

Continuing to

THINK BIGGER

Autonomous Aircraft and the
Transformation in Aviation

AIA and Avascent Report | 2022



About AIA

The Aerospace Industries Association of America (AIA) is the premier trade association representing the nation's leading aerospace and defense manufacturers and suppliers and is the authoritative voice on issues of civil and commercial space, commercial aviation, defense and security and national airspace systems. For nearly 100 years, AIA has been the industry voice shaping the policies that matter most to our members. AIA's expertise represents the interests of manufacturers and suppliers of civil, military, and business aircraft, helicopters, unmanned aerial systems, space systems, aircraft engines, missiles, materiel, and related components, equipment, services, and information technology.

About AVASCENT

Avascent is the leading strategy and management consulting firm with more than 30 years' experience supporting corporate leaders, investors and government stakeholders in the aerospace, defence, security, and public services markets. Working with corporate leaders and financial investors, Avascent delivers sophisticated, fact-based solutions in the areas of strategic growth, value capture, and mergers and acquisition support. With deep sector expertise, analytically rigorous consulting methodologies, and a uniquely flexible service model, Avascent provides clients with the insights and advice they need to succeed in dynamic customer environments.

Continuing to Think Bigger: Autonomous Aircraft and the Transformation in Aviation

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Autonomous aircraft often evoke images of quadcopters buzzing overhead or military systems operating in places far outside the United States. While these aircraft were the origins of the market and bedrocks of expansion, a different revolution in autonomy is now arriving. The next chapter features the advent of autonomous aircraft that are set to change the shape of our daily lives. Expanding on America's longstanding leadership in global aviation, U.S. companies are building large commercial aircraft that will lead to substantial economic activity and quality job creation.

First called out in AIA and Avascent's 2018 report "Think Bigger: Large Unmanned Systems and the Next Major Shift in Aviation," the development and usage of autonomous aircraft has rapidly grown since then. Milestone technological achievements have propelled growth but are not the sole reasons for it. From rising air cargo demand to labor dynamics, macro trends firmly underscore the imperative for autonomous aircraft. The COVID-19 pandemic – with its impact on mobility and e-commerce – has reinforced broader trends already set in motion.



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Autonomous aircraft activity has moved upward in recent years, as evidenced by the arrival of dozens of new entrants that are vying to disrupt air transportation. Building on this early momentum, the market is primed for breakthrough growth, resulting in nearly \$325 billion in spending from 2022 through 2040. Nearly 100,000 jobs are projected to exist in 2040 as a direct result. These quality jobs build on America's longstanding legacy of aerospace and software engineering, positioning the country for the next century of leadership in both.

Underneath this topline growth there are notable activities taking place. Thanks in part to growing e-commerce demand, cargo use cases will expand at a significant rate and offer substantial expansion potential. Passenger aircraft bring strong long-term growth opportunity but will lag other use cases, most likely not arriving at scale until at least well into the next decade after others are more widely adopted.

Innovators – both in government and industry – have led the way with advances that build on proven technologies. Investors have committed to the promise of this technology, underscoring the importance of steadfast private sector support. The U.S. government has taken important steps – such as remote ID, operations over people, and the FAA's establishment of the Beyond Visual Line-of-Sight Operations Aviation Rulemaking Committee (BVLOS ARC) – to ensure safety and progress.

Government and industry have answered the call to think bigger. This joint commitment is reflected by the growth in demand for autonomous aircraft and the critical jobs required to support their ecosystem. The challenge as the market matures is not only to continue to think bigger, but to intentionally act with unity, conviction, and precision.

It is crucial for government and industry stakeholders to consolidate gains of the recent past and align behind a policy and regulatory map for autonomous aircraft. Building such an outlook will ensure that long-term goals are clearly articulated and the paths to achieve them are well understood by all. This understanding will enable government and industry to most appropriately channel aircraft and infrastructure investments. Continued policy actions are essential to translate vision and investments into reality.

The public and private sectors must now move quickly and in harmony. Doing so will be essential to keep pace with technology advancements, build appropriate capacity for long-term growth, and stay ahead of looming macro dynamics. Economic expansion, social benefits, and security – as well as U.S. aviation leadership – depend on it.

(Re)defining Autonomy

Autonomy is a term often used, but not always with a common interpretation. It is not a binary on/off switch, but rather it is a capability trade space in which aircraft operate at the intersection of human and machine control. On one end of this spectrum are the automated aircraft of today. These aircraft independently execute important yet relatively mundane functions, while onboard pilots ultimately maintain control of crucial decisions. On the other end of the trade space are theoretical aircraft that may not arrive for many decades but independently make most – if not all – critical decisions. Within this continuum is the zone in which large autonomous aircraft of tomorrow will thrive. This could include operations in which a remote pilot manages one aircraft, or eventually, perhaps several at the same time. The possibilities are only limited by imagination, and the potential for greater efficiencies is significant.



Recent technology advances in areas such as detect and avoid sensors, secure data links, and computing power are driving the shift to increasing autonomy. As technologies such as onboard processing and artificial intelligence progress, the autonomous functions of aircraft will further expand.

LARGE AUTONOMOUS AIRCRAFT WEIGHT CLASS	
MTOW*	EXAMPLE AIRCRAFT
200-7,999 lbs.	<ul style="list-style-type: none"> Small and medium remotely piloted aircraft Advanced Air Mobility (AAM) aircraft
8,000-45,999 lbs.	<ul style="list-style-type: none"> Large turboprop aircraft Regional jets
46,000+ lbs.	<ul style="list-style-type: none"> Narrowbody commercial air transport aircraft Widebody commercial air transport aircraft

*Maximum Takeoff Weight

These advances in technology must ultimately enable trust as much as form and function. The public must be confident that aircraft will operate as instructed and intended. This trust will be solidified not only through technological progress and safety protocols, but also with broader societal understanding and acceptance. This will not happen immediately and is a key reason – in addition to technology and safety – that autonomy is a trade space defined by varying degrees of task automation and decision-making capabilities.

Size and associated use cases will help determine the autonomy continuum in which future aircraft operate. Most aircraft today include some degree of automation, with widespread research, development, prototyping, and testing activities related to greater autonomy.

Catalyzing Change

Autonomous aircraft will not be luxury goods or one-off technology novelties. They aim to provide indispensable capabilities that address real world challenges and enable greater prosperity in a rapidly changing world. With autonomy, future American society will be better equipped to expand opportunities and combat looming pressures.

Macro dynamics reinforce the need for aircraft that move people and transport goods in new ways. By augmenting onboard and offboard pilots, autonomy allows aircraft to operate more freely and efficiently to better address changing demands.

Underlying air cargo demand – as evidenced by domestic revenue ton-miles – has consistently grown since 2011, and passengers are swiftly returning following the COVID-19 downturn. Remote and flexible work arrangements are set to drive ongoing shifts to areas outside major metropolitan hubs, creating potential need for expanded cargo and traveler access.

Changing labor dynamics have emerged across various sectors, and aviation is no exception to this broader trend. The prospect of future pilot shortages loomed even prior to the pandemic, but with air travel demand returning it is now once again an important consideration. Autonomous aircraft are one way to address this by augmenting existing pilots and supporting fewer days away from home as well as more predictable workdays.

Accelerating Demand and Unlocking Opportunity

Buoyed by macro drivers, spending on autonomous aircraft is poised for dramatic growth over the next two decades. Across passenger, cargo, and industrial use cases the market is expected to total about \$325 billion from 2022 to 2040. The market will expand at a nearly 25% compound annual growth rate (CAGR) over that period.

This growth is underpinned by core aviation capabilities and technology advances that are expected to further

MACRO TRENDS AND LARGE AUTONOMOUS AIRCRAFT BENEFITS	
MACRO TRENDS	BENEFITS OF AUTONOMY
MOBILITY	Open new routes and market opportunities Foster dynamic repositioning of aircraft
LABOR	Enable flexible workforce Promote capabilities to keep pace with demand
E-COMMERCE	More routes can be enabled Less lag time between flights
DATA	Greater pool of data to better inform decisions Real-time data to make faster decisions
CLIMATE	Improved remote monitoring of weather patterns Enhanced disaster management responses

improve. Recent technology demonstrations – such as flights of remotely piloted turboprop aircraft – have proven that these increasingly capable aircraft will soon be ready for operations at greater scale.

Investment has both propelled and followed these proven technology advances. A plethora of startup companies have received significant funding for autonomous aircraft and closely related technologies. While startups have formed, longstanding aviation companies are investing in the promise of this new area, and high-quality jobs are following.

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Autonomous aircraft adoption is set to take place across three primary use cases: industrial, cargo, and passenger. The timing and pace of growth will vary for each, with industrial applications setting the stage for scenarios involving cargo and ultimately passengers. First adopters will focus on operating scenarios that are “dull, dirty, and dangerous” and pose limited risk to humans either onboard the aircraft or on the

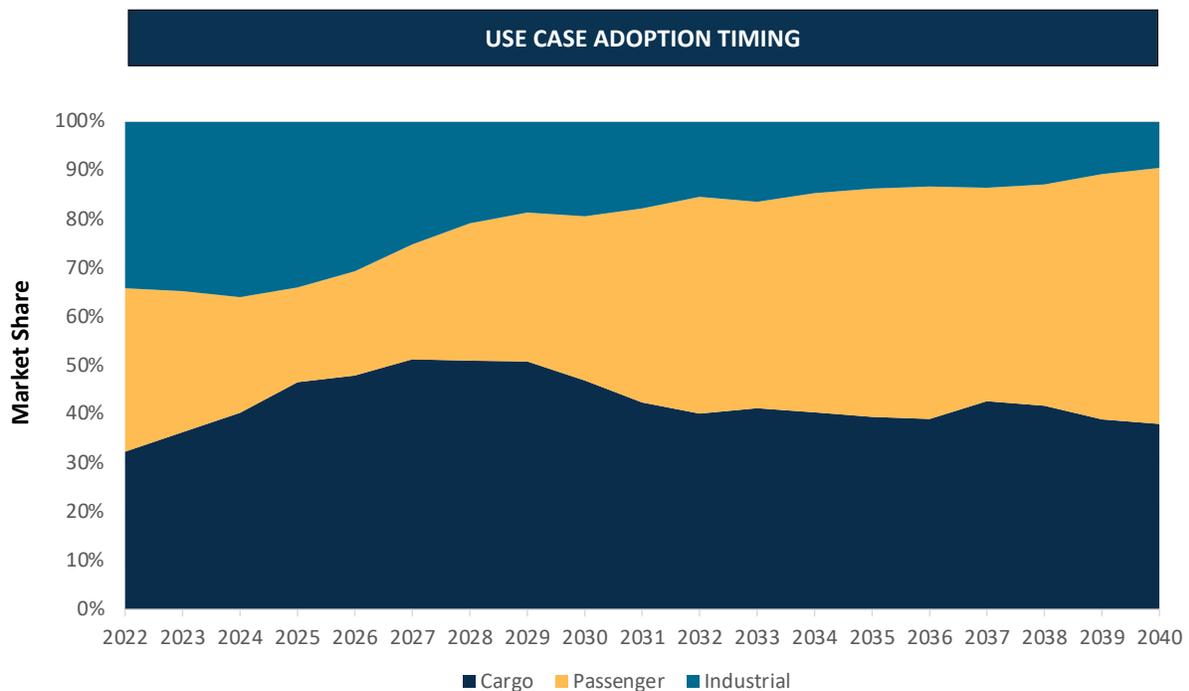
ground. Passenger aircraft will arrive later at scale and may continue to have the option for an onboard pilot to help ensure passenger comfort and safety redundancies.

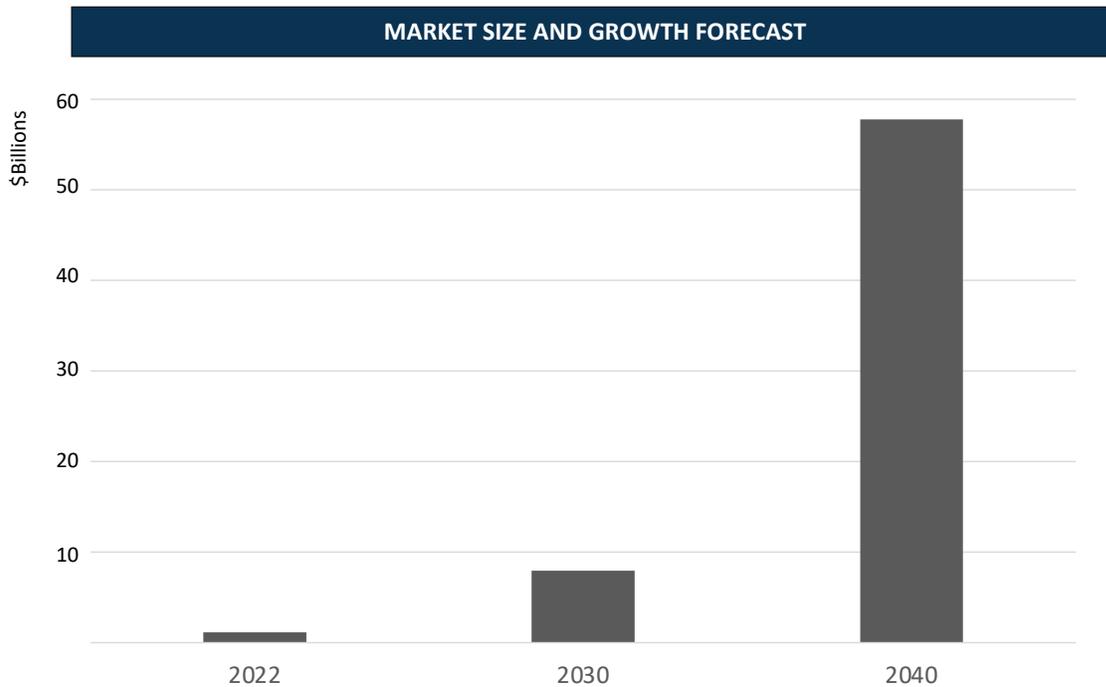
Adoption of autonomy is likely to happen first within the relatively smaller classes of large aircraft (e.g., turboprops, regional jets) before more widely scaling to even larger aircraft. Given the current phase of market development, growth across all uses may both accelerate or slow depending on how government and industry set the stage for further expansion.

Industrial Use Case: First Things First

Building on technology originally developed for the defense sector, industrial use cases have constituted the first wave of autonomous aircraft. Although quadcopters and small systems have their place for certain straightforward situations, larger aircraft are essential for more complex operations that involve sophisticated imaging payloads. The endurance afforded by larger aircraft is also essential for use cases that require aircraft to travel hundreds of kilometers (or more) and stay airborne for long periods of time.

Most aircraft at present focus on point observation and linear inspection use cases, from Arctic Sea ice monitoring to disaster relief surveillance support. Indeed, challenging weather conditions in the Arctic – including extreme temperatures and high winds – make operations difficult for aircraft with onboard pilots or small unmanned aerial systems (sUAS).





Future use cases will move beyond the surveillance applications that have characterized the market up until now. The next generation of aircraft are poised to engage in operations such as forest fire response, aerial applications for agriculture, and on-the-move telecommunications infrastructure. These use cases are well suited for autonomous aircraft and do not face substitution risk from smaller, less expensive UAS.

Utilizing larger autonomous aircraft for these new use cases provides significant benefits. Aircraft with onboard pilots may be teamed with autonomous aircraft that provide a distributed support function. In this scenario, forest fire responses will not be hampered by availability of onsite pilots or the need to transport them to or house them in a remote location.

Likewise, utilizing autonomous aircraft for agricultural aerial applications offers significant potential gains. With more frequent crop monitoring and treatment, farmers can better identify issues and manage them efficiently.

Autonomous aircraft are also essential for longer-endurance multi-day use cases – such as providing a telecom “hot spot” – for which smaller aircraft do not have comparable capabilities. In these cases, the aircraft can provide broadband access to underserved populations or offer connectivity in the aftermath of a natural disaster.

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Cargo Use Case: Carrying Weight

While the notion of using autonomous aircraft for cargo delivery is not a new one, meaningful technology advances are widening the realm of what is possible. The idea of small delivery systems that have captured public imagination in recent years – think miniature aircraft delivering pizzas to doorsteps – are only one part of what ultimately can be achieved in this sector. Complementing this “last mile” delivery, larger aircraft offer transformational promise that will appreciably impact daily lives and broader economic activities.

Autonomous aircraft are particularly well suited for the cargo use case. From a practical standpoint, the cargo use case will precede passenger aircraft given the inherently reduced risks of carrying goods only. By operating over unpopulated areas such as over water or rural land, those risks will be mitigated even further.

The benefit to cargo is also supported by substantial growth in e-commerce. Autonomous aircraft enable increased transportation of goods and can further accelerate economic activity by unlocking new logistics paradigms that meet growing consumer and business demand.

Early cargo use cases will feature both replacements and augmentation of existing small cargo aircraft as well as new Advanced Air Mobility (AAM) aircraft. Together, these new aircraft will meet already growing demand for cargo mobility and help create new market expansion – including in underserved areas – that is made possible by expanding route capacity, options, and flexibility.

Larger narrowbody and widebody aircraft are positioned to expand on these successes. Transoceanic flights of remotely piloted aircraft, for instance, pose relatively limited risks compared to operations over densely populated areas. These routes are especially important for shipments of e-commerce packages, as well as high value and/or time sensitive deliveries.

Ongoing research, development, prototyping, and demonstrations support the rapidly growing trajectory of autonomous cargo aircraft. The promise of these aircraft is already drawing public interest from the package delivery service sector. U.S.-based stakeholders are not alone in these efforts, as developments are also taking place in other countries across the globe.

Passenger Use Case: Over the Horizon

While industrial and cargo missions may provide more near-term opportunity to mature and implement advanced autonomous capabilities, the long-term upside available in the passenger domain has generated tremendous interest from industry, government, and investor stakeholders. Since 2018, over \$4 billion has been invested in the AAM domain, where over 150 manufacturers are looking to transform 2-6 seat passenger transportation within both congested urban environments as well as between underserved intercity markets.

Revolutionary electric propulsion systems powering these aircraft promise significant operational savings relative to helicopters and other small passenger aircraft, thereby helping stimulate new demand for short-haul passenger trips. Yet autonomous flight capabilities will play a critical role in allowing AAM to scale and serve a broad cross-section of urban and suburban communities. Furthermore, the lessons learned from initially applying autonomous technology to AAM missions will support eventual implementation

of greater automation on larger commercial air transport aircraft.

The roadmap for future autonomous passenger aircraft begins with greater levels of task automation that can enable safe, single-pilot operations in the AAM domain. Transferring greater decision-support and flight control authority to the avionics will also likely enable a more streamlined training process that promotes a more robust supply of pilots.

As operators, manufacturers, regulators, and the public become more comfortable with single-pilot flight success for AAM missions and observe zero on-board pilot milestones achieved in industrial and cargo domains, further progress is expected in two ways. First, the graduation of single-pilot operations from small, non-commercial aircraft to larger passenger and cargo aircraft. This is expected to begin in the mid-2030s for regional-sized aircraft and move to larger aircraft classes, thereafter, helping airlines expand and optimize route networks. The second progression is the evolution from one to zero on-board pilots, beginning with select, lower risk AAM missions. Human operators will still be essential, but serve in a new, highly critical oversight role that ensures that AAM operations can safely scale to unprecedented levels.

Impacting the Economy, Jobs, and Society

Autonomous aircraft market growth and technology achievements will lead to myriad economic and social benefits. High quality jobs and consumer choice are just some of these benefits to society. In the end, the next chapter of American aviation and technology leadership will make these advances possible.

Autonomous aircraft are projected to directly lead to nearly 100,000 jobs in 2040, highlighting that there is nothing truly “unmanned” about them. With autonomous aircraft, people do not go away, but what they are doing – and where it takes place – can change.

Additional economic activity that is generated because of this growth will lead to the creation of many other jobs. These jobs have the potential to broadly stretch across the country, from development and manufacturing facilitates to remote piloting and operations centers.

The multitude of jobs to be created will bring forward the best of America’s aviation, technology, and service industries. On the front end of development, aerospace engineers are crucial to designing aircraft and ensuring that visions become reality. Highly skilled and trained pilots will continue to operate aircraft, either

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onboard or in a remote setting. Software developers and engineers are needed in far greater numbers to ensure that artificial intelligence algorithms are properly trained and applied. And on a day-to-day basis, people on the ground – including logisticians, support personnel, and others – are critical to ensuring success of the overall enterprise.

Beyond jobs, autonomous aircraft offer broader potential benefits to society. These include environmental benefits, such as reduced CO2 emissions for those aircraft that include some form of electric propulsion. National security benefits can be gained by ensuring that leadership in this sector remains entrenched in the United States. And quality of life will improve for consumers that are afforded an increasing degree of flexibility and choice, enabled by more options for efficient air transport.

Although autonomous aircraft offer significant promise, their growth and associated benefits are not destinies. Potentially impactful – but not prohibitive – barriers need to be recognized and averted to ensure that growth potential is fully realized. These include but are not limited to: availability of spectrum for aircraft communications and control data links, building technology advances related to artificial intelligence

and trust in greater autonomy, and ensuring adequate infrastructure.

By proactively addressing potential barriers, autonomous aircraft stakeholders will be better positioned to establish a strong foundation for sustained growth. While there are several potential pitfalls, the single largest barrier to market growth is inaction related to policy, regulations, and infrastructure investments.

Overcoming these potential challenges can be done but will require strategic focus, government and industry investment, and adequate regulations. With these foundational elements in place, the market will be in an enhanced position to thrive and achieve its transformational potential.

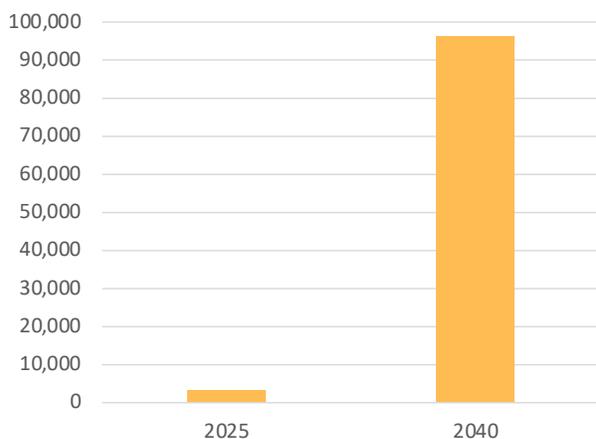
Recommendations

Given the advances that have occurred in recent years the charge now is to go beyond thinking bigger about autonomous aircraft. Significant technological and regulatory changes have taken place, to the credit of innovators in government and industry. With the foundation in place, now is the time to act at a strategic level with unity, conviction, and precision. By doing so, autonomous aircraft stakeholders can better ensure that market growth advances and is rooted in strong linkages between national vision, technology and infrastructure investments, and sensible policies.

Recommendation 1: Build a comprehensive national policy and regulatory map that prioritizes U.S. leadership in automation and autonomy in aviation

The development of a unified national policy and regulatory map for autonomous aircraft is the next step

PROJECTED DIRECT EMPLOYMENT, 2025 and 2040



EXAMPLE JOB POSITIONS

- Aerospace Engineers
- Logisticians and Ground Support
- Operations and Maintenance
- Manufacturing
- Remote Pilots
- RF Engineers
- Services and Support Professionals
- Software Engineers and Developers

that can further drive technological development and market activity. Taking action is essential to ensuring that all stakeholders share an understanding of the market's end state, as well as the technology, infrastructure, and policy steps needed to get there. Establishing this policy and regulatory map can also help ensure unified understanding of key upcoming technology milestones, as well as conceptions of autonomy and automation. These efforts would further place autonomy for aircraft in a holistic context that ensures investments and regulations are most effectively developed.

The policy and regulatory map may consider elements such as, but not necessarily limited to:

- » Holistic and comprehensive government coordination to promote and streamline regulations that facilitate the safety and security of autonomous technology
- » Establish public-private partnerships to leverage innovation in both industry and government to enable novel aircraft designs, facilitate transformative operation, and enable investment in infrastructure and other sectors

Building such a map requires a comprehensive approach to include state and local entities, federal agencies, academia, non-profit organizations, operators, and the private sector. Stakeholder representation from this wide range of groups ensures that multiple perspectives are brought to the table and will help to further reinforce the benefits of public and private sector cooperation. Indeed, at this stage in the market's development, more cooperation and greater partnership will benefit all stakeholders who seek to drive progress.

Importantly, a national policy and regulatory map for autonomous aircraft need not be a static document but rather the product of living, evolving dialogue that changes at the speed of technology and use case developments. Given the rate of technology change, it will be essential to ensure that any map is the result of recurring engagement and not a one-time process that reflects only a snapshot of time.

Recommendation 2: Invest in key infrastructure and technology development areas that accelerate innovation in all of aviation

The aviation ecosystem has always benefited from significant government investments in infrastructure, such as airports and airways, and further investments will be needed to fully realize the benefits of large autonomous aircraft. Although many required pieces are in place today (or are moving in the right direction), there are additional areas that can benefit from further scaling. Some areas of investment include:

- » Aircraft charging infrastructure to enable electric aviation, which is critical to sustainable scaling of many AAM concepts
- » On and off-airport vertiports to enable the rapid movement of people and goods at scale
- » Low altitude airspace surveillance to support the safe integration of more aircraft into the existing national airspace system
- » Alternative Position, Navigation, and Timing (PNT) solutions to augment GPS, especially at low altitudes and in metropolitan environments
- » Enhancements to the National Airspace System to enable digital integration with the existing Air Traffic Management system, especially as it pertains to voice communications

In tandem with infrastructure, onboard technology advances are also critical to expanding the market. Many elements are already in place, especially related to remotely piloted aircraft. However, especially as aircraft move towards greater degrees of autonomy, there are technologies that will benefit from further development. These include onboard processing, artificial intelligence algorithm development and enabling fully digital, non-voice communications.

Recommendation 3: Develop performance-based regulations that facilitate innovation while ensuring safety and security

Sensible policies are crucial for safety and progress, as well as ensuring public trust and acceptance of autonomous aircraft; however, aviation is a highly regulated space and the ecosystem needs regulations that provide clarity and guidance in order for investments to have immediate impact. In the near-term there are three broad areas that can serve as the focus of ongoing regulatory activities.

Ensuring reliable spectrum is a crucial foundation, and protecting aviation C-Band access for Control and Non-Payload Communications (CNPC) and promoting its use through operating rules is a central part of this. Ensuring a portion of C-Band spectrum for autonomous aircraft usage is a critical step toward ensuring safe operations in the national airspace.

Beyond spectrum, it is important to consider other policy stepping-stones and how to most effectively build on those that are in place today. This can include critical technologies like Detect and Avoid (DAA), which will ensure that safety is maintained as more automated and autonomous aircraft enter our skies. Several advisory committees have made recommendations to the FAA

on how regulations can be amended to enable DAA capability and several standards development organizations have published performance-based standards that the FAA can adopt.

Recognizing the speed at which autonomous capabilities change, in some cases additional performance-based rule development and implementation will be needed. These rules need not be prescriptive, but they can rather focus on outcomes that enable the market to scale most effectively.

Closing Thoughts

Autonomy is not a luxury or a choice. It is an essential capability needed for a changing world in which people require augmentation to drive growth and keep pace with demand. Many of the technology pieces are in place today, but unity of vision is needed to drive the right future investments and policy. With those elements in place, the market is poised to build on recent growth and establish a strong foundation for long-term expansion, job creation, and enduring American leadership.

The vision has been cast, the gaps have been identified, now the U.S. government needs to embrace a future where higher levels of automation and autonomy in aviation bring enhanced safety, high-quality jobs, and the movement of goods and people that will accelerate economic growth. This policy prioritization will bring focus to the various parts of the government that need to act to enable and promote safe and secure innovation in aviation. ■

About the Authors



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