Evaluating AI Use for Navigation in Commercial and Aerial Flights

Aidan Zhang

Abstract

This paper reviews research on the use of artificial intelligence (AI) in aerospace navigation, focusing on how these technologies are currently being used in unmanned aerial vehicles (UAVs). By analyzing 10 peer-reviewed studies and articles with various topics like drones and passenger air taxis, this review showcases both the promise and current gaps of using AI in aerospace application. AI technologies are now allowing UAVs to avoid collisions, coordinate in multi-agent missions, and navigate without GPS. AI-enhanced systems are also emerging in satellites for autonomous orbit determination and robot maintenance and in commercial aircraft for predictive maintenance and air traffic control. Despite these advancements, current limitations such as high computational demands, lack of real environment testing, and concerns about reliability and safety persist. Ultimately, this paper provides knowledge about AI strengths and weaknesses that helps enable the future of autonomous passenger air flight.

Introduction

As aerospace systems evolve toward Artificial Intelligence-implemented software, ranging from satellites to unmanned aerial vehicles (UAV) and future deep space probes, navigation without human pilots have become a necessity and a technological challenge. Vehicles like UAVs, which can fly without a human onboard, are increasingly vital in modern aerospace missions. Their high mobility, rapid deployment, and Artificial Intelligence(AI) adaptability capability make them necessary not only in terrestrial environments, but in research, satellite services, and potentially a foundation for passenger aircraft.

Recent reports highlight our current systems under strain. A 2025 review coauthored by Georgia Tech aerospace professor Karen Feigh found that 19 of the FAA's largest air traffic control(ATC) facilities are operating with staffing levels 15% below efficiency. While it is difficult to measure the exact number of lives ATC save, data shows how ATC intervention is crucial for avoiding collisions and managing daily traffic.

By introducing AI-assisted or autonomous decision-making systems into aviation, airspace can be improved efficiently and enhance safety. According to CNN and the New York Post, the FAA currently experiences up to 1,000 equipment failures per week due to outdated copper wire systems, with outages now expected to increase. These failures, paired with controller shortages and aging technology, have already led to flight delays lasting hours at major airports such as Newark Liberty International. With over 50,000 flights managed per day and a 9% drop in certified controllers since 2012, the system faces unacceptable strain that AI could help relieve.

Traditionally used in military operations, UAVs are now central to a growing number of civilian and aerospace applications. This includes wildfire detection, search and rescue, medical delivery, emergency communication, and autonomous eVTOL aircraft. However, in the context of commercial airspace and aerospace, UAVs face growing complexity due to their reliance on human control and radio frequency communication as key limitations, especially for scalable and reliable operation in future aerospace networks that may include passenger-carrying aircraft.

Current UAV navigation methods, such as inertial measurement units (IMU), satellite-based GPS, and vision-based systems, struggle in scenarios demanding real-time decisions, rapid adaptation, and reliable obstacle avoidance. IMUs rely on accelerometers and gyroscopes to estimate motion and orientation, but they tend to drift over time without external correction. GPS offers global positioning by using satellite signals to determine location, but its accuracy decreases in obstructed or jammed environments. Vision-based systems, which use cameras to recognize surroundings, are sensitive to lighting and weather conditions, limiting their reliability. Although technologies like 5G offer improved connection, traditional optimization approaches often fail in large-scale, unpredictable environments common in aerospace operations. These methods are difficult to scale and adapt for autonomous systems in passenger aircraft, where conditions change rapidly and safety is critical.

With AI, these issues could have a promising solution. Its ability to learn from data, adapt in real time, and operate with minimal human intervention makes it well-suited for aerospace navigation. AI can extract features, predict scenarios, and support decision making far beyond the capacity of conventional algorithms. These capabilities are particularly important to explore UAV-derived autonomy for air taxis and future commercial aircraft systems.

AI navigation solutions generally fall into two different categories: optimization-based systems that perform better in predictable environments, and learning-based systems that make decisions in uncertain conditions. The latter is essential for aerospace contexts where systems must adapt to changing environments and unexpected obstacles.

Despite their potential, AI systems face challenges in aerospace implementation. These include long training times, high computational demands, lack of certification-ready models, and potentially real-time performance limitations. These concerns are heightened with the involvement of passenger aviation, where reliability and regulatory compliance are a must. Thus, this paper reviews literature on AI in UAV navigation with its potential use in passenger aerospace systems. It will compare different algorithm methods and highlight the challenges of using AI efficiently.

Analysis

Saeid Emami, Rosario Castaldi, and Ali Barazadeh (2022) aimed to improve adaptability and decision-making in flight control. They used neural networks to optimize control algorithms based on real-time flight data. Their study found that AI enhanced real-time decision-making and adaptability in dynamic environments. However, they noted challenges in complex model training and validation. This work supports the development of fully autonomous flight control systems in future aerospace applications.

Eduardo Cuellar, Alvaro Medina, and Francisco Mojica (2022) focused on enhancing traffic flow optimization and reducing congestion. By applying machine learning algorithms to predict air traffic patterns from air traffic data, they achieved improved safety and efficiency. Despite these benefits, the researchers faced real-time implementation challenges. Their findings could be instrumental in expanding to global air traffic management and autonomous systems.

Wen Tan, Changcheng You, Jianhua Zhang, and Tony Q. S. Quek (2023) sought to improve real-time aircraft monitoring systems. They used reinforcement learning for real-time fault diagnosis based on aircraft sensor data. The study showed that AI could deliver faster and more accurate fault detection while reducing downtime. One of the major hurdles was ensuring data diversity for generalization. Their approach lays the groundwork for fully automated fault monitoring in aircraft systems.

Aurel Zeqaj (2023) focused on designing an orbit determination computer for autonomous navigation. Using AI algorithms and an Extended Kalman Filter, he reconstructed spacecraft trajectories based solely on onboard optical data. The system showed strong performance in avoiding dependency on Earth-based tracking. Challenges included limited sensor accuracy and computational demands. The DeepNav system demonstrates how AI can reduce mission costs and improve spacecraft autonomy.

Sikandar Khan, Ahmad Waqas, and Abdul Basit (2023) explored the role of AI in real-time UAV navigation through deep reinforcement learning. Their model allowed UAVs to autonomously learn obstacle avoidance and path optimization in dynamic environments. Results showed significant improvement in mission efficiency. However, training time and adaptability across different scenarios remained issues. This work could influence future development of smart UAV traffic networks.

Shahrukh Khan, Tariq Ahmad, and Tanveer Hussain (2023) developed an AI-driven UAV simulation platform for multi-agent systems. Their research focused on optimizing pathfinding and network communications in emergency environments. The AI model showed high adaptability and robust performance. However, challenges like system scaling and real-world unpredictability limited its effectiveness. This study suggests new ways to deploy drones in complex missions like disaster relief.

Ashok Murugesan, Lihui Wang, and Juan José Cerrada (2020) developed an explainable AI model for predictive aerospace maintenance. By analyzing large datasets from aircraft systems, their method identified early signs of component failure. The benefit was enhanced safety and reduced maintenance costs, but they faced challenges in integrating explainable AI with complex system diagnostics. Their research could lead to more transparent, trustworthy AI systems in commercial aviation.

Adewale Abiodun, Nathaniel McMahon, and Paula T. Griffin (2023) investigated multi-UAV coordination using federated learning. This method enabled decentralized data sharing without compromising privacy. The key benefit was improved swarm behavior and cooperative decision-making. Limitations included high computational load and communication latency. Such techniques are vital for large-scale UAV deployment in areas like disaster response or urban air mobility.

Ruotong Xie, Rajmohan Madhavan, and William K. Chambliss (2021) examined robotics and AI in on-orbit operations, such as satellite servicing. They showed that AI-enhanced robotics can autonomously perform inspections and repairs. Benefits included lower operational risks and mission longevity. Challenges were technical—like manipulation in microgravity—and organizational, such as regulatory approvals. This work bridges robotics and AI for sustainable space operations.

Results/Methods

Common Goals and Themes

Across all the reviewed papers, one major goal stood out: using artificial intelligence to improve autonomy, efficiency, and decision-making in aerospace systems. Whether the focus was on UAVs (drones), satellites, or aircraft, the purpose of AI was usually to help systems respond to their environment with less human input. For example, Khan, Waqas, and Basit (2023) used deep reinforcement learning to train UAVs to fly and avoid obstacles on their own, showing the push toward fully autonomous navigation. Researchers consistently aimed to reduce human error, improve safety, and allow flight systems to adapt in real time to changing conditions.

Different AI Methods Used

Each paper explored different artificial intelligence (AI) methods depending on the specific needs of the aerospace application. Reinforcement learning was especially important in the studies by Khan et al. and Tan et al. (2023), where it was used to train unmanned aerial vehicles (UAVs) to navigate complex and unpredictable environments, or to diagnose faults in real time. This method allowed systems to learn optimal strategies through trial and error, which is particularly useful when pre-programmed rules are insufficient.

Neural networks also played a major role in AI-based aerospace systems. Emami, Castaldi, and Barazadeh (2022) used them to enhance real-time flight control systems, allowing UAVs to adapt to rapidly changing conditions mid-flight. Similarly, Murugesan et al. (2020) applied neural networks to predictive maintenance systems, enabling early detection of component failures based on large datasets from aircraft sensors. These neural models allowed for continuous learning and pattern recognition from complex data streams.

Explainable AI (XAI) was another critical area, especially in applications involving human operators or maintenance teams. Murugesan et al. emphasized the importance of transparency in AI decisions, especially for safety-critical industries like commercial aviation. Their XAI framework helped maintenance crews understand and trust the AI's diagnostic predictions, making it more likely for these systems to gain regulatory and operational acceptance.

Lastly, Abiodun, McMahon, and Griffin (2023) used federated learning in their multi-UAV coordination model. This approach allowed different drones to share learned data with each other while keeping their raw data local, protecting sensitive information. Federated learning proved to be especially valuable for swarm operations in which privacy and coordination were both priorities.

However, each of these AI techniques came with trade-offs. Reinforcement learning, for example, required long training times and extensive computational resources. Explainable AI increased transparency but sometimes reduced accuracy or performance in complex systems. Federated learning introduced latency and required more advanced communication networks. Despite these limitations, the variety of approaches used across the studies illustrates how AI is being tailored to fit the unique challenges of aerospace navigation.

Where AI Is Being Applied

The reviewed research primarily explored AI applications across three major aerospace domains: UAVs, satellites and spacecraft, and passenger aircraft. Drones were the most common focus, with studies like Khan et al. (2023) and Shahrukh Khan, Ahmad, and Hussain (2023) demonstrating how UAVs can use artificial intelligence to autonomously navigate, avoid obstacles, and even operate in coordination with other drones during multi-agent missions.

These capabilities are particularly useful in scenarios such as search-and-rescue, package delivery, and emergency response. In the realm of space, Aurel Zeqaj (2023) developed an autonomous orbit navigation system that allows satellites to determine their position without relying on ground-based stations. Similarly, Xie, Madhavan, and Chambliss (2021) discussed how AI could enhance satellite robotic arms for functions like inspection and in-orbit repairs. While AI integration in commercial aviation is still emerging, it is already being explored: Murugesan et al. (2020) designed an explainable AI model that predicts component failures, reducing unnecessary maintenance and increasing safety, while Cuellar, Medina, and Mojica (2022) implemented machine learning techniques to manage air traffic flow and reduce delays. Although UAVs currently dominate the field in AI usage, these technologies are paving the way for future applications in autonomous passenger aircraft, such as air taxis or unmanned delivery planes.

Challenges and Limitations

Despite AI's promise, several studies outlined significant challenges that still need to be addressed. One major issue is training time. Models like deep reinforcement learning require enormous datasets and extended periods to train, especially when coordinating multiple UAVs or learning complex behaviors, as emphasized by Khan et al. and Abiodun et al. Another challenge lies in the computational demands of AI systems. Small aircraft and satellites typically operate with limited power and onboard processing capabilities, making it difficult to run advanced AI models in real time. Additionally, trust and explainability are critical concerns in safety-critical environments like aviation. As Murugesan et al. noted, pilots, engineers, and regulatory bodies need to understand how AI reaches its decisions in order to confidently rely on those systems. A final, recurring limitation is the gap between simulation and real-world performance. While many AI systems perform well in controlled virtual environments, researchers such as Zeqaj and Shahrukh Khan et al. highlighted the difficulty of proving that these models will work reliably in unpredictable, real-life conditions. As a result, further testing, validation, and refinement are necessary before these technologies can be widely adopted in operational aerospace systems.

Trends and Takeaways

AI for UAVs is clearly the most developed field, but research is already spreading into satellites and passenger aircraft. The use of explainable AI, swarm coordination, and fault prediction shows that AI will likely become a key part of autonomous aerospace systems. While full autonomy in passenger aviation may still be years away, these studies show that the groundwork is already being laid—using drones as a testing ground for larger, more complex applications.

Conclusion

The analysis of these nine articles demonstrates how artificial intelligence (AI) is quickly changing aerospace navigation on passenger planes, drones, and satellites. AI systems have already shown that they can avoid obstacles, plan multi-vehicle missions, make decisions in real time, and anticipate maintenance problems before they become problems. In addition to increasing efficiency and safety, these developments pave the way for future operations that are more autonomous.

Expanding these systems for commercial passenger applications, like automated aircraft and air taxis, is the next frontier. Since the same technologies that enable drones to maneuver through congested urban airspace can be modified for larger aircraft, the transition will be guided by lessons learned from UAVs. But there are still difficulties. Future AI systems need to be certifiable, explainable, and extensively tested in real-world scenarios in order to win over the public and regulators.

Aerospace engineers can lessen the need for human input for routine decisions, free up pilots to concentrate on important duties, and pave the way for new types of air travel by further integrating AI into navigation. AI-powered navigation may replace GPS in aviation within the next ten years, opening the door to safer skies, more satellite capabilities, and ground-breaking passenger services. Promoting the prudent application of AI in aerospace today will guarantee that these technologies develop to their full potential without endangering public safety.

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