FLIGHT PATH FOR THE FUTURE OF MOBILITY

BOEING NEXT
Building the flight path for the future of mobility takes more than imagination. Success relies on the proven ability to transform vision into reality for the betterment of humankind.

As an aviation pioneer and industry leader, Boeing supports the growth of the global economy with aircraft and services to move people, goods and ideas around the world. As we enter our second century, Boeing is focusing on emerging technologies, unmanned aircraft systems (UAS) operations and the safe introduction of these vehicles into the airspace—while preserving the flying public’s confidence in air travel.

With increasing urbanization, a growing global population, aging infrastructure and the explosion of ecommerce, there is a need for new, sustainable and accessible modes of transportation. Urban air mobility (UAM) presents an opportunity to provide seamless, safe and rapid transportation to mitigate existing and future challenges faced by urban areas.

Some studies forecast the UAM market will be worth tens of billions of dollars across the value chain. The promise of UAM has led to numerous industry efforts; today, there are over 100 vehicles in various stages of development globally. In addition to Original Equipment Manufacturers (OEMs), other parts of the UAM value chain will include passenger operations, UAS traffic management, operations and maintenance, infrastructure, insurance and financing.

While the players and structure of the market continue to evolve, it will likely include a range of solutions operated by various operators, unlocked by business models that include ride-sharing. This growth will be facilitated by key enablers, including airspace integration, infrastructure expansion, market acceptance, seamless integration into connected mobility systems and a wide range of other ecosystem elements—many of which are yet to be imagined.

Advances in autonomy, artificial intelligence, data analytics, hybrid and fully electric propulsion have unlocked new possibilities that are guiding us to reimagine travel and transportation. We are working with regulators around the world to enable the next generation of unmanned aviation.

Airspace access is foundational for the future

Introducing large numbers of autonomous air vehicles to an air traffic management system that never anticipated this level of disruption requires creative thinking, problem solving and innovation. Boeing is committed to leveraging our experience and expertise gained in over 100 years in the aviation industry to work with regulators to enable critically-needed airspace access while maintaining safety.

When it comes to establishing routine, safe access to the global airspace, there is no “one size fits all” solution. We must address the challenges incrementally with an understanding of the limitations that exist and work within the scope of an evolving regulatory landscape. The challenges to the growth of the UAM industry are both regulatory and technical. Emerging and required solutions will be interrelated and complementary. These solutions must do no harm to safe airspace operations while at the same time, allow for growth of scalable business opportunities.

It will take the focused effort of industry and regulators to develop new and innovative approaches to operating in the current and future airspace environment. Our overarching goal is to accelerate the transition from regulatory and operational accommodation of autonomous systems to advancement toward full airspace integration.

Specifically, Boeing plans to address these challenges by:

- **Assessing and recommending** changes to the current air traffic rules and procedures to increase airspace accessibility and interoperability.
- **Modeling and simulating** multiple end state operational scenarios supporting UAM and the requirements of our customers.
- **Designing, building and testing** UAS in multiple airspace models incorporating current and future technologies.
- **Employing** live, virtual, constructive methodology.
- **Collecting, analyzing and sharing** our lessons learned with regulators and air navigation service providers globally.
Collaboration is critical to integration

The list of challenges remains somewhat daunting, but with focused effort and leadership, none are insurmountable.

Identifying and prioritizing the challenges will be an important step in developing a fully integrated air mobility ecosystem. Boeing intends to design and conduct solution-bearing tests and demonstrations that will advance access needs and move us gradually to full UAS integration.

To move from vision to reality, industry and regulators need to work together to focus their attention on building a comprehensive ecosystem to support and sustain safe autonomous flight on a large scale:

- Air traffic control policy, procedure and standards facilitating cooperative traffic management for all classes of autonomous air vehicles in all classes of airspace
- New regulations, or revised rules, to allow for either modified visual or instrument flight rules appropriate to autonomous air vehicles
- An integrated ecosystem of technologies that reliably and safely address detect-and-avoid capabilities. This may include ground-based, airborne or space-based solutions that ensure all aircraft operating in the airspace remain safely “well clear”
- Clearly defined vehicle performance requirements to safely share the airspace with all classes of vehicles
- International flight planning requirements and information input (file and fly requirements)
- Standard contingency management procedures
- Performance-based navigation-centric procedure and requirements for autonomous vehicle operations in the terminal and en route environment
- Communication protocol
As levels and acceptance of vehicle autonomy increase over time, unmanned air vehicles will become well-suited to operate in an environment minimally controlled by traditional surface-based procedures. Performance Based Navigation (PBN) requirements and standards for manned aviation are now well established and, combined with advancements in data link/data communication, may provide a near-term path that supports integration. While size, weight and power limitations remain for some classes of autonomous air vehicles, Boeing feels that technology will soon permit the incorporation of certified avionics and equipage in unmanned vehicles suited for urban air mobility applications. The exploitation and demonstration of this proven navigation approach could be foundational to solving many of the challenges previously identified.
Ten Keys to Unlocking the Future of Autonomous Mobility

**Air Routes**
The design of performance-based routes for low altitude trajectory-based operations and new operations in and around existing terminal areas.

**Air Traffic Management Procedures**
Standard procedures for managing contingencies for new autonomous airspace users in existing controlled airspace, including:

- New procedures for convoys of autonomous aircraft and procedures for managing failures in the Air Traffic Management System (ATMS).
- 4D trajectory-based separation management to maintain a safe distance for autonomous aircraft operating in free flight, including during approach and departure for operations around hubs and terminal locations.

**Digital Information Management**
An autonomous cloud-based system for the rapid collection, processing and real-time distribution of aeronautical data to large numbers of subscribing aircraft.

**Performance Based Communication, Navigation, and Surveillance (CNS)**
A framework of performance-based CNS requirements and standards enabling new operations on established routes, and the design and certification of new routes, separation standards, and infrastructure and equipment for high-complexity operations in obstacle-rich environments.

**Aircraft Autonomy**
A level of aircraft autonomy where systems exhibit operational behavior undistinguishable from that of a human pilot.

**Autonomous Flight Planning**
On-board algorithms for real-time predictive flight planning and route generation in complex and dynamic airspace environments. Systems will make use of near real-time updates to aeronautical data to plan safe and efficient routes, consistent with dynamic changes to airspace, predicted weather, and other operational restrictions (e.g., noise).

**Contingency Management Systems**
Robust autonomous systems that enable aircraft to safely and efficiently manage contingency situations, including situations requiring a precautionary or forced landing.

**Detect And Avoid (DAA)**
A suite of automated DAA systems that:

- Are compatible with existing Airborne Collision Avoidance Systems
- Concurrently address the full scope of potential operational hazards (e.g., adverse weather, birds, obstacles and terrain);
- Dynamically adjust well clear and collision avoidance volumes to account for specific operating conditions (e.g., parallel approaches) and the quality of available surveillance information;
- Can be used during both airborne and surface movement phases of operation, and those airborne phases where there is significant aircraft maneuvering;
- Are suitable for vertical take-off and landing in cluttered obstacle environments; and
- Provide efficient and safe recovery to a flight plan.

**Autonomous Flight Rules**
A new set of flight rules tailored to account for the varying levels of autonomy in emerging aviation systems.

**Certification Framework**
A framework for the comprehensive and efficient certification of complex autonomous aviation systems. The framework would supplement existing software and hardware assurance approaches, with the aim of providing an acceptable level of assurance in the behaviour of adaptive autonomous aviation systems for a wide range of operational conditions.
The next-generation airspace operating system

SkyGrid, a Boeing and SparkCognition company, is developing an airspace management software platform that will enable the future of urban aerial mobility. SkyGrid will deliver an artificial intelligence and blockchain-powered platform capable of providing safe, secure airspace operations—a key step toward enabling broad integration of autonomous air vehicles in the global airspace.

Using blockchain technology, AI-enabled dynamic traffic routing, data analytics and cybersecurity features, SkyGrid’s platform will go beyond UAS traffic management. Its customers will be able to perform a broad range of missions and services using UAS, including package delivery, industrial inspections and emergency assistance.

Learn more at www.skygrid.com.
The NeXt step

As we chart the flight path for the future of urban mobility, industry and regulators alike must prioritize the safety, reliability and environmental impact of the UAM ecosystem. As an enabler, UAM has the potential to dramatically improve the way people, goods and ideas move around the world—but that potential hinges on building and maintaining public confidence in the system’s safety. **UAS regulations and airspace management are crucial for unlocking the potential of this disruptive market.**

Developing the regulatory framework will pace adoption of these emerging technologies and development of the mobility ecosystem. Boeing’s focus on expanding the entire mobility ecosystem beyond air vehicle development and requirements will be essential in our future work. Components of the overall UAM ecosystem may likely include interoperability with ground vehicles and space-based technologies. Demonstrations adaptable to global requirements and the unique needs of the international community will play a crucial role in the design and execution of our efforts.
Boeing is building a future of time-saving, low-stress mobility that will make it easier to connect the people, cultures, economies and products of the world. Our proven safety record, risk-based approach, rigorous testing and robust development processes uniquely position us to make the future ecosystem a reality.

www.boeing.com/NeXt