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An Overview of Advanced Air Mobility Research at NASA

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Advanced Air Mobility (AAM) is expected to enable new types of aircraft to provide local-area transportation more cleanly, efficiently, and quietly than today, complemented by higher levels of autonomy and automation, and supported by air traffic management systems and infrastructure. A varied set of missions and use cases is envisioned. The United States' National Aeronautics and Space Administration (NASA) has established a broad research portfolio that leverages internal activities and external collaborations with industry and government. As the AAM concept has evolved, compelling new applications to disaster response have emerged, posing new challenges for the research community. To address these challenges, NASA is leveraging its foundational work performed in partnership with the Japan Aerospace Exploration Agency (JAXA) on integrated unmanned and manned aircraft operations in disaster response situations. The joint NASA and JAXA work, along with the ongoing AAM efforts, have contributed to the formulation of a new project that will expand the scope of technology integration with an initial focus on wildland firefighting.

Key Words: Advanced Air Mobility, Disaster Response, Automation

1. Introduction

The convergence of new technologies, such as electric propulsion and autonomy, and new business models, such as app-based ride sharing, are propelling the emergence of new aviation markets known as advanced air mobility (AAM). The concept of AAM refers to the transport of passengers and cargo from last-mile delivery to up to 800-kilometer distances using new and emerging aircraft technologies. While the present-day conversation around the future of AAM primarily revolves around the transportation of goods and people using next-generation electric vertical takeoff and landing aircraft (eVTOL), the general concept of local air transportation by small aircraft is realized today at heliports across the country that utilize traditional helicopters. Recent technological advances in aircraft technology, such as the electric-propelled aircraft, advances in ground infrastructure development, such as UAS Traffic Management (UTM), and advances in automation and autonomy technology, are expected to enable next-generation eVTOL aircraft to execute air mobility missions beyond the urban environment. To be economically and socially viable, these future missions are expected to occur at a much greater operational tempo, in a far more environmentally compatible fashion, and at a much lower cost point compared to today's helicopter operations.

The National Aeronautics and Space Administration (NASA) implements AAM research across a diverse portfolio and leverages collaborations with international research organizations, federal, state, local, and tribal government agencies, standards development organizations, industry leaders, and academia. This paper provides a description of AAM missions and the NASA research that aligns with these missions.

2. AAM Missions

NASA defines AAM as safe, sustainable, affordable, and accessible aviation for transformational local and intraregional missions. This definition is relatively broad but has an implication of making aviation capabilities more accessible to average citizens, often leveraging small aircraft to perform functions that historically have been accomplished via cars or other ground transportation. It encompasses a variety of missions and aircraft types, including (but not limited to) small package delivery via unmanned aircraft systems (UAS), transport of cargo between existing community airports with automated regional aircraft, and movement of passengers around metropolitan areas via novel small electric aircraft.

Figure 1: Advanced air mobility missions.

The NASA Aeronautics Research Mission Directorate (ARMD) has an AAM portfolio that spans across various technology domains, however there are four main types of applications, as depicted in Fig.1, that align with NASA research investments: (1) regional passenger and cargo transport, (2) delivery of consumer goods and services, (3) urban passenger transport, and (4) public good operations. The regional passenger and cargo transport application, sometimes referred to as regional air mobility, focuses on the movement of passengers and goods over distances of 50 to 800-kilometers and leverages existing airports and infrastructure, whereas delivery of consumer goods and services is mostly focused on low-altitude operations envisioned with small or medium sized UAS delivering small cargo, taking photographs, and performing infrastructure inspection. Urban passenger transport, more commonly referred to as urban air mobility,[1] is the transportation of passengers or cargo within metropolitan areas. Public-good operations are envisioned to provide non-commercial benefits to the general population or are conducted in the public's interests. Examples of these operations could include wildland firefighting, air ambulance, movement of doctors to rural areas or medical supply delivery.

While NASA research addresses a variety of different challenges within these AAM missions, Sections 3 and 4 below provide a brief overview of NASA research areas that support the urban passenger transport and public good missions, respectively.

3. NASA Research in Advanced Air Mobility

Through the introduction and ongoing development of the AAM concept at NASA, several key research areas have emerged that serve as cornerstones aimed at enabling the safe and efficient integration of AAM missions into the nation's airspace. With respect to urban passenger transport and public good AAM missions, these research focus areas span the domain to include aspects related to aircraft autonomy, air traffic management, vertiports and infrastructure, as well as the integrated test capability referred to as NASA's National Campaign. Research, development, and testing with an integrative perspective of these areas, in collaboration with industry and federal stakeholders, are considered key to realizing the potential of AAM.

3.1. Aircraft Autonomy

The types of aircraft that will be carrying out AAM missions in the future will be revolutionary in many respects. Not only does that apply to the manufacturing methods, materials, propulsion, etc., but it also applies to how that aircraft is operated in the airspace. To achieve the scalability envisioned for AAM, a paradigm shift is envisioned from onboard piloting to remote and potentially fully autonomous operation. This shift will require advances in autonomy that will enable the aircraft to navigate, sense and avoid, and handle contingencies with limited to no human intervention.

3.2. Air Traffic Management

In addition to advances in aircraft capabilities, another key enabler for the AAM vision is the application of new concepts and technologies to the domain of air traffic management. Current methods of air traffic management in the nation's airspace will likely not allow for the scalability desired by industry and may place an undue burden on air traffic control personnel and supporting infrastructure. Borrowing from the service-based approach explored and advanced in NASA's UAS Traffic Management (UTM) research, [2,3] combined with the agency's rich history in traditional air traffic management research in collaboration with the FAA, NASA is conducting research into the services, procedures, stakeholder roles and responsibilities, autonomy, and other aspects needed to manage AAM operations in the airspace. How the air traffic and supporting services interact with traditionally controlled airspace along with the procedures and supporting technologies is an additional aspect of the research that not only covers the different types of operating areas but provides a framework for examining operational concepts across different AAM maturity levels.

3.3. Vertiports and Infrastructure

While air traffic management is a key enabler for scalable airspace integration of AAM operations, potential bottlenecks exist if operations at and around vertiports from which aircraft will be departing and arriving are not managed flexibly. To that end, careful consideration and supporting research have been devoted to the management of operations at and around vertiports and the collection of inter-connected vertiports known as a vertiplex. NASA is conducting research into a variety of areas including the technologies, services, supporting infrastructure, procedures, contingency management, and interoperability with air traffic management systems and stakeholders to address the need for airspace and resource management at the terminal areas of vertiports and vertiplexes.[4]

3.4. National Campaign Demonstrations

The ongoing work within AAM in the areas of aircraft autonomy, air traffic management, and vertiport management each have testing components in their portfolios that involve simulation and/or flight testing at varying levels of complexity. Given that each of the elements addressed in the different research thrusts are envisioned to ultimately be part of the future AAM environment, a testing framework was developed at NASA to provide a means to bring together the research outcomes and technologies through a series of integrated simulations and flight demonstrations. Referred to as the National Campaign, this effort brings together multiple partners from industry, projects from across the ARMD portfolio, and the FAA along with other federal entities to demonstrate the combined AAM capabilities and collect valuable data that will provide insight into the paths toward certification and inform the regulatory and policy decisions to be made in the future to make AAM a reality.

4. NASA Research in Disaster Response

Natural disasters can lead to many lives lost and billions of dollars in costs across the U.S. each year. To address a growing trend of increasingly severe natural disasters, NASA is conducting research and development that spans across different missions within the agency. The subsequent sections outline the ongoing and upcoming aeronautics AAM research that addresses disaster response.

4.1. Post-Disaster Recovery

Recent natural disasters have increased in frequency and intensity, globally. With that increase has come a renewed focus on improving disaster response efforts. In response to this global trend, JAXA and NASA have been in collaboration since 2016 to explore improved airspace management for disaster response through the integration of manned aircraft and small UAS. The approach to this integration has leveraged JAXA's Disaster Relief Aircraft Information Sharing Network (D-NET) system for the coordinated management of manned aircraft assets combined with NASA'S UTM system for the management of UAS assets. To drive innovation in improved response, JAXA and NASA have successfully connected respective systems and conducted a series of live flight tests, first as part of a large-scale disaster drill and later in dedicated research flights. [5-7]

The current focus on the JAXA and NASA collaboration is to demonstrate how disaster relief operations can be conducted in a more efficient manner by integrating conventional aircraft and AAM aircraft (e.g., UAS) more cohesively into disaster response operations within the same airspace. This research will continue to leverage advancements in UTM and D-NET and work to generate results and recommendations to inform standards development organizations on requirements for disaster response operations.

4.2. Wildland Fire Management

Over the past decade the rate and severity of wildland fires in the United States has become detrimental to public health, to climate change, and to substantial economic loss. To help reduce these impacts, NASA has started a new project, called the Advanced Capabilities for Emergency Response Operations (ACERO) project, that focuses on developing and maturing advanced aviation technologies to better assist emergency responders by enabling their interventions to be more efficient, more targeted, and more responsive to changing circumstances. The ACERO project is aimed at improving aerial responses to wildfires and will extend these technology advancements to other natural disasters.

The ACERO project will modernize wildland fire airspace management operations by providing technologies to address three challenges in operations: (1) inability to conduct air attacks at night due to the risk to flight crews, (2) dependence on manual airspace coordination which limits the aerial response, and (3) the lack of safety systems to enable UAS and crewed aircraft to conduct integrated operations.

NASA will also leverage research, under the System-Wide Safety Project, to validate the application of an In-Time Aviation Safety Management Systems (IASMS), [8] to the wildland fire missions and other natural disaster operations by demonstrating relevant functions, capabilities, and services that assure safety within the operations.

These NASA Aeronautics projects contribute to a broader NASA approach to addressing natural disasters that includes contributions from the NASA disasters program and the new science wildland fire program, under the NASA Applied Earth Sciences Mission Directorate, and ongoing technology maturation supported through the NASA Space Technology Mission Directorate.

5. Summary

Advanced Air Mobility has the potential to revolutionize air transportation in the way in which passengers and cargo are transported, how new enterprise services and infrastructure are woven into the fabric of the airspace system, and the ways in which missions for public good can be complemented and improved. NASA is helping to lead the way through its dedicated research portfolio in AAM that leverages the knowledge and capabilities of multiple projects within ARMD and applies them to development and testing that involve collaborations across industry and government. The advances in AAM, particularly for public good and disaster response operations, will also build upon ongoing collaborations between NASA and JAXA that have examined the integration of unmanned air assets into disaster situations. The outcomes and results of this collaboration and others will be expanded upon as part of a broader effort encompassed by the ACERO project with its initial focus on wildland fire management. Cumulatively, these NASA efforts are expected to have broad applicability, significant benefits, and positive impact at a societal level.

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