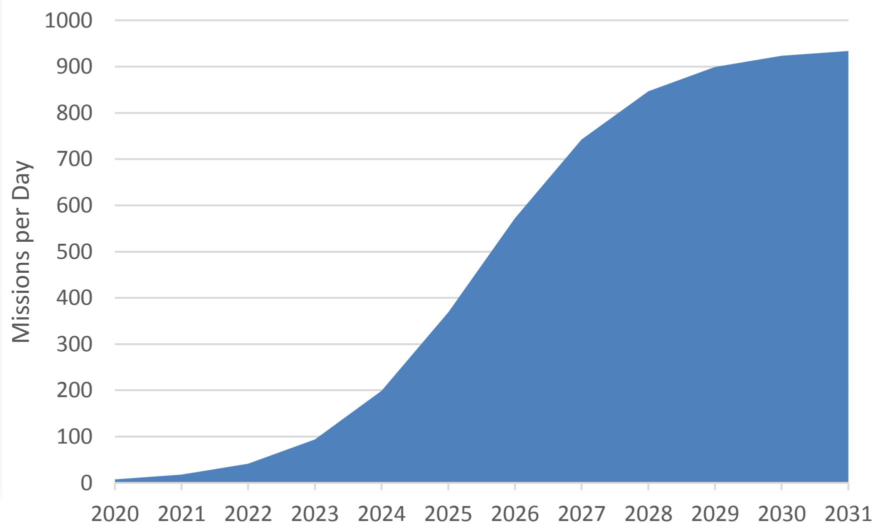
Cumulative Future Total: D

Description	Calculated Estimates
Miles of border miles	94,112
Total missions/day	**941**

Date Projections:

Start year A	2020
10% Growth B	2023
90% Growth C	2028
Total Saturation D	941

UAS Demand:



VF-5 Large Area Surveillance
Sea Ice

Key Assumptions:

- MISSION: 1 TO/Land
- Assume full coastal sea ice assessment monthly
- 1 mission covers 100 miles
- Assume 200 flights per full assessment

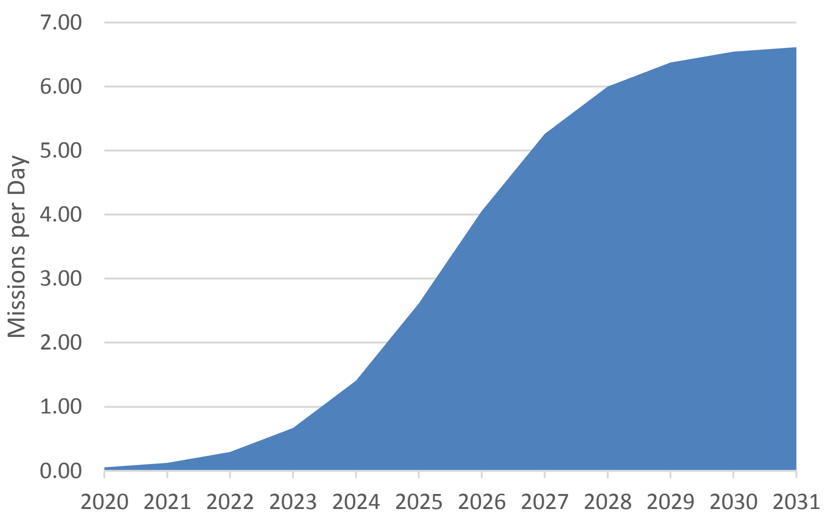
Cumulative Future Total: D

Description	Calculated Estimates
Flights / month	200
Total missions/day	**7**

Date Projections:

Start year A	2020
10% Growth B	2023
90% Growth C	2028
Total Saturation D	7

UAS Demand:



VF-6 Large Area Science Monitoring
Hurricane Monitoring

Key Assumptions:

- MISSION: 1 TO/Land
- Hurricane is 500 miles in diameter.
- Directional travel speed of 20 mph.
- Avg. duration of a hurricane is 9 days or 216 hours
- Drone covers a 500 acre area in a single mission

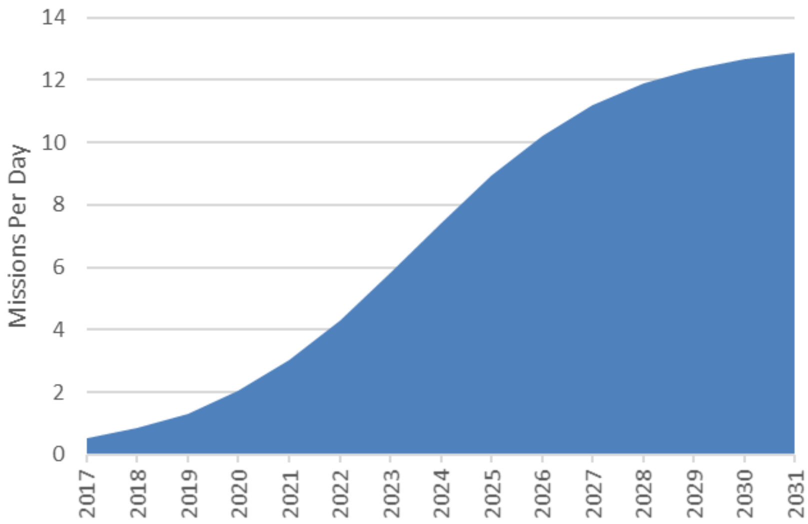
Cumulative Future Total: D

Description	Estimates
Average hurricanes per year	6.3
Named storms per year (including subtropical)	11.7
Average hurricane duration	216 hours
Total missions/day	**13**

Date Projections:

Start year A	2017
10% Growth B	2019
90% Growth C	2028
Total Saturation D	13

UAS Demand:



VF-7 Localized Area Infrastructure Surveillance
Interstate Traffic Monitoring

Key Assumptions:

- MISSION: 1 TO/Land
- Assume that like traditional Automatic Traffic Recorders, that UAS will collect data 24/7, 365 days annually, for each lane
- UAS will record traffic volumes, speed and perform classification of vehicles
- Only accounts for arterial roads in US (does not include minor/smaller roads)
- 1 mission = 6 hours

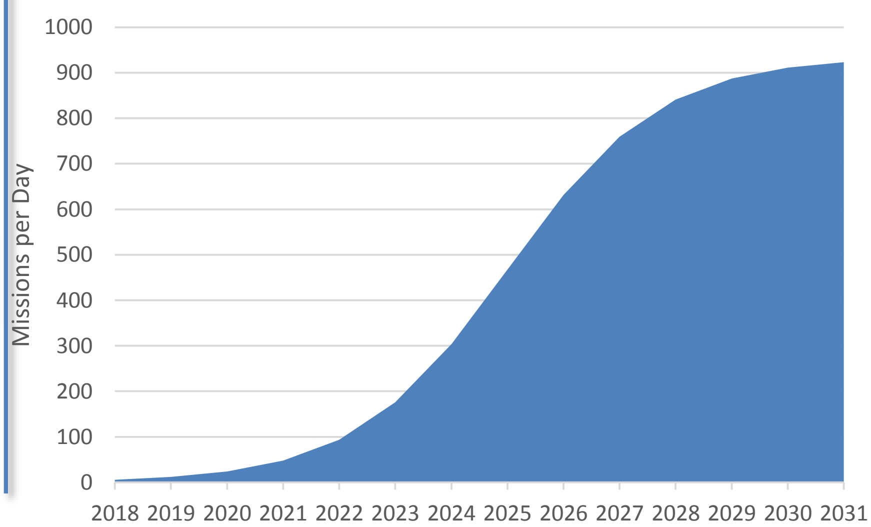
Cumulative Future Total: D

Description	Estimates
Rural traffic counting stations	2,436
Urban traffic counting stations	2,238
Total traffic counting stations	4,674
% stations benefit from UAS ops	5%
Total missions/day	**935**

Date Projections:

Start year A	2018 (Testing in Ohio and start-ups)
10% Growth B	2022 (Research periods end and adoption begins)
90% Growth C	2028 (Purchasing and replacing infrastructure)
Total Saturation D	935

UAS Demand:



VF-8 Localized Area Science Monitoring
Weather Monitoring

Key Assumptions:

- MISSION: 1 TO/Land
- UAS covers a 500 acre area in a single mission (Roadway & Science Area)
- Weather readings done at a single altitude (3000ft)
- Used paved roadways (Roadway WX)
- Assuming 10.5 hours of sunlight on average for VFR (Local WX)
- 2 missions per hour max (Local WX)

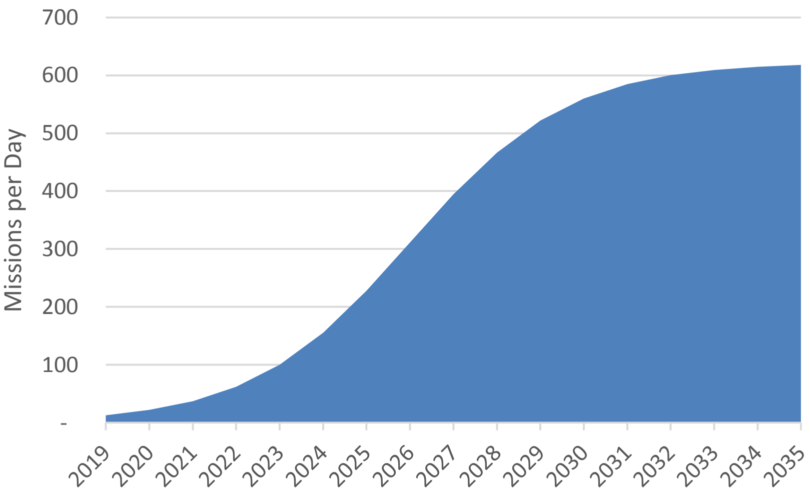
Cumulative Future Total: D

Sub Use Cases	Estimates
Local WX Monitoring	440
Science Area Monitoring	28
Roadway Weather	154
Total missions/day	**622**

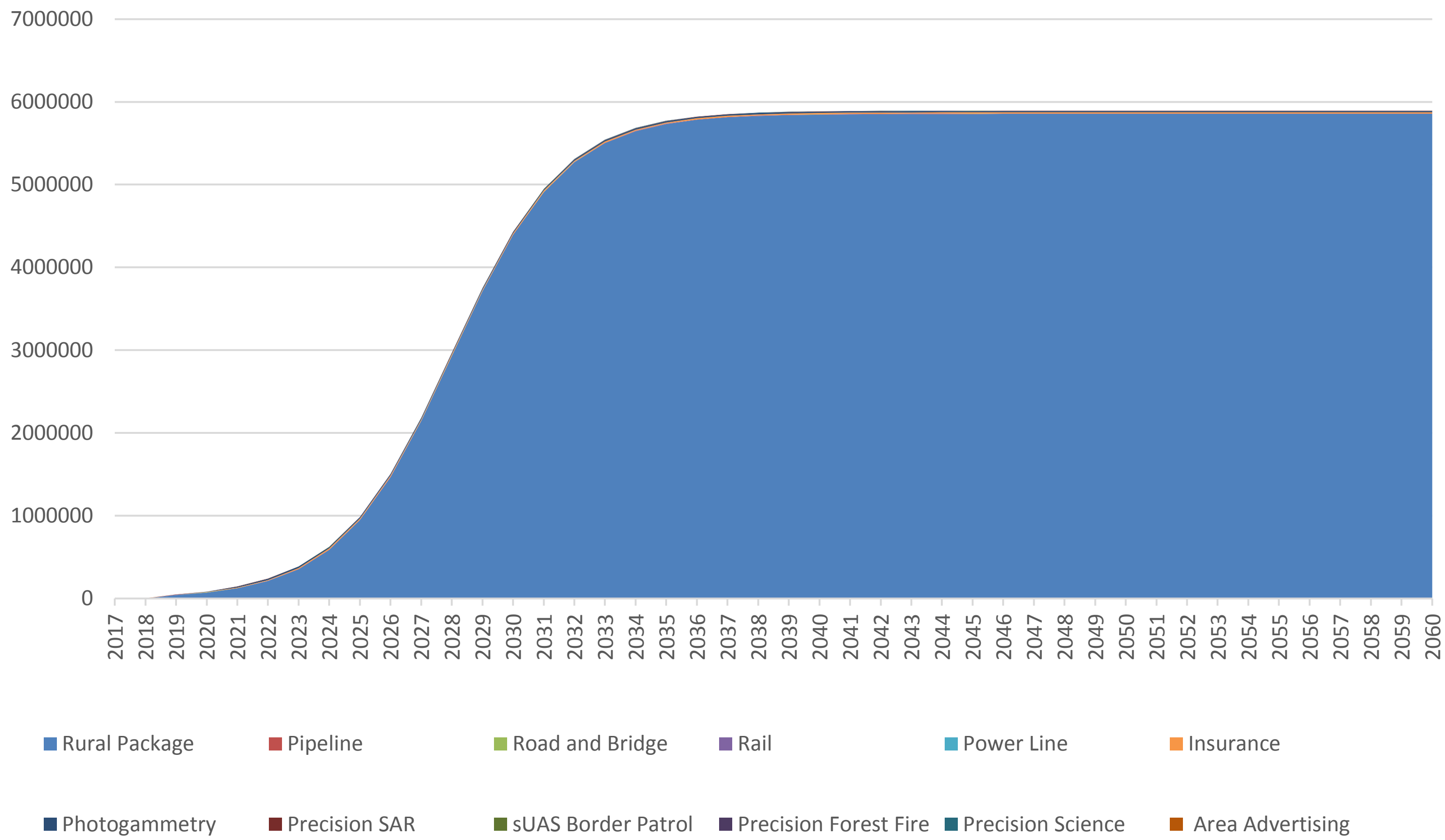
Date Projections:

Start year A	2019 (First use)
10% Growth B	2022 (micro-weather need grows)
90% Growth C	2030 (Technology improvement)
Total Saturation D	622

UAS Demand:



UAS Demand Forecast: Rural Low Altitude Use Cases



RL-1 Rural Package Delivery
Remote Town Package Delivery

Key Assumptions:

- **MISSION: 1 Completed Delivery (1-2 TO/Land)**
- **Preliminary testing begins in 2017**
- **Future Markets that cannot yet be quantified: Prescription delivery, Letters/General Mail**
- **UAS weighing under 55 lbs. will have a faster growth because of both FAA regulations and battery life of the UAS.**
- **Due to greater distances between delivery locations, assume 50% of deliveries by UAS**

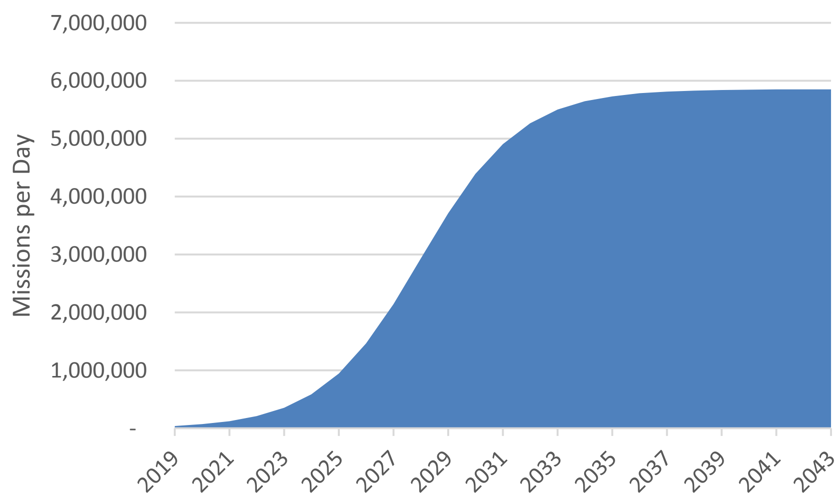
Cumulative Future Total per Day: D

Sub Use Cases	Calculated Estimates
Parcels	10,797,656
Prepared Food	840,764
Groceries	46,484
Flowers	23,035
% of UAS deliveries	50%
Total missions/day	**5,853,970**

Date Projections:

Start year A	2019 (Initial ops, trial cases)
10% Growth Year B	2024 (Regs/Infrastructure finalized)
90% Growth Year C	2032 (Country-wide ops)
Total Saturation D	5,853,970

UAS Demand:



RL-2 Infrastructure Inspection
Pipeline

Key Assumptions:

- MISSION: 1 TO/Land
- An oil and gas company is about to conduct its required monthly pipeline inspection. The company would usually hire a $2,500-an-hour helicopter crew for the job.
- UAS can survey 150 miles of pipeline per day
- $41 million market by 2020

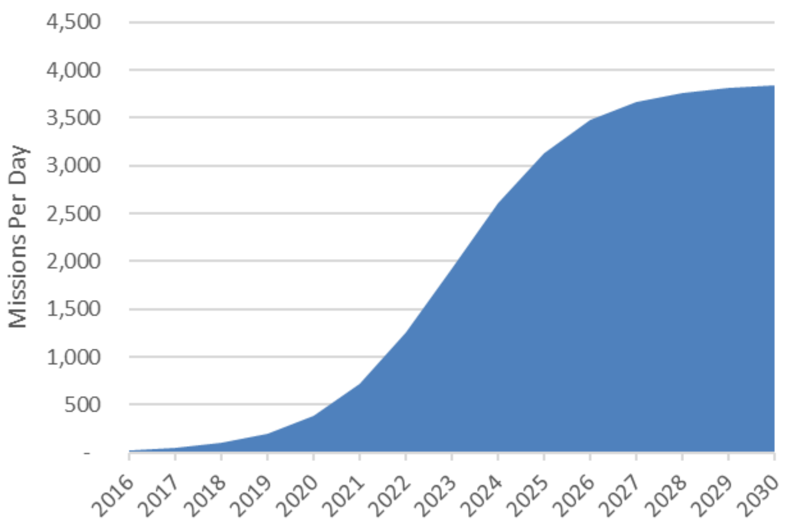
Cumulative Future Total: D

Sub Use Cases	Estimates
Pipeline	1,661
Non-pipeline (plants, tanks)	2,199
Total missions/day	**3,861**

Date Projections:

Start year A	2016 (Ops begin)
10% Growth B	2019 (Transition to UAS)
90% Growth C	2022 (Sensors used reach desirable price)
Total Saturation D	3,861

UAS Demand:



RL-3 Infrastructure Inspection
Road and Bridge

Key Assumptions:

- MISSION: 1 TO/Land
- All roads in state must be inspected annually
- Cars have a much longer range than UAS. This impacts the adoption year along with the miles surveyed per mission.
- Only 1 in 3 bridges need to be inspected by a UAS (rest are easier by foot)
- Each bridge must be inspected every 24 months

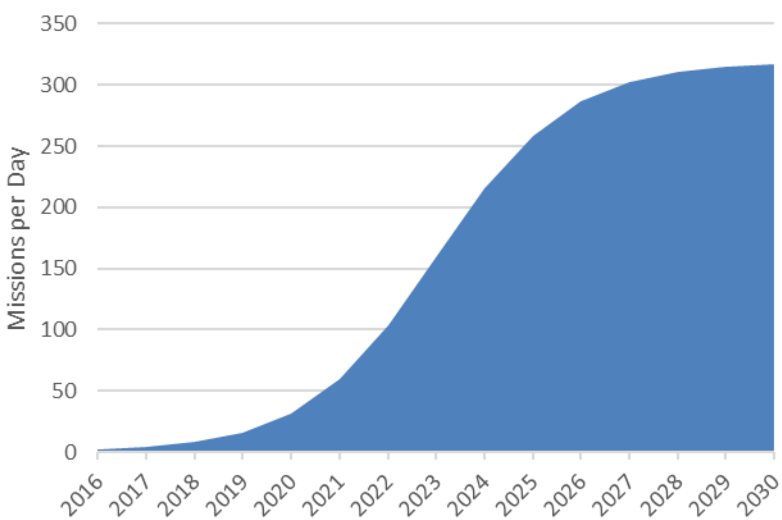
Cumulative Future Total: D

Sub Use Cases	Calculated Estimates
Roads	73
Bridges	245
Total missions/day	**318**

Date Projections:

Start year A	2016
10% Growth B	2020
90% Growth C	2026
Total Saturation D	318

UAS Demand:



RL-4 Infrastructure Inspection
Rail

Key Assumptions:

- MISSION: 1 TO/Land
- Whatever inspection methodology BNSF uses, will be adopted by the rest of the industry
- Assume all classes of tracks need inspections bimonthly
- Assume 1 mission can inspect 10 miles of track
- Small, local, rural railroads will contract with the larger carriers for UAS inspections

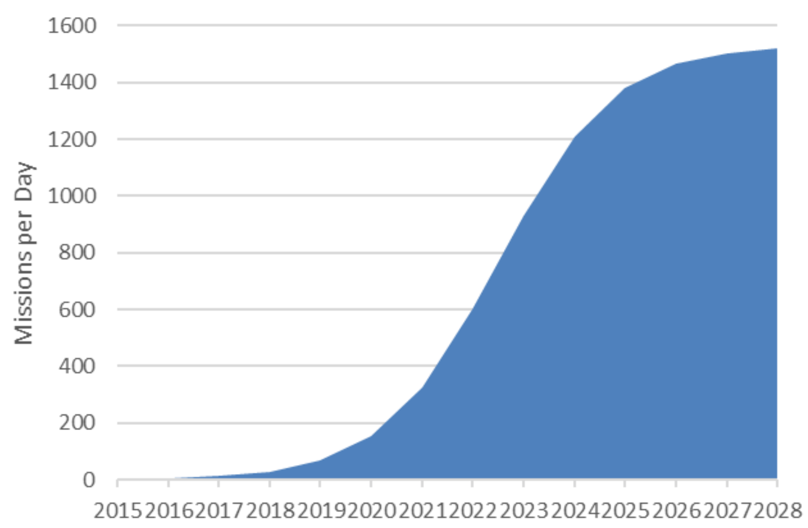
Cumulative Future Total: D

Description	Estimates
Miles of railroad tracks in US	233,000
Miles of track inspected per year	5,592,000
Total missions/day	**1,532**

Date Projections:

Start year A	2015 (BNSF Railway has been flying BVLOS)
10% Growth B	2020
90% Growth C	2025
Total Saturation D	1,532

UAS Demand:



RL-5 Infrastructure Inspection
Power Line

Key Assumptions:

- MISSION: 1 TO/Land
- Operations are limited on the number of tower inspections in a day with one UAS based on geographic separation
- Communication towers will be inspected annually

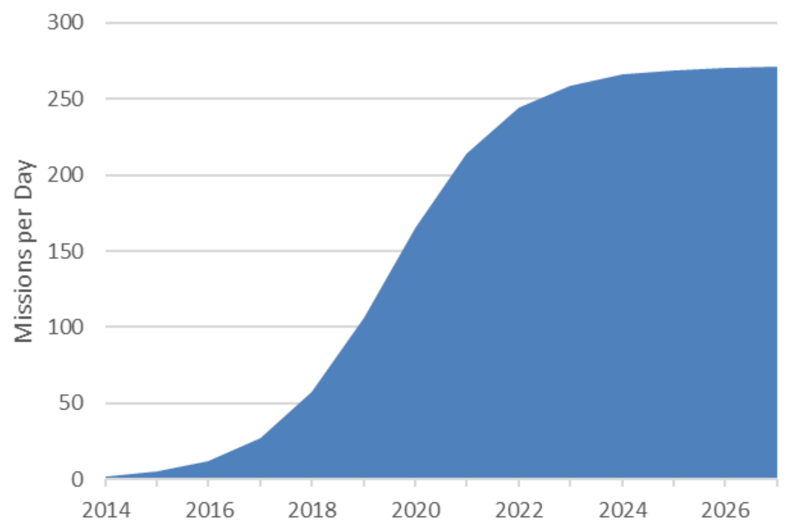
Cumulative Future Total: D

Description	Estimates
Miles of power lines in US	5,950,000
Large UAS missions per day	25
Small UAS missions per day	246
Total missions/day	**271**

Date Projections:

Start year A	2014
10% Growth B	2018
90% Growth C	2022 (BVLOS regulations adopted)
Total Saturation D	271

UAS Demand:



RL-6 Infrastructure Inspection
Post-Disaster/Insurance

Key Assumptions:

- MISSION: 1 TO/Land
- 15% of retail buildings & households have claims per year.
- Assume 1 building per mission.

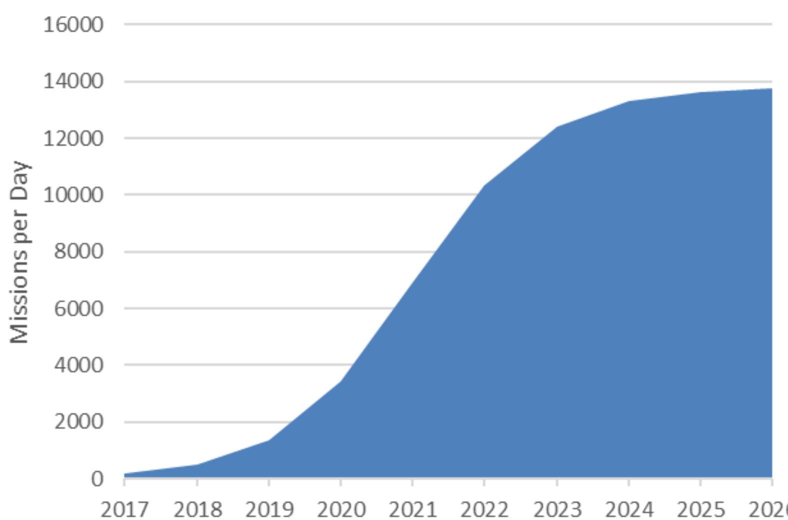
Cumulative Future Total: D

Sub Use Cases	Estimates
Household claims per day	12,785
Commercial claims per day	1,023
Total missions/day	**13,808**

Date Projections:

Start year A	2015 (First use by Eerie Insurance)
10% Growth B	2018 (Industry Adoption grows)
90% Growth C	2023 (Regulations for industry lifted)
Total Saturation D	13,808

UAS Demand:



RL-7 Photogrammetry
Surveying, Mapping

Key Assumptions:

- MISSION: 1 Property Survey (1+ TO/Land)
- Property survey is to ensure that property boundaries are accurate
- NOAA data includes nautical charting and habitat mapping
- Assume that 80% of property surveys would benefit from utilizing UAS v. traditional methods

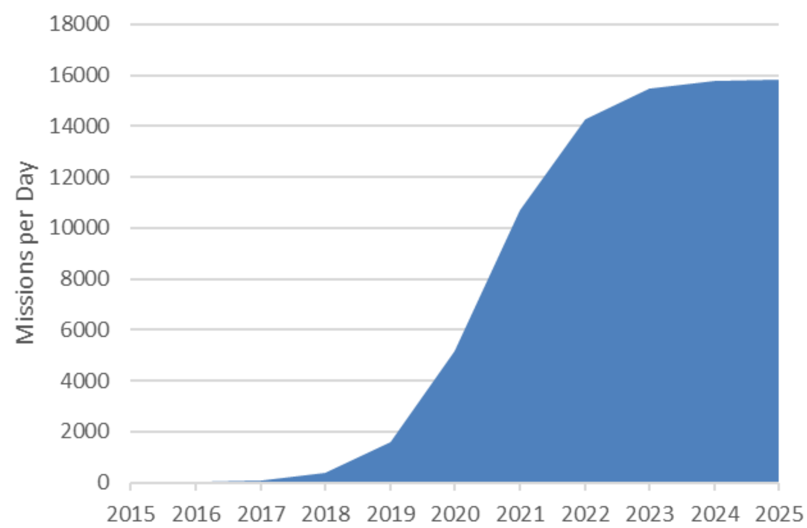
Cumulative Future Total: D

Sub Use Cases	Estimates
NOAA surveying	4
New private housing units	2,204
Existing housing units	11,198
Commercial building units	2,455
Total missions/day	**15,862**

Date Projections:

Start year A	2015 (NOAA began BVLOS mapping surveys)
10% Growth B	2019 (price will drive use)
90% Growth C	2022 (after regulations are adopted + transition to technology)
Total Saturation D	15,862

UAS Demand:



RL-8 Precision First Responder
Search & Rescue, Shark Spotting

Key Assumptions:

- MISSION: 1 TO/Land
- Assume 10 hours of operation per day with 2 missions per hour for shark spotting
- Shark spotting data is derived from areas across the US that have experienced a shark incident over the past 10 years
- SAR hours are derived from Coast Guard resource hours. Apply an order of magnitude of 3 to account for other agencies

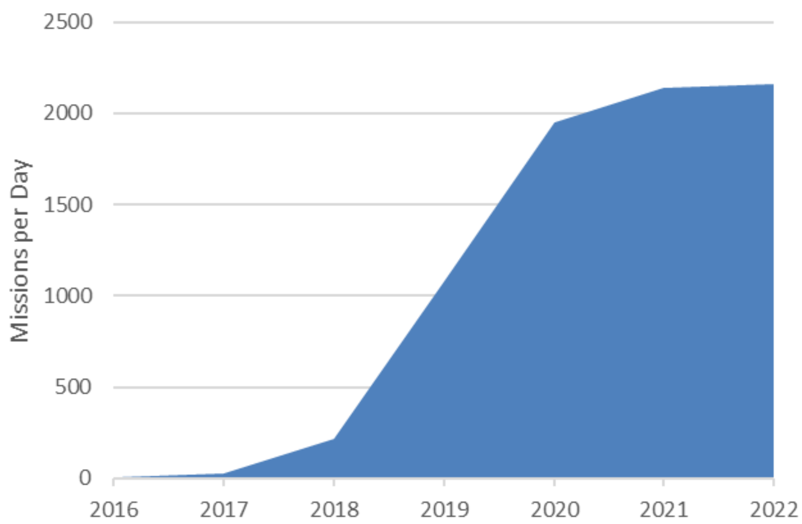
Cumulative Future Total: D

Sub Use Cases	Estimates
Search & rescue	1,013
Shark spotting	1,153
Total missions/day	**2,166**

Date Projections:

Start year (A)	2016
10% Growth (B)	2018
90% Growth (C)	2020
Total Saturation (D)	2,166

UAS Demand:



RL-9 Precision First Responder
sUAS Border Patrol

Key Assumptions:

- MISSION: 1 TO/Land
- CBP is currently flying 6 missions per day
- Assume that by 2022 this will grow 50x as technology becomes less expensive to allow for a limited budget and UAS operations become more efficient
- Assume that border patrol ops will be 24/7

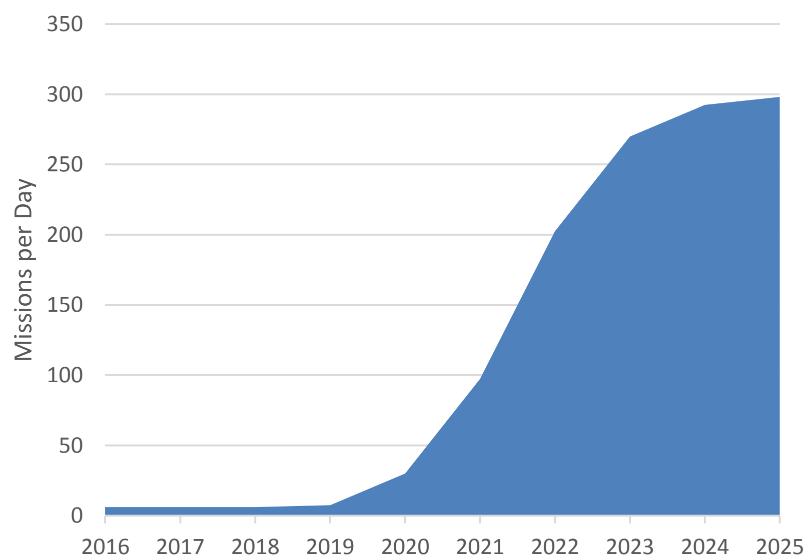
Cumulative Future Total: D

Description	Estimates
Miles of border that CBP monitors	6,900
Total missions/day	**300**

Date Projections:

Start year A	2010
10% Growth B	2020
90% Growth C	2024
Total Saturation D	300

UAS Demand:



RL-10 Precision First Responder
Forest Fires

Key Assumptions:

- MISSION: 1 TO/Land
- Assume 270 days/yr. of fire fighting season
- There is currently no night aerial fire fighting capability (high risk assessment), assume by 2020 there will be that capability
- Swarms of drones would require a many vehicles (the most retardant a drone has been proposed to carry to date is 7 gal - DARPA)

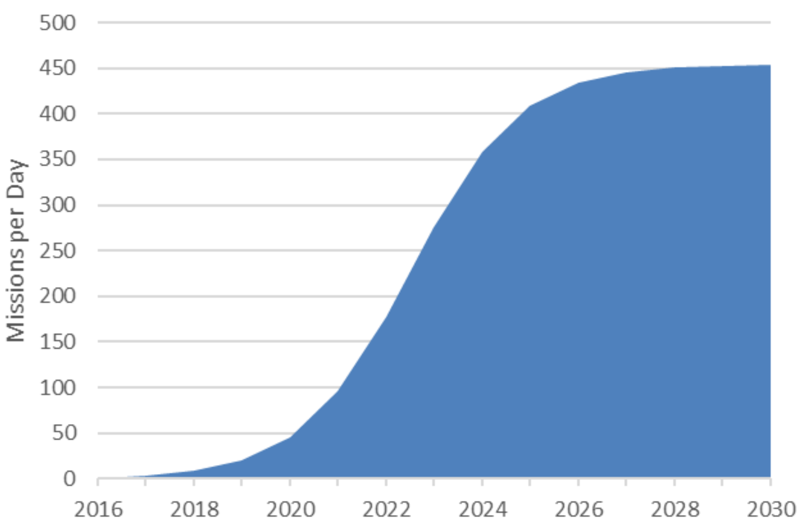
Cumulative Future Total: D

Description	Estimates
Total DOI UAS forest fire flights	707
Total mi^2 of national forests	294,275
Total missions/day	**454**

Date Projections:

Start year A	2017 (Ops began in few high risk areas)
10% Growth B	2020 (High risk areas begin to adopt)
90% Growth C	2025 (US wide adoption)
Total Saturation D	454

UAS Demand:



RL-11 Precision Science Monitoring
Tornado Watching, Flood Damage

Key Assumptions:

- MISSION: 1 TO/Land
- Flood damage missions based on amount of policy claims made.
- One drone per claim for flood use case.
- Mission covers distance travelled by tornado.
- Average amount of tornados per year 1,262.
- Every new tornado is a new mission.

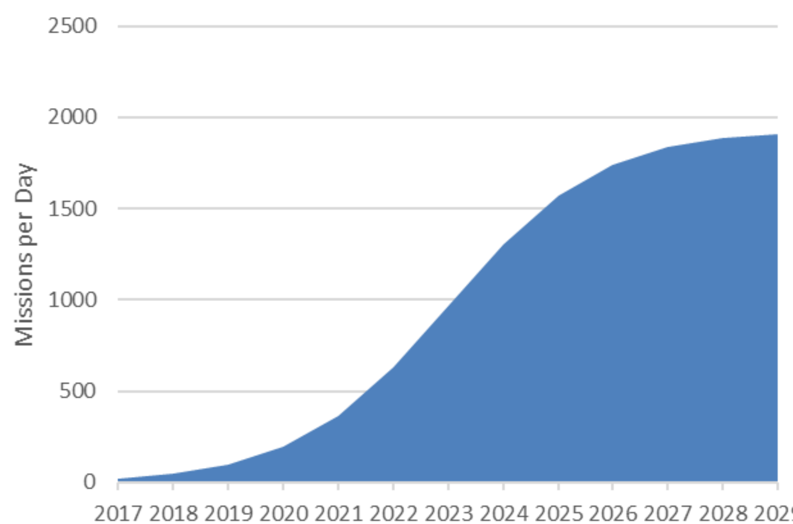
Cumulative Future Total: D

Description	Estimates
Total Floods	1926
Tornado missions per day	4
Total missions/day	**1,930**

Date Projections:

Start year A	2017 (First use with waivers)
10% Growth B	2020 (Usefulness accepted)
90% Growth C	2026 (Technology improves)
Total Saturation D	1,930

UAS Demand:



RL-12 Advertising

Beach Banner Advertisements

Key Assumptions:

- MISSION: 1 TO/Land
- Assume similar operations across all aerial advertising in CONUS to High Exposure Aerial Advertising (HEAA)
- 5,839 total miles of coast in CONUS
- Assume ¼ of total miles will be flown for aerial advertising = 1,460 miles
- Due to weather, assume operations occur for 1/3 of year

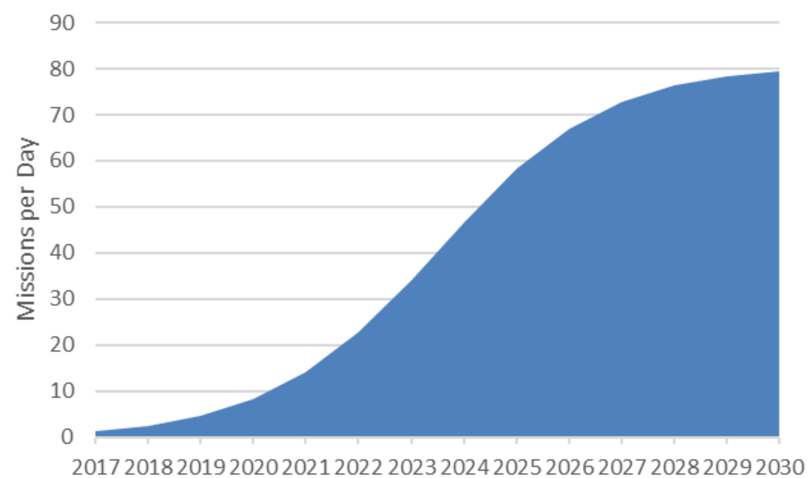
Cumulative Future Total per Day: D

Sub Use Cases	Calculated Estimates
Number of HEAA flights in 2017	3,200
Miles of coast covered by HEAA	182
Order of magnitude -> total coastal aerial advertising flight	8
Total flights per year	29,516
Total missions/day	**81**

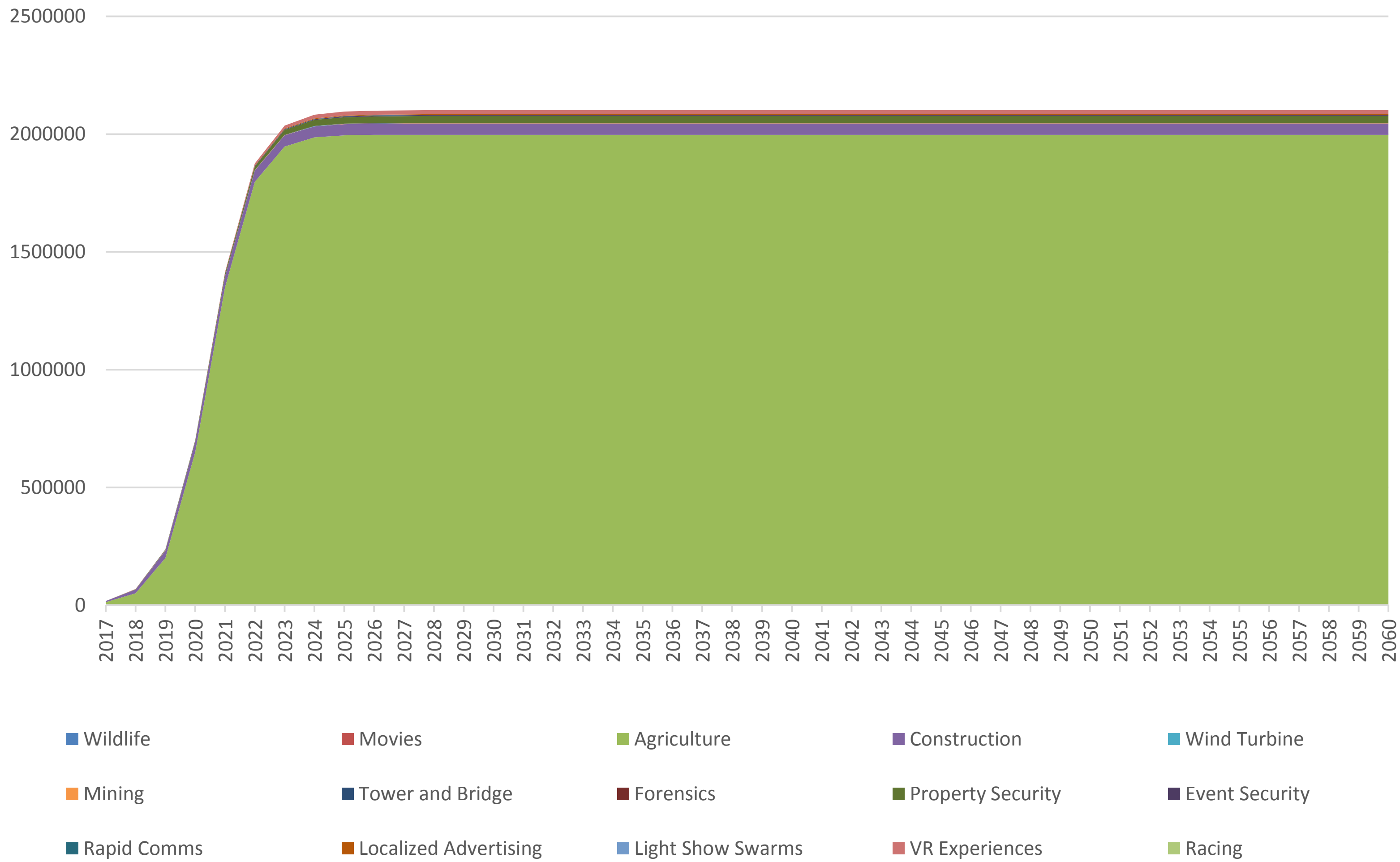
Date Projections:

Start year A	2017 (Part 107 regulations)
10% Growth Year B	2020 (Dave Dempsey, HEAA)
90% Growth Year C	2027 (Dave Dempsey, HEAA)
Total Saturation D	81

UAS Demand:



UAS Demand Forecast: VLOS Use Cases



VL-1 Aerial Photography
Wildlife Monitoring

Key Assumptions:

- MISSION: 1 TO/Land
- Assume 1 operation = 4 missions per day
- 1 mission = 3 hours of flight
- Data obtained from the National Oceanic and Atmospheric Administration (NOAA)
- Assume other organizations will utilize UAS for wildlife monitoring (e.g. United States Fish and Wildlife Service (NSFWS))

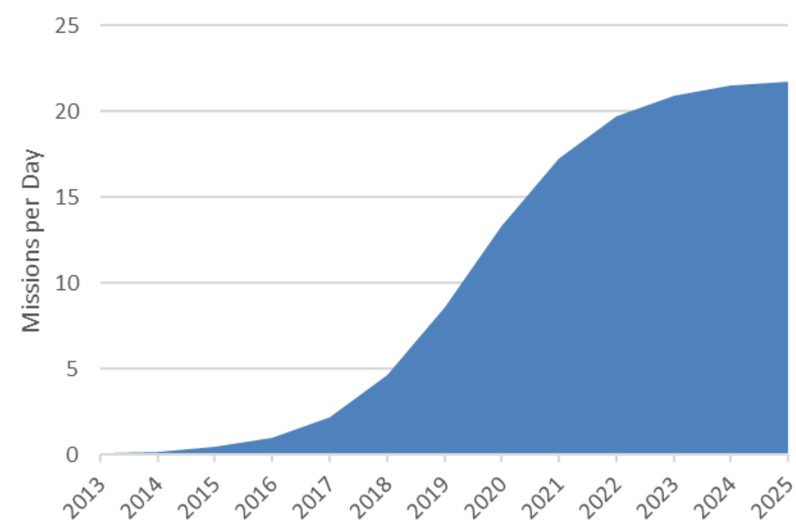
Cumulative Future Total per Day: D

Description	Estimates
NOAA manned/unmanned operations per year	1,000
NOAA missions per year	4,000
Other organizations (e.g. NSFWS)	4,000
Total missions per year	8,000
Total missions/day	**22**

Date Projections:

Start year (A)	2013 (NOAA began wildlife surveys via UAS)
10% Growth Year (B)	2017 (Significant growth in NOAA UAS ops)
90% Growth Year (C)	2022 (Wildlife monitoring can be accomplished with current FARs)
Total Saturation (D)	22

UAS Demand:



VL-2 Aerial Filming/News

Movies

Key Assumptions:

- MISSION: 1 TO/Land
- Some films will be primarily indoors (i.e. won't be utilizing UAS in the NAS)
- Other films will fly more than 2 missions per day (i.e. action films, war films)
- To counter these, assume on average 3 missions are flown per 1 day of shooting

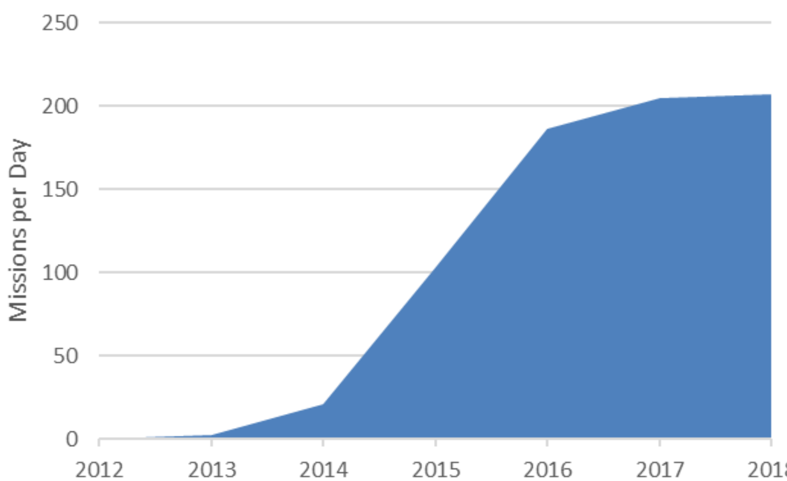
Cumulative Future Total per Day: D

Description	Estimates
Movies filmed in 2017	238
Days of shooting per 1 movie	106
Total missions/day	**207**

Date Projections:

Start year (A)	2012 (UAS used in Skyfall)
10% Growth Year (B)	2014 (FAA grants waivers)
90% Growth Year (C)	2016 (FAA establishes final regulations for filming)
Total Saturation (D)	207

UAS Demand:



VL-3 Structure/Low Area Inspection/Survey
Agriculture

Key Assumptions:

- MISSION: 1 TO/Land
- Assume 1 mission covers 2,000 acres
- 1 mission = 1 UAS in flight for 30 minutes
- Assume UAS will be flown 250 days a year

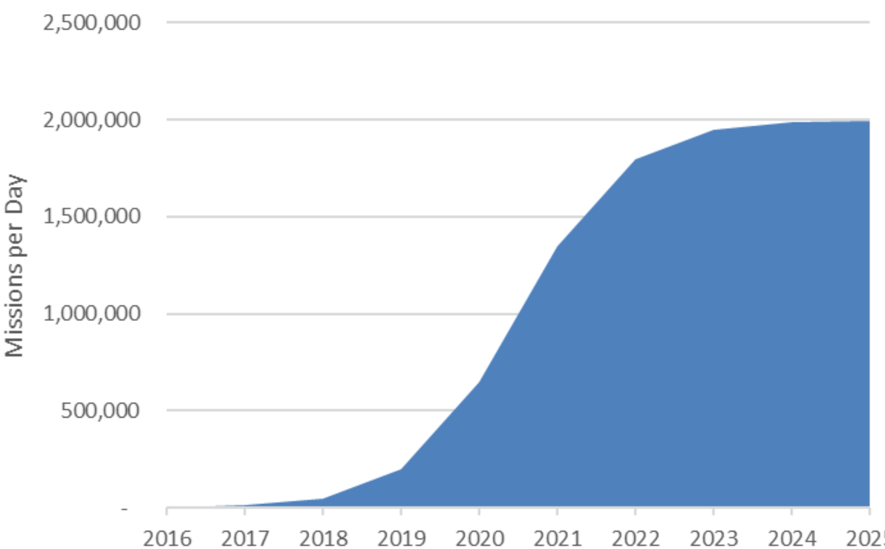
Cumulative Future Total per Day: D

Sub Use Cases	Calculated Estimates
Farms	1,994,700
Orchards	826
Vineyards	2,180
Total missions/day	**1,997,706**

Date Projections:

Start year	A	2016 (ops begin)
10% Growth Year	B	2019 (become economically necessary to compete)
90% Growth Year	C	2022 (standard practice across industry)
Total Saturation	D	1,997,706

UAS Demand:



VL-4 Structure/Low Area Inspection/Survey
Construction

Key Assumptions:

- MISSION: 1 TO/Land
- 75% of US housing constructions are capable of VLOS missions
- 50% of housing construction will fly 2x month
- 75% of commercial building constructions are capable of VLOS missions
- 75% of commercial building construction will fly 3x week

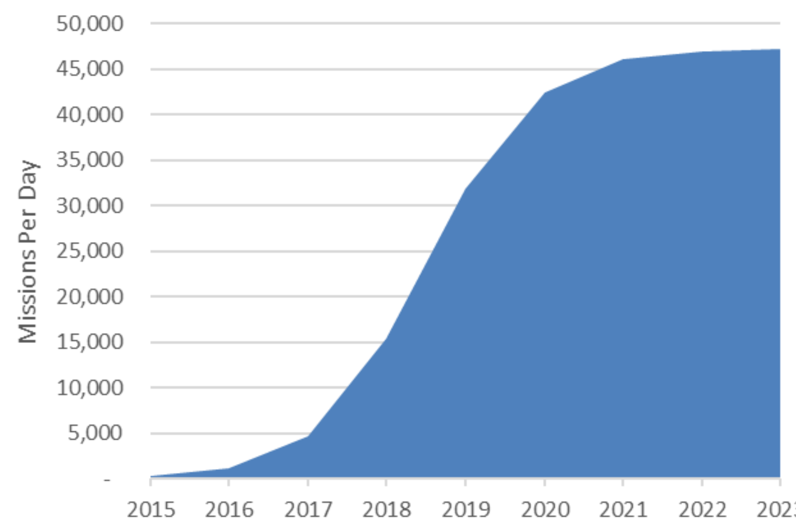
Cumulative Future Total per Day: D

Sub Use Cases	Estimates
Housing Construction	24,800
Commercial Construction	22,438
Total missions/day	47,239

Date Projections:

Start year A	2015 (Companies begin ops)
10% Growth Year B	2017 (Goldman Sachs UAV Report)
90% Growth Year C	2020 (sensor outperform, GPS improves)
Total Saturation D	47,237

UAS Demand:



VL-5 Structure/Low Area Inspection/Survey
Wind Turbine Inspection

Key Assumptions:

- MISSION: 1 TO/Land
- Each wind turbine must be inspected once per year
- One UAS is used to inspect one turbine and completes one mission per day

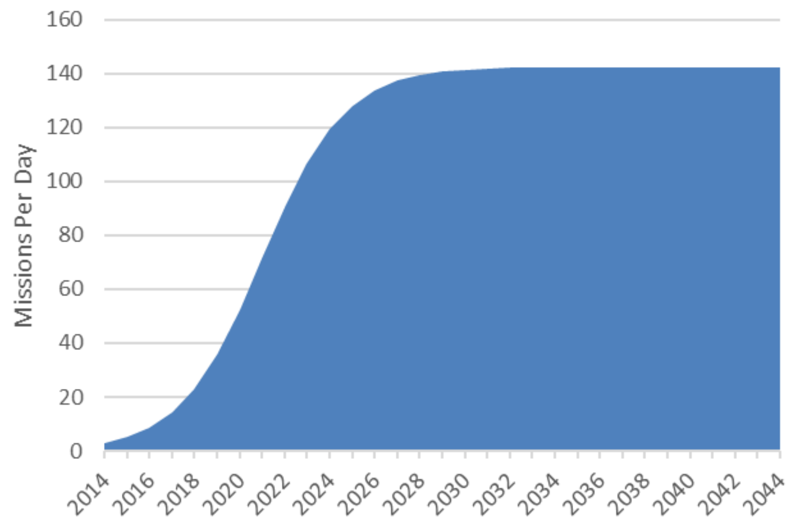
Cumulative Future Total per Day: D

Description	Estimates
# of wind turbines in US	52,000
Total missions/day	**142**

Date Projections:

Start year A	2014 (waivers were granted for this use case)
10% Growth Year B	2017 (Part 107 implementation)
90% Growth Year C	2025 (Assume similar technology growth)
Total Saturation D	142

UAS Demand:



VL-6 Structure/Low Area Inspection/Survey
Mining/Landfill

Key Assumptions:

- MISSION: 1 TO/Land
- UAS will be used for surveys, surveillance, real time analysis, inventory, search for new deposits and safety assessments
- Each mine needs three weeks of flying per visit (based on 990 min to survey 80 hectares at 1 km/min)
- Major mines own at least 2 UAS per site
- Most smaller miles will contract out for services

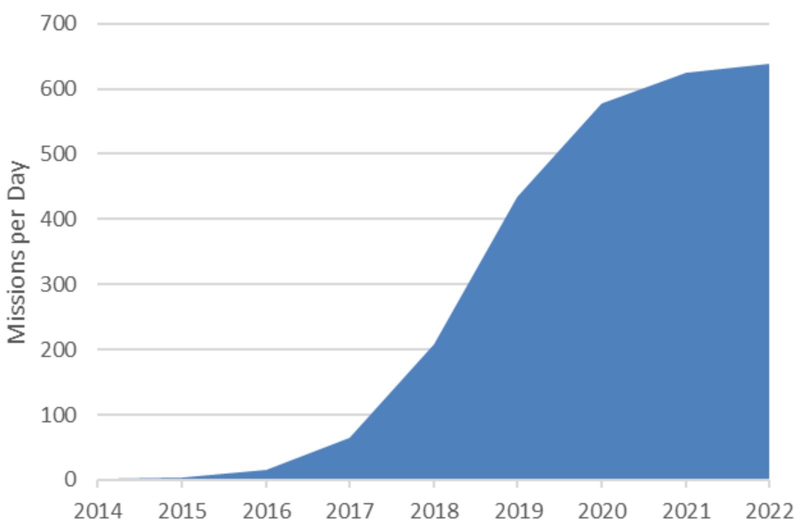
Cumulative Future Total per Day: D

Sub Use Cases	Calculated Estimates
Active surface mines in US	12,637
# of mines large enough to own UAS	632
# of minor mines needing UAS brought in	5,687
Total missions/day	**642**

Date Projections:

Start year A	2014 (Year that mining operators began testing and utilizing UAS)
10% Growth Year B	2017 (Adoption of Part 107 + 1 year of ramp-up time)
90% Growth Year C	2020
Total Saturation D	642

UAS Demand:



VL-7 Structure/Low Area Inspection/Survey
Tower/Bridge Inspection

Key Assumptions:

- MISSION: 1 TO/Land
- 1 in 3 bridges require aerial inspection, the rest can be inspected from the ground
- Bridge inspections every 24 months
- Telecom Tower inspections every 12 months
- 200 workdays/year
- Large chimneys were considered, but data was extremely subjective, and most would not benefit from regular inspections.

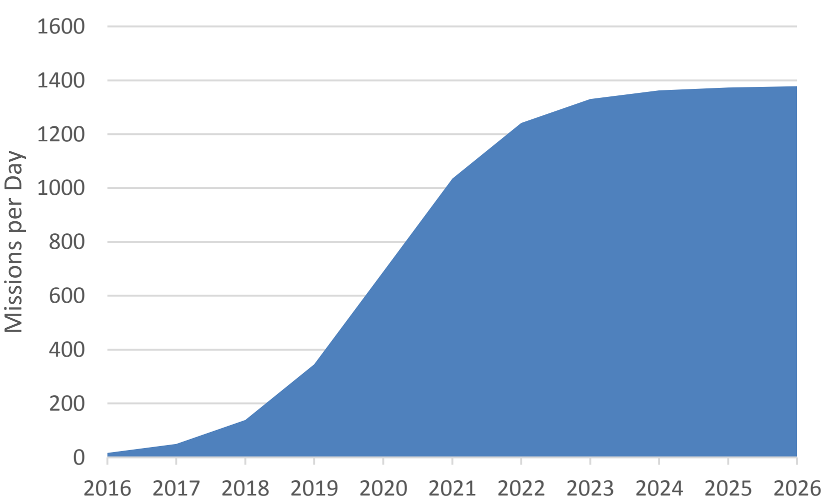
Cumulative Future Total per Day: D

Sub Use Cases	Calculated Estimates
# of US Bridges	587,840
Missions/day	537
# of US Telecom Towers	307,626
Mission/day	843
Total missions/day	**1380**

Date Projections:

Start year A	2016 (Inspections initiated)
10% Growth Year B	2019 (Increased usage)
90% Growth Year C	2022 (Industry normalization)
Total Saturation D	1,380

UAS Demand:



VL-8 Structure/Low Area Inspection/Survey
Forensic/Accidents

Key Assumptions:

- MISSION: 1 TO/Land
- Covering only serious vehicle accidents resulting in fatalities
- Assessing murder scenes, assuming ½ require UAS assistance (not indoors)

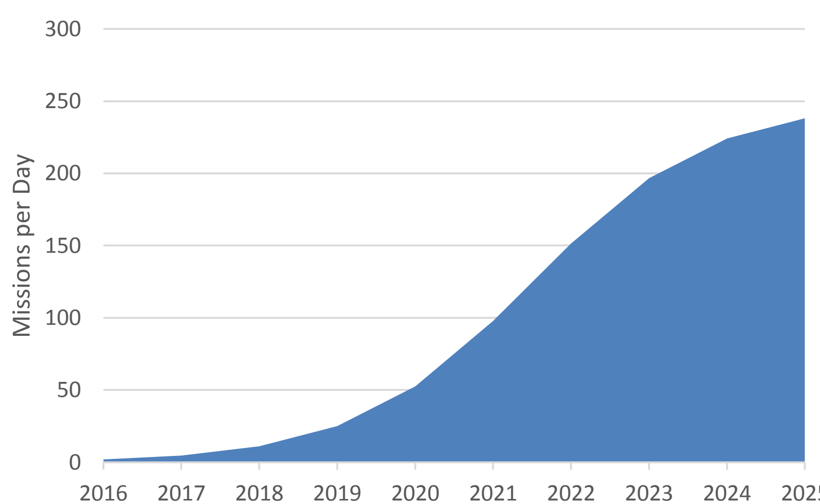
Cumulative Future Total per Day: D

Sub Use Cases	Calculated Estimates
Accidents/day	89
Missions/accident	2
Murders/day	48
Missions/murder	3
Total missions/day	**249**

Date Projections:

Start year A	2016 (Police forces using UAS)
10% Growth Year B	2019 (Increased usage)
90% Growth Year C	2024 (Widespread usage)
Total Saturation D	249

UAS Demand:



VL-9 Security/Emergency Management

Property Fence Line Security

Key Assumptions:

- MISSION: 1 TO/Land
- 24/7 UAS security for one building would require 2 missions per day
- 25% of commercial buildings will use UAS
- 25% of commercial buildings using UAS will use 24/7 UAS security
- 75% of commercial buildings will use 15 hours of UAS security per day, on average
- 11% of households will use UAS security
- 1% of total to use UAS over surveillance cameras due to uniqueness of property

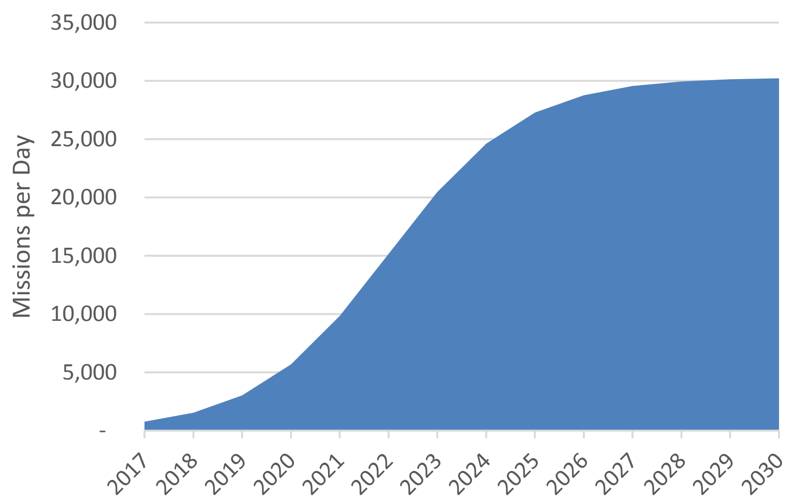
Cumulative Future Total per Day: D

Sub Use Cases	Estimates
Missions per day – 24/7 commercial	700,000
Missions per day – 15 hr. commercial	1,312,500
Missions per day – households	1,017,500
% of mission unique to UAS over standard surveillance cameras	1%
Total missions/day	**30,300**

Date Projections:

Start year A	2017 (Nightingale deploys to consumers)
10% Growth Year B	2019 (Commercial adoption grows)
90% Growth Year C	2025 (Technology becomes viable for homeowners)
Total Saturation D	30,300

UAS Demand:



VL-10 Security/Emergency Management
Event Security

Key Assumptions:

- MISSION: 1 TO/Land
- Event is defined as a gathering of >1,000 people
- Data includes stadiums, amphitheaters with capacity to seat >1,000 people
- 1 mission = 1 UAS operating for 30 minutes

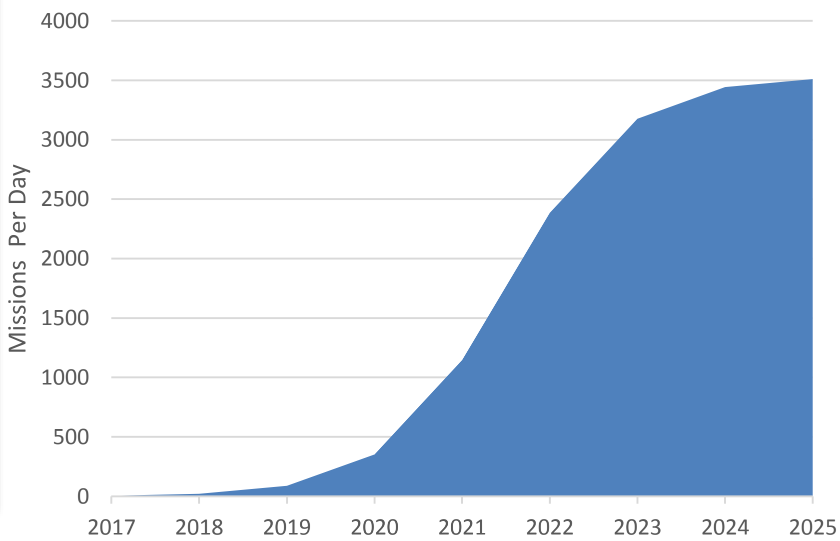
Cumulative Future Total per Day: D

Sub Use Cases	Calculated Estimates
Stadiums	3,057
Amphitheaters	475
Total missions/day	**3,531**

Date Projections:

Start year (A)	2017 (used at the Super Bowl and inauguration)
10% Growth Year (B)	2020 (Begin to become economically viable)
90% Growth Year (C)	2023 (Standard tool for security personnel)
Total Saturation (D)	3,531

UAS Demand:



VL-11 Security/Emergency Management
Rapid Aerial Communications

Key Assumptions:

- MISSION: 1 TO/Land
- Assume for every incident, ten missions will be flown

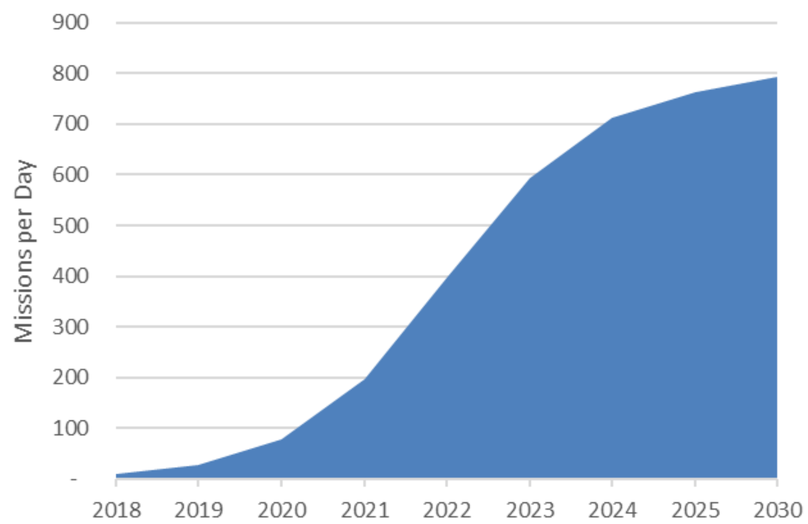
Cumulative Future Total per Day: D

Description	Estimates
Incidents per year causing communication failures	28,909
Incidents per day causing communication failures	79.2
Total missions/day	**792**

Date Projections:

Start year A	2018 (First use in live scenario)
10% Growth Year B	2020 (Agencies begin adopting)
90% Growth Year C	2024 (Agencies required to adopt)
Total Saturation D	792

UAS Demand:



VL-12 Advertising/Entertainment
Sporting Event Advertising

Key Assumptions:

- MISSION: 1 TO/Land
- Data accounts for professional sports events
- Data assesses stadium and non-stadium sport events
- Baseline of 10 UAS to advertise per event
- Factor of 2 to account for winter and summer sports (e.g. bike races, marathons, boat races)

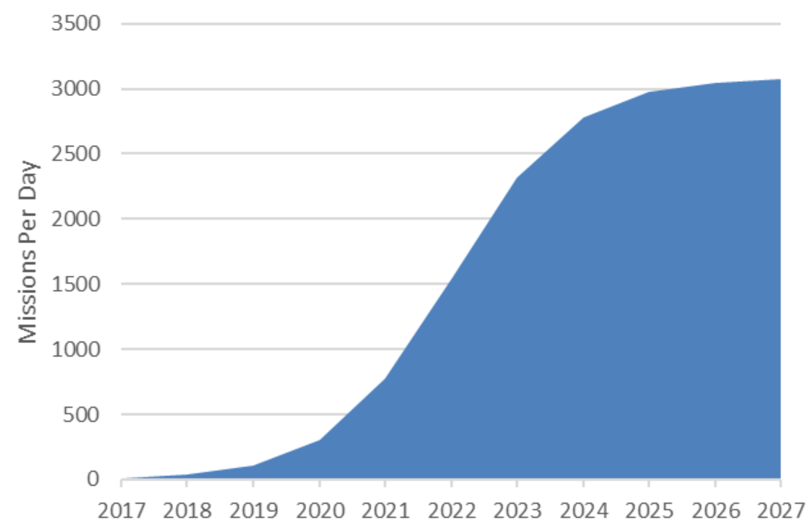
Cumulative Future Total per Day: D

Sub Use Cases	Calculated Estimates
Stadium sports	2,052
Auto racing	2
Golf	3
Fishing	1
Total missions/day	**3,086**

Date Projections:

Start year A	2017
10% Growth Year B	2020
90% Growth Year C	2024
Total Saturation D	3,086

UAS Demand:



VL-13 Advertising/Entertainment
Light Show Swarms

Key Assumptions:

- MISSION: 1 Swarm TO/Land (Multiple UAS)
  - 1 light show could have 2000+ UAS airborne simultaneously
- Miscellaneous sub use cases include, but are not limited to – festivals, large celebrations, weddings, etc.
  - Account for these unknowns with 2x of the other sub use cases

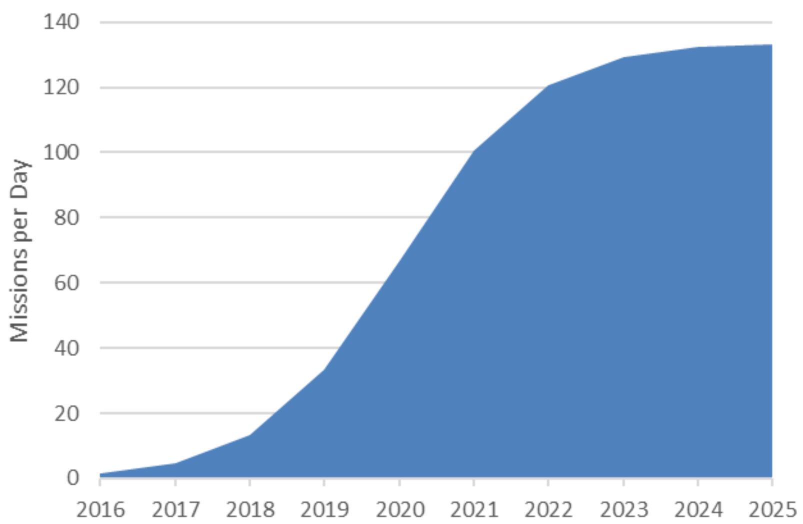
Cumulative Future Total per Day: D

Sub Use Cases	Estimates
Amusement Parks	27
Firework Replacement	36
Sporting Events	4
Misc. Use Case Factor	x2
Total missions/day	**134**

Date Projections:

Start year A	2016 (1st show in the NAS at Disney)
10% Growth Year B	2018 (Significant growth in shows – Intel)
90% Growth Year C	2022 (Transition from traditional methods – cost, training, infrastructure, etc.)
Total Saturation D	134

UAS Demand:



VL-14 Advertising/Entertainment
VR Experiences

Key Assumptions:

- MISSION: 1 TO/Land
- Assume all flight schools would use VR UAS as a training tool
- Assume people using VR UAS technology for entertainment are hobbyist and not commercial entities
- For entertainment it is assumed 365 days a year and no weather or time assumption was made

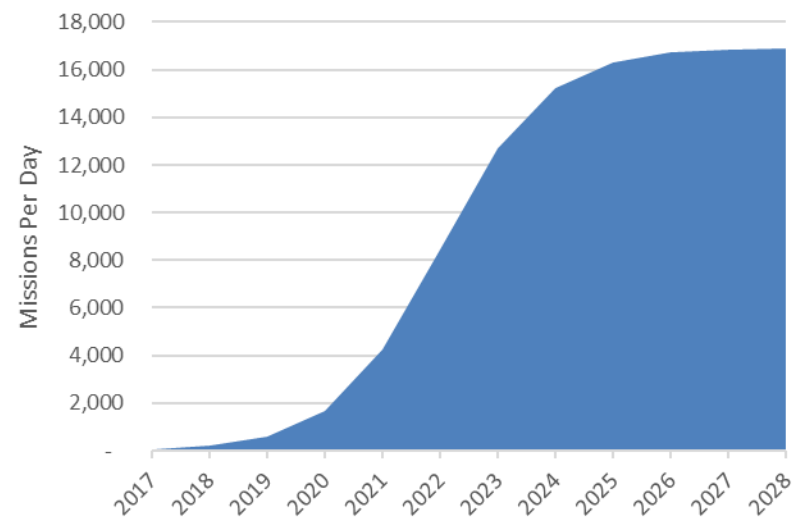
Cumulative Future Total per Day: D

Sub Use Cases	Calculated Estimates
VR Training	9,962
VR Entertainment	1,316
Factor for growth	1.5
Total missions/day	16,917

Date Projections:

Start year A	2017 (Ops began)
10% Growth Year B	2020 (Capabilities improve)
90% Growth Year C	2024 (Replacement of traditional methods)
Total Saturation D	16,917

UAS Demand:



VL-15 Advertising/Entertainment
Racing

Key Assumptions:

- MISSION: 1 Race TO/Land (Multiple UAS)
  - 1 mission/1 race would have anywhere from 2-20+ UAS flying in the same course at a time
- Currently, a large amount of drone racing is done indoors with structured obstacle courses.
- Large race = Tier 1 registered with MultiGP
- Assume popularity will increase and steady out to 5,000 registered races per year

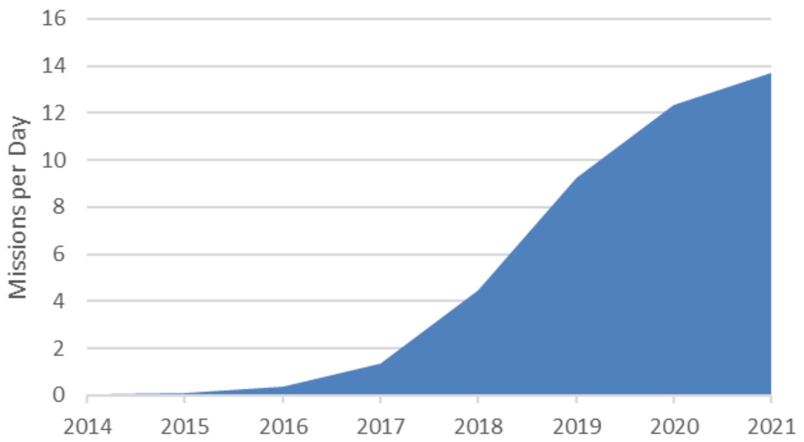
Cumulative Future Total per Day: D

Description	Estimates
# of large registered races per year	3,117
Small races and growth per year	1559
Total missions per year	5,000
Total missions/day	**14**

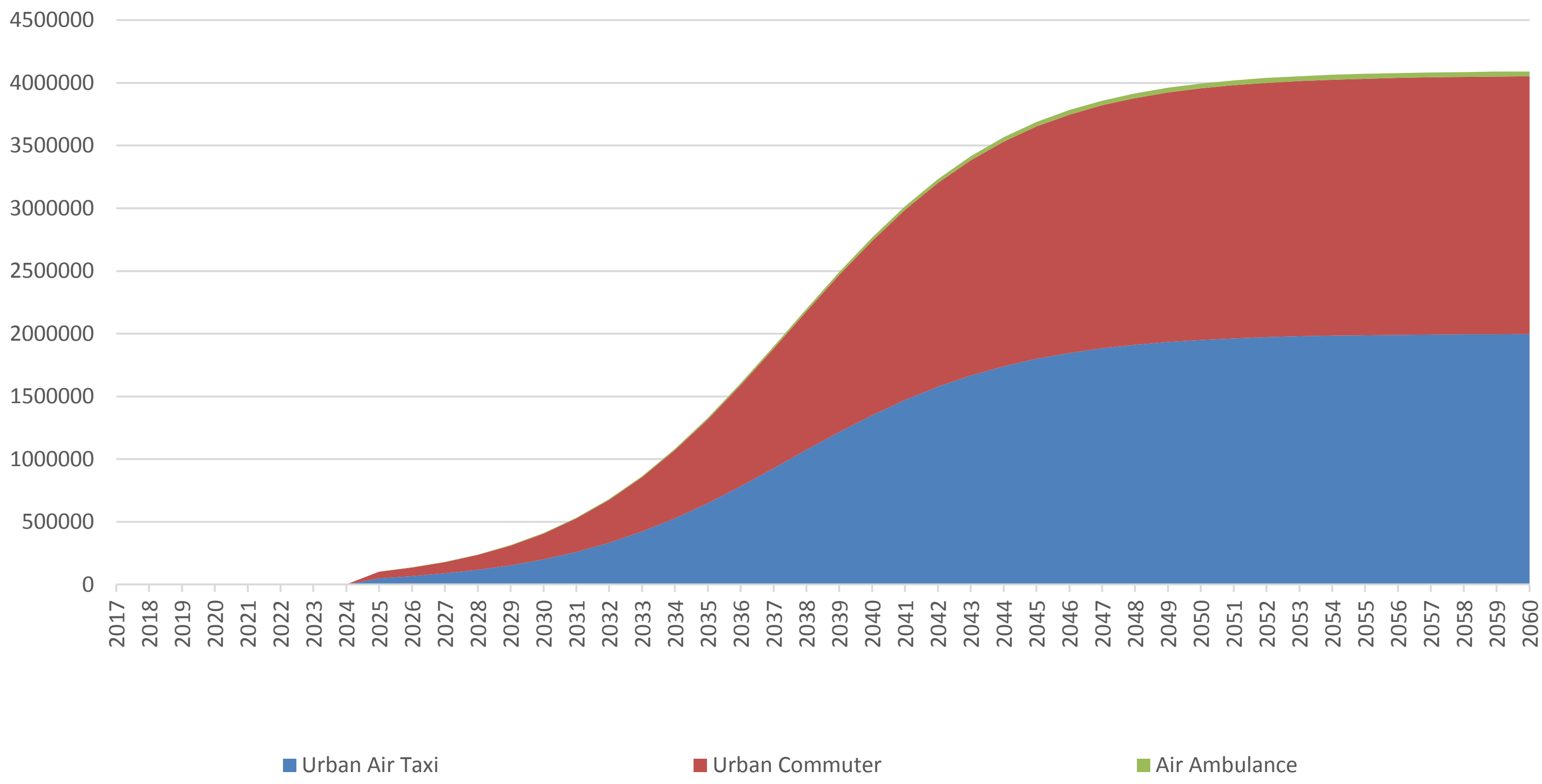
Date Projections:

Start year A	2014 (1st official race in CA)
10% Growth Year B	2017 (dramatic increase in registered races)
90% Growth Year C	2020 (price and popularity will drive growth)
Total Saturation D	14

UAS Demand:



UAS Demand Forecast: Urban Passenger Use Cases



UP-1 Urban Air Taxi
Point to Point

Key Assumptions:

- MISSION: 1 Passenger Delivery (1-2 TO/Land)
- Demand is based off of 10 urban areas (New York, Los Angeles, Dallas, Miami, Houston, San Francisco, Washington D.C., Phoenix, Denver, Hawaii)
- Different aircraft will have different seating capacities. Assume 1-5 seat configurations
- Numbers are conservative to acknowledge demand reduction due to operations in specific time of day. Factors include demand, legal/regulatory restrictions, weather etc.

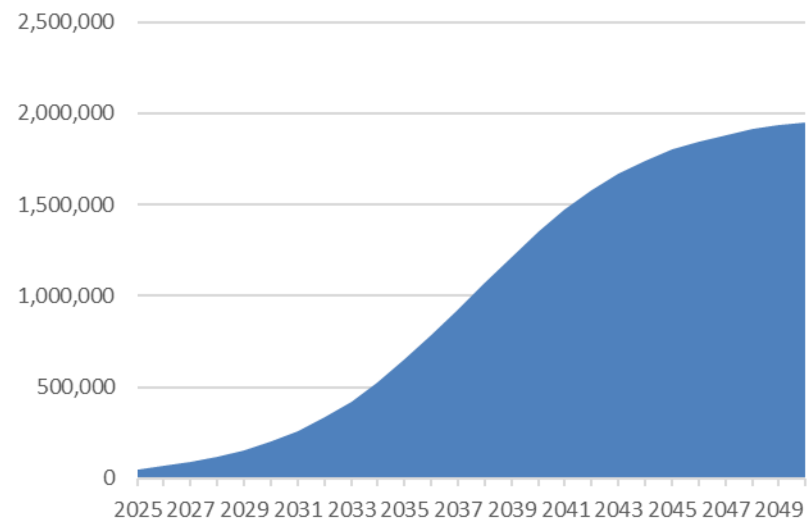
Cumulative Future Total: D

Sub Use Cases	Calculated Estimates
Time of day constraint	125,000
Capacity constraint	150,000
Infrastructure constraint	270,000
Total missions/day	**1,949,926**

Date Projections:

Start year A	2025 (Uber's goal)
10% Growth B	2030 (Uber's goal)
90% Growth C	2045 (Regulations, technology, public acceptance)
Total Saturation D	1,949,926

UAS Demand:



UP-2 Urban Commuter
Set Routes/Schedule

Key Assumptions:
- MISSION: 1-Way Passenger Delivery (1 TO/Land)
- Routes are predetermined and scheduled well in advance of flight time
- Data looks at top 10 urban metro areas (New York, San Francisco, Washington D.C., Chicago, Boston, Seattle, Philadelphia, Atlanta, Los Angeles, Portland)
- 1 mission transports 5 passengers

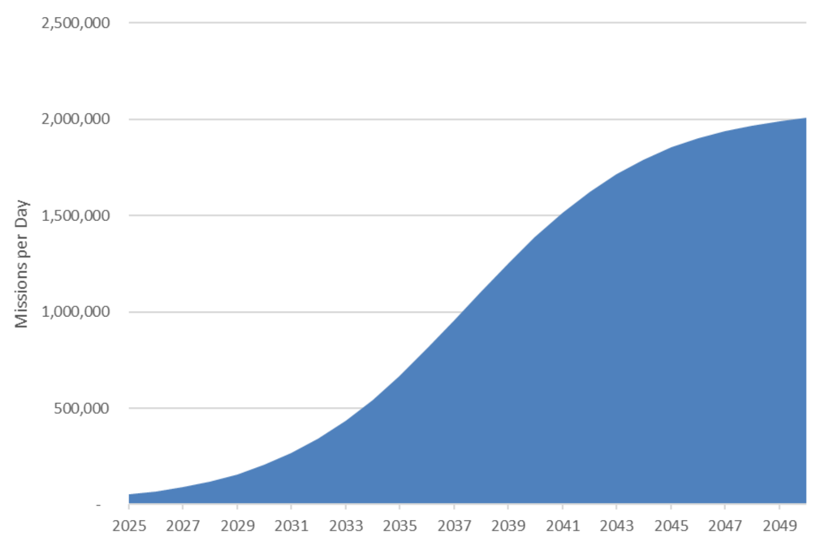
Cumulative Future Total: D

Sub Use Cases	Calculated Estimates
Annual transit passenger individual trips	3,755,236,133
Daily transit passenger individual trips	10,288,318
Passengers per mission	5
Total missions/day	**2,057,664**

Date Projections:

Start year A	2025 (Ops begin in select areas)
10% Growth B	2030 (Service begins to be profitable)
90% Growth C	2045 (Standard form of transportation)
Total Saturation D	2,057,664

UAS Demand:



UP-3 Urban Ambulance
Medical Evacuation

Key Assumptions:

- MISSION: 1 MedEvac (2-3 TO/Land)
- Medical evacuation includes transport to hospitals, dialysis centers, and skilled nursing facilities
- Assume medical evacuation will be a front-runner in passenger carrying missions due to the high risk/high reward nature of ambulatory services.
- Estimate assumes a conservative number of UAS ambulance rides

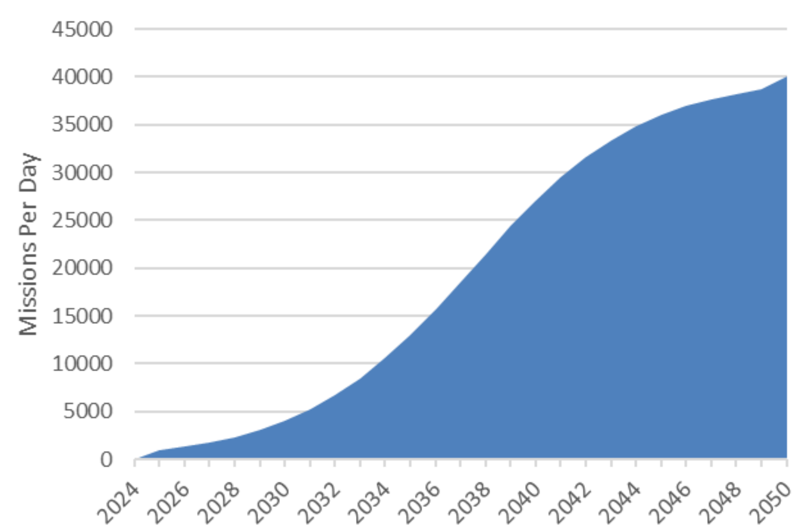
Cumulative Future Total: D

Description	Estimates
Daily manned air ambulance missions	235
Daily ground ambulance rides	49,125
Total missions/day	**39,300**

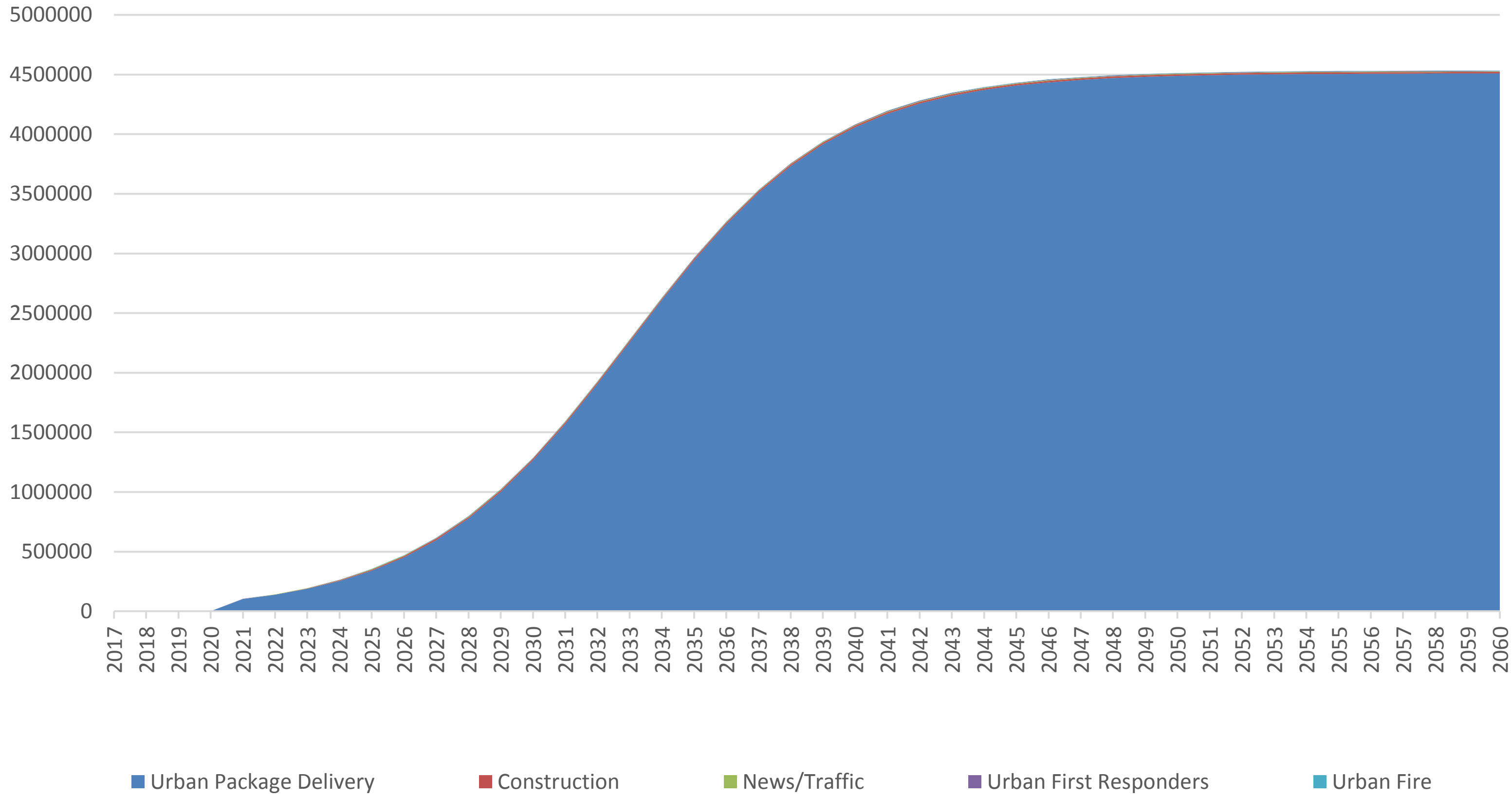
Date Projections:

Start year (A)	2025
10% Growth (B)	2030
90% Growth (C)	2045
Total Saturation (D)	39,300

UAS Demand:



UAS Demand Forecast: Urban Low Altitude Use Cases



UU-1 Urban Package Delivery

Key Assumptions:

- MISSION: Package Delivery (1-2 TO/Land)
- Preliminary testing begins in 2017
- Future Markets that cannot yet be quantified: Prescription delivery, Letters/General Mail
- UAS weighing under 55 lbs. will have a faster growth because of both FAA regulations and battery life of the UAS.
- Assume only 15% of deliveries by UAS, due to other efficient delivery methods

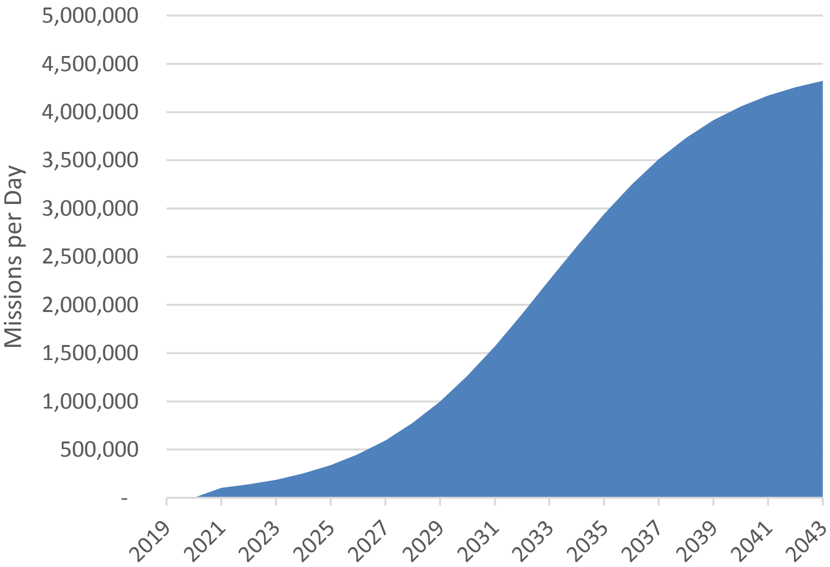
Cumulative Future Total per Day: D

Sub Use Cases	Calculated Estimates
Parcels	27,730,344
Prepared Food	2,159,236
Groceries	119,380
Flowers	59,157
% of UAS deliveries	15%
Total missions/day	**4,510,218**

Date Projections:

Start year A	2019 (Initial ops, trial cases)
10% Growth Year B	2026 (Regs/Infrastructure finalized)
90% Growth Year C	2040 (Country-wide ops)
Total Saturation D	4,510,218

UAS Demand:



UU-2 Urban Infrastructure Inspection

High-rise Construction, City Renovation

Key Assumptions:

- MISSION: 1 TO/Land
- 5% of US housing constructions are in "urban" airspace (i.e. high-rise apartments)
- 75% of urban housing construction will fly 1 mission a week
- 25% of commercial building constructions are in "urban" airspace (multi-story office buildings)
- 100% of urban commercial building construction will fly 3 missions a week

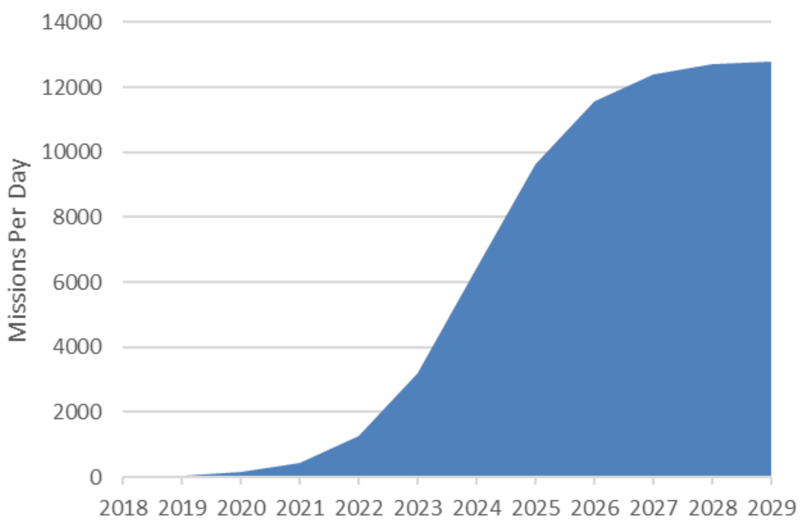
Cumulative Future Total per Day: D

Sub Use Cases	Calculated Estimates
Housing Construction	5,373
Commercial Construction	7,479
Total missions/day	**12,853**

Date Projections:

Start year A	2018 (Use in urban areas)
10% Growth Year B	2022 (Technology is simple enough for fast adoption)
90% Growth Year C	2026 (Technology & price allows for wide adoption)
Total Saturation D	12,853

UAS Demand:



UU-3 Urban Surveillance/Traffic/News

Key Assumptions:

- MISSION: 1 TO/Land
- Car accidents resulting in fatalities and injuries define a "serious accident"
- 50% of "serious accidents" will be broadcast via UAS per day
- 25% miles of US interstate and major highways will be monitored via UAS

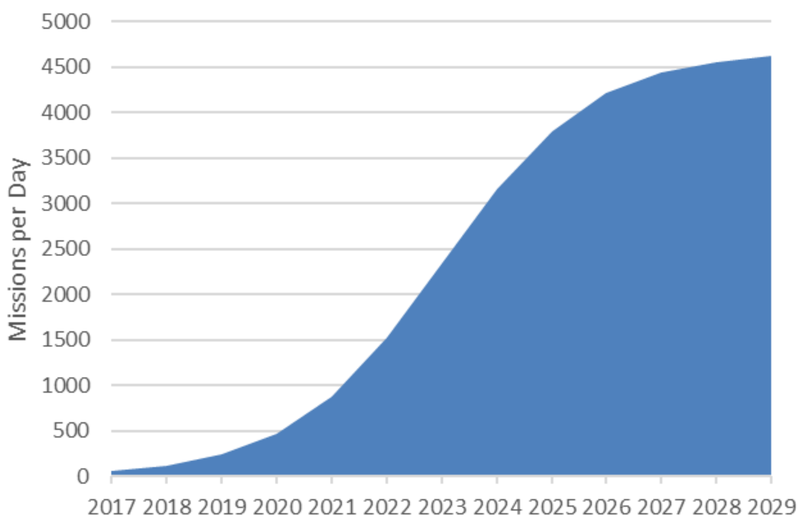
Cumulative Future Total per Day: D

Sub Use Cases	Calculated Estimates
Car Accidents	2,394
Traffic	2,272
Large News Stories	12.6
Total missions/day	**4,679**

Date Projections:

Start year A	2017 (CNN receives waiver to fly over people)
10% Growth Year B	2020 (more companies adopt UAS)
90% Growth Year C	2026 (regulation environment allows for widespread adoption)
Total Saturation D	4,679

UAS Demand:



UU-4 Urban First Responders
Law Enforcement, Crowd Monitoring, Roadway Speed Control

Key Assumptions:

- MISSION: 1 TO/Land
- Assume 1 UAS per 50k people for cities with population 50k+
- Cities with population over 50k will have a PD UAS by 2025
- Cities with population over 25k will have a PD UAS by 2030
- 50% of cities 10k<x<25k will start obtaining PD UAS in 2035

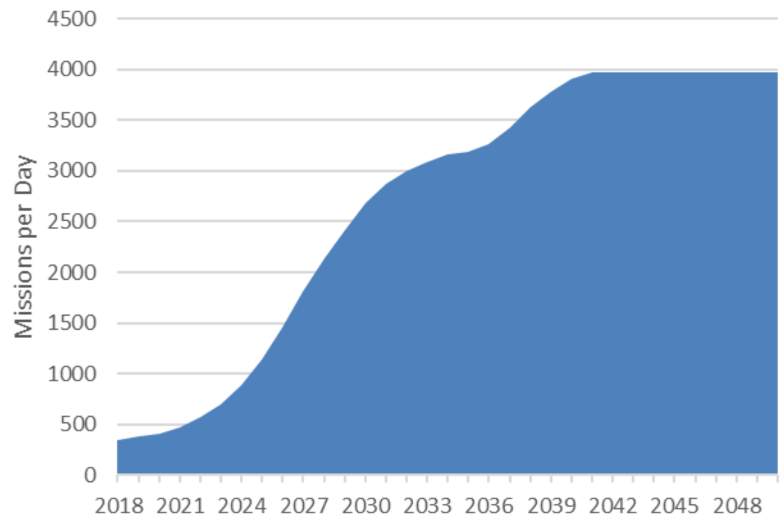
Cumulative Future Total per Day: D

Description	Estimates
# of cities with population >50k	754
# of cities with population >25k	1,480
# of police departments in US	12,000
Total daily UAS missions by 2035	3,194
Total missions/day	**3,972**

Date Projections:

Start year A	2018 (Early use of UAS)
10% Growth Year B	2025 (BLOS regulations adopted)
90% Growth Year C	2035 (cost point where smaller cities can obtain UAS)
Total Saturation D	3,972

UAS Demand:



UU-5 Urban First Responders
Fire Department

Key Assumptions:
- MISSION: 1 TO/Land
- Cities with populations over 50K will have a UAS for at least one fire department by 2025
- There are over 29,727 Fire Departments in the US
- There were 1,345,500 fires in 2015
- By 2030, cities with populations over 100K will have a UAS to supplement fire fighting (provide water on fire)
- ISR accounts for scene monitoring, intelligence gathering

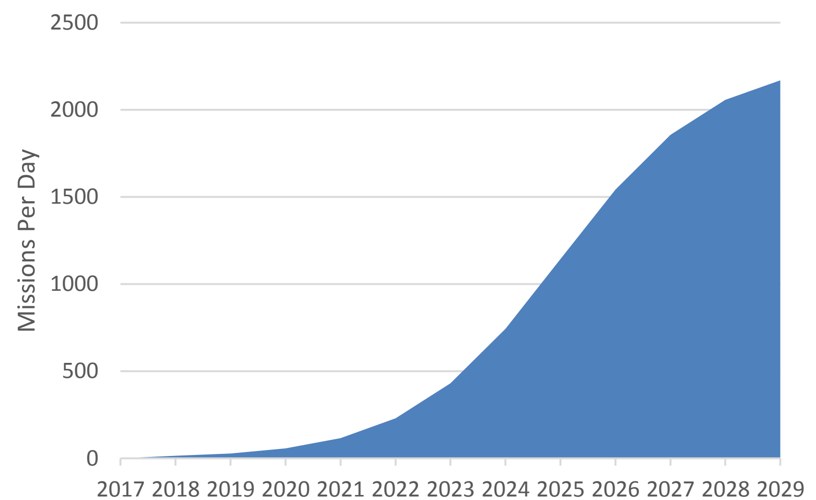
Cumulative Future Total per Day: D

Sub Use Cases	Calculated Estimates
ISR	1,851
Fire Fighting	43
Post Event	370
Search & Rescue	7
Gas Detection	13
Total missions/day	**2,284**

Date Projections:

Start year A	2018 (FD have begun to purchase UAS)
10% Growth Year B	2022 (No major breakthrough required. Greatest driver for growth and takeover will be cost and proven capabilities)
90% Growth Year C	2028
Total Saturation D	2284

UAS Demand:



Cumulative UAS Economic Benefit

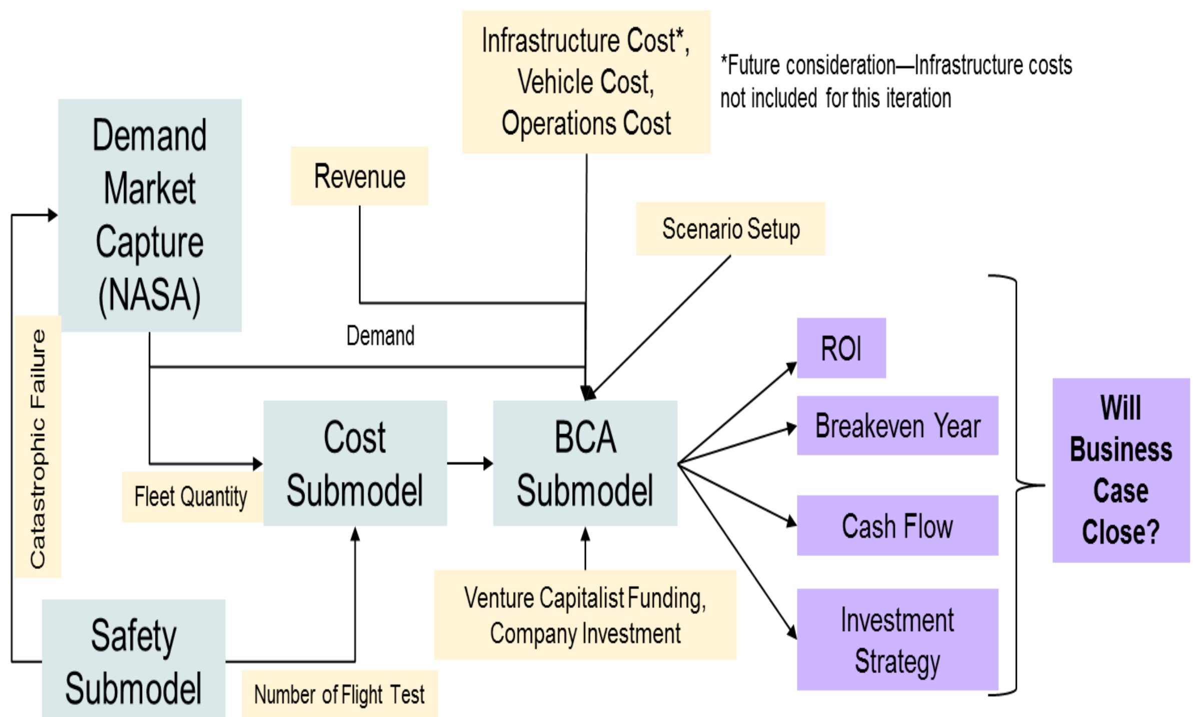
Objective: To forecast economic benefit and return on investment (ROI) for each aviation market. Compare results of the economic analysis across markets to identify the markets that provide the largest overall benefit to the nation.

Approach:

- Conduct financial analysis to determine ROI multipliers for each UAS business case
- Develop initial ROI curves for each category to validate the tool works properly

Results / Benefits:

- Converted use-case demand values into economic revenue
- Determine feasibility of closing a business cases based on the input assumptions and values
- Provide insight into which aviation markets provide the largest ROI potential



UAS Economic Benefit: Package Delivery

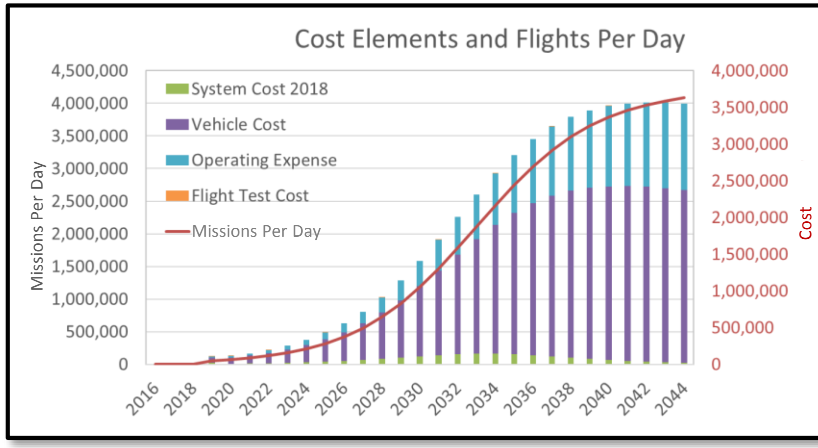
Assumptions:

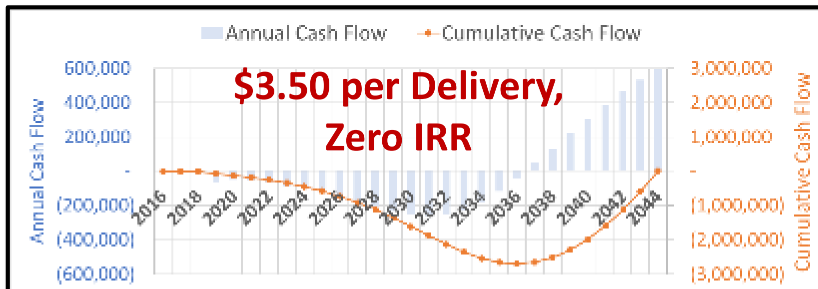
- Vehicle design life = 1 yr
- Av. delivery time = 0.5 hrs
- Return/Recharge time = 1.5 hrs
- Utilization = 60%
- Operational days/yr = 365
- Vehicle specifications
  - VTOL
  - Distribution hub to receiving vessels or custom location
  - Distance: 10 mile radius
  - Speed: Up to 50 mph
  - Altitude: 200-500 feet
  - Payload capacity: 5 lbs

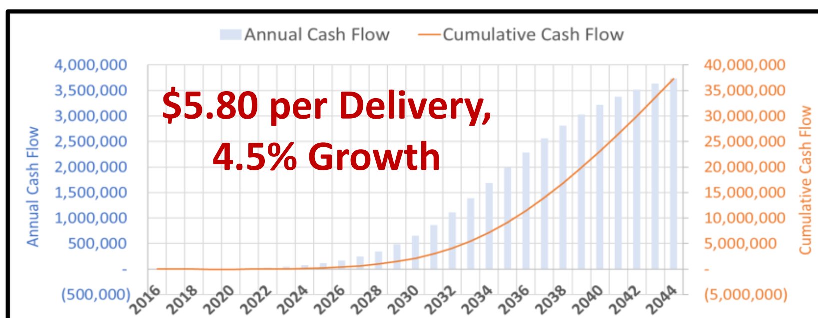
Key Findings:

- Feasible for business case to close within next 10 to 20 years
- Closure timing dependent on customer willingness to pay higher delivery surcharge
- Larger companies will likely be more willing to provide this type of service due to delay in achieving positive cash flow

Economic Benefit Plots:







UAS Economic Benefit: HALE Internet Service Provider

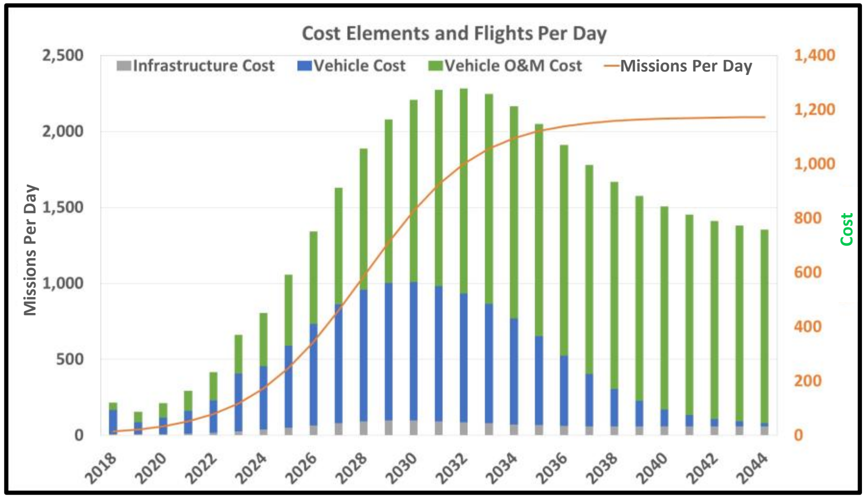
Assumptions:

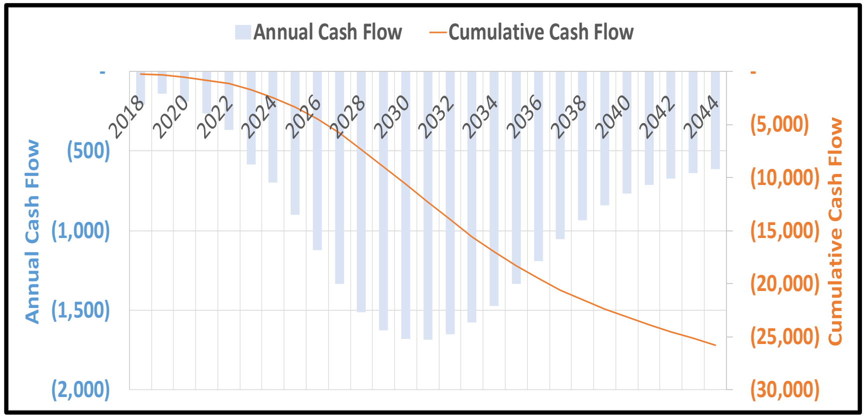
- Vehicle design life = 5 yr
- Average endurance time = 3 months
- Utilization = 75% (3 months in air, 1 month O&M)
- Operational time = 365 days/year, 24 hrs/day
- Vehicle specifications
  - Solar powered vehicle
  - Number of UASs per Base Station = 6
  - Cruising Speed: 25 mph
  - Altitude: 60,000 to 90,000 feet
  - Vehicle empty weight: 400 kg
- One commercial company with 50% market

Key Findings:

- The HALE Internet Service Provider (ISP) use case **does not close for a single payload vehicle**
- For the HALE use case to be viable, the following should be considered:
  - Add more than one payload to provide multiple funding streams
  - Reduce O&M costs for operations
  - Charge higher service charge (may not be feasible if there are cheaper alternatives)
  - Business case may be limited to areas of world without existing infrastructure.

Economic Benefit Plots:





UAS Economic Benefit: Cargo

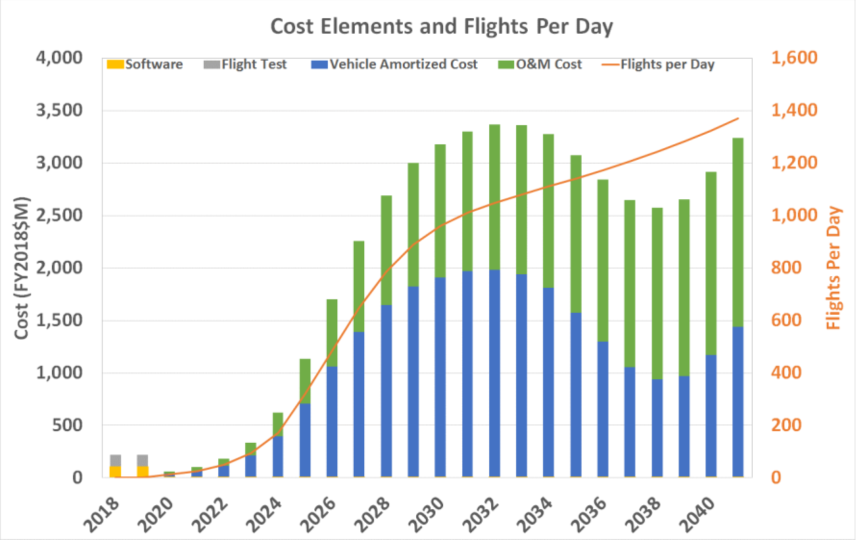
Assumptions:

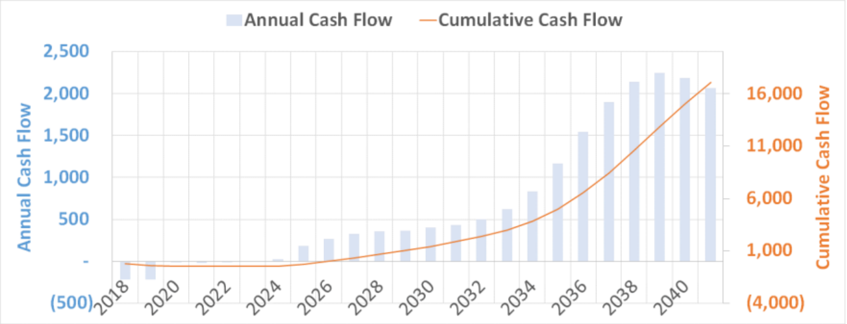
- Vehicle design life = 15 yr
- Tblock time = 8 hrs (gate to gate)
- Utilization = 60%
- Operational days/year = 365
- Financing: 10 year term, 6.2%
- Capture rate for 1 company = 33%
- 1 operator = 10 UAS
- Cost include: Amortized vehicle costs, Operations cost, Flight test cost, Software cost
- Vehicle specifications
  - Payload Capacity = 23 tons
  - Distance: 1,000 mile
  - Speed: Up to 528 mph
  - Altitude: 36,100 feet
- Not Included: Infrastructure & Sunk costs, Taxes on profit

Key Findings:

- Payback period in 9 years, IRR is 24% (Financing terms: 10 year, 6.2%)
- Business case is sensitive to financing terms in addition to the inputs used to derive cost elements, revenue and demand
  - Highest 10 year term interest rates in past 30 years is 10.12%, using this rate results in 17 year payback period and IRR of 16%

Economic Benefit Plots:





UAS Economic Benefit: Fire Fighting

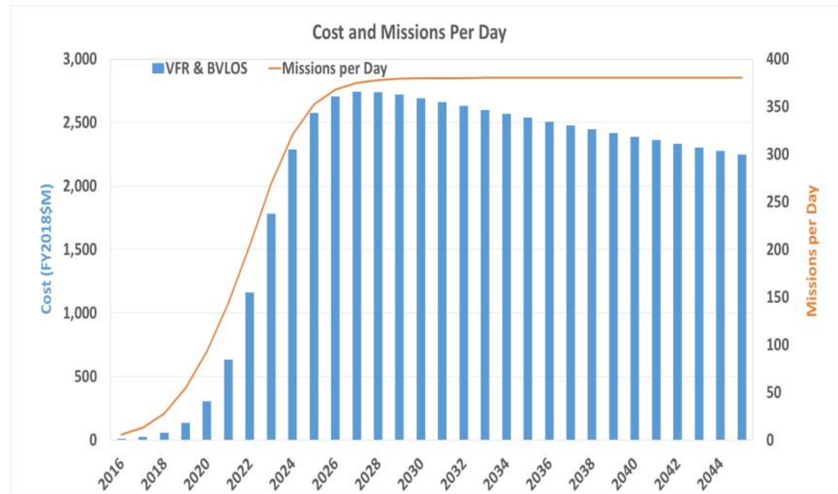
Assumptions:

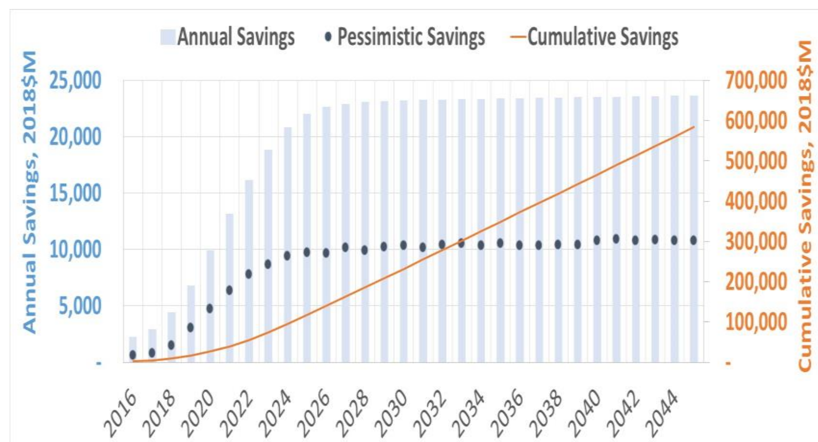
- **Covering Rural Low Alt and VFR-like use cases**
- Top 3 damage costs are firefighter deaths, injuries, timber loss and potential impact on housing price
- Assumes $9.6 million dollar value of statistical life
- Estimates of 15 civilians and 18 firefighters direct wildlife deaths, between 2,940 and 21,095 indirect deaths
- Price reduction impact for one fire is estimated at 10%, price impact with 2nd fire estimated at 23%)
- Estimated Total Damage Cost per Year: **$64B to $284B**
- UAS suppression savings approximately 14%
- Firefighting season of 270 days per year
- Cost includes: Leasing availability cost and flight cost for VFR vehicles, Acquisition and operations cost for BVLOS vehicles
- Not Included: Infrastructure Costs, Sunk costs

Key Findings:

- Savings from potential damage cost is huge relative to cost of UAS
- Payback is immediate due to relatively huge savings from potential damage cost compared to UAS cost
- Estimated mid-point savings was used in point estimate analysis
- Pessimistic savings still positive throughout timespan analyzed

Economic Benefit Plots:





UAS Economic Benefit: Urban Passenger

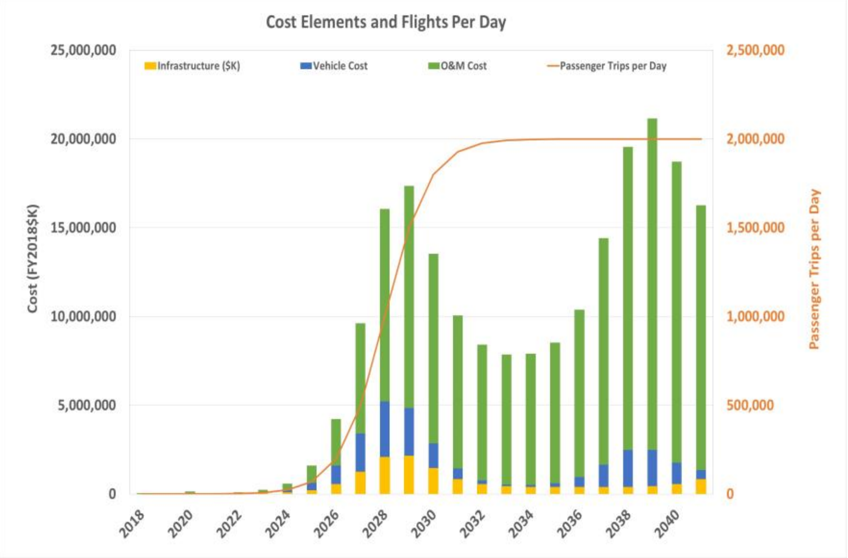
Assumptions:

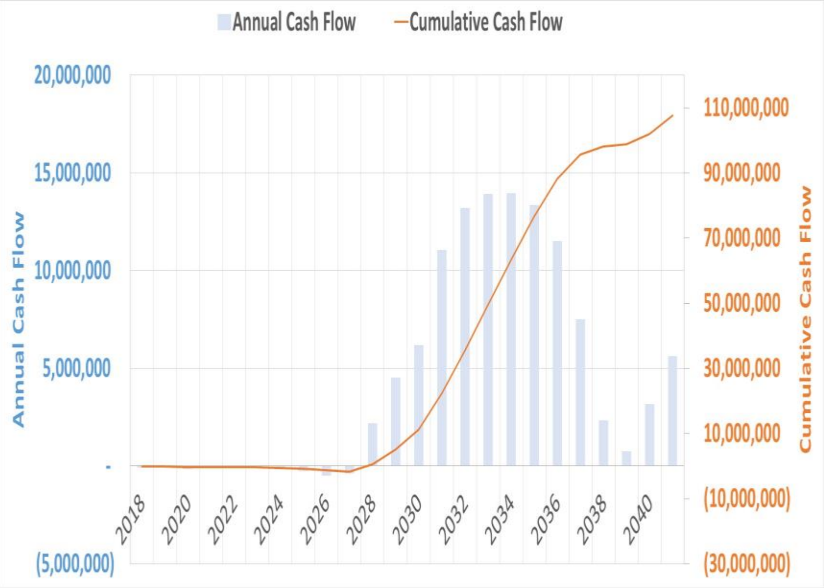
- Ground-rules and assumptions are taken from the NASA Urban Air Mobility report
- Additional Ground-rules and Assumptions:
  - Taxes/fees: 5-10% of total cost (8% average)
  - Identified in NASA Urban Air Mobility report but cost not provided
    - Payment system cost = 1.5% of revenue cost
    - Digital services (website, apps)
    - Servers for autonomous functionality
    - Charging stations
    - Beacon cost
    - Number of vertiports
- Revenue Calculations based on NASA Urban Air Mobility report

Key Findings:

- Cost declines ~2030 due to infrastructure completion
- Cost increases ~2036 due to vehicle replenishment
- Breakeven at 2028 consistent with NASA Urban Air Mobility report1
- Cumulative cash flow post-2028 more optimistic than NASA Urban Air Mobility report 1
- Cost items not found in report had to be estimated
- Revenue extrapolated for years not identified in report

Economic Benefit Plots:





UAS Economic Benefit: Urban Passenger (More Constrained)

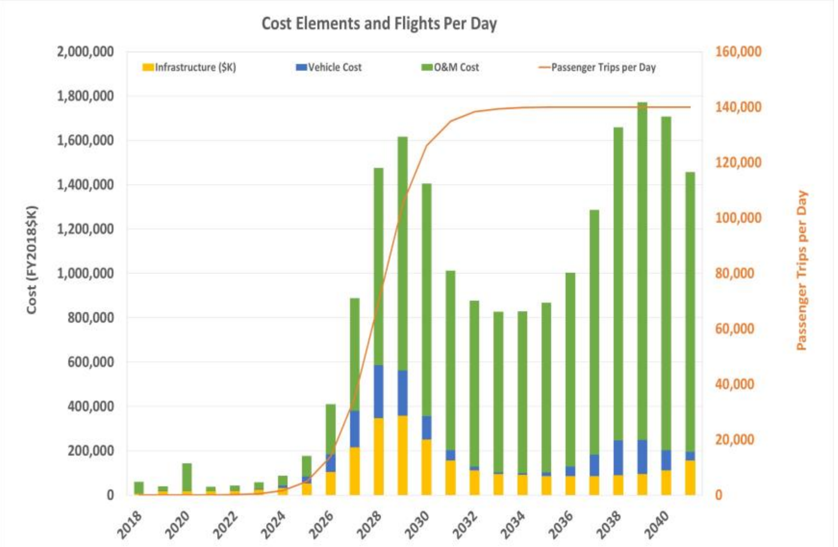
Assumptions:

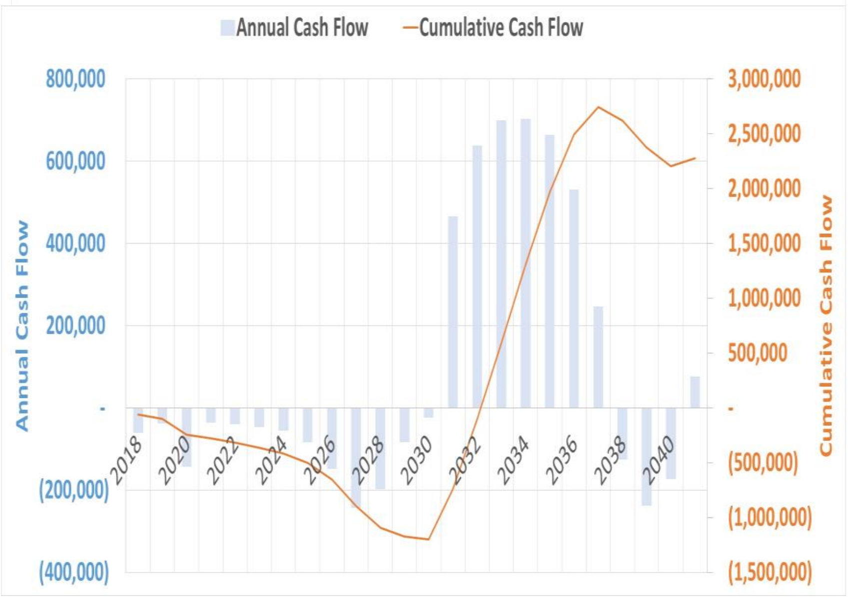
- Trips per day drastically reduced to account for demand prediction of more constrained case from Detailed Project Discussion – Air Taxi, Urban Air Mobility (UAM) Study1
- Most costs re-adjusted for lower demand
- Some costs remain fixed or partially fixed, independent of demand (i.e. Air Traffic Management infrastructure, Flight Exception Management locations)

Key Findings:

- Breakeven in 2033
- Number of years to breakeven (over 10 years) is not attractive to investors
- Decrease starting in 2038 caused by vehicle replenishment due to end of life and tail certification replenished vehicles

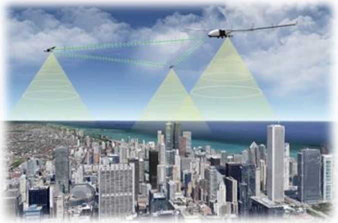
Economic Benefit Plots:





Summary

- Presented overview of this NASA-sponsored study
- Shared insights analytical framework and approach being used
- Provided demand results across all Use Cases
- Provided economic benefit results of selected representative use cases



Questions

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