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Uncrewed Aircraft Systems and Advanced Air Mobility Operations – A Practitioner's Perspectives

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Abstract: ***Uncrewed Aircraft Systems (UAS) and Advanced Air Mobility (AAM) operations are increasing in number, complexity, and sophistication, offering significant benefits to the national economy, businesses, public safety agencies, and individuals. Realizing these benefits requires scalable, economically viable integration into the National Airspace System while addressing key regulatory and technical challenges to ensure safe, secure, and efficient operations.***

Keywords: ***National Economy, Businesses, Public Safety Agencies***

Nomenclature:
UAS: Uncrewed Aircraft Systems
AAM: Advanced Air Mobility
UTM: Unmanned Aircraft System Traffic Management
NPRM: Notice of Proposed Rulemaking
GBSS: Ground-Based Surveillance Systems
DAA: Detect and Avoid
ACAS: Airborne Collision Avoidance System
FAA: Federal Aviation Administration
UAM: Urban Air Mobility
BVLOS: Beyond Visual Line of Sight
NAS: National Airspace System
UAS: Uncrewed Aircraft Systems
DOJ: Department of Justice
DHS: Department of Homeland Security
LiDAR: Light Detection and Ranging
RF: Radio Frequency
EO: Electro-Optical
AI: Artificial Intelligence
ML: Machine Learning
DTI: Detect, Track, and Identify
TCCA: Transport Canada Civil Aviation
eVTOL: Electric and Vertical Takeoff and Landing
CAAC: Civil Aviation Administration of China
EASA: European Union Aviation Safety Agency
TC: Type Certificate
CS: Control Station
USS: UAS Service Supplier
SDSPs: Supplementary Data Service Providers

I. INTRODUCTION

The document *"Uncrewed Aircraft Systems and Advanced Air Mobility"*, referred to below as the document, is part of the toolbox, together with referenced documents, providing a one-stop shop of methodologies for UASs and AAM practitioners. The document is the benchmark for UAS and AAM professionals working to advance and enable safe and scalable UAS and AAM operations in the National Airspace System. Drawing upon the document authors' experiences in UAS and AAM, the document covers careful and practical considerations in the following areas:

- **A.** Small UAS and Beyond Visual Line of Sight (BVLOS) operations
- **B.** Medium, large UAS and BVLOS operations
- **C.** AAM
- **D.** Counter-UAS
- **E.** Aircraft automation, artificial intelligence, and digital flight
- **F.** Business development and marketing

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II. BEYOND VISUAL LINE OF SIGHT UNCREWED AIRCRAFT SYSTEMS

This section and the sections that follow provide a structured review of the document *"Uncrewed Aircraft Systems and Advanced Air Mobility" and discuss the key regulatory and technical challenges*.

The document covers careful and practical considerations for small UAS (UA < 1320 lbs.) and Beyond Visual Line of Sight operations, including package delivery, agriculture, aerial surveying, public safety, operations training, demonstration, recreation, and flight testing.

Various factors may affect the safety risk presented by a BVLOS operation. It is worth considering an acceptable level of safety risk for various use cases and how certain factors (whether individually or in concert) affect that level. For example, an operation in a less-populated area would seem to reduce the potential risk from heavier aircraft/payload. Similarly, an operation that flies a short distance BVLOS would also reduce the potential risk associated with aircraft weight. Operations in controlled airspace would benefit from greater Remote Pilot awareness of uncrewed traffic, given transponder and Automatic Dependent Surveillance-Broadcast (ADS-B) requirements.

sUAS and their operations have unique characteristics, including the following capabilities:

- **A.** Command and Control (C2) link.
- **B.** Detect and Avoid (DAA) provides detection, alerting and guidance against intruding traffic.
- **C.** Beyond visual line of sight, operations over people or over moving aircraft.

The document also outlines the technical and operational requirements that enable routine BVLOS and advanced sUAS operations, including Remote ID, detect-and-avoid systems, command-and-control links, ground-based surveillance systems (GBSS), Airborne Collision Avoidance System (ACAS) sXu, and third-party Unmanned Aircraft System

Traffic Management (UTM) services. It describes how strategic and tactical deconfliction reduces midair and ground risk. It reviews the Federal Aviation Administration (FAA)'s evolving regulatory pathway from current Part 107 waivers to the proposed Part 108 Notice of Proposed Rulemaking (NPRM) [1], which would establish performance-based requirements for scalable BVLOS operations, operational permits and certificates, population-based operating categories, and structured oversight for operators and flight coordinators.

The proposed Part 108 creates the framework required for routine BVLOS UAS operations at scale. BVLOS is scaling toward volumes that Part 107's waiver-based system was never designed to support. Delivery, inspection, maritime, and public safety operations cannot operate indefinitely on a case-by-case basis. The Detect and Avoid provision is where the proposed rule becomes demanding in practice. It requires the UAV to detect conflicting aircraft, determine collision risk, and execute avoidance manoeuvres, including against aircraft not broadcasting their position. In crewed aviation, see-and-avoid is a human responsibility. In the proposed Part 108, it becomes a regulated technological capability with defined performance requirements for UAS operations. While the requirement sounds straightforward, meeting it consistently across different environments, platform types, and traffic conditions becomes far more challenging in practice. Another challenging part of the proposed Part 108 implementation will be the applicant building an organisation capable of sustaining the level of operational discipline and accountability the framework requires.

III. UTM OPERATIONS

UTM is the FAA-supported framework for enabling safe, scalable low-altitude UAS operations—especially BVLOS—through a federated network of automated services rather than direct FAA air traffic services. It coordinates operators, UAS Service Suppliers (USSs), and supplemental data providers to support flight planning, airspace authorisation, strategic and tactical deconfliction, conformance monitoring, and shared situational awareness. The document highlights UTM as critical to increasingly complex operations, including package delivery, emergency response, and urban air mobility, especially in dense airspace where multiple aircraft must operate safely together.

UTM includes a wide range of services, such as UAS Service Suppliers (USSs) and Supplementary Data Service Providers (SDSPs) for UAS operators [2]. A key component of UTM is the UAS Service Supplier (USS), which acts as the operator's interface for mission planning, conflict detection, airspace coordination, and information exchange across the USS network. The document also describes FAA near-term approval efforts and proposed regulatory requirements that strengthen the role of automated data service providers, including conformance monitoring and strategic deconfliction capabilities for BVLOS operations.

IV. TYPE CERTIFICATED UNCREWED AIRCRAFT SYSTEMS

Type-certificated uncrewed aircraft systems—generally medium and large UAS—must follow a rigorous FAA certification process to demonstrate airworthiness, safety, and operational compliance before entering service. These BVLOS operations include cargo transport, passenger transport, logistics and supply, such as emergency management services, offshore energy facilities services, and medical transport.

The approval framework comprises several interrelated approvals: the Type Certificate (TC) for aircraft design approval, the Production Certificate for manufacturing, the Airworthiness Certificate for each aircraft, and the Operating Certificate for commercial operations. Each certificate involves specific entities with defined airworthiness responsibilities to ensure compliance with safety standards.

Major capabilities enabling these uncrewed aircraft to operate in the National Airspace System include:

A. Detect and avoid providing detection, alerting and guidance against intruding traffic.

B. Command and Control link.

A DAA system enables the remote pilot to "see and avoid" all traffic using sensor and guidance technology. This traffic includes avoiding both non-transponder-equipped aircraft and transponder-equipped aircraft. DAA systems use combinations of cooperative and non-cooperative surveillance technologies—such as transponders, ADS-B, radar, electro-optical sensors, LiDAR, RF, and acoustic sensors—to detect traffic, generate alerts, and provide guidance to maintain well clear and prevent collisions [3] [4]. The C2 link system allows the UA to operate within the visual line of sight (VLOS) and beyond the visual line of sight (BVLOS of a Control Station (CS). Examples of C2 link systems are SATCOM or terrestrial links [5]. These DAA and C2 systems are supported by performance, installation, software, cybersecurity, and flight-test requirements. They may be complemented by ACAS Xu and robust command-and-control (C2) links to ensure safe BVLOS and higher-altitude operations.

These UAS are expected to be type certificated as special class under 14 CFR § 21.17(b). Section 21.17(b) offers a certification approach that provides flexibility and enables the utilisation of industry consensus standards, such as RTCA and ASTM standards, to define a certification basis. The FAA issued a memorandum, "FAA Approval of Unmanned Aircraft Systems (UAS) Special Class UA Projects and their Associated Elements" [6], clarifying the certification process for UAS. The FAA memorandum describes a major step forward in defining the UAS TC and approval process, defining the TC boundary for UA as the uncrewed aircraft (UA) itself, and identifying the FAA Operational Approval (i.e., waivers, exemptions, and/or operating certificates) as the means for approval of the Associated Elements (AE).

V. ADVANCED AIR MOBILITY

Advanced Air Mobility is an emerging aviation ecosystem that uses advanced aircraft—especially electric and vertical takeoff and landing (eVTOL) designs—to move people and cargo more efficiently, sustainably, and affordably. It includes operations in both controlled and uncontrolled airspace, under visual and instrument conditions, and is expected to reduce emissions, noise, and operating costs through electrification, automation, and remote or multi-aircraft supervision. AAM aircraft are being certificated under evolving FAA frameworks for powered-lift and special-class aircraft, with commercial operations expected under Part 135.

AAM aircraft are expected to be type certificated as special class under 14 CFR § 21.17(b). Because these aircraft have novel airframes and powerplants, the FAA uses many of the performance-based regulations in 14 CFR part 23, Airworthiness Standards: Normal Category Aeroplanes, for the certification basis [7]. AAM commercial operators are expected to be certified to operate under 14 CFR part 135, Operating Requirements: Commuter and on Demand Operations and Rules Governing Persons on Board Such Aircraft [8].

A major technical enabler of AAM is the supporting network of safety, coordination, and infrastructure systems needed for scalable urban air mobility (UAM). These include detect-and-avoid technologies such as ACAS Xr, command-and-control links, providers of service to UAM (PSUs), third-party service providers, and vertiport management systems. Together, these systems support strategic deconfliction, demand-capacity balancing, surveillance, weather awareness, flight planning, and automated vertiport operations, while keeping humans involved in oversight and decision-making. Example use cases include emergency response, healthcare delivery, cargo transport, passenger movement, and the Disney Orlando AAM passenger transport use case.

The document also highlights the broader regulatory, infrastructure, and sustainability challenges facing AAM deployment. The FAA, the European Union Aviation Safety Agency (EASA), Transport Canada Civil Aviation (TCCA), and the Civil Aviation Administration of China (CAAC) are all developing or adapting rules to enable eVTOL certification and operations. At the same time, battery safety, charging infrastructure, electrification, and cybersecurity remain major implementation concerns. Vertiports and vertiport automation systems will be essential for managing high-density operations, but they must be integrated with existing transportation systems, local communities, and environmental planning. Overall, AAM promises transformative mobility benefits, but success depends on coordinated advances in regulation, energy systems, safety technologies, automation, and public acceptance.

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VI. SECURITY FOR UAS AND AAM

The proposed "Normalising Unmanned Aircraft Systems Beyond Visual Line of Sight (BVLOS) Operations" [1] rule places strong emphasis on cybersecurity for UAS. To maintain the security and airworthiness of UAS equipment, systems, and networks, proposed § 108.875 would require that UAS equipment, systems, and networks be protected from unauthorised electronic interactions, addressed separately and in relation to other systems. It requires UA manufacturers to protect the UAS from intentional unauthorised electronic interactions and physical security threats.

The proposed BVLOS NPRM also calls for limiting physical access to launch sites, preparation areas and control rooms to only those personnel who need to be there. The proposed rule also includes provisions for TSA background checks for anyone who will operate UASs, including checks of criminal history, immigration status, and intelligence-related databases and watchlists.

In addition, the BVLOS NPRM proposed that Part 146 require Part 146-certificated automated data service providers to take certain actions to maintain their cybersecurity. Malicious attempts to disrupt the approved automated data service systems could affect the safety and efficiency of the NAS. Malicious actors may seek to compromise services for financial gain through ransomware attacks or to cause damage and disruption. Personal or proprietary information may be sought for the attacker's financial gain. To prevent or mitigate such events, the automated data service provider must ensure that appropriate cyber and data security measures are in place for all connected systems. Preventing and mitigating negative outcomes from a malicious actor by ensuring the integrity and reliability of the information exchanged between service providers and, ultimately, their users. The proposed Part 146 includes performance-based requirements to mitigate risk to the NAS posed by a service provider’s vulnerability to cyber or data security threats. The proposed rule requires certificated service providers to develop and implement cybersecurity policies and processes to protect networks, devices, and data from unauthorised access and to help ensure the integrity, accuracy, and reliability of the services provided to customers or service users. This includes, but is not limited to, cyber threats that could compromise the authenticity or integrity of data, thereby undermining the safety and efficiency of the NAS. The proposed Part 146 requires each certificated service provider to develop the following cybersecurity policies to protect data, including processes for protecting software, hardware, networks, and employee access, and for ensuring data integrity, while also preparing for, responding to, and learning from cyber incidents. As UTM systems expand, the document highlights growing risks such as unauthorised access, malware, data breaches, and network intrusions, underscoring the need for verification testing, security assessments, and standardised checklists to ensure the reliability and safety of these increasingly networked aviation environments.

VII. COUNTER–UAS

UAS operations are increasing in number, technical complexity, and sophistication. The deployment and use of UAS in the National Airspace System (NAS) is on the verge of a significant breakthrough with many beneficial outcomes for the U.S. economy, industry, and society. At the same time, the growth of these new aircraft and operations has presented several regulatory and technical challenges. The clueless, careless, or criminal (3 Cs) unauthorised use of small Uncrewed Aircraft Systems (UAS), also known as drones, poses a significant risk to the security of critical infrastructure and public safety. Unauthorized UASs represent a considerable escalation in the threats to national security and critical infrastructure. Future drone threats will involve autonomous, AI-coordinated systems, increasing both the scale and unpredictability of attack. This underscores the critical need and timeliness of conducting research to pave the way for effective regulations on UAS detection, identification, and mitigation in the U.S.

Counter-UAS (C-UAS) addresses the growing threat posed by careless, negligent, or malicious use of unauthorised drones near critical infrastructure and other sensitive areas. The federal law 6 U.S.C. § 124n authorises certain Department of Justice (DOJ) and Department of Homeland Security (DHS) personnel to detect UAS and to conduct mitigation actions if a detected UAS is determined to be a “credible threat”. The Bill S. 1250, April 2, 2025, authorises Counter-UAS activities on and off commercial service airport property, and for other purposes. The FAA requires airspace restrictions, such as those in 14 CFR 99.7 and Special Security Instruction (SSI). 14 CFR 99.7 allows the FAA to restrict airspace access to “…address situations determined to be detrimental to the interests of national defence,” if requested by “the Department of Defence, or other Federal security/intelligence agency…” In addition to establishing a 14 CFR 99.7 over a given area, the FAA also publishes an accompanying airspace restriction Notice to Airmen (NOTAM) to protect a federal entity.

C-UAS technologies and systems used to detect and/or mitigate potential risks posed by clueless, careless, or criminal sUAS operations must not adversely impact or interfere with safe airport operations, navigation, air traffic services, or the safe and efficient operation of the NAS. In fact, the use of many current C-UAS Detect, Track, and Identify (DTI) systems adversely impacts or interferes with safe airport operations, air navigation, air traffic services, or the safe and efficient operation of the NAS [9]. The document emphasizes that many current detection technologies—such as radar, Light Detection and Ranging (LiDAR), Radio Frequency (RF), electro-optical (EO), and acoustic sensors—have significant limitations depending on conditions such as clutter, weather, line-of-sight, or RF density. These shortcomings can degrade performance, create false positives or miss threats, and require careful calibration, testing, and integration into broader security plans.

Finally, the document notes that the use of Artificial Intelligence (AI) / Machine Learning (ML) in C-UAS Detection, Tracking, and Identification technologies is rapidly expanding. These new technologies include highly secure AI/ML-enabled DTI systems. Examples of AI/ML-enabled DTI systems include Electro-Optical (EO) vision systems [3] that incorporate AI/ML to detect, track, and identify the 3 Cs of unauthorised sUASs. These systems provide real-time aircraft and obstacle detection and classification through AI/ML algorithms, providing unparalleled situational awareness for intelligent decision-making, including alerts.

VIII. AIRCRAFT AUTOMATION, ARTIFICIAL INTELLIGENCE, AND DIGITAL FLIGHT

Artificial intelligence and Digital Flight are presented as key enablers of future BVLOS UAS and advanced air mobility operations. For BVLOS UAS and AAM operations, there is a spectrum of automation, including various levels of artificial intelligence and automated and autonomous operations. One of the main challenges of using Artificial Intelligence for security- and safety-critical applications is that AI reliability depends on its completeness and correctness. This can be de-risked through rigorous validation/verification of AI use in the application.

As digital processors are increasingly used in aviation, digital information exchange becomes ever more central to the safe operation of aircraft, for example, UAS, AAM, and conventional aircraft throughout the airspace. It introduces the opportunity to overcome human-centred limitations, thereby increasing airspace capacity and operational tempo under all visibility conditions. A new operational construct built to leverage this data and enable these benefits is needed; it is called Digital Flight. Digital Flight is a proposed new operating mode for all airspace users. NASA/TM-20220013225 [10] defines Digital Flight as “an operating mode in which flight operations are conducted by reference to digital information, with the operator ensuring flight-path safety through cooperative practices and self-separation enabled by connected digital technologies and automated information exchange”. The document emphasizes that broader implementation will require clear accountability structures, regulatory foundations, and a transition path that integrates increasingly autonomous aircraft alongside conventional VFR and IFR operations.

IX. UNCREWED AIRCRAFT SYSTEMS AND AAM BUSINESS DEVELOPMENT AND MARKETING

UAS and AAM business development is key to the innovation and deployment of UAS/AAM projects and must occur concurrently with the project's technical scope and goals. A strategic process that involves effective tactics, the planning of critical steps, and essential skills for understanding the target market and goals that drive successful outcomes within the UAS/AAM landscape.

What are the business development steps before receiving funding? Why does building a business development profile matter? The goals and resources must be aligned with the business, the opportunity, the market, and the vision and the level of understanding of technology maturity. We will walk you through developing a checklist for successful execution.

Methods are explored for identifying and driving business opportunities before receiving funding, using modern marketing techniques, with explanations on how to make the most of them.

The importance of analysing existing entities within the ecosystem and applying pressure to drive opportunities toward your goals. We look at how to determine viable opportunities, the “real” vs “unreal,” market realities, financial constraints and competitive landscapes—the when-to-apply-and-not-apply approach.

The purpose of the roadmap, and why it must be broad, scalable, and regularly evaluated, reassessed, and adjusted to meet the requirements, must be clear within the UAS/AAM market.

Collaboration with regional entities, industry partners, and regulatory agencies, and the types of agreements that govern the relationship.

Knowing your competitors, both directly and indirectly, influences the success of an opportunity and its deployment. How to navigate the difference between the two by not allowing your competitors to drive your decisions and actions.

Markets and marketing know existing players, their strengths, weaknesses, market share and influence within the industry. How to use this to your advantage as you build market presence. Why credibility is so important in this industry, and why resisting the norm of overpromising and overextending is a trap to avoid.

How to balance business risk and evaluation related to investment costs, revenue uncertainty, operational risks, supply chain, workforce, local and regulatory changes, governmental and consumer tolerance or preferences and technological advancements.

X. CONCLUSION

This document presents UAS and AAM as rapidly evolving fields shaped by many new technologies, safety considerations, operational challenges, and new business opportunities. It concludes that, because the ecosystem is still developing, the ideas in the document should be viewed as foundational guidance rather than fixed procedures, with future success depending on prudent policies and a phased implementation approach to ensure a safe, scalable, and efficient integration of UAS and AAM into the National Airspace System.

DECLARATION STATEMENT

I must verify the accuracy of the following information as the article's author.

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- **Author's Contributions:** The authorship of this article is contributed solely by the author.

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Lee Nguyen is an adjunct faculty member in the College of Aviation Worldwide Campus at Embry-Riddle Aeronautical University, USA. He received his PhD in Chemical Engineering from Purdue University in 1983. In his first year, he worked as a system engineer at IBM. During the next 10 years, as an aerospace engineer at NASA, Dr Nguyen served as project manager for in-house and contractual research and development programs in aircraft engine technologies, aircraft and engine flight control, electronic display technologies, system engineering, and safety risk analysis. For the following 26 years, he was an aerospace engineer with the FAA Aircraft Certification Service, where he worked on certification, regulations, safety and security standards, and continued airworthiness for aircraft, uncrewed aircraft systems, avionics, communication, surveillance, navigation, and flight deck systems. From 2022 to 2025, he worked as a consultant at the Northeast UAS Airspace Integration Research Alliance, NY UAS Test Site. Currently, he is a consultant at the Nevada Centre for Applied Research, Nevada UAS Test Site, and Precision Approach, LLC.