radius capital

Civil and Military UAS Market Assessment

Avionics and Services Supporting Complex UAS Operations

October 2021

About the Authors

radius capital

Venture capital investors and national thought leaders in advanced aerial mobility

Peter Shannon
Managing Director

BS Systems Engineering
MBA

Firelake Capital

ATLASVENTURE

NASA

The National Academies of SCIENCES ENGINEERING MEDICINE

TRB
TRANSPORTATION RESEARCH BOARD

Appointee, NASA Aeronautics Research Technology Roundtable

Advisor, NASA Data & Reasoning Fabric Project

Co-Author, *Advanced Aerial Mobility – A National Blueprint*, National Academies of Science, Engineering, and Medicine

Standing Member, New Users of Shared Airspace Committee, Transportation Research Board

Luka Tomljenovic
Partner

BS Aeronautical Engineering
MBA

AIRBUSVENTURES

APTIV

HRZ I PZO

Contents

Acknowledgement

We are grateful to the following individuals for their contribution to this report:

Jim Barry (CEO, Celerity05)

Steve Jacobson (CEO, Autonodyne)

Jesse Kallman (VP Commercialization & Strategy, Xwing)

Parimal “PK” Kopardekar (Director, NASA Aeronautics Research Institute)

Chris Kucera (Co-Founder and Head of Strategic Partnerships, OneSky)

Andrew Patton (Head of US, Manna Drone Delivery)

James Poss (CEO, ISR Ideas)

Christian Ramsey (President, uAvionix)

Ken Stewart (CEO, NUAIR)

Tine Tomažič (Group CTO, Pipistrel)

Executive Summary

In the context of civil Unmanned Aircraft Systems (UAS) industry evolution, the integration of UAS into the national airspace in complex operations (e.g. flight beyond visual line of sight, BVLOS) will turn out to be either its holy grail or kryptonite. The outcome will depend on the delicate interplay between technology, regulations, and communities in a similar pattern that characterizes early days of every technological revolution. Here we offer our view on how this dynamic might evolve, with a particular focus on the market opportunity for avionics and services necessary to make complex UAS operations a safe, scalable, and economically viable reality.

As is so often the case in looking ahead into technology markets, our investigation of the market for avionics and services solutions in the unmanned aviation segment is a story of technology enablement. Beyond assessing macro and industry level drivers of background demand, we examine the dimensions by which technology advancements will gain traction and by which solutions in communications, situational awareness, risk management, and increasing implementation of artificial intelligence are likely to deliver capabilities to end customers that catalyze new demand. Throughout the history of aviation, civil and military markets have been two sides of the same coin, each benefiting from the other in unique ways. The same is true for the UAS industry: technologies and standards developed by the military tend to migrate into the civil domain where high volumes drive costs down. Here we separate the two markets due to their unique drivers and sensitivities. Furthermore, other important factors in addition to technology shape the trajectory of the civil UAS market. We consider public tolerance for low flying small UAS, various regulatory gates, standards development activities, communications spectrum allocations and other factors in our view of the market evolution, industry adoption, and by taking a scenario-based approach.

In this report, we review the demand picture for United States military UAS and associated small form factor avionics solutions necessary to accelerate new capabilities and realize their potential when operating in today's complex battlefield environments, particularly in large swarms against a spectrum of logistical and combat objectives. Among such capabilities, GPS-denied navigation, increasing automation, resilient networks, data fusion and processing, as well as assured identification are some of the most critically important. Because of limited visibility into international military UAS programs, we focus on the United States and build up estimated production volumes through program level granularity. Similarly, the services market is not estimated for military UAS operations, as most of the flight planning, compliance, risk management, and command and control network management is either done in-house or obtained through the acquisition of solutions with larger scope.

(continued on next page)

Executive Summary (cont.)

In the civil UAS market, we examine emerging use cases for drones operating BVLOS and the need for aviation-grade command and control communications, robust GPS-denied navigation, surveillance / detect-and-avoid (DAA) capabilities, as well as sophisticated avionics for on-board sensor fusion and data processing. With particular focus on enabling operations at safety levels and scale beyond today's demonstrations, we assess the market opportunities created by specialized service providers in the areas of command and control, traffic information, risk management, and UAS traffic management (UTM). These services are closely linked to avionics solutions via concepts of operations and integration. From our assessment of the services market, we exclude a wide range of professional services (e.g. data analytics, use case-specific services, training, systems integration, maintenance, insurance etc.) and focus only on those services that are expected to directly support complex UAS operations.

Key Takeaways:

- $71.9B in aggregate Total Available Market (TAM) opportunity between 2021 and 2029 for avionics and services supporting complex UAS operations, growing from $1.5B in 2021 to $23.0B in 2029. These figures exclude international military markets, as well as services that are not directly and specifically supporting complex operations
- The civil UAS market is poised for substantial growth with three significant adoption inflection points expected by 2025 on the back of greater regulatory clarity, type certifications of drones, and certifications of DAA and command & control (C2) systems
- Among the most desired dual-use avionics capabilities are those that improve situational awareness, assured identification, reliable communications, and sophisticated AI-enabled mission-specific avionics. DAA and C2 solutions are key bottlenecks to scaling complex commercial UAS operations
- Specialized service providers will emerge to manage safety- and mission-critical systems enabling complex operations, including C2 communications, traffic information, risk management, and UTM. Where adequate complementarity exists, their offerings will be bundled to increase competitiveness. Varying levels of robustness and reliability required across the spectrum of mission risk profile will drive consolidation and specialization

Scope

Avionics and services directly supporting complex UAS operations across civil and military markets

Military UAS

- **United States** military UAS production volumes and corresponding **avionics** market opportunity (excluding services and international markets)

Avionics

- **Auto-flight systems:** flight control, surveillance / Detect-And-Avoid (transponders, ADS-B, Remote ID, IFF, AIS, cameras, radars), navigation (including GPS-denied navigation, combined GNSS/INS sensors etc.), guidance, actuation
- **Advanced and mission-specific systems:** payload data processing, sensor fusion, precise localization / landing etc.
- **Communications:** datalinks (LOS, BLOS), airborne routers and switches

Services

- **Command and Control (C2) network services:** managed C2 network service providing reliable and resilient communications as well as network management for BVLOS missions
- **TIRU (Traffic information, risk management, UTM) services:** real-time composite surveillance picture; non-real-time flight planning, airspace authorizations, regulatory compliance; various risk assessment services (e.g. cellular and GNSS coverage and availability analysis etc.)

Civil UAS

- **Global** civil UAS production volumes, complex operations fleet size / utilization
- **Avionics** and **services** market opportunity

Out of Scope

What is **NOT** included in this report

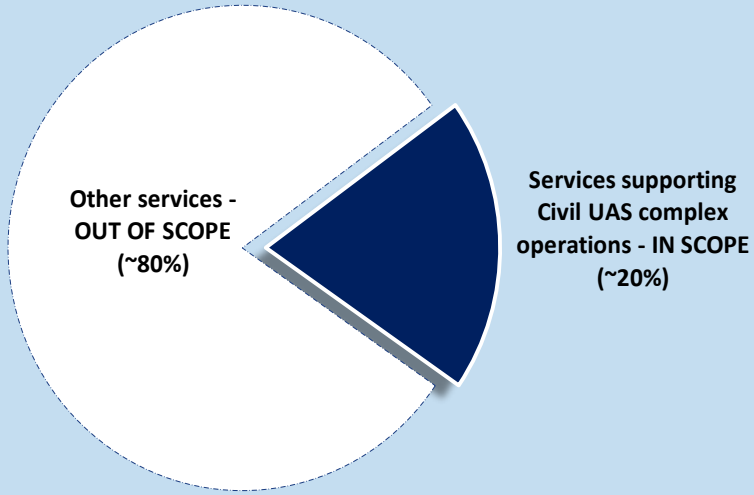
Military UAS

- **International** military UAS market is not included in the market opportunity

- **Services** supporting military UAS operations are not considered in this report
- Micro and Nano UAVs, as well as quadcopters (e.g. Army's SRR program) are not assessed in this analysis

Civil UAS

- Civil UAS services that are not directly and specifically supporting complex UAS operations, such as service revenues from various end-use applications (e.g. delivery/cargo services), data analytics, training, insurance, maintenance, and other services supporting regular UAS operations are outside of scope of this report. We estimate these other services represent ~80% of the total services market



Methodology

In producing this report, we relied on primary and secondary research as well as our own insights resulting from deep domain knowledge and visibility that we have as early-stage investors.

Primary research involved interviews with our trusted network of advisors and contributors, including active and retired military personnel, industry executives and practitioners, technology innovators, drone service providers and others. Secondary research included a wide range of research that has already been published by others.

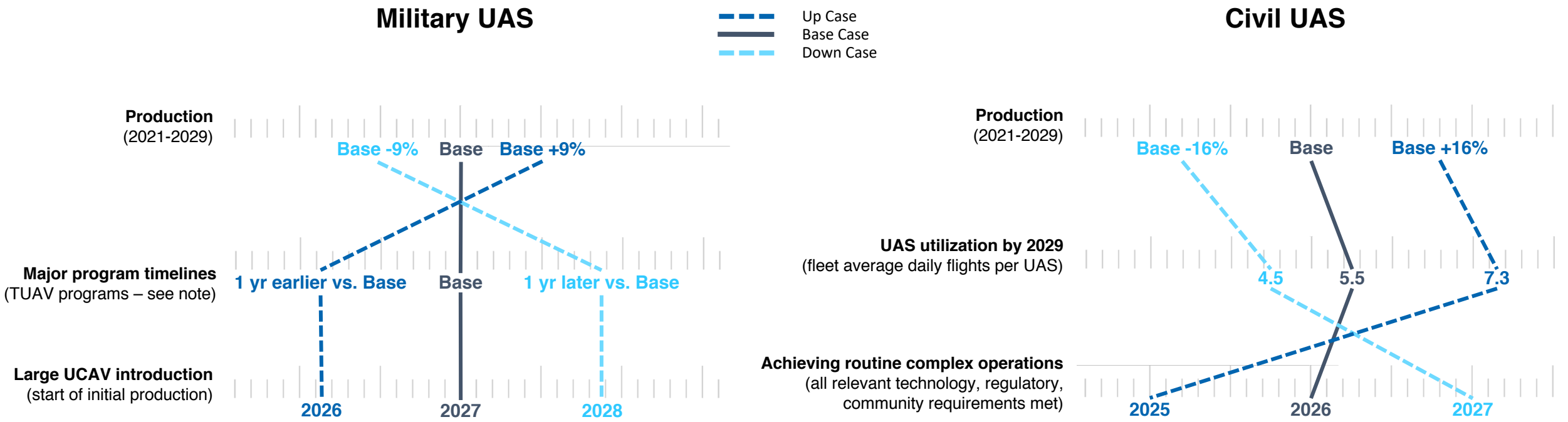
In assessing the United States military UAS production forecast, we relied on primary research, DoD budget data, publicly available reports, and layered our own insights to produce a proprietary bottom-up analysis that considers all major Group 1 through Group 5 programs across U.S. military service branches. Micro and Nano UAS, including quadcopters (e.g. Army's SRR program) were not included in this analysis.

For the global civil UAS production forecast, we relied primarily on Teal Group's *World Civil Unmanned Aerial Systems 2020/2021 Market Profile & Forecast* and complemented it with additional production in the Tactical UAV (TUAV) category vehicles involved in cargo delivery. With this production forecast as the foundation, we layered our own assumptions and insights to estimate future fleets and market opportunity. Among such assumptions, we considered the following:

- Avionics replacement rates by UAS type
- Avionics share of total aircraft cost by UAS type
- Fleet replacement rates by UAS type
- Civil UAS complex operations ramp-up timeline by use case and type
- Civil UAS fleet utilization ramp-up timeline by type
- Technology and regulatory (FAA) gates impacting industry adoption
- Technology maturity levels
- Vehicle certification timelines

Scenarios

Forecasting is mostly an art, and its challenge is further compounded by the emerging nature of the advanced aerial mobility industry. Technology, regulatory, and geopolitical forces may significantly influence the pace at which the assessed markets mature. Therefore, the reader is encouraged to recognize the large potential of this subset of the advanced aerial mobility market and focus on its key themes and drivers. In addition, we utilize a scenario-based approach to further show where sensitivities exist and how they impact the expected market opportunity.



We consider three scenarios for both the military and civil UAS markets, each defined by three key variables (production levels, UAS utilization, technology/program/regulatory timelines). The charts above describe how these key variables change across scenarios. For example, Civil UAS Up Case assumes 16% greater production levels compared to the Base Case, a higher UAS utilization (7.3 daily flights by 2029 on a fleet weighted average basis), and an accelerated timeline for reaching routine levels of complex operations (2025).

Note: Major programs include: Army FTUAS, future tactical version of the MUX family, Marines RQ-21 replacement. Large UCAV represent USAF Loyal Wingman-like programs.

Airspace Integration Challenge

Framing the market opportunity

The future of our airspace is about new aircraft and new missions flown. This increase in activity, including by autonomous aircraft, portends an increase in flight density and the stretching of usable airspace to include both the highest and lowest extents of our atmosphere. **Maintaining communications and separation between all these aircraft is one of the significant challenges of the next era of aviation**.

Integrating autonomous drones and other aircraft into the airspace system is a **significant challenge and likewise a great opportunity**. Significant technology integration and scale-up based on acquired operating experience is required to support the safe operation of autonomous aircraft, both in nominal and contingency situations, alongside legacy manned aviation, other UAS, and infrastructure, while retaining support from the general public.

Current airspace configuration, operational rules, and procedures did not anticipate the emergence of an autonomous aviation ecosystem, including drones. Introducing autonomous UAS alongside manned aviation operations is highly complex. From a design standpoint, vehicles incorporating increasingly automated software capabilities will have to be designed, developed, and certified. Further, operations will have to be defined and procedures for the airspace system created to work with autonomous flight. These efforts require precise coordination and agreement on the exact overall capabilities the efforts are directed toward.

Current challenges to integrating autonomy into the airspace system include further research and development of core technologies as well as systems engineering to integrate the different components into a system that is fieldable and able to scale. Among the many examples of gaps within this field is the need for deployment of remote identification technology, detect and avoid capability, and the ability of the autonomous vehicle to remain "well clear" of other users of the airspace to prevent a collision hazard.

At present, operation of autonomous drones is generally relegated to segregated airspace volumes and over water or rural areas. The expectation is for introduction to follow a gradually evolving risk profile based on experience, first favoring lower risk operations such as over sparsely populated areas[1]. Initially, support of such expanded operations might be achieved through effective interfaces between UTM and the traditional Air Traffic Management (ATM) system. However, in the long-term, an integrated National Airspace System will be most efficient when capable of supporting aircraft operations of all types without the need for segregation to separate airspace for manned and unmanned traffic.

Most of the civil UAS activity will continue to take place at altitudes below 400 ft, where airspace integration and traffic management is currently envisioned by some as separate but complementary to traditional ATM. Flying at higher altitudes comes with distinct technical challenges and avionics equipage requirements in order to integrate into the existing ATM airspace infrastructure.

Digital technologies and infrastructure are already signaling new opportunities and challenges for an increasingly automated traffic management system required to manage dense and integrated manned and unmanned flight operations, perhaps even coupled with new flight rules and airspace structure.

Ultimately, routine and streamlined access—the ability to operate "at will" without the need for one-off special approval for each operation—to all classes of airspace, subject to constraints of airspace design and airspace use by other traffic, is essential to the success of later applications of advanced aerial mobility.

[1]Risk is a combination of ground risk and air risk. Sparsely populated risk areas provide lower ground risk, but might require additional resources to mitigate potentially higher air risk (e.g. when operating in airspace without mandatory ADS-B equipage). In certain cases, flight above urban areas might have a lower combined risk profile.

The two sides of the airspace “coin” offer distinct challenges and requirements

Airspace below 400 ft
“Good enough” is often adequate

- For most Part 107 operations (e.g., within visual line of sight, below 400 ft, single drone per operator etc.), there is more flexibility in how to achieve lower risk-based performance targets (e.g. web-based services, non-certified off-the-shelf electronics, cellular-based C2 etc.)
- Operators may get instantaneous authorization to fly small UAS in controlled airspace around airports up to a certain altitude provided they adhere to Part 107 limitations[1]

The “real” airspace
Greater robustness is required

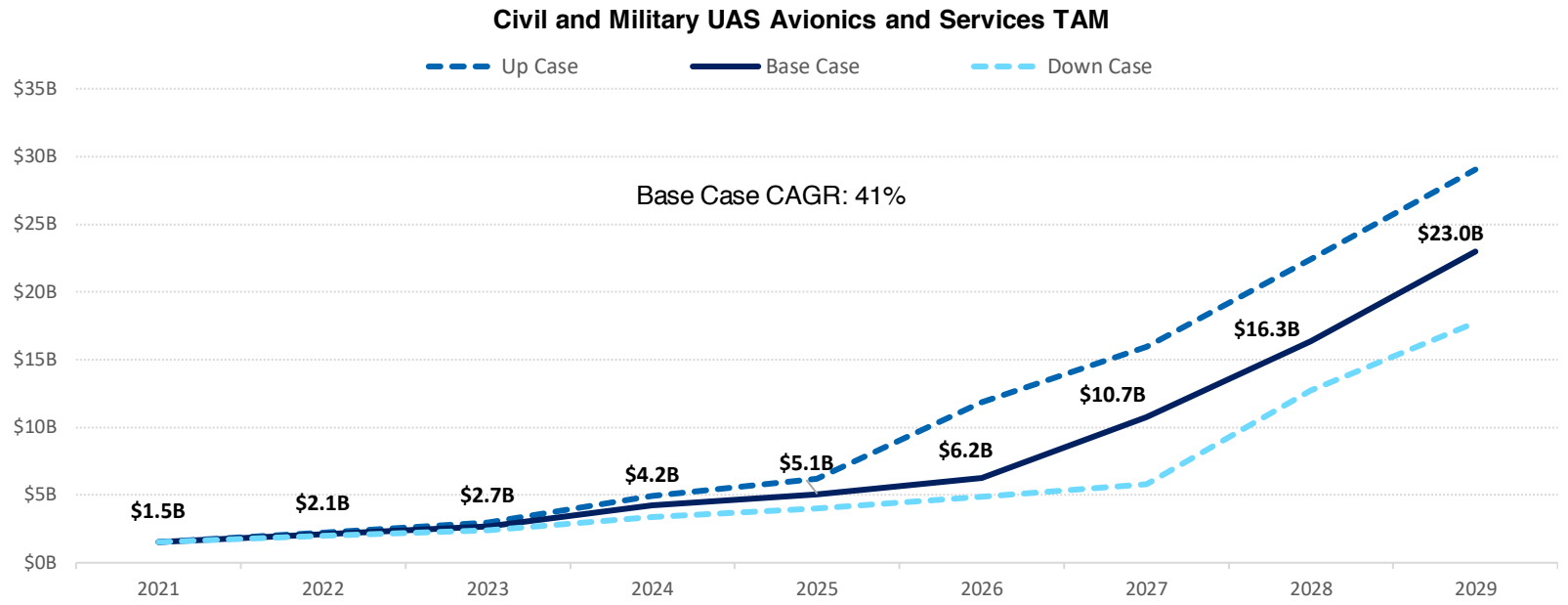
- When flying above 400 ft and in controlled airspace, traditional airspace equipage requirements and procedures must usually be met for purposes of airspace integration
- Avionics and services of greater robustness (defined in terms of both integrity and assurance levels) are necessary to meet safety objectives

As use cases increase in complexity (e.g. those requiring Part 107 waivers), traffic density grows, and airspace becomes truly integrated, avionics and services of greater reliability and robustness will be needed to demonstrate safety and mitigation of increased air/ground risk, even in airspace below 400 ft

[1]In the U.S., such altitudes are shown on UAS Facility Maps and represent maximum altitudes (between 0-400 ft Above Ground Level, AGL) in controlled airspace around airports where the FAA may authorize Part 107 operations without additional safety analysis.

Market Overview

Multi billion-dollar markets for certified avionics and services supporting complex UAS operations



Aggregate 2021-2029 Avionics and Services TAM

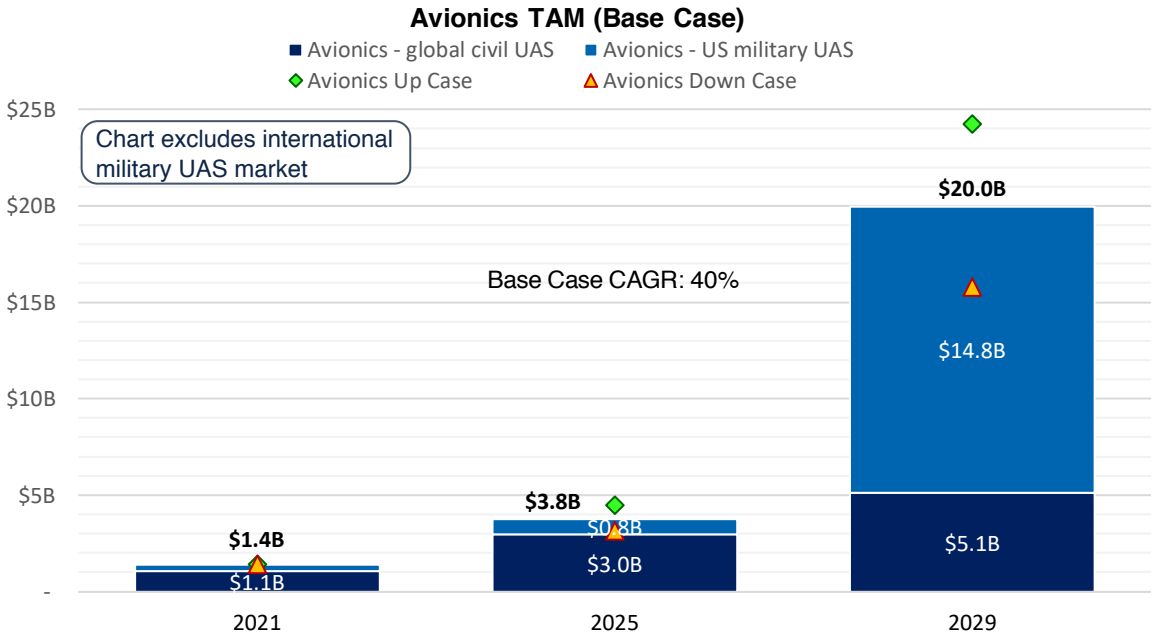
(Base Case)

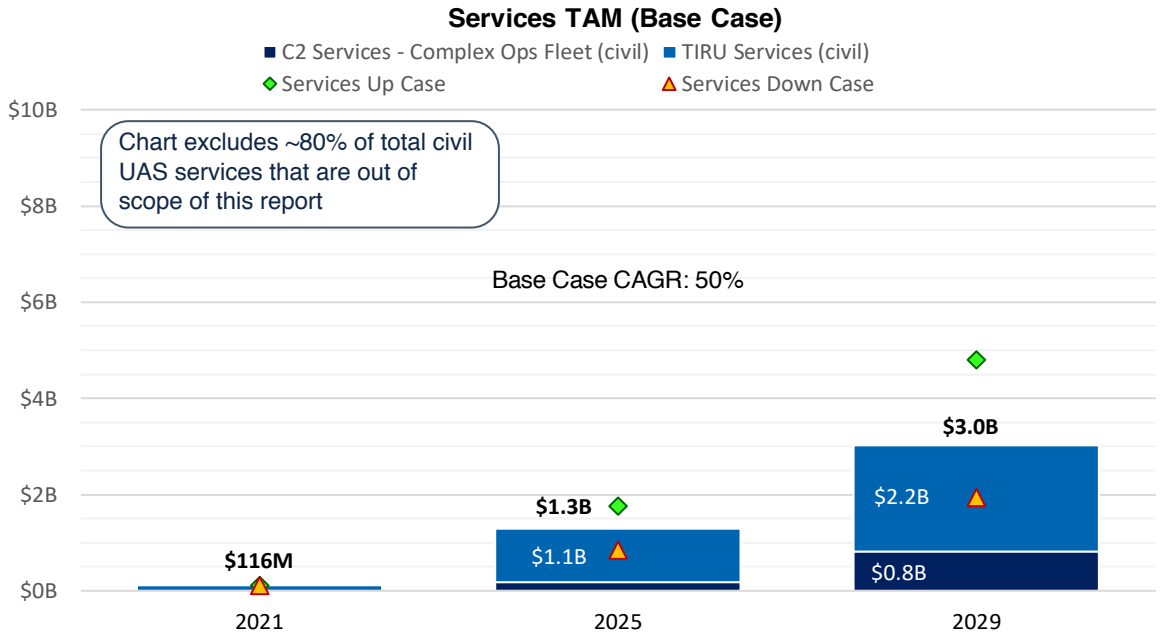
Note: TAM represents total available market expressed as annual revenues for global civil and United States military markets.
Source: Teal Group (civil UAS production volumes), Radius Capital analysis

radius capital

Market Overview (cont.)

Global demand, maturation of enabling technologies, and regulatory milestones support strong market growth





- Technological progress of enabling technologies continues unabated, ushering in new capabilities, concepts, and use cases for both civil and military UAS
- Growing airspace complexity and increasingly demanding missions require solutions that improve situational awareness, assured identification, reliable communications, and sophisticated mission-specific avionics
- The “age of the UCAV” in the second half of the decade, and its corresponding large avionics content per vehicle, drives a disproportionately large U.S. military market opportunity
- Commercial UAS market is primed for substantial growth with three significant adoption inflection points expected by 2025 on the back of greater regulatory clarity, UAS type certifications and DAA/C2 TSOs

- As the UAS industry evolves, specialized service providers emerge to manage safety- and mission-critical systems enabling complex operations, including command and control communications, traffic information, risk management, and UTM. This trend becomes even more pronounced as parts of the on-board technology stack are supplemented and/or replaced by ground-based infrastructure, and as airborne sensors become increasingly connected
- The nature of the regulatory environment (accommodating vs. restrictive) as well as public acceptance of UAS greatly influence the pace of the market
- Robust communications and aviation-grade network management services play a critical role in ensuring safety, scalability, and extensibility of UAS networks and operations

Note: TAM represents total available market expressed as annual revenues for global civil and United States military markets.
Source: Teal Group (civil UAS production volumes), Radius Capital analysis

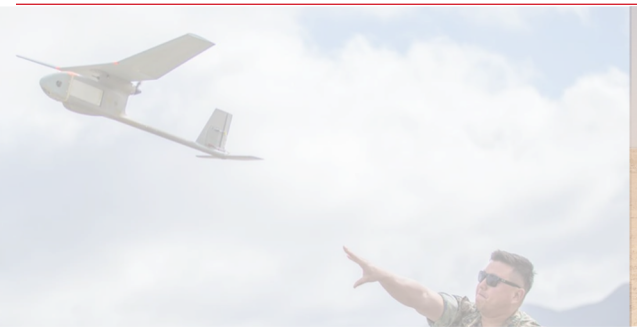
Contents

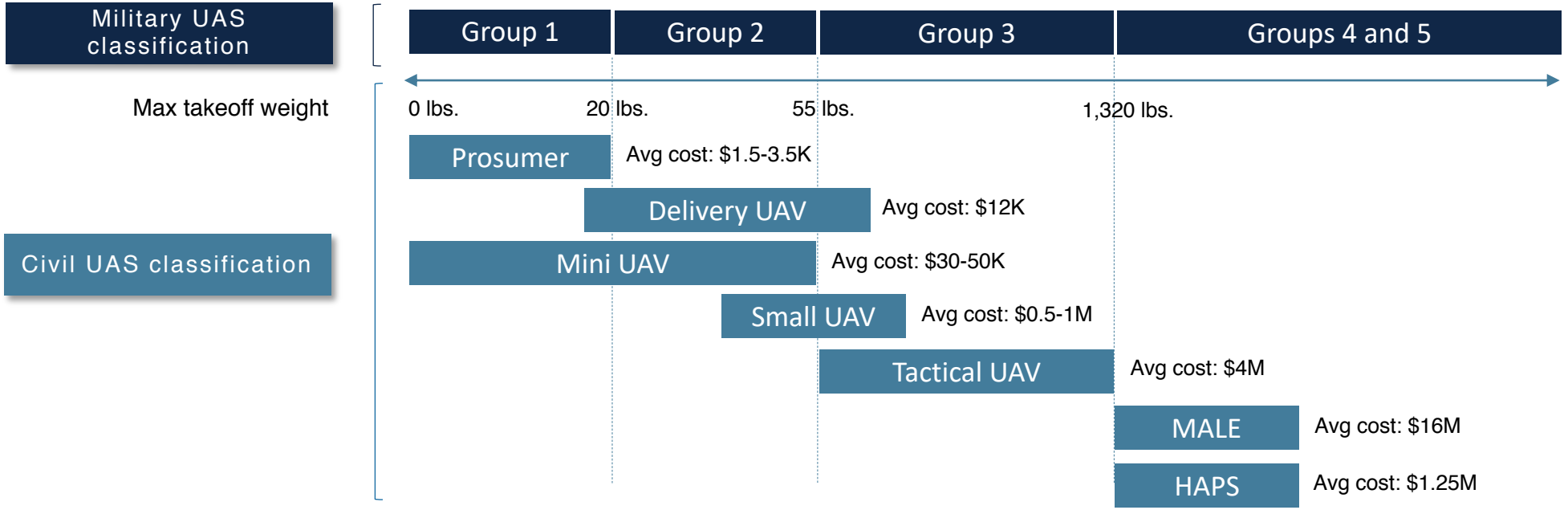
Global Civil UAS Market: Key Themes

Approaching a creative explosion of applications	Upcoming waves of UAS type certifications as well as C2 / DAA TSOs are expected to supercharge industry adoption of UAS across a range of increasingly complex operations. Certified reliability will drive dispatchability and utilization, leading to a Cambrian explosion of applications
Regulatory convergence on complex operations and spectrum	The recently formed Aviation Rulemaking Committee for BVLOS operations will build on operator and use case-specific approvals to develop rulemaking for complex operations. FAA confirms C-Band requirements for safety critical data exchange and for controlled airspace integration. FAA certification of SATCOM and cellular LTE / 5G networks for C2 expected in the next 3-5 years[1]
Continued progress on foundational technologies	New technologies will continue to improve utilization, airspace integration, economics, and quality of insights, supporting operations at scale. DAA and C2 solutions are key bottlenecks especially for complex operations
Technologies migrating from unmanned to manned aviation	Technologies supporting the unmanned ecosystem will migrate to manned aviation to improve return on investment, safety, operational efficiency, and enable optionally-piloted operations (e.g. ADS-B transponders, connectivity, non-cooperative traffic surveillance, autonomous capabilities, aspects of UTM)
Services will complement hardware	Cost and weight penalties associated with having numerous on-board sensors will pave the way for DAA services to meet regulatory requirements. Specialized C2 service providers and a host of risk management services will emerge to cope with airspace and operational complexity
Robust communications and positioning are key foundational technologies	The role that C2 plays is critical in ensuring safety, scalability, and extensibility of UAS networks. Its value proposition will not decrease as autonomy increases. High-integrity positioning, especially in GPS-degraded/denied environments, is a key enabler of complex UAS operations at low altitude
Optimized SWaP-C is a key enabler	Low SWaP solutions will be in increasing demand as UAS weight, payloads, and mission complexity grow. Affordability will be a key catalyst for growth

[1] *Cellular-based C2 has great long-term potential, especially for small and low-flying UAS (indeed, drones using 4G LTE and 5G are in use today). However, it will take several years until certified cellular-based C2 for UAS conducting higher risk profile missions and operating in controlled airspace*

Unmanned Aviation Air Vehicle Classifications are Based on Weight and Sophistication





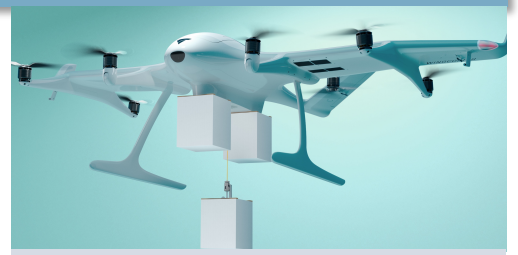

Source: Teal Group

radius capital

Civil UAS Categories

Delivery UAV
Purpose-built UAVs for scaled delivery use cases

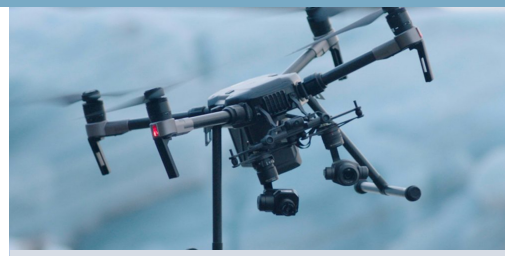
Zipline Model Zip



Wingcopter W198

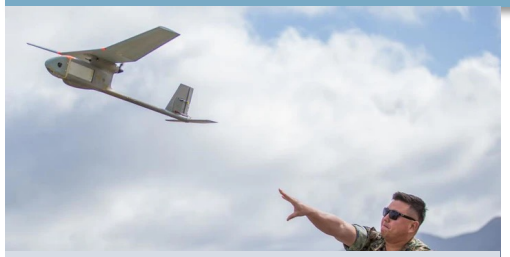
Prosumer
High-end consumer systems used for commercial use cases

DJI Inspire



DJI Matrice

Mini UAV
Commercial UAVs under 55lb

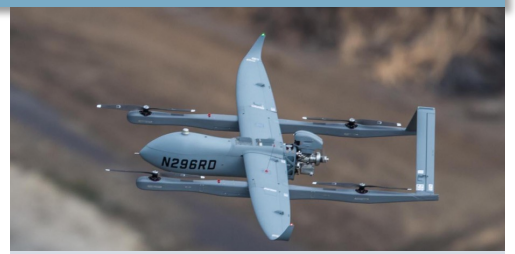


Aerovironment RQ-11 Raven

Delair UX11

Small UAV
Higher-end Group 2 and lower-end Group 3 UAVs

Volansi C10



Textron Aerosonde

radius capital

Civil UAS Categories

Tactical UAV (TUAV)

Group 3 UAV with hundreds of miles in range and 5-15+ hours in endurance

Schiebel S-100 Camcopter

Leonardo Falco EVO

MALE

Group 4 UAVs used by civil government agencies

General Atomics MQ-9 Reaper

Elbit Hermes 900

HAPS

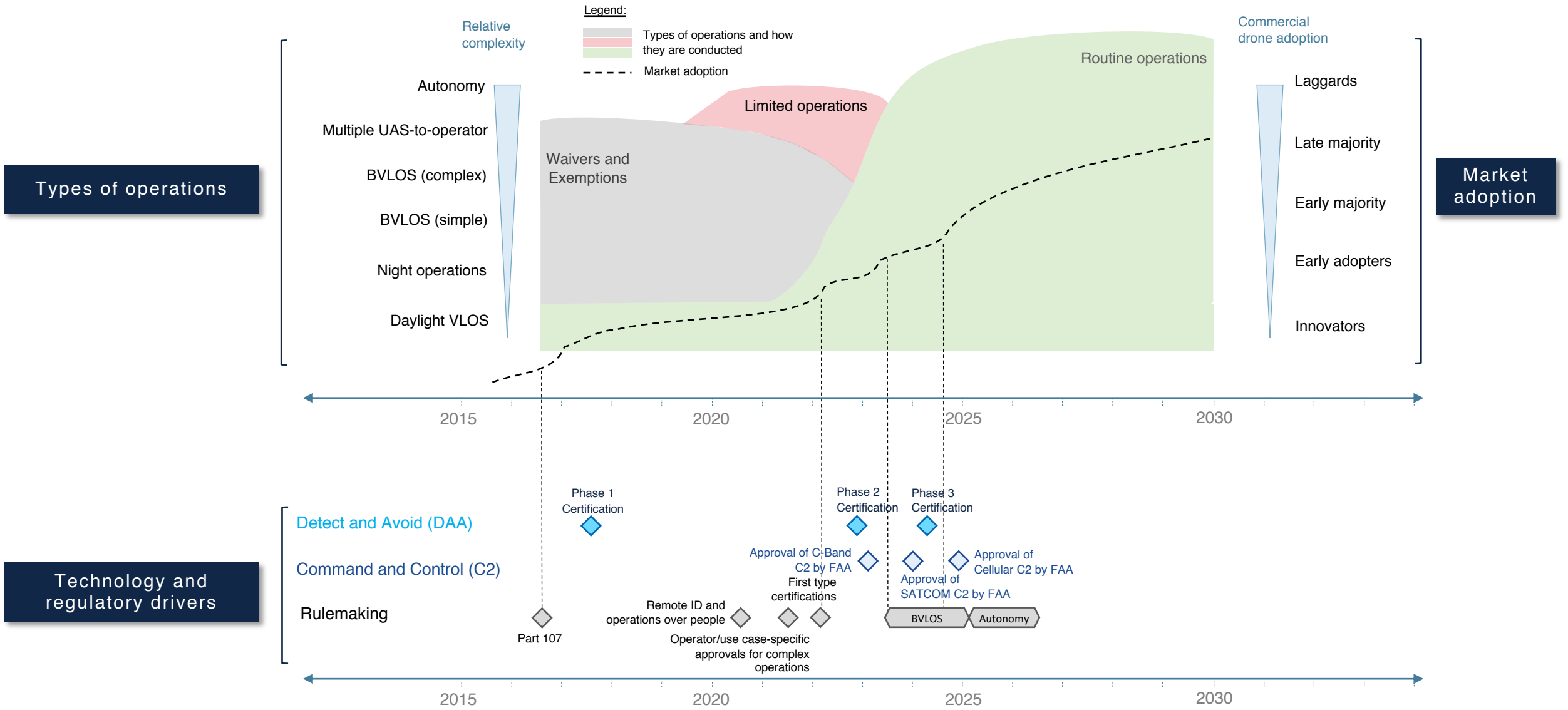
Stratospheric UAVs employed in communications use cases

HAPSMobile Hawk30

BAE Systems PHASA-35

Civil UAS Market Evolution

Market evolution depends primarily on C2 and DAA technology and regulatory gates

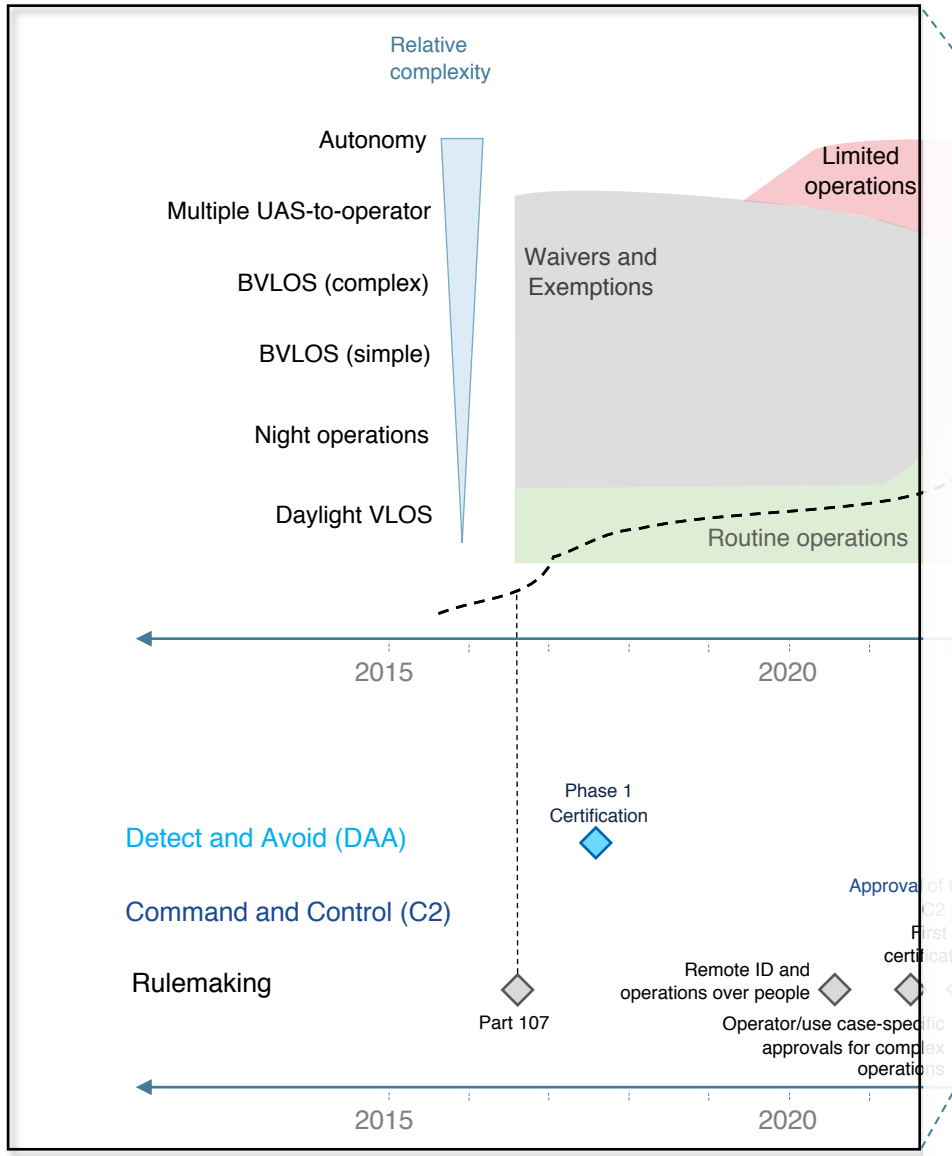


Note: "Drone" refers broadly to fixed-wing or multirotor Unmanned Aircraft Systems, from hand-launched to those requiring takeoff and landing infrastructure. Types of operation and adoption rates vary by geography and use case. Regulatory timelines represent U.S. (FAA). Source: Radius Capital analysis

radius capital

Civil UAS Market Evolution: Past Five Years

Rapid growth in recent years as drones confirm their value across a variety of use cases



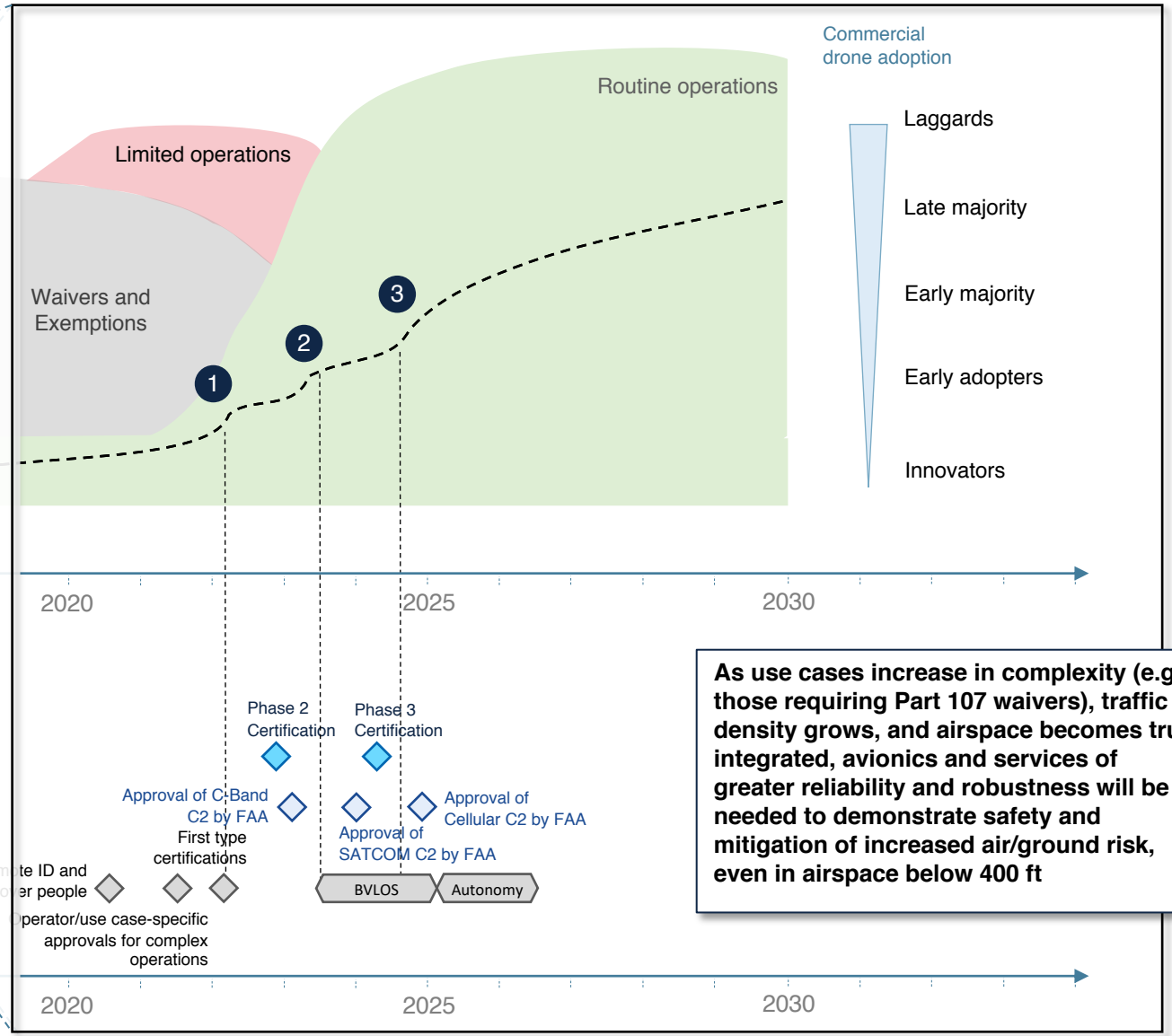
- Part 107 rules (2016) streamline access to airspace for small drone commercial users (under 55 lbs.)
- Initial use cases rely on inexpensive consumer and prosumer drones flying within visual line of sight for photography and business intelligence
- More complex use cases are conducted through onerous regulatory exemptions and waivers. Handful of large enterprises receive approvals to conduct complex operations with limitations
- Advanced payloads, data analytics, and workflow integration start to mature
- Venture capital investment grows from $25M in 2012 to $550M in 2017
- Major technology companies begin to invest across the drone value chain (Intel, Qualcomm, Samsung, Sony, Amazon, Google, Verizon, AT&T etc.)
- Drone services industry begins to develop
- Innovators pave the way to early adopters as business cases become increasingly compelling
- Covid-19 pandemic highlighted the importance of the drone delivery use case

Note: "Drone" refers broadly to fixed-wing or multirotor Unmanned Aircraft Systems, from hand-launched to those requiring takeoff and landing infrastructure.
Types of operation and adoption rates vary by geography and use case. Regulatory timelines represent U.S. (FAA). Source: Teal Group, Radius Capital analysis

Civil UAS Market Evolution: Next Five Years

Three important adoption inflection points anticipated by 2025

- Sophisticated early adopters obtain use-case specific approvals to conduct complex operations at scale (e.g. BNSF's recent regulatory approval for remote day/night infrastructure inspection operations). Performance-based language of these approvals makes them inherently scalable to other users. Combined with the first wave of commercial drone type certifications, this will result in a meaningful adoption inflection point (1) within the next 12 months
- Second inflection point anticipated in 2023 on the back of C-band data link and Phase 2 DAA certifications (2)
- Increasing airspace integration improves business cases, especially for higher-end systems that can operate BVLOS
- Third significant inflection point expected in the next 3-4 years with the third phase of DAA technology certification (tailored to drones under 55 lbs. and eVTOLs) and certification of SATCOM / cellular C2, coinciding with BVLOS rulemaking (3)
- SBS data sharing between ATM and UTM combined with ACAS sXu collision avoidance algorithms will further accelerate adoption by providing more robust DAA solutions
- Rulemaking on BVLOS and increasing levels of autonomy enable routine operations of increasing complexity
- Adoption accelerates on the back of compelling safety / efficiency ROI, value chain evolution, and the emergence of platforms

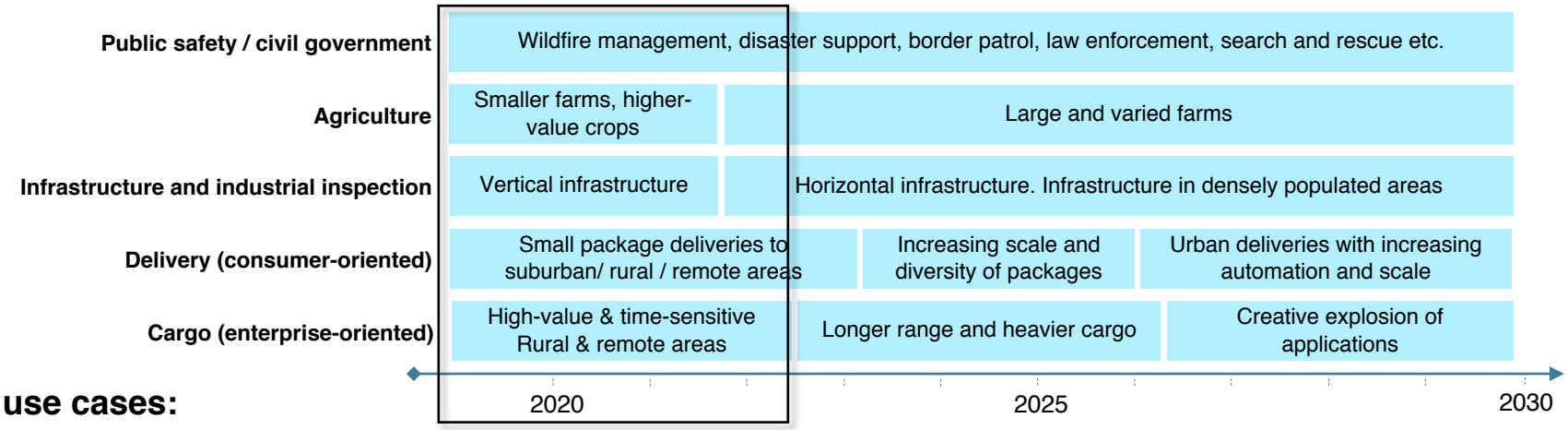


As use cases increase in complexity (e.g. those requiring Part 107 waivers), traffic density grows, and airspace becomes truly integrated, avionics and services of greater reliability and robustness will be needed to demonstrate safety and mitigation of increased air/ground risk, even in airspace below 400 ft

Note: "Drone" refers broadly to fixed-wing or multirotor Unmanned Aircraft Systems, from hand-launched to those requiring takeoff and landing infrastructure. Types of operation and adoption rates vary by geography and use case. Regulatory timelines represent U.S. (FAA). Source: Radius Capital analysis

Civil UAS Market Evolution: Use Cases

Use case complexity evolves in response to technology and regulations



Select existing use cases:

Delivery (consumer-oriented):

- Medical prescriptions, certain grocery / general merchandize items, and premium small package delivery to less complex and traditionally under-served areas (e.g. suburban, rural, remote, weather/disaster struck areas). Concept of operations involves flying in uncontrolled airspace – or in certain classes of controlled airspace with one-off approvals – with a high degree of human supervision on extended VLOS or limited BVLOS routes. Early operators pioneer end-to-end development.

Cargo (enterprise-oriented):

- Time-sensitive missions (e.g. lab sample deliveries, emergency response, critical supplies, wildfire hotshot team resupply, less price-sensitive end users)
- Where opportunity cost is greater than cost of delivery (e.g. urgent factory inputs, wildfire management)
- Where no alternatives exist (e.g. islands, remote areas, lacking infrastructure, weather/disaster struck areas, ship-to-shore)
- Concept of operations includes a mix of small and larger UAS flying in uncontrolled or certain controlled airspace over extended VLOS and pre-panned BVLOS routes with direct operator oversight (1:1 ratio)

Infrastructure and industrial inspection:

- VLOS mapping, surveying and inspection of vertical/spot infrastructure in oil&gas, utilities, construction, renewables, telecommunications, mining, transportation (e.g. wind turbines, solar farms, bridges, tunnels, railroad terminals, cell towers, oil rigs, transmission poles, cell towers). Limited BVLOS inspection of horizontal infrastructure

Agriculture:

- Spraying and imaging of mostly smaller farms with higher-value crops. Finding and monitoring herds on large farms

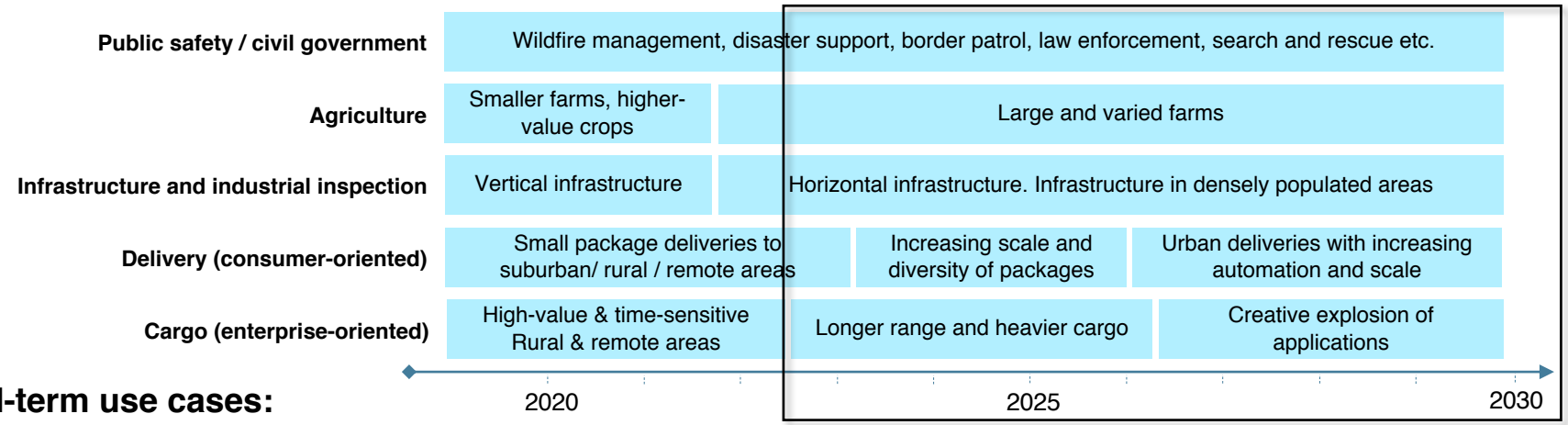
Public safety / civil government:

- Wide range of use cases, from border/maritime patrol, to animal/plant habitat monitoring, to wildfire/forest management, to disaster response and law enforcement. Mostly VLOS and single UAS-to-operator scenarios

Note: not all use cases are included. Maturity varies depending on geography. Source: Radius Capital analysis

Civil UAS Market Evolution: Use Cases

Creative explosion of use cases transforms businesses across the economy



Select near/mid-term use cases:

Delivery (consumer-oriented):

- As UAS dispatchability, capability and utilization improve, scale of operations increases to include larger packages, greater selection of delivered products, and flight in more complex geographies
- Remote operations of multiple increasingly autonomous UAS over ad-hoc BVLOS routes enable growing share of e-commerce and food delivery
- Value chain evolves into specialized service providers and platforms differentiating on markets, geographies, and capabilities

Cargo (enterprise-oriented):

- Greater airspace integration, more robust vehicles, and certification of enabling technologies introduce the premium package and middle mile cargo use case with 500+ mile ranges and payloads of up to 1,000 lbs
- Novel ways of adopting cargo UAS capability by enterprises result in business transformation and a creative explosion of applications. For example, internal courier capability unlocks new business models, productivity gains, and new services. UAS become another tool for operational efficiency improvements, easy to use and tightly integrated with core workflows

Infrastructure and industrial inspection:

- BVLOS operations enable more efficient utilization of higher-end vehicles in mapping, surveying, and inspection of horizontal infrastructure (e.g. railroads, oil and gas pipelines, transmission lines)
- Gradually increasing operations in densely populated areas

Agriculture:

- Spraying and imaging of larger farms with higher-end vehicles conducting BVLOS or remote operations, making the business case compelling for lower-value crops
- Better hyperspectral sensors and analytics tools extend applicability to a broad variety of crops
- Parts and supplies logistics across large farms and ranches

Public safety / civil government:

- Improving efficiency of existing use cases with BVLOS operations and higher UAS-to-operator ratios

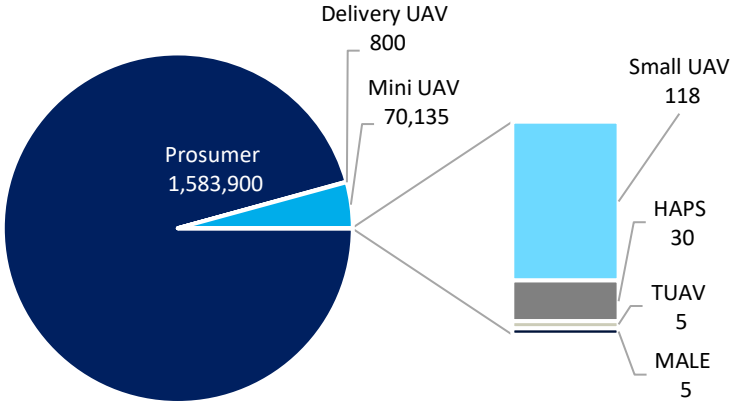
Note: not all use cases are included. Maturity varies depending on geography. Source: Radius Capital analysis

Civil UAS Market: Global Fleet Size (Base Case)

Prosumer systems dominate fleets but yield increasing share to larger and more sophisticated aircraft. Significant part of future commercial UAS are expected to be certified, making it easier to conduct complex operations.

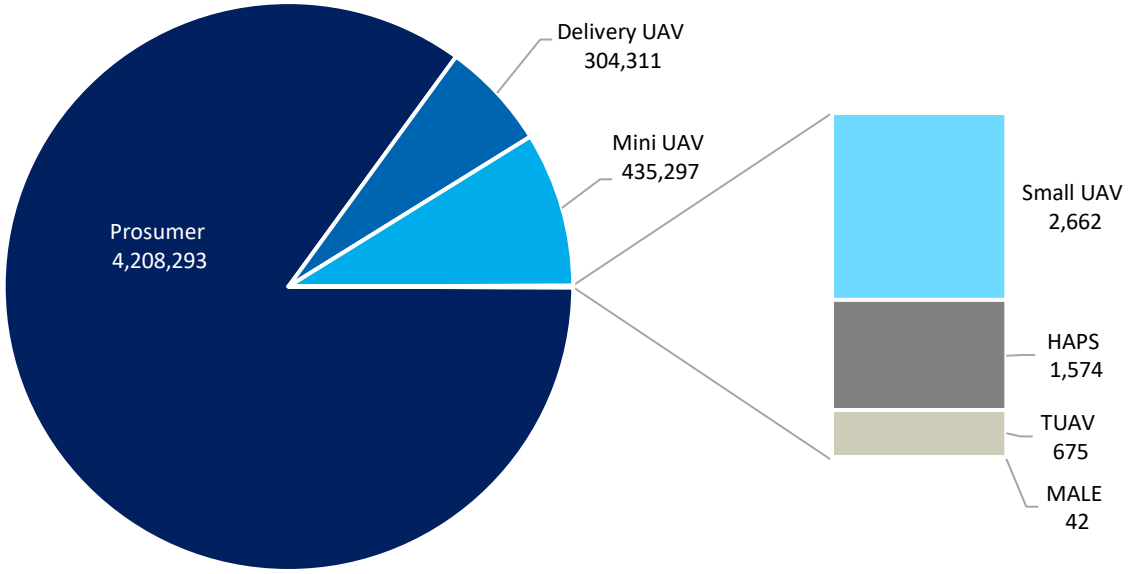
2021 Fleet

~1.7M total UAVs



2029 Fleet

~5M total UAVs



Source: Teal Group (civil UAS production volumes), Radius Capital analysis

Civil UAS Market: Complex Operations Fleet Size (Base Case)

Gradual increase in complex operations generates demand for enterprise-grade services in addition to certified avionics

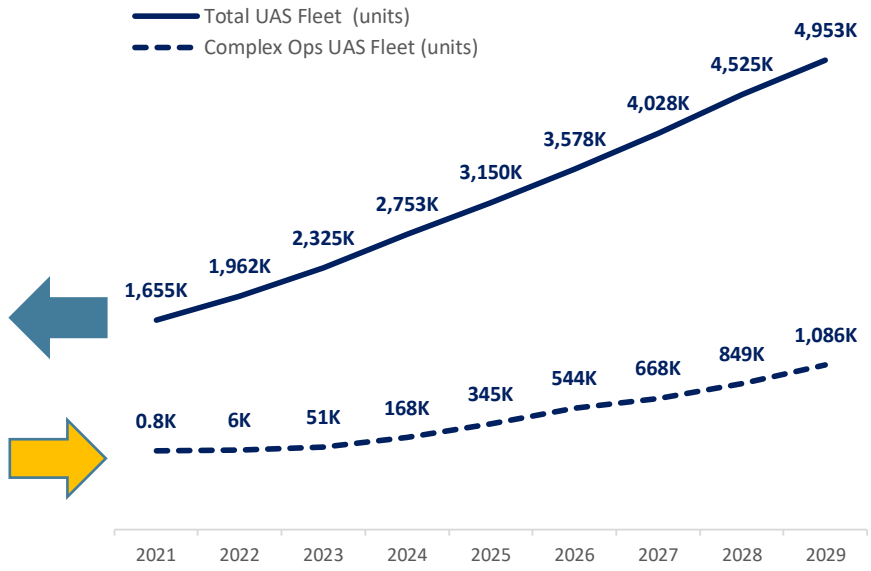
Reaching routine complex operations

Achieving relevant technology, regulatory, community requirements

Operational efficiency improvements

Complex operations as a share of all operations

Market	UAS Type	2021	2022	2023	2024	2025	2026	2027	2028	2029
Agriculture	Mini UAV	0%	2%	14%	35%	56%	70%	70%	70%	70%
Agriculture	Prosumer	0%	1%	6%	15%	24%	30%	30%	30%	30%
Communications	HAPS	20%	40%	60%	80%	100%	100%	100%	100%	100%
Communications	Mini UAV	0%	2%	10%	25%	40%	50%	50%	50%	50%
Construction	Mini UAV	0%	2%	10%	25%	40%	50%	50%	50%	50%
Construction	Prosumer	0%	1%	6%	15%	24%	30%	30%	30%	30%
Delivery	Delivery UAV	1%	3%	20%	50%	80%	100%	100%	100%	100%
Cargo	Small UAV	1%	3%	20%	50%	80%	100%	100%	100%	100%
Cargo	TUAV	1%	3%	20%	50%	80%	100%	100%	100%	100%
Energy	Mini UAV	0%	2%	10%	25%	40%	50%	50%	50%	50%
Energy	Prosumer	0%	1%	8%	20%	32%	40%	40%	40%	40%
Energy	Small UAV	80%	80%	80%	80%	80%	100%	100%	100%	100%
EU Civil Government - Border and Maritime	MALE	100%	100%	100%	100%	100%	100%	100%	100%	100%
EU Civil Government - Border and Maritime	Small UAV	80%	80%	80%	80%	80%	100%	100%	100%	100%
EU Civil Government - National Governments	Mini UAV	0%	2%	10%	25%	40%	50%	50%	50%	50%
EU Civil Government - National Governments	Prosumer	0%	1%	8%	20%	32%	40%	40%	40%	40%
Insurance	Mini UAV	0%	1%	6%	15%	24%	30%	30%	30%	30%
Insurance	Prosumer	0%	1%	4%	10%	16%	20%	20%	20%	20%
Other Industrial Inspection	Mini UAV	0%	2%	16%	40%	64%	80%	80%	80%	80%
Other Industrial Inspection	Prosumer	0%	1%	4%	10%	16%	20%	20%	20%	20%
Photography	Mini UAV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Photography	Prosumer	0%	0%	0%	0%	0%	0%	0%	0%	0%
US Civil Government - Federal	MALE	100%	100%	100%	100%	100%	100%	100%	100%	100%
US Civil Government - Federal	Mini UAV	0%	2%	10%	25%	40%	50%	50%	50%	50%
US Civil Government - Federal	Small UAV	80%	80%	80%	80%	80%	80%	80%	80%	80%
US Civil Government - State and Local	Mini UAV	0%	2%	10%	25%	40%	50%	50%	50%	50%
US Civil Government - State and Local	Prosumer	0%	1%	8%	20%	32%	40%	40%	40%	40%



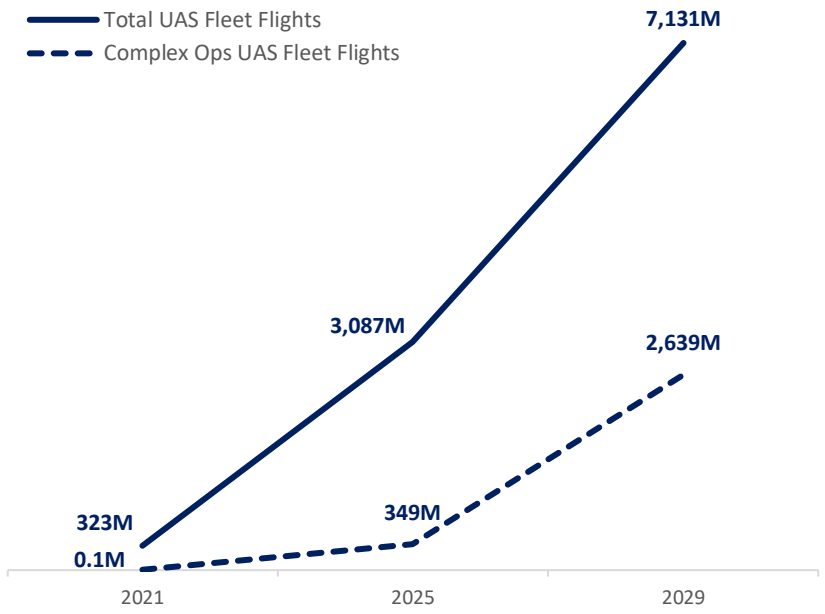
Complex operations are those involving any combination of BVLOS, remote operations or multiple UAS per operator (e.g. large farm imagery and spraying, long-range infrastructure inspections, cargo delivery, remotely-operated dock-based drone services, border / maritime patrol, search & rescue, security & surveillance etc.)

Source: Teal Group (civil UAS production volumes), Radius Capital analysis

radius capital

Civil UAS Market: UAS Utilization (Base Case)

Growth in fleets as well as rising frequency of flights contribute to the increase in UAS utilization



Total UAS Fleet Flights

	2021	2025	2029
Prosumer	309M	2,837M	4,924M
Mini UAV	14M	216M	424M
Delivery UAV	0.2M	33M	1,780M
Small UAV	0.0M	0.7M	2.1M
TUAV	0.0M	0.2M	0.5M
MALE	0.0M	0.0M	0.0M
HAPS	0.0M	0.0M	0.0M
Total	**323M**	**3,087M**	**7,131M**

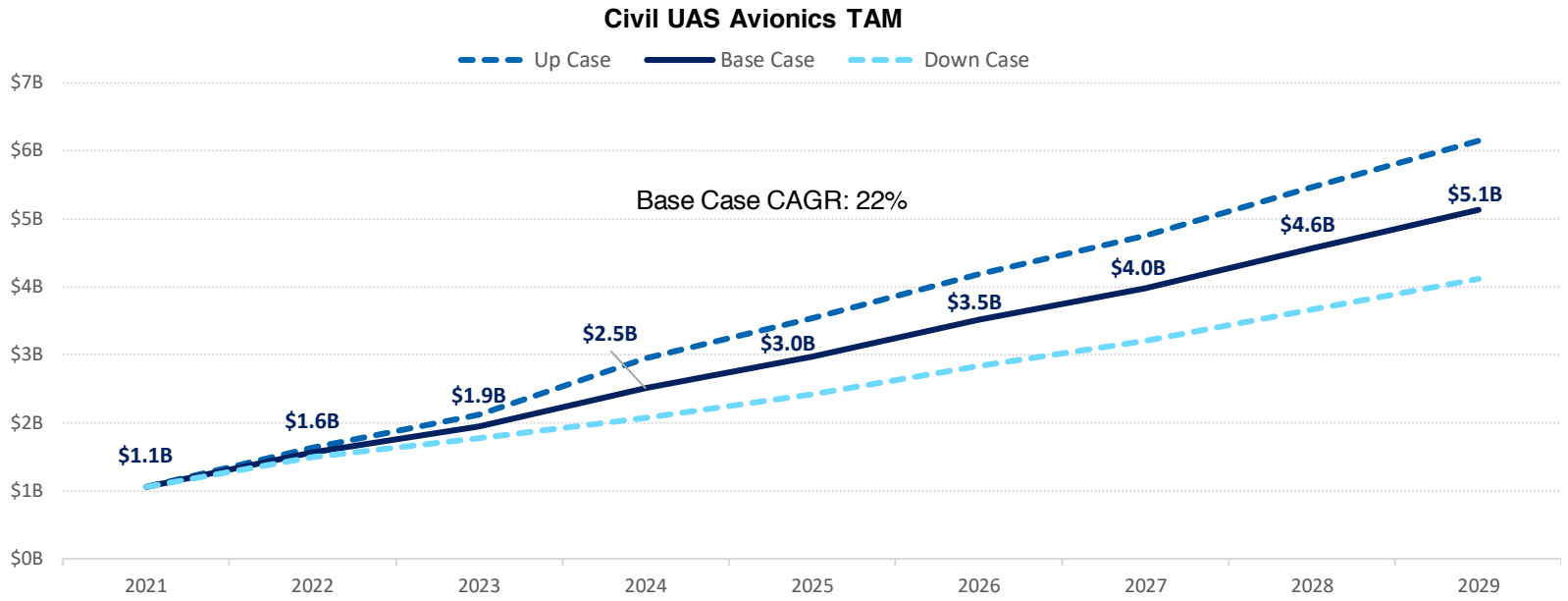
Complex Ops UAS Fleet Flights	2021	2025	2029
	2021	**2025**	**2029**
Prosumer	0.1M	215M	596M
Delivery UAV	0.0M	26M	1,780M
Mini UAV	0.0M	107M	260M
Small UAV	0.0M	0.6M	2.1M
TUAV	0.0M	0.1M	0.5M
MALE	0.0M	0.0M	0.0M
HAPS	0.0M	0.0M	0.0M
Total	**0.1M**	**349M**	**2,639M**

Source: Teal Group (civil UAS production volumes), Radius Capital analysis

Contents

Civil UAS Avionics Market Overview

$27B of aggregate available market through 2029 globally for certified, low form-factor avionics



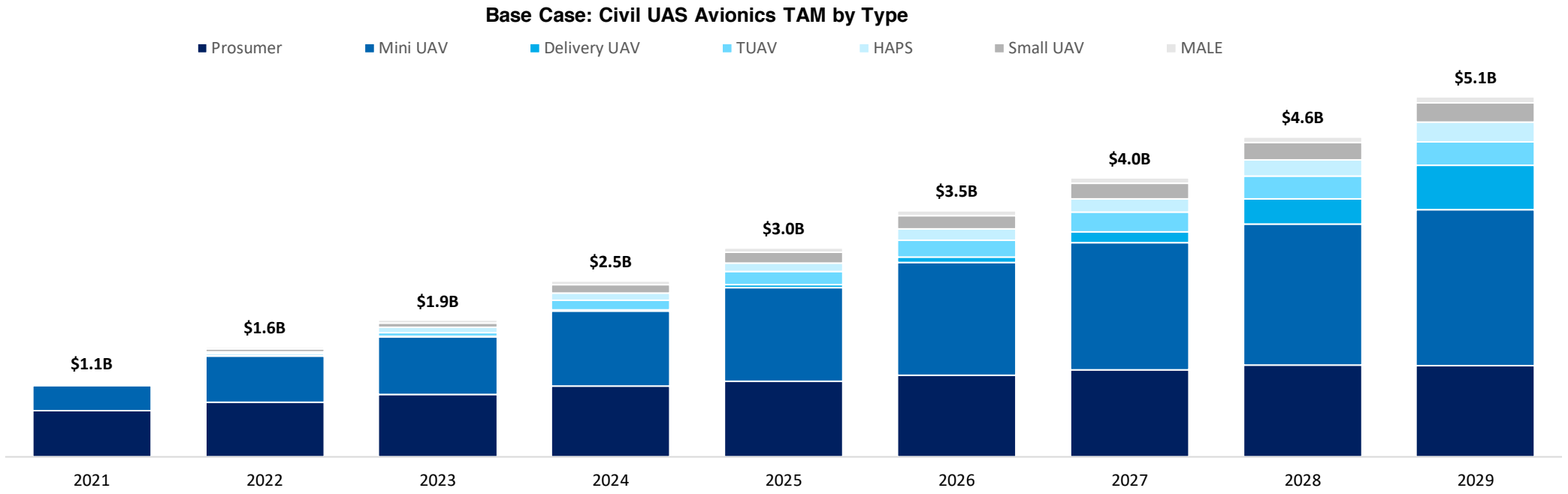
Aggregate 2021-2029 Avionics TAM
(Base Case)

Note: TAM represents total available market expressed as annual revenues for global civil markets.
Source: Teal Group (civil UAS production volumes), Radius Capital analysis

radius capital

Civil UAS Avionics Market (Base Case)

Large market opportunity, progress in foundational technologies, and greater regulatory clarity drive continuous innovation in mission- and safety-critical avionics



	2021	2022	2023	2024	2025	2026	2027	2028	2029
MALE	$14M	$27M	$41M	$57M	$59M	$72M	$74M	$77M	$86M
Small UAV	$17M	$38M	$58M	$120M	$156M	$193M	$223M	$253M	$269M
HAPS	$8M	$33M	$74M	$99M	$120M	$161M	$187M	$227M	$279M
TUAV	$5M	$26M	$57M	$138M	$189M	$237M	$281M	$322M	$340M
Delivery UAV	$2M	$4M	$7M	$14M	$45M	$80M	$156M	$367M	$632M
Prosumer	$660M	$778M	$891M	$1,012M	$1,077M	$1,164M	$1,246M	$1,314M	$1,304M
Mini UAV	$358M	$662M	$821M	$1,072M	$1,335M	$1,607M	$1,810M	$2,005M	$2,222M

Note: TAM represents total available market expressed as annual revenues for global civil markets.
Source: Teal Group (civil UAS production volumes), Radius Capital analysis

Key Drivers of the Civil UAS Avionics Market

Technology proving baseline flight capabilities drive regulatory clarity. This drives market growth and new applications

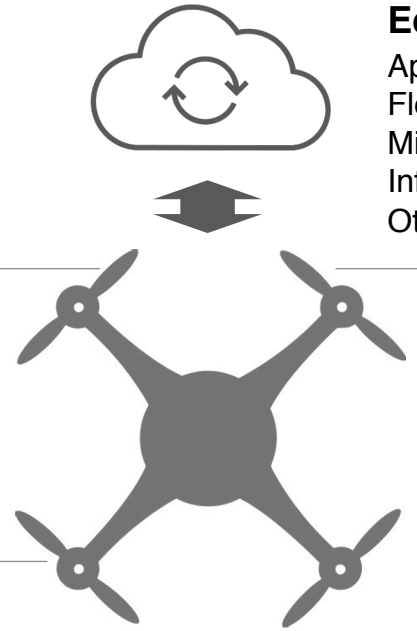
Proliferation of drone use-cases and complex operations drives a feedback loop of further development in advanced avionics, payload data processing and increasing automation

Communication
Redundant LOS or BLOS datalinks
Airborne routers and switches
Mesh networking capability
Cyber-resilience

Detect and Avoid
Transponders
ADS-B and Remote ID
Automatic Identification System
Cameras, radars
Software, signal processing

Navigation
GNSS
Inertial navigation systems
Visual sensors

TAKEAWAY:
Certification of baseline flight capabilities is a key gating factor to use-case expansion, drone proliferation, and further innovation throughout the avionics technology stack



Edge Services
Approved comms network services
Fleet ops management
Mission-specific applications
Infrastructure management
Other services and solutions

TAKEAWAY:
Technologies solving:
- UAS airspace integration
- Dispatchability/utilization
- Large scale operations

-> are key growth catalysts for innovative avionics solutions

TAKEAWAY:
Constant demand for more on-board energy

Energy Management and Safety
Energy storage
Energy management
System redundancy

Airspace integration of increasingly autonomous UAS create demand for DAA / surveillance solutions, software capabilities to support autonomous machine interactions, as well as robust communications

Payload Data Processing
Preliminary data analysis
Video and signal processing
Multi-sensor fusion

Advanced Flight Control
Autopilots
Precision landing capability
Complex maneuvers, behaviors
Multi-ship swarming

TAKEAWAY:
Generally, a premium on:
- Increasing on-board compute power
- Decreasing Size, Weight and Power (SWaP)
- Use of certified components

Civil UAS Avionics Market (Base Case)

Mini and Prosumer UAVs are expected to account for 78% of the aggregate avionics market.
65% of the market will support UAS involved in moderate and high degrees of operations complexity

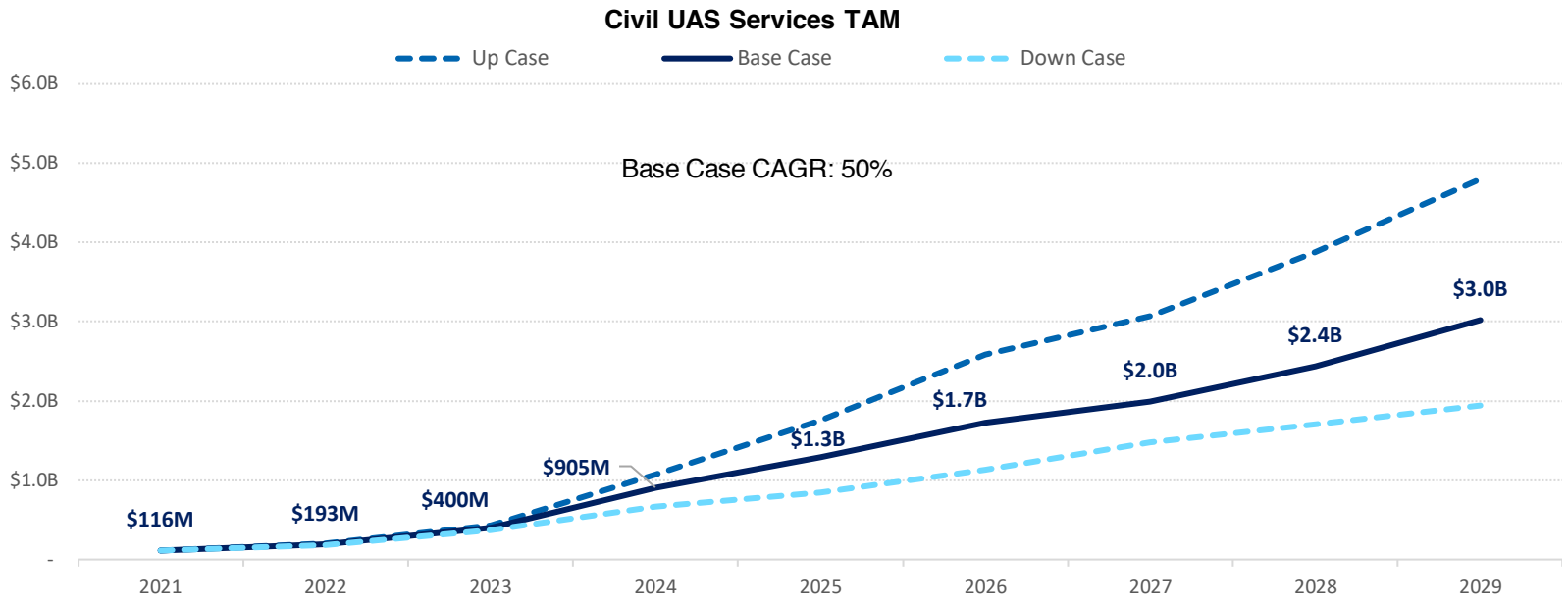
Degree of Operations Complexity	
Occasional	< 30%
Moderate	30-80%
High	>80%

Cumulative 2021-2029 Avionics TAM	Prosumer	Delivery UAV	Mini UAV	Small UAV	TUAV	MALE	HAPS	Total
Agriculture	$1,395M		$6,597M					**$7,993M**
Photography	$6,246M		$93M					**$6,339M**
Construction	$913M		$2,556M					**$3,469M**
Energy	$405M		$1,646M	$644M				**$2,695M**
Cargo				$636M	$1,594M			**$2,231M**
Delivery		$1,308M						**$1,308M**
Other Industrial Inspection	$168M		$427M					**$596M**
Communications			$347M				$1,188M	**$1,535M**
Insurance	$244M		$84M					**$328M**
EU Civil Government - National Governments	$40M		$62M					**$102M**
US Civil Government - State and Local	$35M		$57M					**$91M**
US Civil Government - Federal			$18M	$23M		$233M		**$274M**
EU Civil Government - Border and Maritime				$23M		$275M		**$298M**
Total	**$9,445M**	**$1,308M**	**$11,889M**	**$1,326M**	**$1,594M**	**$508M**	**$1,188M**	**$27,258M**

Note: TAM represents total available market expressed as annual revenues for global civil markets.
Source: Teal Group (civil UAS production volumes), Radius Capital analysis

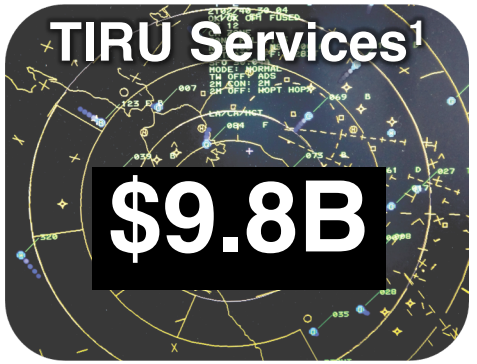
Services Supporting Civil UAS Complex Operations: Market Overview

$12B of aggregate available market through 2029 globally for C2 network management, traffic information, risk management, and UTM services



Aggregate 2021-2029 Services TAM

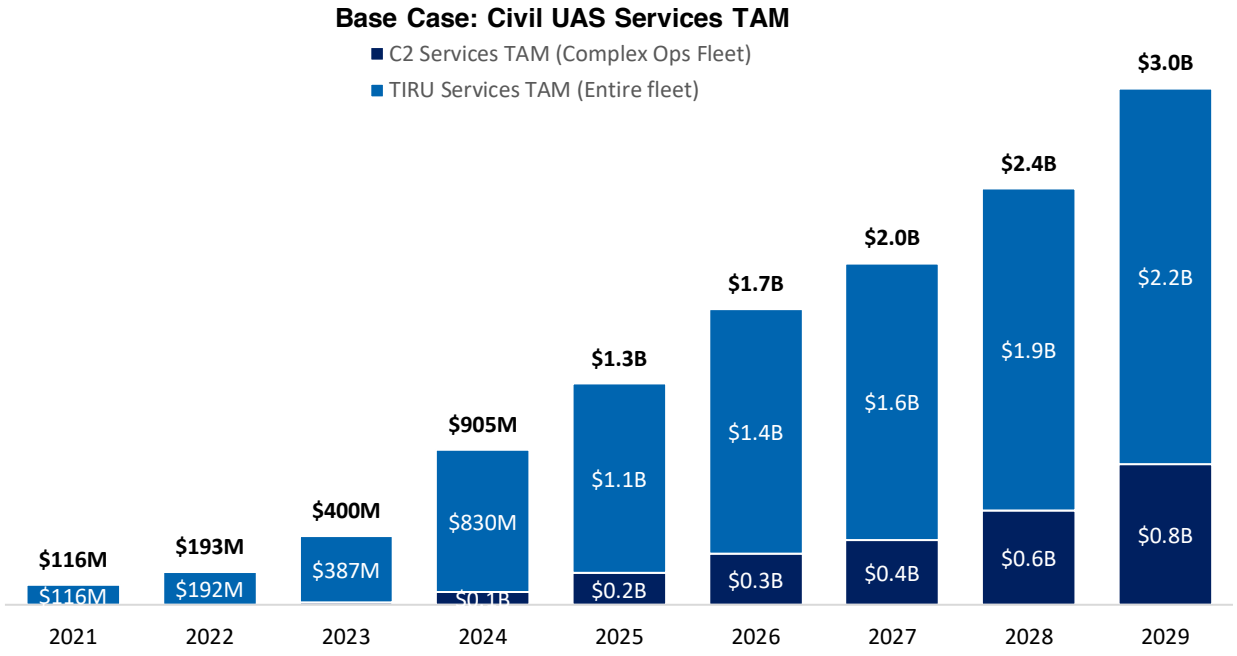
(Base Case)



Note: TAM represents total available market expressed as annual revenues for global civil markets.
[1]TIRU services represent Traffic Information, Risk Management, and UTM. Source: Teal Group (civil UAS production volumes), Radius Capital analysis

Services Supporting Civil UAS Complex Operations (Base Case)

Increasing complexity of UAS operations pave the way for dedicated aviation-grade C2 and TIRU services



	2021	2022	2023	2024	2025	2026	2027	2028	2029
HAPS	$0M	$0M	$0M	$1M	$1M	$1M	$1M	$1M	$1M
MALE	$0M	$0M	$0M	$1M	$2M	$3M	$3M	$4M	$4M
Small UAV	$0M	$0M	$1M	$5M	$12M	$18M	$21M	$32M	$35M
TUAV	$0M	$0M	$1M	$7M	$23M	$34M	$41M	$65M	$71M
Delivery UAV	$0M	$0M	$0M	$2M	$16M	$52M	$135M	$380M	$837M
Mini UAV	$23M	$45M	$108M	$294M	$486M	$639M	$734M	$821M	$912M
Prosumer	$93M	$148M	$290M	$596M	$753M	$983M	$1,060M	$1,129M	$1,158M

Key Market Drivers

- As C2 / DAA technology and regulatory milestones start to be gradually met over the coming years, frequency of complex operations increases significantly, driving growth in per-flight business models
- C2 network management service is expected to be consumed by the complex operations fleet only, whereas the addressable market for TIRU services is the entire fleet
- Due to cost and weight penalties associated with additional sensors, traffic information services will complement on-board avionics for meeting DAA requirements
- Aviation-purposed and certified C2 network systems will play a critical role in ensuring safety, scalability, and extensibility of UAS operations, and will give rise to specialized third-party service providers. Furthermore, spectrum scarcity will drive dynamic frequency allocation and other bandwidth management solutions, particularly for high-density operations
- Risk management and mitigation services (e.g. GNSS coverage and availability forecasting, RF coverage mapping, weather, air/ground risk assessment etc.) will grow in importance as mission complexity increases
- Service providers will bundle offerings to increase competitiveness (e.g. C2 network service providers will be well placed to offer tracking / traffic information services)
- Reliability and robustness of services will increase from less robust web-based services to much more reliable and robust infrastructure and services catering operations with higher risk profiles. This will result in industry consolidation and specialization
- The industry is still exploring appropriate service pricing models, creating both risks and opportunities in estimating TAM

Note: TAM represents total available market expressed as annual revenues for global civil markets.
Source: Teal Group (civil UAS production volumes), Radius Capital analysis

radius capital

Services Supporting Civil UAS Complex Operations (Base Case)

Broad applicability of TIRU services across UAS types and use cases of all levels of operations complexity

Degree of Operations Complexity

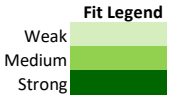
Occasional	< 30%
Moderate	30-80%
High	>80%

2021-2029 Cumulative Services TAM	Prosumer	Delivery UAV	Mini UAV	Small UAV	TUAV	MALE	HAPS	Total
Agriculture	$929M		$2,323M					**$3,252M**
Photography	$4,071M		$20M					**$4,091M**
Construction	$622M		$845M					**$1,467M**
Energy	$265M		$524M	$59M				**$849M**
Cargo				$61M	$242M			**$303M**
Delivery		$1,422M						**$1,422M**
Other Industrial Inspection	$114M		$165M					**$278M**
Communications			$116M				$6M	**$122M**
Insurance	$160M		$24M					**$184M**
EU Civil Government - National Governments	$26M		$20M					**$46M**
US Civil Government - State and Local	$23M		$19M					**$42M**
US Civil Government - Federal			$6M	$2M		$9M		**$16M**
EU Civil Government - Border and Maritime				$2M		$9M		**$11M**
Total	**$6,209M**	**$1,422M**	**$4,061M**	**$124M**	**$242M**	**$17M**	**$6M**	**$12,082M**

Note: TAM represents total available market expressed as annual revenues for global civil markets.
Source: Teal Group (civil UAS production volumes), Radius Capital analysis

Services Supporting Civil UAS Complex Operations (Base Case)

C2 Services



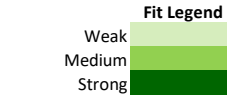
2021-2029 Cumulative C2 Service TAM	Prosumer	Delivery UAV	Mini UAV	Small UAV	TUAV	MALE	HAPS	Total
Agriculture	-		$876M					$876M
Photography	-		-					-
Construction	-		$262M					$262M
Energy	-		$160M	$29M				$190M
Cargo				$30M	$118M			$148M
Delivery		$710M						$710M
Other Industrial Inspection	-		$69M					$69M
Communications			$37M				$3M	$40M
Insurance	-		$5M					$5M
EU Civil Government - National Governments	-		$6M					$6M
US Civil Government - State and Local	-		$6M					$6M
US Civil Government - Federal			$2M	$1M		$4M		$7M
EU Civil Government - Border and Maritime				$1M		$4M		$5M
Total	-	$710M	$1,423M	$61M	$118M	$9M	$3M	$2,323M

- Managed C2 network service is not expected to offer a compelling fit among Prosumer systems, or within the photography and insurance use cases, since most of those use cases will not require aviation-grade communications systems
- For those use cases involving flights beyond visual range, over people, where multiple UAS are supervised by a single remote operator, or in controlled airspace, a C2 network management service will provide additional assurances in order to build a more robust safety case

Note: TAM represents total available market expressed as annual revenues for global civil markets.
Source: Teal Group (civil UAS production volumes), Radius Capital analysis

Services Supporting Civil UAS Complex Operations (Base Case)

TIRU Services



2021-2029 Cumulative TIRU Services TAM	Prosumer	Delivery UAV	Mini UAV	Small UAV	TUAV	MALE	HAPS	Total
Agriculture	$929M		$1,447M					$2,375M
Photography	$4,071M		$20M					$4,091M
Construction	$622M		$583M					$1,205M
Energy	$265M		$364M	$30M				$659M
Cargo				$31.1M	$123.8M			$155M
Delivery		$713M						$713M
Other Industrial Inspection	$114M		$96M					$209M
Communications			$79M				$3M	$82M
Insurance	$160M		$19M					$179M
EU Civil Government - National Governments	$26M		$14M					$40M
US Civil Government - State and Local	$23M		$13M					$36M
US Civil Government - Federal			$4M	$1M		$4M		$9M
EU Civil Government - Border and Maritime				$1M		$4M		$5M
Total	**$6,209M**	**$713M**	**$2,638M**	**$63M**	**$124M**	**$9M**	**$3M**	**$9,759M**

- Unlike the C2 service which is most relevant to UAS involved in complex operations, TIRU services are expected to generate demand from all UAS types engaged across all use cases. Much like flight planning and authorizations in manned aviation, TIRU services will enhance safety, operational efficiency, regulatory compliance, and ultimately use case value proposition

Note: TAM represents total available market expressed as annual revenues for global civil markets.
Source: Teal Group (civil UAS production volumes), Radius Capital analysis

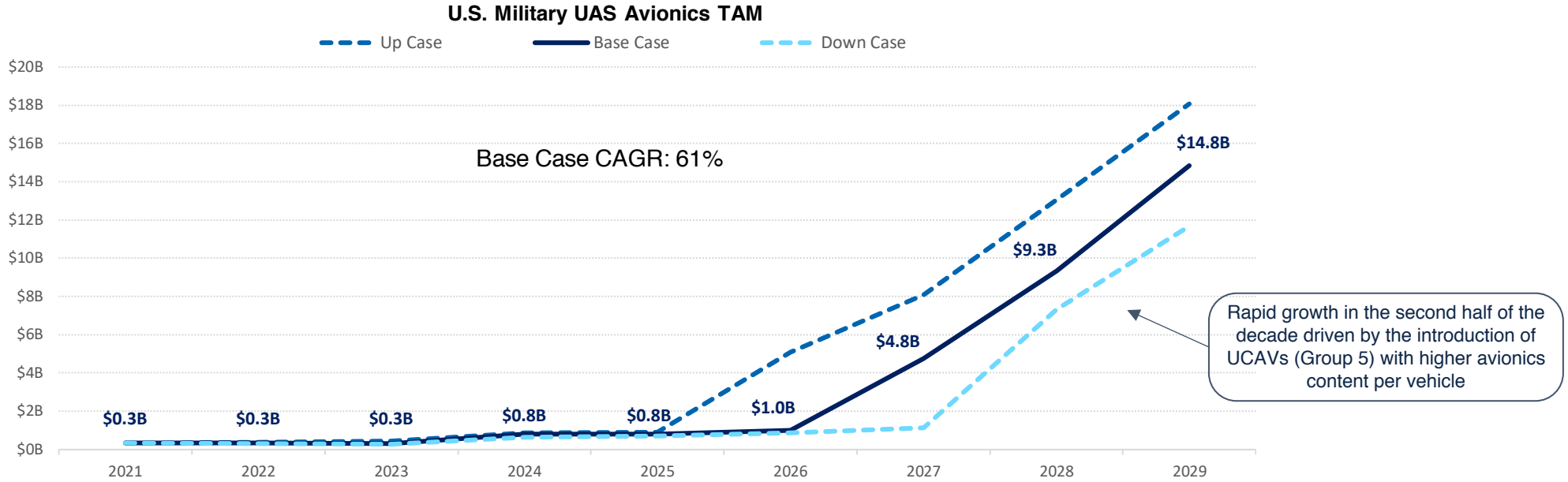
Contents

U.S. Military UAS Market: Key Themes

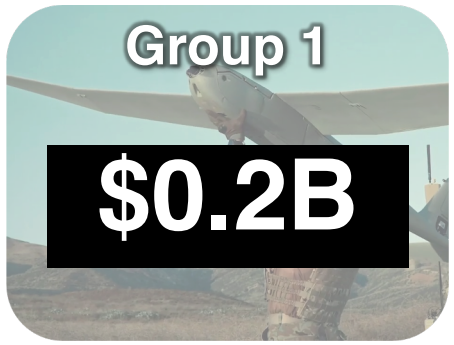
Calm before the storm	The next two years will reflect preliminary acquisition rates while the Biden administration's strategy on defense spending matures. Several waves of new programs, upgrades, and capabilities will follow from year 2-3 onward
Increasing battlefield complexity	The complexity of scaled employment of UAS alongside other platforms on both sides of the fight are shown to create chaos in the battlefield. Solutions that increase situational awareness and improve counter-UAS operations at compelling SWaP levels will play a critical role
Technological progress continues unabated	New technologies are accelerating novel UAS capabilities, concepts and missions for forces worldwide, amplifying competition and demand for effective operational integration at scale
Changing global threat environment	Addressing strategic competition with China and managing other persistent global threats will require increased reliance and investment in UAS that are scalable and integrated with overall force structure
International militaries accelerate UAS adoption	As UAS become more affordable and available, militaries around the world increasingly acquire UAS to obtain capabilities previously available to only the most sophisticated and well-funded forces

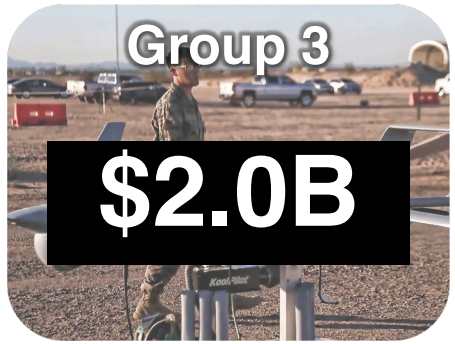
U.S. Military UAS Avionics Market Overview

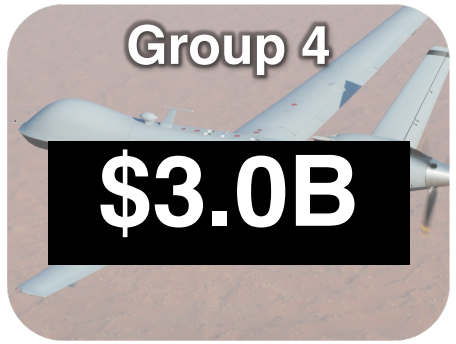
Rapid global proliferation of UAS and their mass employment in conflicts will create more complex and chaotic battlefields favoring solutions that increase situational awareness at low SWaP levels

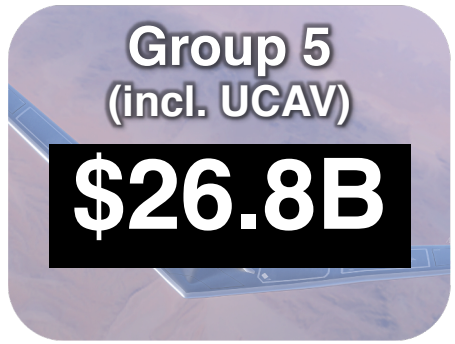


Aggregate 2021-2029 Avionics TAM
(Base Case)





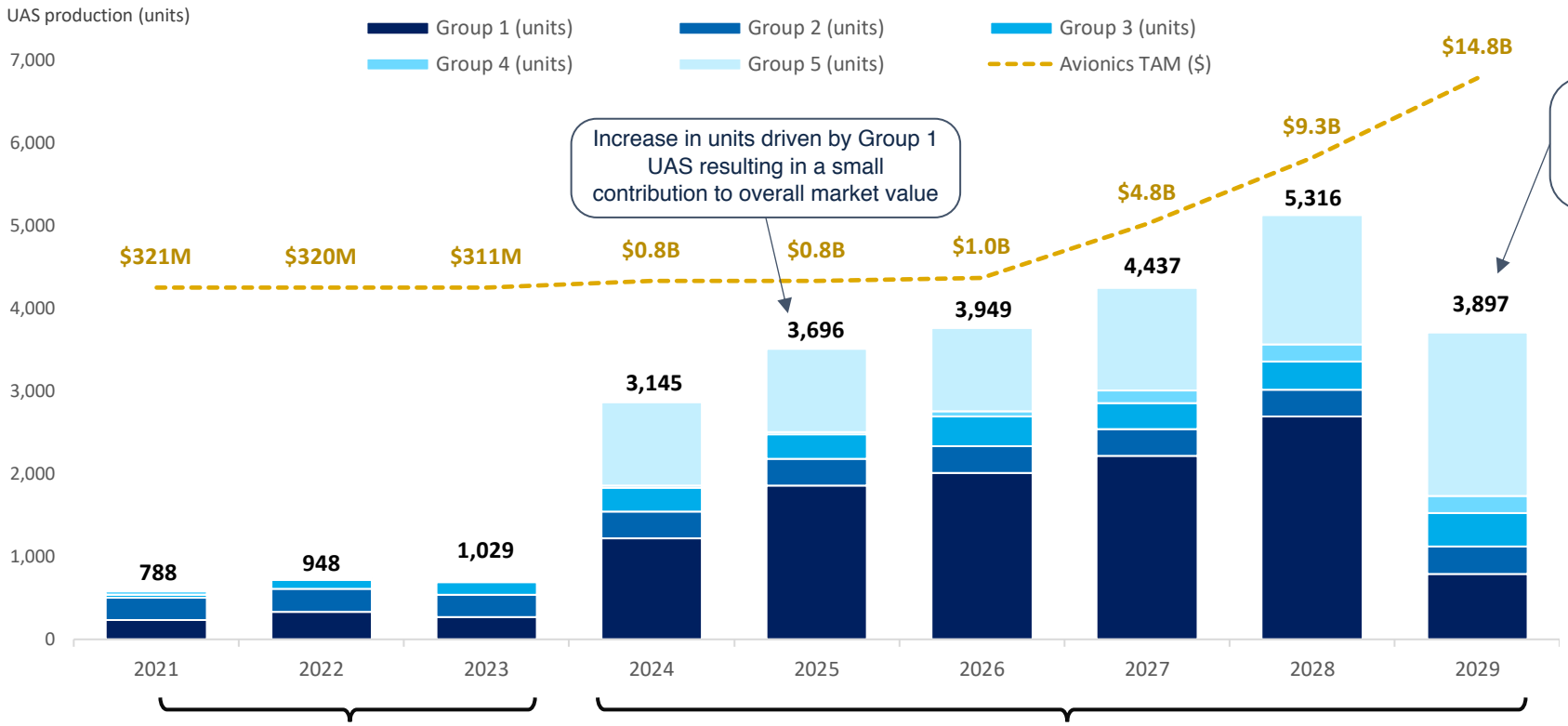




Note: TAM represents total available market expressed as annual revenues for the U.S. military market.
Source: Radius Capital analysis

U.S. Military UAS: Production Volumes and Avionics TAM

Steady and tempered growth in the first two years followed by a buying spree across all UAS groups



	2021-29 Fleet CAGR	2021-29 TAM**
Group 1*:	3.4%	$194M
Groups 2 and 3:	16.4%	$2,469M
Group 4:	10.2%	$3,018M
Group 5:	81.3%	$26,794M

With the Biden administration still developing a long-term defense spending strategy, large procurement efforts for new programs are less likely to occur in the next two years (although geopolitical events may accelerate timeline)

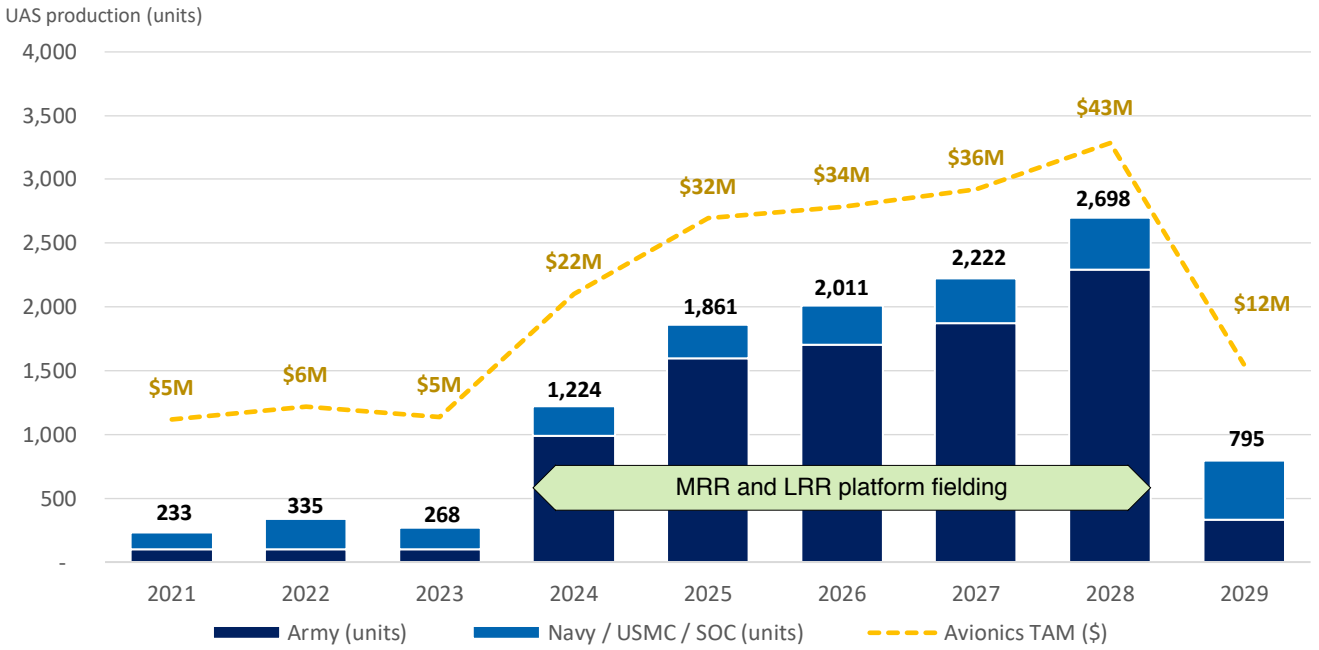
A wave of new programs and upgrades (e.g. MRR, LRR, FTUAS, RQ-7B Block III upgrade, MEUAS IV, USMC RQ-21 replacement, USN ScanEagle replacement) as well as the introduction of new concepts and capabilities (e.g. Loyal Wingman, ULS-A, ALE) support significant growth throughout the decade.
As fleet mix evolves to a 25%+ UCAV share, TAM continues to grow even as volumes come down at the end of the forecast period

- Key national security focus areas – addressing strategic competition with China, dealing with persistent threats from Russia, Iran, and North Korea, as well as innovation and modernization – provide strong macro tailwinds for the rapid growth of dual-use technologies underpinning UAS, and their accelerated adoption by the warfighters

*Quadcopters, Micro UAS and Nano UAS are not included. **TAM represents 2021-29 cumulative total available market expressed as annual revenues for the U.S. military market. Source: Radius Capital analysis*

U.S. Military UAS – Group 1 Production and Avionics TAM

As one of the greatest contributors to the complexity and chaos of future battlefields, Group 1 UAS stand to benefit greatly from solutions that provide increased situational awareness, including miniaturized Mode 5 IFF micro-transponders



	2021-25	2021-29
Fleet CAGR	2.6%	3.4%
DoD production (units)	3,920	11,645
TAM ($)	$70M	$194M

Group 1 *

Weight: 0-20 lbs.

Altitude: <1,200 ft

Speed: <100 kts

Small and light hand-launched systems typically employed at the company level for tactical ISR

Examples:

RQ-11 Raven

RQ-20 Puma

Key Market Drivers

- Army's legacy RQ-11B Raven fleet will be replaced by the MRR platform (RQ-11C) starting ~2024. New procurement is expected to account for appx. 2/3 of the fleet, the balance being modifications of existing fleets
- Army's RQ-20A Pumas are expected to be replaced by the LRR platform beginning mid-decade
- Continued and increasing demand from Navy, USMC, and SOC

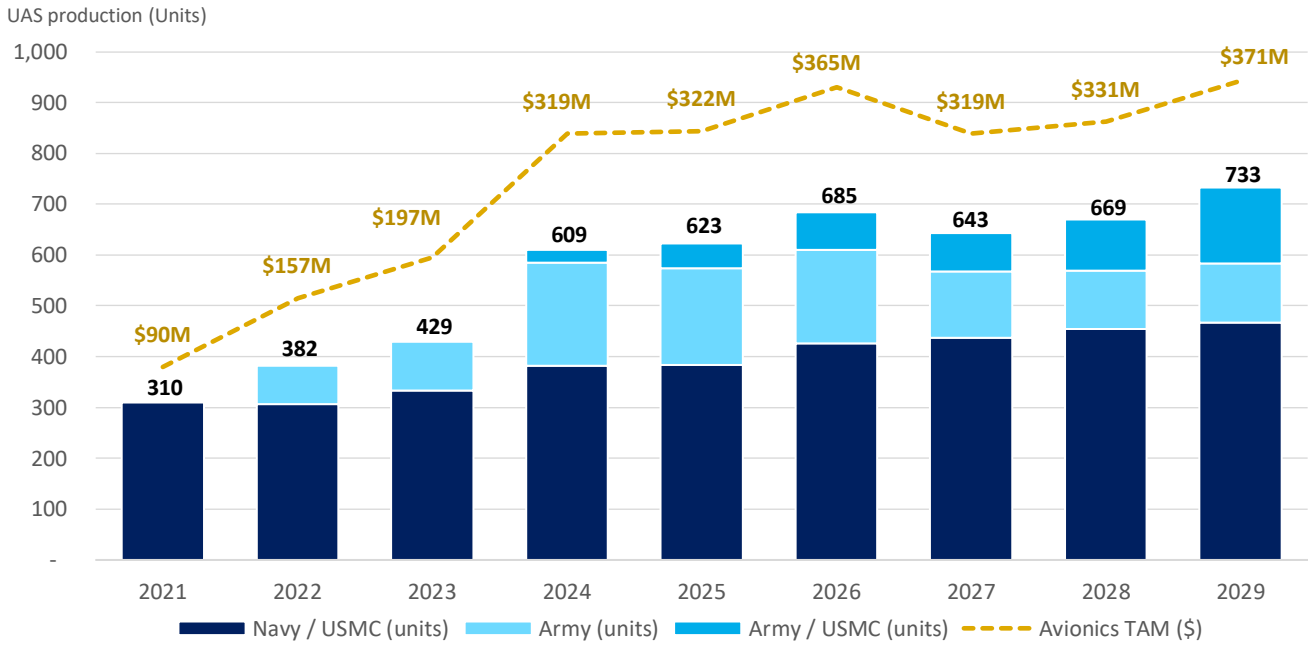
Risks / Opportunities

- Group 1 UAS represent a significant opportunity for small form factor avionics solutions, including micro-transponder solutions (Mode 5 IFF). While the IFF requirement is not certain for Group 1 UAS, this is primarily because no such capability previously existed at required SWaP-C levels
- Army's SRR program (quadcopter) is not considered in this analysis, but represents additional upside
- Risk of delay in the ramp up of MRR and LRR programs

**Quadcopters, Micro UAS and Nano UAS are not included. Source: Radius Capital analysis*

U.S. Military UAS – Groups 2 and 3 Production and Avionics TAM

The fastest-growing near-term market segment showing strong demand for advanced avionics solutions



	2021-25	2021-29
Fleet CAGR	16.9%	16.4%
DoD production (units)	2,354	5,083
TAM ($)	$1,084M	$2,469M

Group 2

Weight: 21-55 lbs.
Altitude: <3,500 ft
Speed: <250 kts

Larger rail-launched systems with better payloads compared to Group 1, usually employed at the company/battalion level for tactical ISR

Examples:


Boeing ScanEagle


Lockheed Martin Stalker XE

Group 3

Weight: <1,320 lbs.
Altitude: <18,000 ft
Speed: <250 kts

Higher-flying and heavier UAS than Group 2 conducting more complex tactical missions, including strike. Can be rail- or runway-launched, and may also include VTOL capability

Examples:


Textron RQ-7 Shadow


RQ-21 Blackjack

Key Market Drivers

- Introduction of Army's FTUAS program with full rate production in 2024, and a partial upgrade of current RQ-7Bv2 Shadow fleet to the Block III standard
- Mid-decade replacement of Marines' RQ-21 Blackjacks
- MEUAS IV contract for ISR services averaging 25 Group 3 units annually
- Replacement of existing US Navy ScanEagle fleet in the second half of the decade

Risks / Opportunities

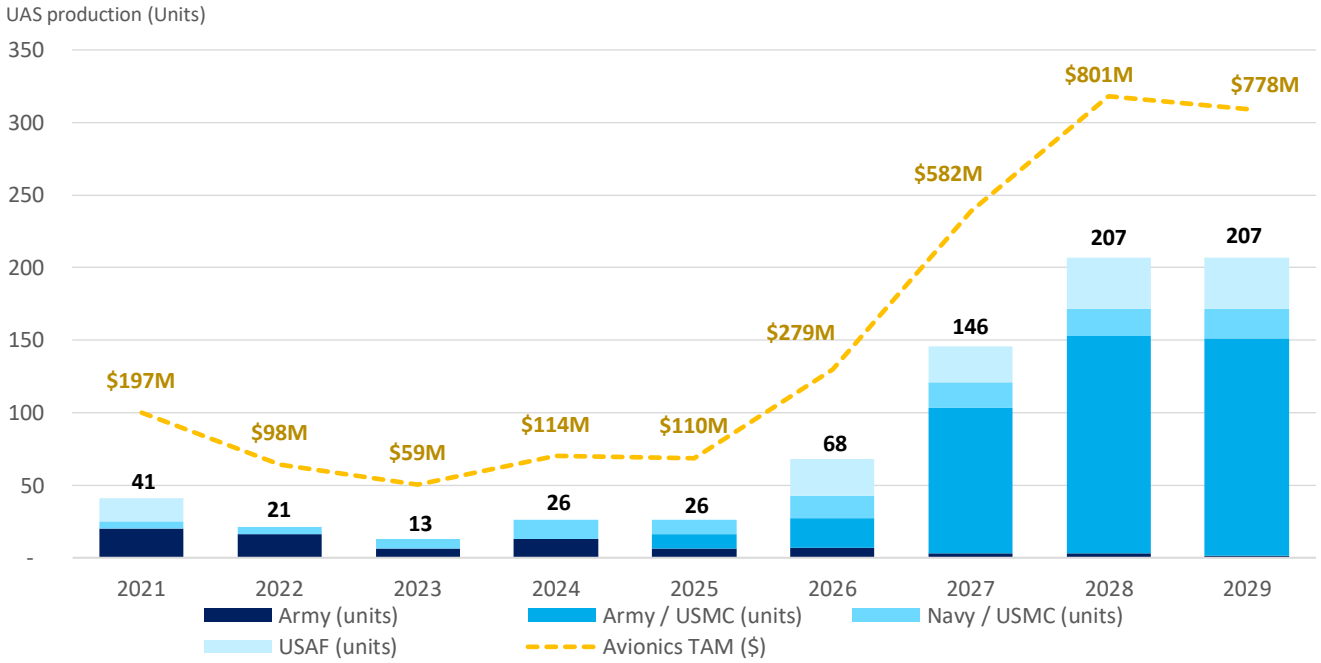
- Textron's recent contract award (up to $607M) to upgrade Army's existing RQ-7Bv2 Shadow fleet to the Block III standard introduces some uncertainty to the timeline of the FTUAS program
- There is growing interest in unmanned aerial logistics capabilities by the Army (ULS-A) and USAF, both of which are targeting a mid-decade initial operational capability for small and medium cargo UAS. Several hundred Group 3 aircraft could be sold in the second-half of the decade for this mission

Source: Radius Capital analysis

radius capital

U.S. Military UAS – Group 4 Production and Avionics TAM

Strong growth in the out-years with new programs and additional waves of Reaper variant procurements



	2021-25	2021-29
Fleet CAGR	3.2%	10.2%
DoD production (units)	127	754
TAM ($)	$578M	$3,018M

Key Market Drivers

- Continued buildup of Army's Gray Eagle fleet with an additional buy of ~75 aircraft
- Marines are expected to grow its Reaper fleet to 30-40 aircraft, up from 2 currently
- The future of USAF Reaper procurement has been a topic of heated debate. Despite USAF pushback, Congress added 16 aircraft to the FY21 budget. We expect additional Reaper acquisitions in the second half of the decade as a substitute for the LCAAT

Group 4

Weight: >1,320 lbs.

Altitude: <18,000 ft

Speed: Any

Manned aircraft-like systems capable of conducting complex operations including strike. Either VTOL or conventional runway-based launch and recovery

Examples:

MQ-9 Reaper

MQ-8 Fire Scout

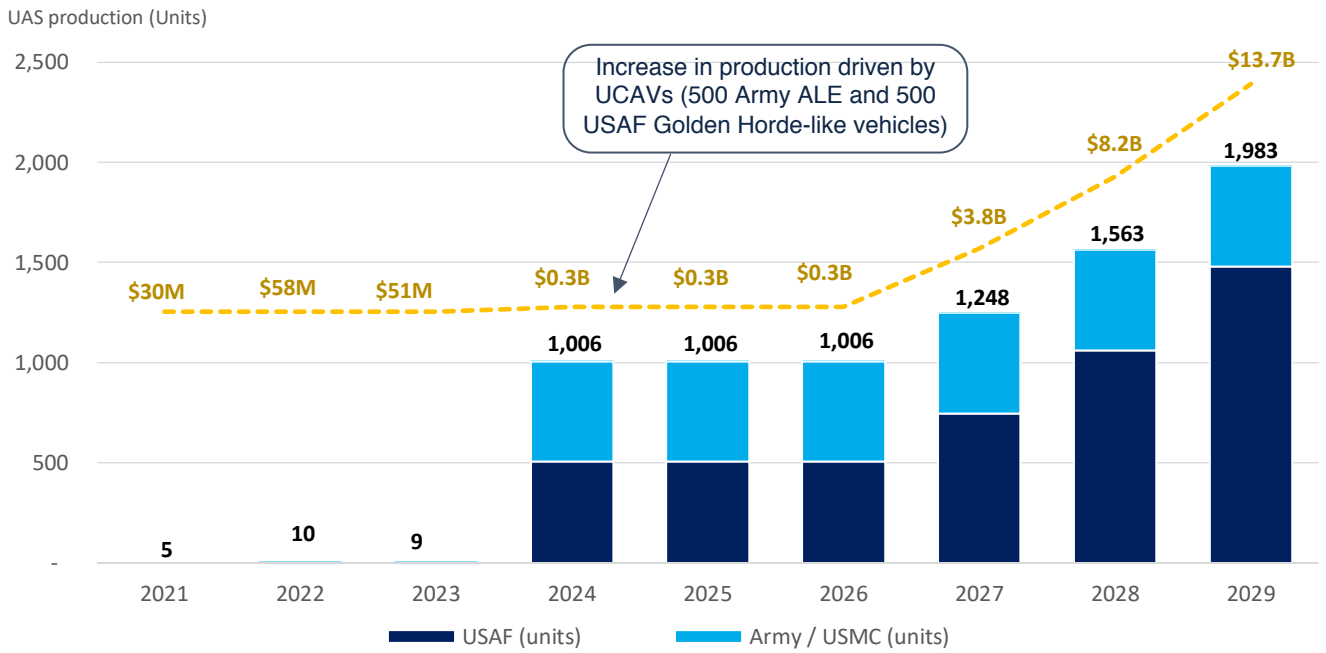
Risks / Opportunities

- A major concern with existing Group 4 (and 5) UAS is their questionable survivability in complex air defense environments expected in the future. This has led to a lot of discussion about a Reaper replacement program, yet it is unlikely that such an aircraft will achieve operational capability in this decade (same with the Marines' Group 4 MUX aircraft). Instead, we expect additional modified Reaper procurement throughout the decade
- Several hundred Group 4 cargo UAS capable of carrying 300-500lb payloads over a 20-125 mi radius (ULS-A) are expected to be fielded in the second half of the decade across branches

Source: Radius Capital analysis

U.S. Military UAS – Group 5 Production and Avionics TAM

Expecting significant growth in UCAV fleets with lots of upside in Loyal Wingman and logistics use cases



	2021-25	2021-29
Fleet CAGR	134.0%	81.3%
DoD production (units)	2,036	7,835
TAM ($)	$802M	$26,794M

Group 5

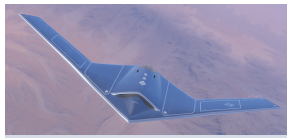
Weight: >1,320 lbs.

Altitude: >18,000 ft

Speed: Any

Similar to Group 5, but capable of operating at higher altitudes. Includes UCAV combat systems

Examples:



RQ-180

RQ-4 Global Hawk

Key Market Drivers

- No additional USAF RQ-4 purchases through the end of the decade and a pause on Navy's MQ-4C Triton procurement
- Steady annual production of several RQ-180 stealth ISR aircraft throughout the forecast period
- ~1,500 Loyal Wingman UCAVs for adversarial air combat training and as compliment to F-22/F-35s[1]
- Mid-decade fielding of ALE and Golden Horde-like UCAVs. Production rates mimic stand-off weapons

Risks / Opportunities

- Very high probability of significant Group 5 (ISR and UCAV) classified activity in USAF presents unknown upside opportunity in this market segment
- Risk of Loyal Wingman production delay until early 2030s
- IFF requirements for Army's ALE and USAF's Golden Horde programs are not yet obvious
- No LCAAT aircraft are included in the forecast due to concerns around ability to make such UAS affordably enough to justify their attritable nature. Additional Group 4 (Reaper) aircraft are assumed instead

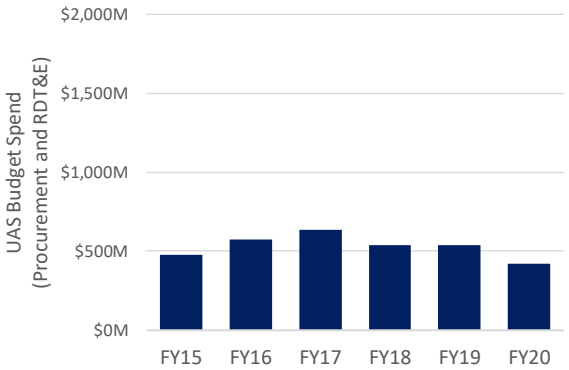
[1]*Loyal Wingman forecast assumes 2-4 such UCAVs for every F-22/F-35 by 2030 (1,500 represents the midpoint of this range). Source: Radius Capital analysis*

radius capital

United States DoD UAS Spending Trends

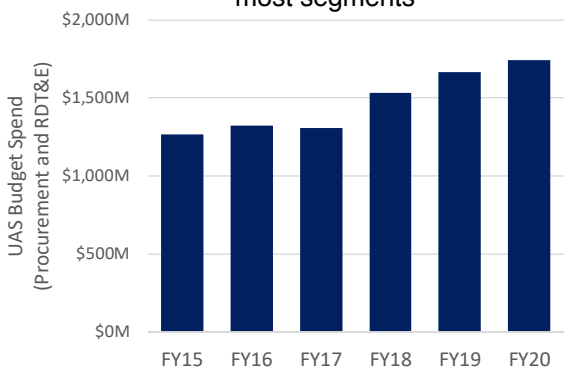
Strengthened, continuing, or pent-up demand for all UAS segments across every service branch

Decreasing trend in historical spend across most UAS groups indicate strong pent-up demand for several upcoming new programs (MRR, LRR, FTUAS, ALE)



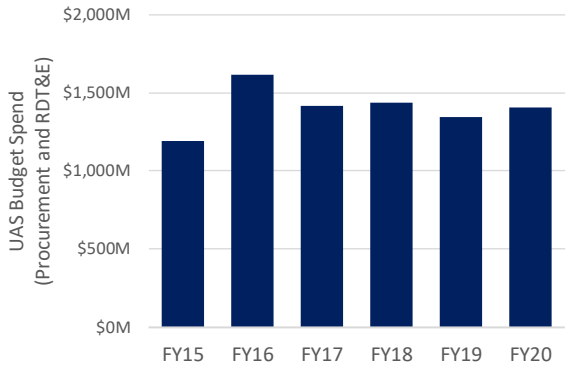
- Group 1 procurement in recent years (Raven and SRR) broke a long pause of no meaningful purchases since mid 2010s
- Recent pick-up in next-gen tactical system / FTUAS RDT&E funding
- Decreasing budget for Group 4 UAS since the MQ-1C Gray Eagle procurement peak in early 2010s, partly offset by recent increases in Gray Eagle modifications

Traditionally a laggard in UAS adoption, the Navy and Marines have considerably invigorated UAS plans and funding through a family of systems approach spanning most segments



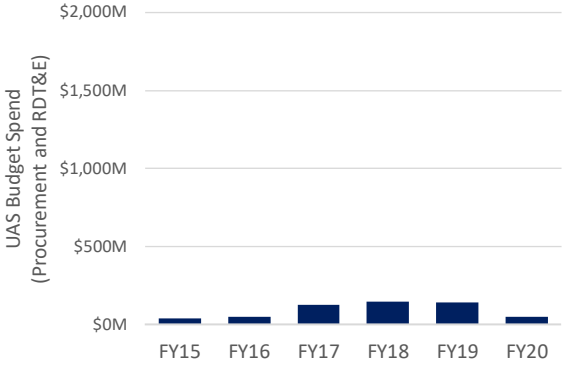
- Recent pick-up in Raven purchases for the Marines confirm increasing appetite for ISR capability at the tactical level
- Drop-off in Group 3 procurement as Marines discontinue MQ-21 Blackjack purchases
- Significant increase in Group 4 spend, primarily related to RDT&E funding for the MQ-25 program
- Somewhat decreasing procurement and RDT&E funding for the MQ-4C over the recent years

Stable and predictable funding trend coupled with increased RDT&E investment in future technologies



- After a long pause, Group 1 RQ-20 Puma procurement funding reappeared in the last couple of budget cycles
- Choppy historical Group 4 funding, but recently on the rise with Reaper procurement, modifications, and new payloads
- Increased investment in advanced technologies and concepts (LCAAT, Skyborg, Golden Horde and others)

Decreased Group 1 procurement in FY20 breaks an otherwise impressive growth in UAS funding



- Despite a decrease in Group 1 funding in FY20, SOC has demonstrated an insatiable appetite for this segment, which is expected to continue

Source: Teal Group (DoD budget data), Radius Capital analysis

Glossary

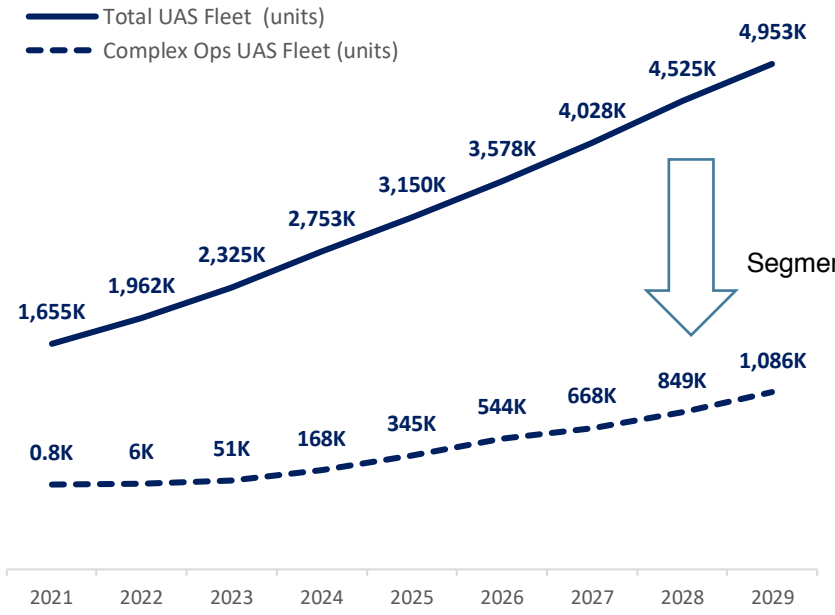
- **AAM**: Advanced Aerial Mobility
- **ADS-B**: Automatic Dependent Surveillance – Broadcast
- **AIS**: Automatic Identification System
- **ALE**: Air Launched Effects
- **ATM**: Air Traffic Management
- **BLOS**: Beyond Line of Sight
- **BVLOS**: Beyond Visual Line of Sight
- **C2**: Command and Control
- **CNS**: Communications Navigation Surveillance
- **DAA**: Detect And Avoid
- **eVTOL**: electric Vertical Takeoff and Landing
- **FAA**: Federal Aviation Administration
- **FTUAS**: Future Tactical Unmanned Aerial System
- **GNSS**: Global Navigation Satellite System
- **GPS**: Global Positioning System
- **HALE**: High Altitude Long Endurance
- **HAPS**: High Altitude Pseudo Satellite
- **IFF**: Identification Friend or Foe
- **INS**: Inertial Navigation System
- **ISR**: Intelligence Surveillance Reconnaissance
- **LCAAT**: Low-Cost Attritable Aircraft Technology
- **LOS**: Line of Sight
- **LRR**: Long-Range Reconnaissance
- **MALE**: Medium Altitude Long Endurance
- **MEUAS**: Mid-Endurance Unmanned Aircraft Services
- **MRR**: Medium-Range Reconnaissance
- **NAS**: National Airspace System
- **RDT&E**: Research Development Test & Evaluation
- **RID**: Remote Identification
- **RPIC**: Remote Pilot-In-Command
- **SATCOM**: Satellite Communications
- **SBS**: Surveillance Broadcast Services
- **SOC**: Special Operations Command
- **SRR**: Short-Range Reconnaissance
- **STUAV**: Small Tactical Unmanned Aerial Vehicle
- **SWaP-C**: Size Weight and Power – (and) Cost
- **TAM**: Total Available Market
- **TSO**: Technical Standard Orders
- **TUAV**: Tactical Unmanned Aerial Vehicle
- **UAS**: Unmanned Aircraft Systems
- **UAV**: Unmanned Aerial Vehicle
- **UCAV**: Unmanned Combat Aerial Vehicle
- **ULS-A**: Unmanned Logistics System – Air
- **USAF**: United States Air Force
- **USMC**: United States Marine Corps
- **USN**: United States Navy
- **UTM**: UAS Traffic Management
- **VTOL**: Vertical Takeoff and Landing

Photo Credits

- Front page: RQ-180 (Hangar B Productions via The Drive), Nuuva V300 (Pipistrel), Textron Aerosonde (Textron Systems), Zipline UAV (Zipline via IEEE Spectrum)
- Page 13: Drone swarm (The Daily Guardian), Lattitude HQ-60B (BNSF), radar screen image (GlobalAir.com)
- Page 17: RQ-11 Raven (MilitaryAerospace.com), ScanEagle (The Defense Post), RQ-7 Shadow (National Defense Magazine), MQ-9 Reaper (Wikipedia), Zipline UAV (TechCrunch), Delair UX11 (Delair), Volansi UAV (Parcel and Postal Technology International), HAPSMobile Hawk30 (Wikipedia)
- Page 18: Zipline UAV (TechCrunch), RQ-11 Raven (MilitaryAerospace.com), Wingcopter W198 (Wingcopter), Delair UX11 (Delair), DJI Inspire (Petagadget), Volansi UAV (Parcel and Postal Technology International), DJI Matrice (DJI), Textron Aerosonde (Textron Systems)
- Page 19: Schiebel S-100 Camcopter (Schiebel via Airforce Technology), HAPSMobile Hawk30 (Wikipedia), Leonardo Falco EVO (Unmanned Systems Technology), BAE Systems Phasa-35 (BAE Systems), MQ-9 Reaper (Wikipedia), Elbit Hermes 900 (MaxDefense Philippines)
- Page 29: DJI Matrice (DJI), Zipline UAV (TechCrunch), RQ-11 Raven (MilitaryAerospace.com), Volansi UAV (Parcel and Postal Technology International), Schiebel S-100 Camcopter (Schiebel via Airforce Technology), BAE Systems Phasa-35 (BAE Systems)
- Page 33: Vantis network (Vantis UAS via Aviation Today), radar screen image (GlobalAir.com)
- Page 40: RQ-20 Puma LE (AeroVironment), ScanEagle (The Defense Post), RQ-21 Blackjack (Gung Ho Vids), MQ-9 Reaper (Wikipedia), RQ-180 (Hangar B Productions via ArtStation)
- Page 42: RQ-11 Raven (MilitaryAerospace.com), RQ-20 Puma LE (AeroVironment)
- Page 43: ScanEagle (The Defense Post), Lockheed Martin Stalker XE (Defense Blog), RQ-7 Shadow (National Defense Magazine), RQ-21 Blackjack (Gung Ho Vids)
- Page 44: MQ-9 Reaper (Wikipedia), MQ-8 Fire Scout (Wikipedia)
- Page 45: RQ-180 (Hangar B Productions via ArtStation), RQ-4 Global Hawk (Wikipedia)

Contents

Civil UAS Market: Complex Operations Fleet Assumptions (Base Case)



Total UAS Fleet (units)

	2021	2022	2023	2024	2025	2026	2027	2028	2029
Prosumer	1,583,900	1,861,550	2,192,875	2,575,039	2,909,324	3,262,667	3,625,738	3,980,574	4,208,293
Delivery UAV	800	1,680	3,040	5,921	16,961	34,481	69,241	160,621	304,311
Mini UAV	70,135	97,989	127,984	171,031	221,660	278,091	329,479	380,010	435,297
Small UAV	118	245	411	824	1,214	1,609	1,986	2,359	2,662
HAPS	30	106	263	422	572	786	993	1,248	1,574
TUAV	5	30	74	181	287	392	495	598	675
MALE	5	9	14	20	24	30	34	37	42
Grand Total	**1,654,993**	**1,961,609**	**2,324,661**	**2,753,438**	**3,150,042**	**3,578,056**	**4,027,966**	**4,525,447**	**4,952,854**

Segment UAS fleet performing complex operations, assessed by use case and UAS type

Complex Ops UAS Fleet (units)

	2021	2022	2023	2024	2025	2026	2027	2028	2029
Prosumer	498	3,857	34,282	111,363	220,579	335,964	392,663	451,173	509,488
Delivery UAV	4	50	608	2,961	13,569	34,481	69,241	160,621	304,311
Mini UAV	224	1,874	16,013	52,942	109,332	170,797	202,157	232,899	266,774
Small UAV	86	151	241	551	971	1,604	1,981	2,353	2,656
HAPS	6	42	158	338	572	786	993	1,248	1,574
TUAV	0	1	15	91	230	392	495	598	675
MALE	5	9	14	20	24	30	34	37	42
Grand Total	**824**	**5,985**	**51,331**	**168,264**	**345,277**	**544,053**	**667,564**	**848,929**	**1,085,520**

Source: Teal Group (civil UAS production volumes), Radius Capital analysis

Civil UAS Market: Complex Operations Fleet Assumptions (Base Case)

Reaching routine complex operations

Achieving relevant technology, regulatory, community requirements → Operational efficiency improvements

Complex operations as a share of all operations

Market	UAS Type	2021	2022	2023	2024	2025	2026	2027	2028	2029	Rationale
Agriculture	Mini UAV	0%	2%	14%	35%	56%	70%	70%	70%	70%	Longer range enabling BVLOS ops, especially over larger farms. Greater UAS-to-RPIC ratios.
Agriculture	Prosumer	0%	1%	6%	15%	24%	30%	30%	30%	30%	Greater UAS-to-RPIC ratios. Remote operations.
Communications	HAPS	20%	40%	60%	80%	100%	100%	100%	100%	100%	BVLOS flight in controlled airspace.
Communications	Mini UAV	0%	2%	10%	25%	40%	50%	50%	50%	50%	Longer range enabling BVLOS for comms infrastructure inspection. Greater UAS-to-RPIC ratios
Construction	Mini UAV	0%	2%	10%	25%	40%	50%	50%	50%	50%	Greater UAS-to-RPIC ratios. Remote operations. Some BVLOS ops.
Construction	Prosumer	0%	1%	6%	15%	24%	30%	30%	30%	30%	Greater UAS-to-RPIC ratios. Remote operations.
Delivery	Delivery UAV	1%	3%	20%	50%	80%	100%	100%	100%	100%	BVLOS operations with greater UAS-to-RPIC ratios.
Cargo	Small UAV	1%	3%	20%	50%	80%	100%	100%	100%	100%	Long-distance BVLOS flights. Multiple UAS-to-RPIC. Remote operations.
Cargo	TUAV	1%	3%	20%	50%	80%	100%	100%	100%	100%	Long-distance BVLOS flights. Multiple UAS-to-RPIC. Remote operations.
Energy	Mini UAV	0%	2%	10%	25%	40%	50%	50%	50%	50%	Greater UAS-to-RPIC ratios. Remote operations. Some BVLOS ops.
Energy	Prosumer	0%	1%	8%	20%	32%	40%	40%	40%	40%	Greater UAS-to-RPIC ratios. Remote operations.
Energy	Small UAV	80%	80%	80%	80%	80%	100%	100%	100%	100%	BVLOS operations with greater UAS-to-RPIC ratios.
EU Civil Government - Border and Maritime	MALE	100%	100%	100%	100%	100%	100%	100%	100%	100%	BVLOS flight in controlled airspace.
EU Civil Government - Border and Maritime	Small UAV	80%	80%	80%	80%	80%	100%	100%	100%	100%	BVLOS operations with greater UAS-to-RPIC ratios.
EU Civil Government - National Governments	Mini UAV	0%	2%	10%	25%	40%	50%	50%	50%	50%	Greater UAS-to-RPIC ratios. Remote operations.
EU Civil Government - National Governments	Prosumer	0%	1%	8%	20%	32%	40%	40%	40%	40%	Greater UAS-to-RPIC ratios. Remote operations.
Insurance	Mini UAV	0%	1%	6%	15%	24%	30%	30%	30%	30%	Some remote ops and greater UAS-to-RPIC ratios
Insurance	Prosumer	0%	1%	4%	10%	16%	20%	20%	20%	20%	Some remote ops and greater UAS-to-RPIC ratios
Other Industrial Inspection	Mini UAV	0%	2%	16%	40%	64%	80%	80%	80%	80%	Longer range enabling BVLOS for railway infrastructure inspection. Greater UAS-to-RPIC ratios.
Other Industrial Inspection	Prosumer	0%	1%	4%	10%	16%	20%	20%	20%	20%	Some remote ops and greater UAS-to-RPIC ratios
Photography	Mini UAV	0%	0%	0%	0%	0%	0%	0%	0%	0%	No meaningful complex ops
Photography	Prosumer	0%	0%	0%	0%	0%	0%	0%	0%	0%	No meaningful complex ops
US Civil Government - Federal	MALE	100%	100%	100%	100%	100%	100%	100%	100%	100%	BVLOS flight in controlled airspace.
US Civil Government - Federal	Mini UAV	0%	2%	10%	25%	40%	50%	50%	50%	50%	Greater UAS-to-RPIC ratios. Remote operations.
US Civil Government - Federal	Small UAV	80%	80%	80%	80%	80%	80%	80%	80%	80%	BVLOS operations with greater UAS-to-RPIC ratios.

Source: Teal Group (civil UAS production volumes), Radius Capital analysis

radius capital

Civil UAS Market: Complex Operations Fleet Assumptions (Up Case)

Reaching routine complex operations

Achieving relevant technology, regulatory, community requirements → Operational efficiency improvements

Complex operations as a share of all operations

Market	UAS Type	2021	2022	2023	2024	2025	2026	2027	2028	2029
Agriculture	Mini UAV	0%	2%	14%	53%	70%	70%	70%	70%	70%
Agriculture	Prosumer	0%	1%	6%	23%	30%	30%	30%	30%	30%
Communications	HAPS	20%	40%	60%	80%	100%	100%	100%	100%	100%
Communications	Mini UAV	0%	2%	10%	38%	50%	50%	50%	50%	50%
Construction	Mini UAV	0%	2%	10%	38%	50%	50%	50%	50%	50%
Construction	Prosumer	0%	1%	6%	23%	30%	30%	30%	30%	30%
Delivery	Delivery UAV	1%	3%	20%	75%	100%	100%	100%	100%	100%
Cargo	Small UAV	1%	3%	20%	75%	100%	100%	100%	100%	100%
Cargo	TUAV	1%	3%	20%	75%	100%	100%	100%	100%	100%
Energy	Mini UAV	0%	2%	10%	38%	50%	50%	50%	50%	50%
Energy	Prosumer	0%	1%	8%	30%	40%	40%	40%	40%	40%
Energy	Small UAV	80%	80%	80%	80%	100%	100%	100%	100%	100%
EU Civil Government - Border and Maritime	MALE	100%	100%	100%	100%	100%	100%	100%	100%	100%
EU Civil Government - Border and Maritime	Small UAV	80%	80%	80%	80%	100%	100%	100%	100%	100%
EU Civil Government - National Governments	Mini UAV	0%	2%	10%	38%	50%	50%	50%	50%	50%
EU Civil Government - National Governments	Prosumer	0%	1%	8%	30%	40%	40%	40%	40%	40%
Insurance	Mini UAV	0%	1%	6%	23%	30%	30%	30%	30%	30%
Insurance	Prosumer	0%	1%	4%	15%	20%	20%	20%	20%	20%
Other Industrial Inspection	Mini UAV	0%	2%	16%	60%	80%	80%	80%	80%	80%
Other Industrial Inspection	Prosumer	0%	1%	4%	15%	20%	20%	20%	20%	20%
Photography	Mini UAV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Photography	Prosumer	0%	0%	0%	0%	0%	0%	0%	0%	0%
US Civil Government - Federal	MALE	100%	100%	100%	100%	100%	100%	100%	100%	100%
US Civil Government - Federal	Mini UAV	0%	2%	10%	38%	50%	50%	50%	50%	50%
US Civil Government - Federal	Small UAV	80%	80%	80%	80%	80%	80%	80%	80%	80%
US Civil Government - State and Local	Mini UAV	0%	2%	10%	38%	50%	50%	50%	50%	50%
US Civil Government - State and Local	Prosumer	0%	1%	8%	30%	40%	40%	40%	40%	40%

Source: Teal Group (civil UAS production volumes), Radius Capital analysis

radius capital

Civil UAS Market: Complex Operations Fleet Assumptions (Down Case)

Reaching routine complex operations

Achieving relevant technology, regulatory, community requirements

Operational efficiency improvements

Complex operations as a share of all operations

Market	UAS Type	2021	2022	2023	2024	2025	2026	2027	2028	2029
Agriculture	Mini UAV	0%	2%	14%	28%	42%	56%	70%	70%	70%
Agriculture	Prosumer	0%	1%	6%	12%	18%	24%	30%	30%	30%
Communications	HAPS	20%	40%	60%	80%	100%	100%	100%	100%	100%
Communications	Mini UAV	0%	2%	10%	20%	30%	40%	50%	50%	50%
Construction	Mini UAV	0%	2%	10%	20%	30%	40%	50%	50%	50%
Construction	Prosumer	0%	1%	6%	12%	18%	24%	30%	30%	30%
Delivery	Delivery UAV	1%	3%	20%	40%	60%	80%	100%	100%	100%
Cargo	Small UAV	1%	3%	20%	40%	60%	80%	100%	100%	100%
Cargo	TUAV	1%	3%	20%	40%	60%	80%	100%	100%	100%
Energy	Mini UAV	0%	2%	10%	20%	30%	40%	50%	50%	50%
Energy	Prosumer	0%	1%	8%	16%	24%	32%	40%	40%	40%
Energy	Small UAV	80%	80%	80%	80%	80%	80%	100%	100%	100%
EU Civil Government - Border and Maritime	MALE	100%	100%	100%	100%	100%	100%	100%	100%	100%
EU Civil Government - Border and Maritime	Small UAV	80%	80%	80%	80%	80%	80%	100%	100%	100%
EU Civil Government - National Governments	Mini UAV	0%	2%	10%	20%	30%	40%	50%	50%	50%
EU Civil Government - National Governments	Prosumer	0%	1%	8%	16%	24%	32%	40%	40%	40%
Insurance	Mini UAV	0%	1%	6%	12%	18%	24%	30%	30%	30%
Insurance	Prosumer	0%	1%	4%	8%	12%	16%	20%	20%	20%
Other Industrial Inspection	Mini UAV	0%	2%	16%	32%	48%	64%	80%	80%	80%
Other Industrial Inspection	Prosumer	0%	1%	4%	8%	12%	16%	20%	20%	20%
Photography	Mini UAV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Photography	Prosumer	0%	0%	0%	0%	0%	0%	0%	0%	0%
US Civil Government - Federal	MALE	100%	100%	100%	100%	100%	100%	100%	100%	100%
US Civil Government - Federal	Mini UAV	0%	2%	10%	20%	30%	40%	50%	50%	50%
US Civil Government - Federal	Small UAV	80%	80%	80%	80%	80%	80%	80%	80%	80%
US Civil Government - State and Local	Mini UAV	0%	2%	10%	20%	30%	40%	50%	50%	50%
US Civil Government - State and Local	Prosumer	0%	1%	8%	16%	24%	32%	40%	40%	40%

Source: Teal Group (civil UAS production volumes), Radius Capital analysis

radius capital

Civil UAS Market: Complex Operations Fleet Assumptions (Base Case)

Global Civil Complex Ops UAS Fleet (units)

By Region

	2021	2022	2023	2024	2025	2026	2027	2028	2029
Rest of World	488	3,589	30,514	99,461	205,291	318,900	386,535	473,055	565,579
North America	198	1,451	12,843	43,603	90,839	146,950	185,289	257,608	375,353
Europe	138	945	7,974	25,200	49,147	78,203	95,740	118,266	144,588
Grand Total	**824**	**5,985**	**51,331**	**168,264**	**345,277**	**544,053**	**667,564**	**848,929**	**1,085,520**

By UAS type

	2021	2022	2023	2024	2025	2026	2027	2028	2029
Prosumer	498	3,857	34,282	111,363	220,579	335,964	392,663	451,173	509,488
Delivery UAV	4	50	608	2,961	13,569	34,481	69,241	160,621	304,311
Mini UAV	224	1,874	16,013	52,942	109,332	170,797	202,157	232,899	266,774
Small UAV	86	151	241	551	971	1,604	1,981	2,353	2,656
HAPS	6	42	158	338	572	786	993	1,248	1,574
TUAV	0	1	15	91	230	392	495	598	675
MALE	5	9	14	20	24	30	34	37	42
Grand Total	**824**	**5,985**	**51,331**	**168,264**	**345,277**	**544,053**	**667,564**	**848,929**	**1,085,520**

By use case

	2021	2022	2023	2024	2025	2026	2027	2028	2029
Agriculture	436	3,476	28,854	90,421	172,987	258,272	289,866	321,311	355,442
Delivery	4	50	608	2,961	13,569	34,481	69,241	160,621	304,311
Construction	101	822	8,621	33,082	76,438	126,343	159,526	189,000	212,324
Energy	192	1,047	8,338	25,296	47,693	71,144	84,575	101,721	119,783
Other Industrial Ins	17	173	1,680	6,306	13,424	19,998	23,435	27,101	31,754
Insurance	24	183	1,602	5,112	10,567	16,182	18,923	22,960	31,015
Communications	8	56	288	880	2,231	4,219	6,082	8,542	11,087
EU Civil Governmer	7	72	657	1,978	3,810	6,388	7,665	8,372	9,246
US Civil Governmer	8	63	565	1,827	3,671	5,586	6,470	7,154	8,135
Cargo	0	3	44	271	687	1,172	1,481	1,788	2,019
US Civil Governmer	13	19	47	98	166	226	254	311	352
EU Civil Governmer	15	21	26	32	34	42	45	49	53
Photography	-	-	-	-	-	-	-	-	-
Grand Total	**824**	**5,985**	**51,331**	**168,264**	**345,277**	**544,053**	**667,564**	**848,929**	**1,085,520**

Source: Teal Group (civil UAS production volumes), Radius Capital analysis

radius capital

Civil UAS Market: Complex Operations Fleet Assumptions (Up Case)

Global Civil Complex Ops UAS Fleet (units)

By Region

	2021	2022	2023	2024	2025	2026	2027	2028	2029
Rest of World	488	3,693	32,611	170,328	301,268	378,729	461,444	566,185	677,766
North America	198	1,495	13,781	75,117	133,858	175,067	221,635	308,723	450,189
Europe	138	972	8,542	43,168	72,142	93,004	114,407	141,638	173,337
Grand Total	**824**	**6,160**	**54,934**	**288,613**	**507,268**	**646,800**	**797,487**	**1,016,546**	**1,301,292**

By UAS type

	2021	2022	2023	2024	2025	2026	2027	2028	2029
Prosumer	498	3,976	36,819	192,353	325,468	400,455	469,845	540,731	611,047
Delivery UAV	4	52	658	5,195	20,265	41,333	83,068	192,734	365,168
Mini UAV	224	1,923	16,998	89,752	159,069	201,669	240,395	278,017	319,155
Small UAV	86	155	257	737	1,419	1,901	2,357	2,809	3,177
HAPS	6	44	172	394	679	941	1,192	1,497	1,890
TUAV	0	1	16	159	340	466	590	714	806
MALE	5	9	15	23	28	35	40	44	49
Grand Total	**824**	**6,160**	**54,934**	**288,613**	**507,268**	**646,800**	**797,487**	**1,016,546**	**1,301,292**

By use case

	2021	2022	2023	2024	2025	2026	2027	2028	2029
Agriculture	436	3,576	30,796	154,590	253,155	306,177	345,572	384,179	425,658
Delivery	4	52	658	5,195	20,265	41,333	83,068	192,734	365,168
Construction	101	847	9,281	57,378	113,058	150,710	190,913	226,495	254,608
Energy	192	1,076	8,926	43,183	69,963	84,489	100,982	121,769	143,562
Other Industrial Ins	17	179	1,805	10,912	19,802	23,805	28,008	32,453	38,063
Insurance	24	188	1,719	8,817	15,590	19,286	22,640	27,517	37,200
Communications	8	59	311	1,327	3,129	5,035	7,282	10,238	13,298
EU Civil Governmer	7	75	706	3,401	5,604	7,606	9,166	10,029	11,085
US Civil Governmer	8	65	606	3,151	5,411	6,653	7,738	8,570	9,754
Cargo	0	3	48	474	1,016	1,394	1,767	2,137	2,415
US Civil Governmer	13	20	50	151	231	263	300	370	420
EU Civil Governmer	15	21	27	35	44	48	51	57	62
Photography	-	-	-	-	-	-	-	-	-
Grand Total	**824**	**6,160**	**54,934**	**288,613**	**507,268**	**646,800**	**797,487**	**1,016,546**	**1,301,292**

Source: Teal Group (civil UAS production volumes), Radius Capital analysis

radius capital

Civil UAS Market: Complex Operations Fleet Assumptions (Down Case)

Global Civil Complex Ops UAS Fleet (units)

By Region

	2021	2022	2023	2024	2025	2026	2027	2028	2029
Rest of World	488	3,486	28,417	68,262	127,237	207,281	311,625	379,924	453,392
North America	198	1,407	11,907	29,672	55,971	95,126	148,947	206,497	300,525
Europe	138	917	7,405	17,267	30,469	50,778	77,071	94,891	115,835
Grand Total	**824**	**5,809**	**47,729**	**115,200**	**213,677**	**353,185**	**537,642**	**681,311**	**869,752**

By UAS type

	2021	2022	2023	2024	2025	2026	2027	2028	2029
Prosumer	498	3,739	31,746	75,592	135,588	217,177	315,481	361,614	407,928
Delivery UAV	4	48	558	1,966	8,195	22,104	55,416	128,509	243,455
Mini UAV	224	1,825	15,028	36,840	68,556	111,940	163,916	187,780	214,394
Small UAV	86	146	227	440	709	1,051	1,604	1,899	2,139
HAPS	6	41	144	282	466	634	797	999	1,261
TUAV	0	1	14	61	141	254	399	480	540
MALE	5	9	13	18	22	26	29	31	35
Grand Total	**824**	**5,809**	**47,729**	**115,200**	**213,677**	**353,185**	**537,642**	**681,311**	**869,752**

By use case

	2021	2022	2023	2024	2025	2026	2027	2028	2029
Agriculture	436	3,376	26,912	62,227	107,589	168,295	234,159	258,443	285,224
Delivery	4	48	558	1,966	8,195	22,104	55,416	128,509	243,455
Construction	101	796	7,962	22,329	46,822	81,580	128,139	151,504	170,042
Energy	192	1,017	7,751	17,399	29,660	46,240	68,165	81,674	96,004
Other Industrial Ins	17	167	1,555	4,270	8,252	12,952	18,861	21,749	25,445
Insurance	24	177	1,485	3,477	6,496	10,463	15,206	18,403	24,830
Communications	8	54	266	653	1,485	2,852	4,886	6,846	8,879
EU Civil Governmer	7	69	607	1,351	2,353	4,136	6,164	6,715	7,406
US Civil Governmer	8	61	523	1,242	2,260	3,615	5,203	5,737	6,516
Cargo	0	3	40	182	421	759	1,194	1,437	1,619
US Civil Governmer	13	19	45	74	113	157	210	254	286
EU Civil Governmer	15	21	26	30	31	32	39	41	44
Photography	-	-	-	-	-	-	-	-	-
Grand Total	**824**	**5,809**	**47,729**	**115,200**	**213,677**	**353,185**	**537,642**	**681,311**	**869,752**

Source: Teal Group (civil UAS production volumes), Radius Capital analysis

radius capital

Civil UAS Market: Fleet Utilization Assumptions (Base Case)

UAS Utilization

	2021	2022	2023	2024	2025	2026	2027	2028	2029
Target average flights **per day**									
Prosumer	3.00	3.00	4.00	5.00	5.00	6.00	6.00	6.00	6.00
Delivery UAV	3.00	3.00	4.00	5.00	10.00	15.00	20.00	25.00	30.00
Mini UAV	3.00	3.00	4.00	5.00	5.00	5.00	5.00	5.00	5.00
Small UAV	0.29	0.43	1.00	2.00	3.00	3.00	3.00	4.00	4.00
TUAV	0.14	0.29	1.00	2.00	3.00	3.00	3.00	4.00	4.00
MALE	0.07	0.14	0.50	1.00	1.50	1.50	1.50	2.00	2.00
Overall fleet utilization	25%	35%	45%	65%	75%	75%	75%	75%	75%
Actual average flights **per day**									
Prosumer	0.8	1.1	1.8	3.3	3.8	4.5	4.5	4.5	4.5
Delivery UAV	0.8	1.1	1.8	3.3	7.5	11.3	15.0	18.8	22.5
Mini UAV	0.8	1.1	1.8	3.3	3.8	3.8	3.8	3.8	3.8
Small UAV	0.1	0.2	0.5	1.3	2.3	2.3	2.3	3.0	3.0
TUAV	0.0	0.1	0.5	1.3	2.3	2.3	2.3	3.0	3.0
MALE	0.0	0.1	0.2	0.7	1.1	1.1	1.1	1.5	1.5

2029 Total Fleet Size and Utilization

		Daily flights
Prosumer	4,208,293	4.5
Delivery UAV	304,311	22.5
Mini UAV	435,297	3.8
Small UAV	2,662	3.0
TUAV	675	3.0
MALE	42	1.5
Total / Average	**4,951,280**	**5.5**

Source: Radius Capital analysis

Civil UAS Market: Fleet Utilization Assumptions (Up Case)

UAS Utilization

	2021	2022	2023	2024	2025	2026	2027	2028	2029
Target average flights **per day**									
Prosumer	3.00	3.00	4.00	5.00	6.00	7.00	7.00	7.00	7.00
Delivery UAV	3.00	3.00	4.00	5.00	15.00	20.00	25.00	30.00	35.00
Mini UAV	3.00	3.00	4.00	5.00	5.00	6.00	6.00	6.00	6.00
Small UAV	0.29	0.43	1.00	2.00	3.00	3.00	3.00	4.00	4.00
TUAV	0.14	0.29	1.00	2.00	3.00	3.00	3.00	4.00	4.00
MALE	0.07	0.14	0.50	1.00	1.50	1.50	1.50	2.00	2.00
Overall fleet utilization	25%	35%	45%	65%	75%	80%	82%	85%	85%
Actual average flights **per day**									
Prosumer	0.8	1.1	1.8	3.3	4.5	5.6	5.7	6.0	6.0
Delivery UAV	0.8	1.1	1.8	3.3	11.3	16.0	20.5	25.5	29.8
Mini UAV	0.8	1.1	1.8	3.3	3.8	4.8	4.9	5.1	5.1
Small UAV	0.1	0.2	0.5	1.3	2.3	2.4	2.5	3.4	3.4
TUAV	0.0	0.1	0.5	1.3	2.3	2.4	2.5	3.4	3.4
MALE	0.0	0.1	0.2	0.7	1.1	1.2	1.2	1.7	1.7

2029 Total Fleet Size and Utilization

		Daily flights
Prosumer	5,045,486	6.0
Delivery UAV	365,168	29.8
Mini UAV	520,806	5.1
Small UAV	3,184	3.4
TUAV	806	3.4
MALE	49	1.7
Total / Average	**5,935,499**	**7.3**

Source: Radius Capital analysis

Civil UAS Market: Fleet Utilization Assumptions (Down Case)

UAS Utilization

	2021	2022	2023	2024	2025	2026	2027	2028	2029
Target average flights **per day**									
Prosumer	3.00	3.00	4.00	4.00	4.00	5.00	6.00	6.00	6.00
Delivery UAV	3.00	3.00	4.00	5.00	7.00	10.00	15.00	15.00	15.00
Mini UAV	3.00	3.00	4.00	5.00	5.00	5.00	5.00	5.00	5.00
Small UAV	0.29	0.43	1.00	2.00	3.00	3.00	3.00	4.00	4.00
TUAV	0.14	0.29	1.00	2.00	3.00	3.00	3.00	4.00	4.00
MALE	0.07	0.14	0.50	1.00	1.50	1.50	1.50	2.00	2.00
Overall fleet utilization	25%	35%	45%	65%	70%	70%	70%	70%	70%
Actual average flights **per day**									
Prosumer	0.8	1.1	1.8	2.6	2.8	3.5	4.2	4.2	4.2
Delivery UAV	0.8	1.1	1.8	3.3	4.9	7.0	10.5	10.5	10.5
Mini UAV	0.8	1.1	1.8	3.3	3.5	3.5	3.5	3.5	3.5
Small UAV	0.1	0.2	0.5	1.3	2.1	2.1	2.1	2.8	2.8
TUAV	0.0	0.1	0.5	1.3	2.1	2.1	2.1	2.8	2.8
MALE	0.0	0.1	0.2	0.7	1.1	1.1	1.1	1.4	1.4

2029 Total Fleet Size and Utilization

		Daily flights
Prosumer	3,371,099	4.2
Delivery UAV	243,455	10.5
Mini UAV	349,786	3.5
Small UAV	2,144	2.8
TUAV	540	2.8
MALE	35	1.4
Total / Average	**3,967,059**	**4.5**

Source: Radius Capital analysis

UAS Avionics Cost Assumptions

Civil UAS

	Vehicle cost	Avionics CPV as % of UAV cost	Avionics CPV	Notes
Prosumer	$2,500	30%	$750	
Delivery UAV	$12,000	30%	$3,600	
Mini UAV	$30,000	30%	$9,000	
Small UAV	$500,000	40%	$200,000	More sophisticated C2/DAA avionics drive higher vehicle cost
TUAV	$4,000,000	25%	$1,000,000	Most of the vehicle cost represents payloads and mission-related systems
MALE	$16,000,000	30%	$4,800,000	Similar as TUAV, but with more expensive C2 solutions (e.g. satcom)
HAPS	$1,250,000	30%	$375,000	

Note: CPV = Content Per Vehicle. 3% annual pricedowns from 2021-2029

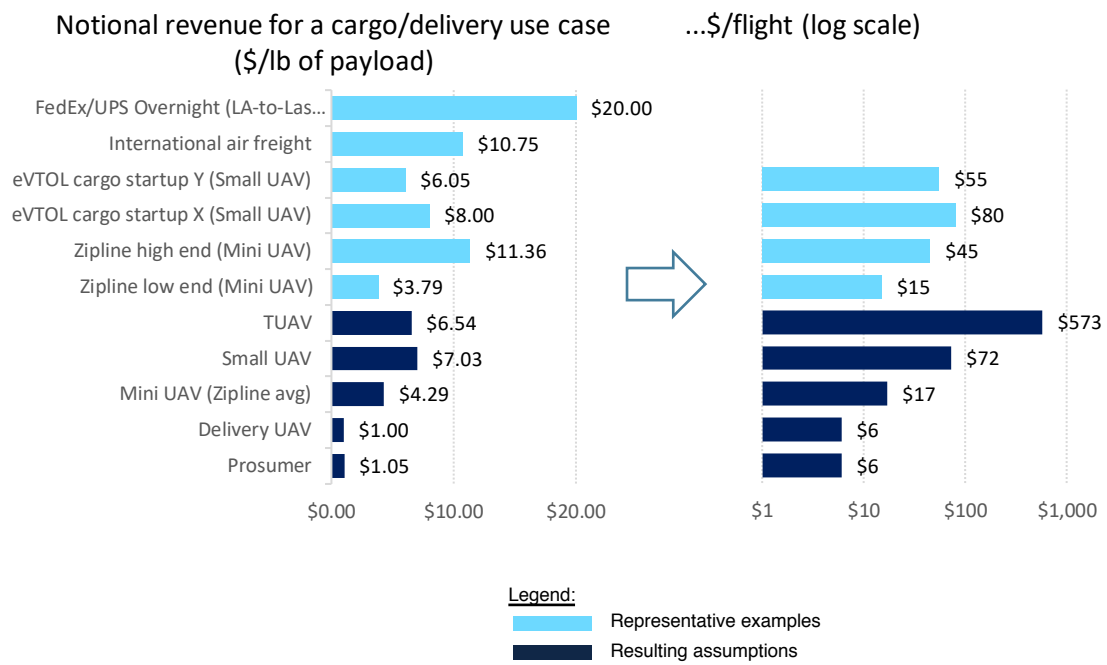
Military UAS

	Vehicle cost	Avionics CPV as % of UAV cost	Avionics CPV	Notes
Mini UAV	$65,000	30%	$19,500	
STUAV	$500,000	40%	$200,000	
TUAV	$4,000,000	25%	$1,000,000	
MALE	$16,000,000	30%	$4,800,000	
HALE	$20,000,000	30%	$6,000,000	
UCAV - small	$950,000	35%	$332,500	Golden Horde / Gremlins / ALE (similar to stand-off A-G missiles and decoys)
UCAV - large	$50,000,000	35%	$17,500,000	Loyal Wingman-like UCAVs

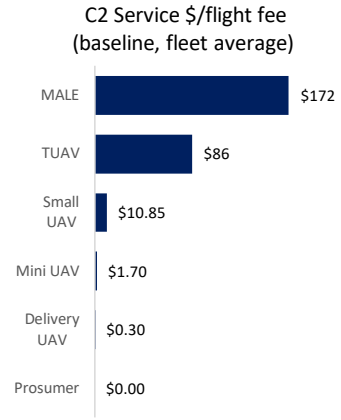
Note: CPV = Content Per Vehicle. 3% annual pricedowns from 2021-2029

Source: Teal Group (UAV cost), Radius Capital analysis

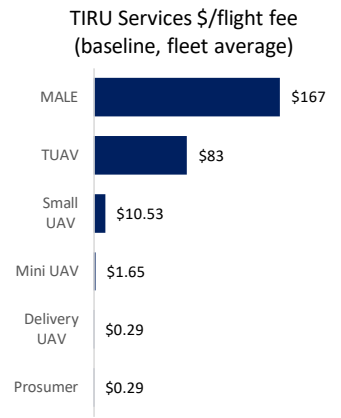
Civil UAS Service Pricing Assumptions



5-15% of operator revenue per flight, depending on UAS type and use case



5-15% of operator revenue per flight, depending on UAS type and use case



Source: http://www.ijirset.com/upload/2019/august/63_Blood.PDF (Zipline delivery fee), Radius Capital analysis

Civil UAS Service Pricing Assumptions

		% of per flight revenue paid for:	
Market	**UAS Type**	**C2 Service**	**TIRU Services**
Agriculture	Mini UAV	10%	10%
Agriculture	Prosumer	5%	5%
Communications	HAPS	15%	15%
Communications	Mini UAV	10%	10%
Construction	Mini UAV	10%	10%
Construction	Prosumer	5%	5%
Delivery	Delivery UAV	5%	5%
Cargo	Small UAV	15%	15%
Cargo	TUAV	15%	15%
Energy	Mini UAV	10%	10%
Energy	Prosumer	5%	5%
Energy	Small UAV	15%	15%
EU Civil Government - Border and Maritime	MALE	15%	15%
EU Civil Government - Border and Maritime	Small UAV	15%	15%
EU Civil Government - National Governments	Mini UAV	10%	10%
EU Civil Government - National Governments	Prosumer	5%	5%
Insurance	Mini UAV	10%	10%
Insurance	Prosumer	5%	5%
Other Industrial Inspection	Mini UAV	10%	10%
Other Industrial Inspection	Prosumer	5%	5%
Photography	Mini UAV	10%	10%
Photography	Prosumer	5%	5%
US Civil Government - Federal	MALE	15%	15%
US Civil Government - Federal	Mini UAV	10%	10%
US Civil Government - Federal	Small UAV	15%	15%
US Civil Government - State and Local	Mini UAV	10%	10%
US Civil Government - State and Local	Prosumer	5%	5%

Source: Radius Capital analysis

United States Military UAS Production and Fleet (Base Case)

Production (units)

	2021	2022	2023	2024	2025	2026	2027	2028	2029
Group 1	233	335	268	1,224	1,861	2,011	2,222	2,698	795
Group 2	275	275	275	325	325	325	325	325	325
Group 3	35	107	154	284	298	360	318	344	408
Group 4	41	21	13	26	26	68	146	207	207
Group 5 (HALE)	5	10	9	6	6	6	6	6	6
Group 5 (small UCAVs)	-	-	-	1,000	1,000	1,000	1,000	1,000	1,000
Group 5 (large UCAVs)	-	-	-	-	-	-	242	557	977
Total	**588**	**748**	**719**	**2,865**	**3,516**	**3,769**	**4,257**	**5,136**	**3,717**

Fleet (units)

	2021	2022	2023	2024	2025	2026	2027	2028	2029
Group 1	9,377	9,680	9,922	10,135	10,377	10,655	10,974	11,542	12,265
Group 2	950	1,200	1,450	1,725	2,000	2,250	2,500	2,800	3,100
Group 3	638	685	692	823	967	1,229	1,532	1,859	2,247
Group 4	583	603	613	639	662	726	869	1,070	1,270
Group 5 (HALE)	59	69	57	62	68	73	78	84	89
Group 5 (small UCAVs)	-	-	-	850	1,700	2,550	3,400	4,250	5,100
Group 5 (large UCAVs)	-	-	-	-	-	-	230	760	1,690
Total	**11,607**	**12,237**	**12,734**	**14,234**	**15,773**	**17,483**	**19,583**	**22,365**	**25,761**

Source: Radius Capital analysis

United States Military UAS Programs

Programs considered in this analysis

Group 1
Aerovironment RQ-11B Raven
Aerovironment RQ-11C Raven (MRR)
Aerovironment RQ-20A Puma and its replacement (LRR)
Aerovironment RQ-20B / LE / LR Puma

Group 2
Lockheed Martin Stalker
Boeing Insitu ScanEagle and its replacement

Group 3
Textron RQ-7B Blocks III Shadow
FTUAS program
Future tactical version of MUX family
Boeing Insitu RQ-21 Blackjack
Boeing Insitu RQ-21 Blackjack replacement for USMC
MEUAS IV program
Small ULS-A logistics (USMC & Army)

Group 4
General Atomics MQ-1 Grey Eagle
Northrop Grumman MQ-8 Fire Scout
Boeing MQ-25 Stingray
General Atomics MQ-9 Reaper
Medium ULS-A logistics (USMC & Army)
Air Force Unmanned Aerial Logistics (USAF)

Group 5 (HALE)
Northrop Grumman MQ-4C Triton
Northrop Grumman RQ-180 or similar ISR next gen

Group 5 (small UCAVs)
Golden Horde / Gremlins-like UCAV
Air Launched Effects (attritable UAS)

Group 5 (large UCAVs)
Loyal Wingman-type concept

Source: Radius Capital analysis

radius capital