SMALL UNMANNED AIRCRAFT SYSTEMS GUIDE

Exploring Designs, Operations, Regulations, & Economics

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FOREWORD

There aren't many "firsts" remaining in aviation. Aviation has become commonplace, overshadowed by advancements in technology that make the miracle of flight seem mundane and archaic to the current generation. The passion for careers and advances in aviation and aeronautics so prevalent through the 1960s and 1970s has been surpassed by the readily available ability to live in a virtual world, inundated with low-cost, intuitive gismos and gadgets that connect us all at the touch of a button. The glamour and excitement associated with traditional aviation endeavors that drove so many of us to dedicate our lives to the science seemed to have waned. All of this was true until the advent of unmanned aviation!

It's quite remarkable to realize that emerging unmanned aviation has such crossover appeal to so many. The technological developments that could have doomed the aviation industry are actually enhancing it through the advent of unmanned aircraft. The skills and interest of a non-traditional pool of engineers and entrepreneurs have driven this new and unanticipated "first" in aviation in directions no one expected even a few years ago. The same technologies we take for granted today have enabled unique and unexpected opportunities to advance an entirely new and exciting path for aviation. The proliferation of "drones" for civil applications and the challenges to integrate them into routine use has birthed a new industry that seems to have no limits. The opportunity to be an active contributor to the possible last significant "first" in aviation should not be taken lightly.

While it may seem that the emergence and acceptance of unmanned aviation would be logical and relatively obvious, it is clear to those of us involved in advancing the industry that significant challenges remain. Global routine use of UAS won't occur until the current aviation "system" evolves, ultimately allowing the safe and full integration of UAS. The current airspace construct and operation, while extremely safe, was never designed to accommodate non-segregated access of unmanned aircraft.

While the technical challenges are significant, the emergence of UAS into everyday life has sparked a debate on a number of social issues associated with their use. Concerns about privacy, security, and the potential for harm caused by inadvertent misuse or hardware failures has prompted a proliferation of state-sponsored rules and restrictions that clearly hinder growth of the UAS industry. While the concerns may very well be legitimate, it is clear that viable solutions exist and that with the concerted effort of the professional UAS community, we will achieve our goals. Education is key. Armed with an understanding and appreciation of the rules and regulations associated with operation of aircraft, the new generation of "pilots" flying unmanned aircraft *will* safely become a reality.

You are taking the first significant step in that direction. This textbook will provide you with a solid, fundamental understanding of the history, technology, and challenges facing unmanned aviation. Elegant solutions to many of the challenges are yet to be discovered. The opportunity lies ahead. You are a pioneer in your own right and have a chance to shape what may be the most significant chapter in aviation history. Seize the moment!

Paul E. McDuffee
Vice President of Commercial Business Development
Insitu, Inc.

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> A single lifetime, even though entirely devoted to the sky, would not be enough for the study of so vast a subject. A time will come when our descendants will be amazed that we did not know things that are so plain to them.
>
> —Seneca, Book 7, first century CE

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INTRODUCTION

The utility and benefits of unmanned aircraft systems (UAS), as valuable capabilities modifiers, are now emerging and being recognized across multiple industries. While this technology is not new, the ability to support domestic operation is becoming better understood, opening up new uses to government organizations and commercial enterprise. Analysis of the unmanned aviation market indicates that small UAS (sUAS) will become the most prevalent and affordable form of unmanned aircraft available, featuring technology developed by contributors ranging from the "do-it-yourself" (DIY) and model aircraft communities to defense contractors. This book contains descriptions of typical sUAS architecture, related technology, common uses, and suggested safety practices, while also providing a narrative to help you determine the most appropriate path forward through complex legal, business, operational, and support considerations. Understanding how these pieces fit together, from the technical and legal perspectives, will shape your own strategy for the safe, efficient, and effective use of this (r)evolutionary technology.

INTENT

There has been an observable swell in public desire to access and domestically operate sUAS. However, there is also a significant learning curve to properly understand the multitude of designs, equipment, operational cases, capabilities, limitations, regulations, and strategies supporting safe and appropriate use. Our intent is to help readers better understand sUAS technology to achieve such use, in accordance with published advisory circulars, guidelines, and regulations. We developed this book to share critical background, concepts, guidance, and lessons learned from our collective experience as researchers, operators, and academic instructors to dispel common myths and provide a starting point to explore how sUAS can be applied to solve challenges and support economic pursuits.

The presentation of information has been structured to help readers better understand how sUAS can be used to realize cost and efficiency gains, while considering how to incorporate potential benefits and address limits and challenges. The following represents the topics and material presented:

- *History of UAS*—history and current path of UAS development, operations, and regulations
- *Application of sUAS*—current, developmental, and perceived uses of sUAS platforms and technology
- *Variety of Design*—types and configurations of platforms, detailed descriptions of elements and their purpose, and an overview of design-specific considerations
- *Legal, Environmental, and Operational Considerations*—major factors affecting use of sUAS, including a detailed overview of the current U.S. regulatory framework, operational requirements and prohibitions, unique considerations of various operational environments, and recommended application processes

- *Business of Unmanned Aviation*—types of organizational structures, purchase and usage considerations, and anticipated economic growth areas
- *Preparing for the Future*—reference sources to stay connected to the rapidly changing landscape

This book was written to support ease of comprehension by the general public, even without a background in aviation. It simplifies and explains existing and impending regulation to address the segment of the public expected to adopt and use this technology for organizational, business, and recreational pursuits. However, it contains sufficient detail to be featured as a suggested text in many UAS-related academic and training programs, ranging from high-school to graduate-level readers.

Upon completion of this book, readers can expect to:

1. Understand what an sUAS is, including common types, configurations, and components, to make well-informed decisions regarding purchase and use.
2. Evaluate how sUAS and their various configuration options can be used to address or support evolving business needs.
3. Formulate a plan to acquire necessary certification approvals and system components to operate sUAS in a safe, efficient, and effective manner.

NOTE TO THE READER

Thank you for taking this first step to learn about and explore the world of unmanned aviation. As sUAS and larger UAS platform technologies are integrated into our society, it will be imperative for users to understand the complexity, benefits, and options, as well as the limitations and major considerations, that affect their responsible application. A broad range of material is covered in this book, from the history of UAS to recommendations for supporting your operation of sUAS.

Information has been presented to help make informed decisions as you consider potential sUAS selection and application options. Many critical aeronautical concepts are introduced and briefly discussed, but may not be described in detail. Rest assured that such material is presented in a manner supporting basic understanding, within the related context, to support further investigation on your own. I strongly encourage you to examine and explore such concepts, in depth and independently, using the resources and references provided throughout the book as well as those found on U.S. government websites, such as the Federal Aviation Administration's (FAA) Unmanned Aircraft Systems webpage (www.faa.gov/uas). The ASA "Reader Resources" webpage for this book (www.asa2fly.com/reader/SUAS) contains additional information and resources relating to sUAS, and will be updated to serve as a valuable reference as the industry continues to grow. Conducting personal research is an essential component of staying informed about the many changes occurring in this rapidly evolving field. We hope you find this book as enjoyable to read and reference as it was for us to write.

Brent A. Terwilliger, Ph.D.

ABBREVIATIONS

2-DOF	two degrees of freedom
3-DOF	three degrees of freedom
AC	advisory circular
ADC	analog-to-digital converter
ADM	aeronautical decision making
ADS-B	Automatic Dependent Surveillance–Broadcast
AGL	above ground level
AMA	Academy of Model Aeronautics
AME	Aviation Medical Examiner
API	application programming interface
APKWS	Advanced Precision Kill Weapon Systems
ARC	Aviation Rulemaking Committee
ARF	almost ready-to-fly
ARP	airport reference point
ASSURE	Alliance for System Safety of UAS through Research Excellence
ATC	air traffic control
AUVSI	Association for Unmanned Vehicle Systems International
BEC	battery elimination circuitry
BIOS	basic input/output system
BLOS	beyond line-of-sight
BNF	bind-and-fly
BTT	Basic Target Training
BVLOS	beyond visual line-of-sight
C3	command, control, and communication
CBO	community-based organization
CCD	charged coupled device
CCPM	cyclic/collective pitch mixing
CFIT	controlled flight into terrain
CFR	Code of Federal Regulations
CG	center of gravity
CMOS	complementary metal oxide semiconductor
COA	certificate of waiver or authorization
COE	Center of Excellence
COTS	commercial off-the-shelf
CRM	crew resource management
CTAF	common traffic advisory frequency
DAC	digital-to-analog converter
DC	direct current
DIY	do it yourself
DOD	Department of Defense
DOT	Department of Transportation
DSA	detect, sense, and avoidance
EAR	Export Administration Regulations
EMI	electrical magnetic interference
EO	electro-optical
ESC	electronic speed control
EVLOS	extended visual line-of-sight
FAA	Federal Aviation Administration
FARs	Federal Aviation Regulations
FL	flight level
FMRA	FAA Modernization and Reform Act
FPV	first-person view
FSDO	Flight Standards District Office
FSTD	flight simulation training device
GCS	ground control station
GHz	gigahertz
GIS	geographic information system
GNC	guidance, navigation, and control
GPIO	general purpose input/output

GPS	global positioning system
GUI	graphical user interface
HALE	high-altitude long-endurance
HMD	helmet-mounted/ head-mounted display
HMI	human-machine interface
HTOL	horizontal takeoff and landing
I2C	inter-integrated circuit
IDE	integrated development environment
IFR	instrument flight rules
IMC	instrument meteorological conditions
IMINT	imagery intelligence
IMU	inertial measurement unit
I/O	input/output
IR	infrared
ISM	industrial, scientific, and medical
ISR	intelligence, surveillance, and reconnaissance
ITAR	International Traffic in Arms Regulations
KSAs	knowledge, skills, and abilities
kts	knots
LBA	lifting body airship
LiDAR	light detection and ranging
Li-ion	lithium-ion
LiPo	lithium-polymer
LOA	letter of agreement
LOS	line-of-sight
LRE	launch and recovery element
mAh	milliampere hour
MALE	medium-altitude, long-endurance
MARS	mid-air retrieval system
MAV	micro air vehicle
MCE	mission control element
MHz	megahertz
mph	miles per hour
MSL	mean sea level
MSRP	manufacturer's suggested retail price
MTI	moving target identification
MTOW	maximum takeoff weight
MTS	multi-spectral targeting system
NAS	National Airspace System
NBC	nuclear, biological, and chemical
NDVI	normalized difference vegetation index
NiCd	nickel-cadmium
NiMH	nickel-metal hydride
NM	nautical mile
nm	nanometer
NOTAM	Notice to Airmen
NPRM	notice of proposed rulemaking
OEM	original equipment manufacturer
OPA	optionally piloted aircraft
OpsCon	Operational Concept
OS	operating system
OSD	on-screen display
PC	personal computer
PIC	pilot-in-command
PWM	pulse width modulation
RADAR	radio detection and ranging
RC	remote control

RC	radio controlled
R&D	research and development
RPA	remotely piloted aircraft
RPM	revolutions per minute
RPV	remotely piloted vehicle
RSSI	received signal strength indication
RTF	ready-to-fly
RX	receiver
SAC	special airworthiness certificate
SAC-EC	special airworthiness certificate —experimental category
SAC-RC	special airworthiness certificate —restricted category
SAR	synthetic aperture radar
SDK	software development kit
SIGINT	signals intelligence
SM	statute mile
SME	subject matter expert
SPDT	single pole double throw
SPST	single pole single throw
STOL	short takeoff and landing
sUAS	small unmanned aircraft system
SUAV	small unmanned aerial vehicle
TFR	temporary flight restriction
TSA	Transportation Security Administration
TX	transmitter
UA	unmanned aircraft
UAS	unmanned aircraft system
UAS	unmanned aerial system
UAV	unmanned aerial vehicle
USB	universal serial bus
UTM	unmanned traffic management
UV	ultraviolet
VFR	visual flight rules
VLOS	visual line-of-sight
VMC	visual meteorological conditions
VO	visual observer
VTOL	vertical takeoff and landing
Wh	watt hours

CHAPTER 1

HISTORY OF UAS: WHERE DID THEY COME FROM AND WHERE ARE THEY HEADED?

INTRODUCTION

Although unmanned aircraft may seem like a relatively recent development, these systems have been in use for quite some time, dating back to as early as the late nineteenth century. Many of the technologies and principles required for operation of modern systems were first envisioned, uncovered, and developed by various scientists and inventors in these early eras. This chapter contains an examination and discussion of crucial pioneers of technology and aeronautics, periods of technological development and operational expansion, the changing role in the modern era, and the technological and regulatory landscape influencing application of unmanned aviation.

EARLY PREDECESSORS

Early aeronautics pioneers and their precursor models and technologies eventually led to the development of early unmanned aircraft, which were used for a range of functions, such as aerial research platforms, weapons, and targets. While the list of contributors to the success of unmanned aircraft provided here is not exhaustive, it does highlight some of the significant research and experimentation that has led to the technologies necessary to successfully operate such unmanned systems.

SIR GEORGE CAYLEY

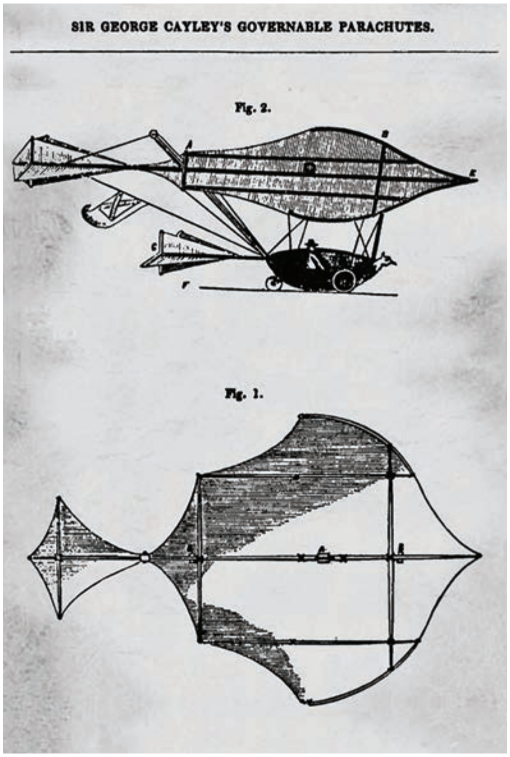
Born in 1773, Sir George Cayley was an early pioneer of aeronautical vehicle design and aerodynamics research. In 1804, he designed a monoplane glider that appears sophisticated even by today's standards. Cayley is credited with discovering that curved surfaces generate lift more effectively than flat ones. Also, he found that some modifications to wings, such as canting them upwards (commonly referred to as dihedral), added stability to his aircraft. In 1849, he created a glider with space for a pilot, which he successfully flew with a young boy as the occupant. Several years later, Cayley built a larger glider, which also successfully flew (*see* Figure 1-1). Cayley's discoveries provided essential foundations for aircraft design and aerodynamics theory.

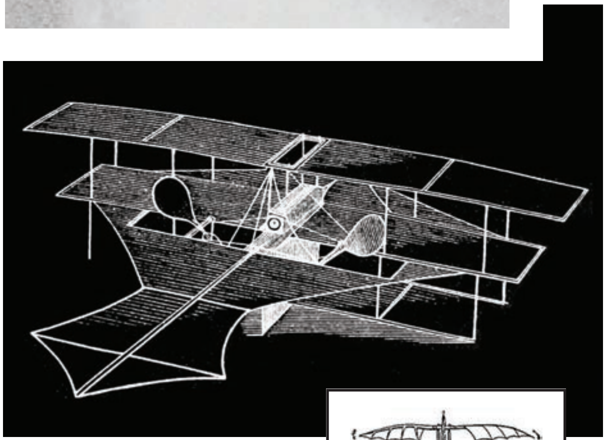
JOHN STRINGFELLOW

John Stringfellow, born in 1799, was fascinated with machinery, in particular with carriages and steam engines. Stringfellow experimented with light steam engines in an effort to propel aircraft designs developed by fellow aviation enthusiasts of the time. By 1848, he had worked to create an aircraft with counter-rotating "propellers" driven by a lightweight steam engine. After several failed attempts, he was able to properly balance the aircraft, resulting in a successful short-distance flight with the ship being guided by wires. Stringfellow's work demonstrated the importance and utility of adding reliable propulsion to aircraft (*see* Figure 1-2). His foundational work would inspire those who followed his efforts.

ALPHONSE PÉNAUD

By age 21, Alphonse Pénaud had established himself as an accomplished aviation inventor, demonstrating one of his early flying inventions in Paris in 1871. Credited with harnessing the power of rubber bands to power aircraft propellers and rotors, Pénaud's designs reliably and successfully flew with ease (*see* Figure 1-3). Pénaud's work is credited with inspiring the Wright brothers early in their lives. In 1876, he developed a sophisticated amphibious aircraft including seemingly modern flight controls





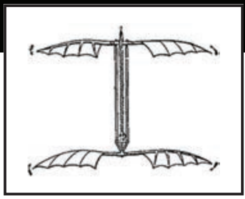


FIGURE 1-1. Cayley glider design (*top*).

FIGURE 1-2. Stringfellow's steam engine aircraft (*middle*).

FIGURE 1-3. Pénaud's rubber band-powered helicopter (*bottom*).

and instrumentation with the help of other aviation enthusiasts, but this design never moved forward. The works of Pénaud certainly were influential to future aircraft experimenters.

OTTO LILIENTHAL

Born in Prussia in 1848, Otto Lilienthal went on to study engineering, leading him to the design of numerous successful gliding aircraft. First experimenting with kites, Lilienthal began to work with different shapes of wings to determine which was the most utilitarian for flight. Most notably, in 1890, Lilienthal began working diligently on flying machines that allowed for the carriage of a pilot. The initial iteration of Lilienthal's glider was flown in 1891 and achieved a flight of approximately 80 feet. By the next year, the distance capability of his revised glider was doubled, and Lilienthal began work on a derivative that used a motor to flap its wings. Lilienthal worked diligently to better understand flight through repeated tests of his works. He was able to successfully fly his numerous models in more than 1,500 total flights, eventually reaching distances of nearly a quarter of a mile (*see* Figure 1-4). By the time of his death in 1896, he had published numerous articles about flight and his endeavors, which were noted by the Wright brothers years later as inspirational to their work.

FIGURE 1-4. Test flight of a Lilienthal glider in 1895.

NIKOLA TESLA

Nikola Tesla fulfilled a peripheral, yet critical, contribution to the advent of modern unmanned aircraft. While not directly associated with the development of aircraft as were Lilienthal, Cayley, and Stringfellow, Tesla developed electrical components essential to the creation of the modern radio. Born in 1856 in Smiljan (modern day Croatia), Tesla went on to study math and philosophy in Graz (Austria) and Prague (Czech Republic), respectively. At age 26, Tesla devised the concept of a brushless alternating current (AC) motor. Tesla then moved to New York and began to work with Thomas Edison, making improvements to Edison's direct current (DC) designs. Within a few years, Tesla began his own company, which eventually led to the adoption of an AC power grid in Massachusetts. This began a competition of sorts between Tesla and Edison as to the future power supply, pitting Tesla's AC power against Edison's DC. In the 1890s, Tesla created a variety of electrical component inventions and improvements including his namesake transformer, the Tesla Coil. He was also able to demonstrate radio communications years before Marconi. In fact, some of Marconi's patents would later be cancelled as a nod to the true originator of the concepts. Tesla used this type of communication to control a model boat in a demonstration in New York City. This last feat truly laid the foundation for future remote control on which current unmanned systems rely. Also, Tesla's legacy of AC power transmission is still the source of choice for the developed world.

FIGURE 1-5. Marconi operating his wireless radio system.

GUGLIELMO MARCONI

Guglielmo Marconi was born in Italy in 1874. By age 20, he was already interested in the works of Heinrich Hertz, in particular the use of radio waves. Marconi soon developed a means of transmitting messages through the use of such waves from up to a mile away. In 1896, he moved to England and within a year developed a wireless station used to communicate with ships over 10 miles away. By 1899, Marconi was able to send transmissions across the English Channel. Soon thereafter, with a bit of ingenuity (including flying an antenna on a kite), he successfully sent Morse Code across the Atlantic Ocean (see Figure 1-5). The radio capabilities realized by Marconi, coupled with the work of Tesla, paved the way for modern radio and the transmission capabilities used to remotely control a range of systems, including unmanned aircraft.

OCTAVE CHANUTE

Chanute, born in 1832, did not get involved in aviation until later in life. He began to experiment with various different aircraft designs including a glider (*see* Figure 1-6) that used numerous adjustable wings for self-compensating stability. He also successfully experimented with automatic flight control utilizing movable control surfaces with several of his designs successfully and reliably taking individuals aloft. He published an influential book, Progress in Flying Machines, in 1894, which helped to interest the Wright brothers. Beginning in 1899, Chanute worked with the famous brothers, acting as a mentor to the inventors.

SAMUEL P. LANGLEY

Langley is often credited with coming very close to beating the Wright brothers to manned, powered flight. He began experimenting with rubber powered aircraft, as he called them "aerodromes," in 1887 with some success. In 1891 he began to work with steam engines on his model Aerodrome 0, which did not live up to expectations, failing to work as planned. He then continued with a series of Aerodromes, eventually building a houseboat from which to launch his inventions (*see* Figure 1-7), which would float on the Potomac River. By the time he reached iterations 5 and 6, the design was sound enough to allow the craft to climb several thousand feet above the launching point. Langley desired for his craft to be able to hoist a person aloft. By 1901, a radial engine was housed on Aerodrome A, which did not provide much success toward manned flight, crashing during the test flight. Langley would rebuild the craft for 1903 launch. Sadly, this also ended badly, crashing immediately on launch. This failure was followed by harsh and negative press. Aerodrome A would live on another day, modified and rebuilt by pioneer Glenn Curtiss, it would take flight in 1914.

FIGURE 1-6. Replica of Chanute 1896 glider (*left*).

FIGURE 1-7. Langley Aerodrome (*center*).

FIGURE 1-8. Wright brothers' famous first controlled, powered flight, December 17, 1903 (*right*).

ARCHIBALD LOW

Labeled the "Father of Radio Guided Systems," Archibald Low began working with the British government to develop a variety of theoretical and actual radio-controlled systems and weapons. In 1917 he began work on an unmanned aircraft, which included the use of a gyroscope to maintain stability. Soon thereafter, Low began work on an electrically guided missile, which the Germans viewed as so threatening that they made attempts to assassinate Low. In an odd twist of fate, the Germans would take Low's findings and improve upon them to develop and implement one of the first regularly used unmanned flying weapon systems, the V-1 rocket.

WRIGHT BROTHERS

While the Wright brothers, Orville and Wilbur, are credited with inventing the modern-day aircraft, much of the foundation work to develop such craft (including that described earlier in this chapter) had already been accomplished prior to their experimentations with flight. The brothers experimented with lift calculations outlined by their mentors, such as Lilienthal and Chanute, and even developed a test bay wind tunnel. What was especially problematic about flying machines when the Wrights became interested in aviation was the general lack of reliable control of the vehicles. The Wrights began to tackle this issue in 1901 using gliders with a wing-warping technique that caused an imbalance in lift on one side of the aircraft versus the other, causing the craft to tilt in one direction and resulting in a change in direction. Other flight controls for pitch and yaw were also developed by 1902. By 1903, the Wrights were finalizing the design of a lightweight gasoline engine to help keep their designs aloft. They designed the predecessor of today's modern propeller and even designed a primitive flight data recorder, which would accompany them on their first flight. Of course, the brothers were successful in flying their Wright Flyer on December 17, 1903 (*see* Figure 1-8), but the craft was far from practical. It was not until 1905 that their updated Flyer showed promise of a practical flying machine with utility beyond demonstration and exhibition. The Wrights continued to make improvements to their designs through 1910, including the ability to carry a passenger. But by 1911, Wright aircraft were increasingly becoming outdated. Wilbur died soon thereafter in 1912, and Orville exited the business four years later. Clearly, the Wrights' inventions and innovations had direct impacts on the practicality of aircraft and, in turn, made modern unmanned aircraft a distinct possibility.

ELMER SPERRY

Elmer Sperry started a career in engineering, but soon became bored and turned instead to research and development. In 1907, while working with a range of electrical components, he became interested in the use of gyroscopes to stabilize vehicles. Sperry originally aimed to help stabilize ships in rough seas using the principle of precession (the reaction of a rotating gyro when a force is applied to it whereby that force is transposed 90 degrees in the direction of the motion of the gyro). By 1910, Sperry had established a business specializing in gyroscopes, which would become essential components in aircraft navigation systems as well as autopilot applications. Although many modern aircraft, both manned and unmanned, use more sophisticated accelerometers and stabilizers rather than gyros, the principles developed by Sperry allowed for reliable, all-weather, and automated flight operations. Gyroscopes were eventually integrated into aircraft for all-weather navigation and guidance. They have also been used to direct autopilot systems, critical to both manned and unmanned flight. Although many aircraft today use updated, solid state accelerometers and sensors for flight instruments and autopilots, the principles developed by Sperry laid the foundations for automated flight control systems in all types of aircraft.

ADVENT OF AEROMODELING

Many of today's civilian unmanned aircraft have more in common with remote-control model aircraft than larger and more sophisticated military platforms. Interestingly, model aircraft of varying sorts have been in use throughout history. One of the first model flying devices, as well as possibly the first rudimentary robot, was created between 400 and 350 BC by a Greek mathematician named Archytas. The device, a steam-powered "pigeon," was constructed of wood and used steam to power its wings. It is purported that Archytas's pigeon could fly up to 600 feet. Most early flying models were based on observable capabilities of birds (biomimicry) or employed basic aeronautical concepts (e.g., kites, parachutes, rotor-wings, and balloons) (*see* Figure 1-9).

Hydrogen airships from the late nineteenth century were used for entertainment purposes in theaters or auditoriums and represent one of the earliest forms of controllable aircraft models. These airships were manipulated by a rudimentary radio signal generated using spark gap transmitters. Once manned aircraft began to become more commonplace, interest in aviation grew as did the market for replications in the form of user-assembled models. Initially, such models were limited to A-frame pusher-propeller designs, but these models were continuously updated to replicate contemporary aircraft configurations and capabilities (*see* Figure 1-10).

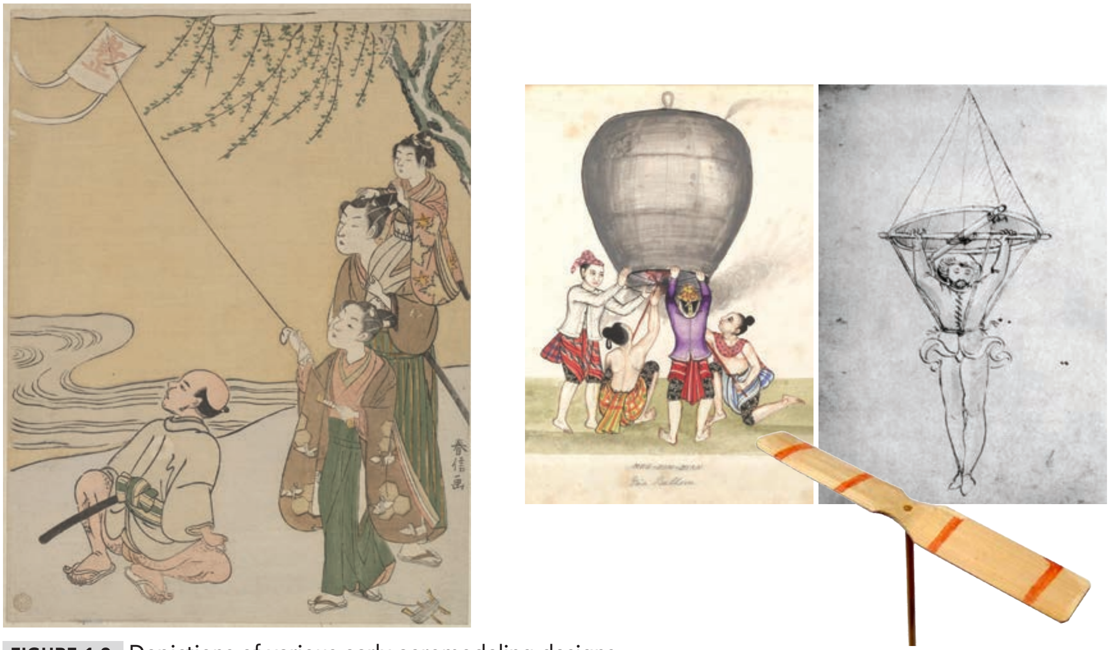


FIGURE 1-9. Depictions of various early aeromodeling designs.

Several European countries founded clubs aimed to increase interest and the study of aviation, as well as to foster aeronautic competitions. Examples included Aero-Club de France (1898), Belgium's Aero Club Royal de Belgique (1901), and the U.K.'s Royal Aero Club (1901). In response to the growing interest in aviation, in particular competitions and record-breaking activities, in addition to efforts by the aforementioned clubs and their counterparts, the Fédération Aéronautique Internationale (FAI) was founded in 1905. Within the FAI is the Commission Internationale d'Aero-Modelisme, which acts as a governing body for international aeromodeling activities and entities.

Aeromodeling continued to grow, truly taking off with the rapid adoption of air travel and power in the 1930s and 1940s. Miniature gas engines and lightweight, inexpensive materials, which enabled the construction of more realistic and capable models, escalated the interest in aeromodeling. In reaction to the growing interest, further clubs and associations were established. In the United States, one of the foremost and currently active organizations supporting development and use of modeling, the Academy of Model Aeronautics (AMA), was founded

FIGURE 1-10. Examples of modern operational model aircraft.

in 1936. Since its inception, the AMA has sanctioned competitions and fly-ins, developed procedures and guidelines (national community-based programs[1]), provided education and training, advocated on behalf of membership, and provided insurance to recreational pilots (members). The AMA has been instrumental in working with its membership and the federal government to coordinate the use of recreational models (e.g., access to radio frequencies, airspace access, maintaining safety) throughout its history. Other countries have aeromodeling clubs with similar histories and functions. For example, the British Model Flying Association stems back to 1922 and provides for encouragement of model flying in the U.K. and coordinates with applicable government agencies to protect and promote such activities. Other examples include the Aero Modelers Association (associate of the Aero Club of India), the Model Aeronautical Association of Australia, the Club Aeromodelistas Newbery (Argentina), Choshi Aeromodellers (Japan), RC Pattaya Flying Club (Thailand), and the Dubai RC Flying Club (United Arab Emirates). These clubs have proliferated interest in remote-controlled model aircraft and are key organizations during the rapid escalation of recreational unmanned aircraft use across the globe.

UNMANNED AIRCRAFT DEVELOPMENT

To grasp the level of sophistication possible in today's unmanned aircraft requires examination of major periods of technical advancement and operational expansion, from the neophyte years of development to the modern day.

LATE NINETEENTH CENTURY

The use of unmanned aircraft, albeit rudimentary, began long before the Wright brothers successfully introduced the world to powered flight. One of the first reports of utilitarian use of an unmanned aircraft was at the Battle of Fleurus in 1794. French forces used a simplistic balloon to observe the battle as it unfolded. It was soon realized that such aerial vehicles could do more than simply observe. At the siege of Venice by Austrian forces in 1849, the Austrians reportedly launched from offshore ships hundreds of balloons carrying shrapnel-filled bombs that were timed to explode when drifting over the besieged city. Although these efforts most likely caused more psychological harm than any sort of strategic value, it presented the potential value of employing such mechanisms. In the U.S. Civil War era, unmanned aerostats were launched to guide subsequent manned balloon reconnaissance flights used to support artillery fire sighting. In the 1870s, unmanned balloons were used to send mail and messages over the siege surrounding the city of Paris. Clearly, these examples demonstrated the usefulness of unmanned aircraft in a variety of venues.

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[1] Per the FAA Modernization and Reform Act of 2012, a nationwide community-based organization is "a membership based association that represents the aeromodeling community within the United States; provides its members a comprehensive set of safety guidelines that underscores safe aeromodeling operations within the National Airspace System and the protection and safety of the general public on the ground; develops and maintains mutually supportive programming with educational institutions, government entities and other aviation associations; and acts as a liaison with government agencies as an advocate for its members."

SMALL UNMANNED AIRCRAFT SYSTEMS GUIDE

Exploring Designs, Operations, Regulations, and Economics

Brent Terwilliger, David Ison, John Robbins, Dennis Vincenzi

The utility and benefits of small unmanned aircraft systems (sUAS) are being increasingly recognized. While this technology is not new, its ability to support domestic public and private operators is becoming better understood, opening up new uses to government organizations and commercial enterprise. Small UAS are expected to become the most prevalent and affordable form of unmanned aircraft available, with applications for both business and recreation ranging from hobby model aircraft communities to defense contracting.

Beginning with the history and evolution of UAS, this book covers typical sUAS designs (including types of multirotor, fixed-wing, and hybrid), major elements and equipment, related technology, common uses, and safety practices. It also provides you with guidance and resources to make well-informed decisions regarding purchase and use, and to determine a path forward through the complex legal, business, operational, and support considerations.

Whether you use sUAS to address a business need or for recreation, the authors furnish knowledge you need to acquire certification approvals, evaluate and purchase an sUAS, and operate in a safe, efficient, and effective manner. Written for experienced aviators as well as those new to aviation and operating in the National Airspace System, the easy-to-read format features full-color illustrations, a list of abbreviations, and an index. The authors' experience and insight into the technical, operational, and regulatory considerations will assist you in shaping your own strategy for use of this (r)evolutionary technology.

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