



Douglas M. Marshall

UAS Integration into Civil Airspace

Policy, Regulations and Strategy

Aerospace Series

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and Allan Seabridge**

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Preface

In early 2009 Fred Smith, founder, chairman and CEO of the venerable cargo airline, FedEx, declared in an interview that he would like to switch the FedEx fleet to unmanned aircraft as soon as possible, but would have to wait for the FAA to sort out the rules for national airspace integration. In his view, unmanned cargo freighters offer many advantages for his company, predicting that they would be safer, cheaper, and would boast a greater capacity. The result would be a reduction of airfreight prices from ten times the cost of surface-carried freight to a factor of two, with all the speed advantages of air over ground or ocean transportation. Smith pointed out that the modern version of the Boeing 777 is already capable of being operated unmanned, in that the aircraft can take off, fly, navigate, and land without human intervention (and could even be equipped with an autonomous ground guidance system so the aircraft can be “driven” around an airport environment without running into or over someone or something). The same is true of most of the newest passenger aircraft types. The cost savings would derive from the fact that even a single-pilot aircraft requires a completely different design, with radically different economics and logistics. Smith might characterize the economic opportunity as “unused capacity,” or what can be removed from the airplane that would allow an increased load. Systems such as oxygen, pressurization system, lavatories, extra seats, galleys, all intended for the comfort of the crew, can be eliminated and replaced with revenue-generating non-breathing cargo. The concept is not a pipe dream. Northrop Grumman’s Global Hawk reconnaissance aircraft, which is the size of a small business jet, has been flying entirely autonomous missions for several years,

meaning that the aircraft is capable of taxiing to the runway, taking off, executing its flight plan, and landing at its intended destination without any human intervention.

Aside from the obvious concerns from those who do not trust technology to safely permit a large commercial aircraft to operate without a pilot on board, even over the oceans rather than populated terrain, Smith hit on one of the key elements that inhibits such operations from being approved by government regulators. The “holy grail” in the small UAS technology space is now national airspace (NAS) integration. Will society ever get to the point where autonomous systems will be allowed to operate in the same airspace as manned or piloted aircraft, or even be sufficiently comfortable with the safety mitigations to travel in an aircraft without a pilot on board? While the concept is no longer in the realm of futuristic representations of how things will be in 2050, as depicted in motion pictures and television productions, scaled-down versions of that vision are in the making now. Electrically powered aircraft are in the airworthiness approval stage with the FAA. Urban air mobility concepts under development by companies such as Airbus, Joby Aviation, Kitty Hawk, Lilium, Terrafugia, and Uber Air are well on their way to securing civil aviation authority approvals to market eVTOL (electric vertical takeoff and landing) prototypes that can operate at low altitudes in urban environments. “Self-flying” air taxis are already taking passengers on test flights in Chinese cities. Researchers, developers, regulators, and others are working very hard to create remotely piloted systems that can share airspace at lower airspace levels, in an environment that is unlikely to confront a remotely piloted B777 loaded to the rafters with computer chips and smart phones, and flying at 400 feet above ground at 250 kts. What is now possible is a remotely or autonomously piloted aircraft carrying emergency medical supplies to a person in

need, dispatched from the nearest public safety facility and operating in your neighborhood at an altitude of less than 250 feet above ground level (AGL), possibly saving a life. Or delivering that FedEx package that may have been carried to a distribution center by a conventional aircraft, but replacing the ground vehicle currently needed to complete the last leg of the journey. While technologically possible now, these scenarios may only take place outside of strictly controlled test environments under the watchful eyes of regulatory agencies such as the US Federal Aviation Administration or its functional equivalents elsewhere, national civil aviation authorities.

There are many moving parts in the realm of unmanned aircraft systems. Capturing all of them and doing them justice would require several volumes. The one essential component of the UAS “big picture” is airspace management; thus the focus of this book. Even that subcategory calls for a recursive analysis, as any technology is made up of many components that themselves are technologies, which have subparts that are also technologies, and so on, in a repeating, or recurring fashion. The airspace management function is typically the exclusive province of civil aviation authorities focused on safety and the fundamental goal of keeping aircraft separated from one another so as to not create a hazard of a mid-air collision. This function has been largely successful for over 60 years, depending upon the country in question. Generally, the denser the airspace traffic, the greater the likelihood of a mishap. Midair collisions, though relatively rare when compared to the number of aircraft in flight at any one time in congested airspace, such as parts of the US and Europe, still happen, often with tragic results. In the list of the top 10 leading causes of fatal general aviation accidents in the US from 2001 to 2017, the last year this statistic is available, midair collisions ranked

number eight. The number of near-midair collisions reported each year is approximately 200, and actual collisions average between 15 and 20. General aviation hours flown (those most important to our analysis because they are more likely to be found at low operating levels), totaled 25.9 million in the calendar year 2019.

The theme of this book focuses on just one of those many moving parts, the integration of unmanned aircraft into controlled and uncontrolled airspace. The ongoing regulatory and policy efforts around the world to achieve full airspace integration will be examined, which requires a functional breakdown of the key elements of the technology that must meet regulatory requirements before the systems will be permitted to go into full operation. Predictions of the future in this technology sector are fraught with uncertainty, but an attempt will be made to outline a probable path forward as revealed by government regulators and myriad interested parties. Among the other moving parts are ongoing regulatory developments for Operations Over People, operations Beyond Visual Line of Sight of the pilot in command, Remote Identification of aircraft, and Night Operations. While these components are critical features of the overall challenge of airspace integration, they will not be discussed in detail in this volume, except to the extent that it is necessary to clarify their role in the integration picture.

The rapid evolution of the technology underlying unmanned aircraft, unmanned aircraft systems, remotely piloted aircraft systems, and, more commonly, drones, among other terms of art, presents a formidable challenge to anyone attempting to encapsulate the entire domain in one book. The broad notion of unmanned or remotely piloted aircraft has been with us for over a century. Society has witnessed extraordinary developments in the field of unmanned aviation over the last 30 years or so. The categories or

topics that now define or bound the current state of the art of this technology are too numerous to list here, but will be discussed in the body of this book.

The media and popular press adopted the catchall label “drone,” while experts and regulators generally prefer UAV, UAS, RPA, or RPAS instead of “drone,” because the term “drone” once had a very specific meaning. The early descriptions of these types of aircraft settled on “drone,” although the historical root of the term remains controversial (likened to a honeybee drone, or perhaps derived from a 1930s British target drone called a “Queen Bee”? No one really knows). In the earliest phases of development of unmanned aircraft, “drone” referred to target aircraft or remotely piloted offensive weapons deployed by both sides in both World Wars. Today’s unmanned aircraft are far more sophisticated, and in most cases more capable of non-military missions than the “true” drones of nine decades ago. This book will use drone, UAS, sUAS, UAV, UAS, and RPAS more or less interchangeably, as a matter of style and continuity, unless the specific term used calls for an explanation of why it is used in the context of the discussion.

Military organizations, primarily in the United States, led the way in developing drone technology from flying targets for aircraft weaponry and surface-based artillery to aerial sensor systems modified for intelligence, surveillance, and reconnaissance (ISR) missions. That capability soon led to development of platforms capable of carrying and deploying highly effective offensive munitions (such as the General Atomics’ Predator and Reaper series used in the first Gulf War and thereafter in subsequent Middle East conflicts).

Alongside the military’s tactical and strategic adoption of unmanned aerial systems, and the emerging market for

civilian or scientific versions of those systems, the consumer sector emerged, which quickly realized the potential for unmanned systems in both the recreational and commercial arenas. Small (weighing less than 55 lb, or 2.2k), fixed-wing and rotorcraft contrivances were soon adapted for aerial photography, agriculture, building and infrastructure inspection, package delivery, entertainment, and any number of other applications having nothing to do with military operations. The sudden “Cambrian Explosion” of affordable and highly capable (consumer based) small UAS soon overwhelmed civil aviation authorities around the world with demands for access to low level airspace for a multitude of civilian uses.

The growth of this technology has outpaced the ability of governing authorities at all levels, international, national, regional and local, to keep up with the changes and promulgate rules, regulations, and standards for the operation of these systems in the public domain, namely the airspace above the surface. As a consequence, rogue operators and abusers of the technology have created havoc with their misuse of consumer drones to invade privacy, disrupt wildlife, interfere with firefighting and law enforcement activities, endanger manned aircraft operations around airports, and any number of irresponsible uses of affordable and readily available off-the-shelf drones. The need for safe and predictable environments for legitimate users of this technology is paramount, and airspace integration strategies are likely to offer the most achievable solutions.

This book will only briefly address the history of this technology, as many other publications have covered the same ground, but will provide a framework for understanding and evaluating just one critical element of this extremely complex environment: how to integrate these systems, large and small, fast and slow, heavy and

light, all without pilots on board, with other occupants of the airspace, namely manned aviation, and how to do it safely, equitably, and efficiently to minimize the risk of disaster and maximize the economic opportunities sought by the users of the airspace. The full solution to the safe integration challenge, which has eluded the experts, developers, and regulators thus far, is the key to the further advancement of the technology beyond its current status. The ongoing global efforts characterize the potential solutions to this challenge as Unmanned Aircraft Traffic Management (UTM), or Unmanned Aircraft Systems Space (U-Space), or Advanced/Urban Air Mobility (AAM/UAM), depending upon in which part of the world the effort originates.

Organization of the Book

The following chapters will introduce the reader to the major issues confronting the developers of these strategies and provide a brief introduction to what each nation or group of nations is doing to address those issues. The templates adopted by the major contributors as they work their way through the often conflicting and sometimes overlapping regulatory environments in which they must operate to be successful are discussed in greater detail. There are many parallel efforts to identify a path to full integration of unmanned systems with manned aviation, and they do not all agree on the strategy or the architecture to make it so. For this reason, this book is unashamedly broad in scope in some respects and rather narrow in others. The goal is to identify a common way forward for the evolving UAS industry and the regulatory authorities that must enable and monitor its growth to ensure public safety and economic viability.

Chapter 1 “Background” introduces a thumbnail history of aviation regulations, derived in some respects from the ancient Law of the Sea. This chapter briefly summarizes the first attempts to regulate airplanes and their pilots in the UK, the creation of an international regulatory body (ICAO) in 1944 as a product of the Chicago Convention on International Civil Aviation, and then moves on to the present-day regulatory system, both national and international, that oversees all aspects of commercial and private aviation.

Chapter 2 “UAS Airspace Integration in the European Union” is a longer chapter, and attempts to cover historical and ongoing regulatory efforts in the European Union regarding unmanned aircraft operations and standards. The EU has been very busy adopting regulations for UAS that will apply across all of its Member States, and more recently embarked upon the concept of a “U-space” that is intended to integrate UAS/RPAS into the European airspace by establishing a new concept for how the airspace can be managed while not disrupting existing commercial and general aviation activities.

Chapter 3 “ICAO” covers the International Civil Aviation Organization and its airspace integration activities with specific focus on remotely piloted aircraft systems.

[Chapter 4](#) “UAS Airspace Integration in the United States” discusses airspace integration efforts in the United States, in coordination with Europe’s EASA and other national aviation authorities.

[Chapter 5](#) “Global Airspace Integration Activities” takes a look at UAS integration efforts in a few selected countries that are considered to be representative of similar efforts in a growing number of ICAO’s 193 Member States.

Chapter 6 “The Role of Standards” examines the role of Standards Development Organizations (SDOs) in the development of regulations and best practices.

Chapter 7 “The Technology” discusses the various domains of the evolving UAS and UTM/U-space technology, and includes suggestions for methodologies for conducting a risk assessment and functional decomposition of complex systems. Chapter 8 “Cybersecurity and Cyber Resilience” offers a historical view of global cybersecurity failures and ties that history to current efforts to identify risks and defensive mechanism to ensure the security of aviation systems.

This is not an engineering text, nor is it a law book, but is a bit of a hybrid of both, focused on the study of one highly technical sector of innovation and economic growth from the proverbial “30,000 ft” view. The reader is cautioned, however, that the technology advances are extremely dynamic, and innovation, or “the next best thing,” is almost a daily occurrence, so that accurately predicting the future is a fool’s errand. As new challenges emerge, entrepreneurs and developers will step up to meet them, occasionally creating a new technology or new subset of existing technology that may not have existed even a year ago. The best we can do is to understand what is happening at this point in time and acquire the tools to respond to the breakneck pace of innovation in unmanned aircraft systems.

Aerospace Series Preface

The field of aerospace is multidisciplinary, covering a large variety of products, disciplines and domains, not merely in design and engineering but in many related supporting activities. The interaction of these diverse components enables the aerospace industry to develop innovative and technologically advanced vehicles and systems. The *Aerospace Series* aims to be a practical, topical, and relevant series of books aimed at people working in the aerospace industry, including engineering professionals and operators, engineers in academia, and allied professions such as commercial and legal executives. The range of topics is intended to be wide ranging, covering design and development, manufacture, operation and support of aircraft, as well as infrastructure operations and advances in research and technology.

Unmanned air vehicles are a growing and increasingly accepted part of the aerospace environment. Small UAVs equipped with appropriate sensors can carry out leisure, small industry and official roles in the visible and IR spectrum. As their use expands, unmanned air systems will inevitably become involved with, and potentially conflict with, manned vehicles – as has already been demonstrated by numerous encounters near airports. There will need to be new regulations to allow the co-existence of UAVs with GAS, rotary wing, regional and transnational operations. These new regulations could require changes to on-board navigation and proximity warning systems as well as to ATM practices and standards.

This book – *UAS Integration into Civil Aerospace* – explores the integration of unmanned aircraft into controlled and uncontrolled airspace. It provides a comprehensive

overview of regulatory and policy efforts required to move towards full airspace integration, as well as the technology that must be developed and approved for full operation of UAV systems. It also addresses the critical questions of cybersecurity and cyber resilience as they relate to UAV airspace integration. The global ATM system depends heavily on electronic communications and interconnectivity, any interruption of which could lead to potentially catastrophic consequences.

With the rapid evolution of UAV technology, aviation regulators at international, national, and local levels have struggled to keep pace with appropriate rules and standards to ensure that UAV systems operate in shared airspace in a safe, equitable, and efficient manner. This book outlines a path forward that minimizes the safety risks while maximizing potential economic benefits for all users of the airspace. In line with the mission of the Aerospace Series, it combines elements of engineering and emerging technology with an accessible discussion of the important related legal and regulatory issues.

Peter Belobaba, Jonathan Cooper, and Allan Seabridge

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List of Acronyms and Abbreviations

3GPP	3rd Generation Partnership Project
AAM/UAS	Advanced Air Mobility/Urban Air Mobility
ACs	Advisory Circulars
ACAS	Aircraft Collision Avoidance System
ADR	Aerodrome
ADSB-Out	Automatic Dependent Surveillance Broadcast-Out
AFAC	Civil Aviation Federal Agency (Mexico)
AGL	Above Ground Level
AIAA	American Institute of Aeronautics and Astronautics
AIP	Aeronautical Information Publications
AIS	Aeronautical Information Service
ALJ	Administrative Law Judges
AMA	Academy of Model Aeronautics
AMC	Acceptable Means of Compliance or Alternate Means of Compliance
AMQP	Advanced Message Queuing Protocol
ANS	Air Navigation Services
ANSI	American National Standards Institute
ANSP	Air Navigation Service Providers
ARAG	Aviation Rulemaking Advisory Group (FAA)
ARC	Aviation Risk Category/Aviation Rulemaking Committee
ASBU	Aviation System Block Upgrade
ASTM	ASTM International (formerly American Society for Testing and Materials)
ATC	Air Traffic Control

ATCO	Air Traffic Control Organization
ATM	Air Traffic Management
ATO	Air Traffic Organizations
ATS	Air Traffic Services
AURA	Air Traffic Management U-space Project
BCAs	Bridge Certificate Authorities
BVLOS	Beyond Visual Line of Sight
C2	Command and Control
CA	Certificate Authority
CAA	Civil Aviation Authorities
CAAC	Civil Aviation Administration of China
CAAS	Civil Aviation Authority of Singapore
CANSO	Civil Air Navigation Services Organization
CAPSCA	Public Health events in civil aviation
CASA	Civil Aviation Safety Authority (Australia)
CAST	Commercial Aviation Safety Team
CIR	Commission Implementing Regulation
CIS	Common Information Service
CISA	Cybersecurity and Infrastructure Security Agency
CFR	Code of Federal Regulations
CNS	Communications/Command, Navigation, Surveillance
COA	Certificate of Authorization or Waiver (USA)
CONOPs	Concept of Operations
CORUS	Concept of Operation for EuRopean Unmanned Air Traffic Management

	Systems
CORUS-XUAM	Concept of Operations for European UTM Systems – Extension for Urban Air Mobility
CPDLC	Controller Pilot Data Link Communications
CSIS	Center for Strategic and International Studies
CU	Command Unit
C-UAS	Counter UAS
DAA	Detect and Avoid (system)
DAIM	Drone Aeronautical Information Management
DD/ASF	Deputy Director, Aviation Security and Facilitation
DDoS	Distributed Denial of Service
DNS	Domain Name System
DNSSEC	Domain Name System Security Extensions
DOC	Declaration of Compliance
DOD	Department of Defense (USA)
EASA	European Aviation Safety Agency
EC	European Commission
ENAC	Italian Civil Aviation Authority
ENCASIA	European Network of Civil Aviation Safety Investigation Authorities
EPAS	European Plan for Aviation Safety
EU	European Union
EUROCAE	European Organization for Civil Aviation Equipment