THE COMPLETE REMOTE PILOT

Bob Gardner and David Ison

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by Bob Gardner and David Ison

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Foreword

I have always loved stuff that is up in the air. When I was a child, my father was also a big fan, so we went to air shows, flew model airplanes, and would pull over and stop alongside the road in our rural area to watch big Stearmans spraying the farm ground. My fascination with model airplanes never left, and many years later I find myself making a living out of my hobby. If you're considering the same, this publication is for you.

You can fly sUAS (small unmanned aircraft systems) platforms professionally, but there are required steps you must take and information you have to know. In fact, you have to become an aviator. The lines between a UAV (unmanned air vehicle) flight and a piloted aircraft are really becoming blurred. To fly an sUAS, you will need to understand weather, the National Airspace System, airport operations, and other items previously held for manned aircraft. One of the largest tasks ahead will be learning a new language. Aviation has its own terminology, and to make it even more challenging, so much of it is referred to with acronyms. Authors Bob Gardner and David Ison have laid all of this out for you, organized it well for future reference, and included great graphics.

I remember watching an entire battalion surrender to a drone on the nightly news in late 1990 and thinking that all of those bad guys threw their hands up to a model airplane. Well, sort of…. The connection is real, and it's been very gratifying to see so many drone pilots for the military come out of the model airplane ranks. Today, the technology of multi-rotors and their built-in stabilization allow flying by many more operators with fewer "stick and rudder" skills. This knowledge, however, is still a major part of being an aviator. David Ison and Bob Gardner have written a great flight plan to obtain all of the aviation knowledge required for becoming "The Complete Remote Pilot."

Enjoy your flight!

Bill Pritchett
Director of Education
Academy of Model Aeronautics

Getting Started

INTRODUCTION

by David Ison and Bob Gardner

It is hard not to want to explore the possibilities of becoming a drone pilot. Drones, officially referred to as unmanned aircraft systems (UAS), provide tremendous opportunities for commercial and personal use. They provide a unique view of our world, are relatively simple to use, and have become increasingly affordable. While UAS have often been viewed as toys, they have become very sophisticated vehicles capable of performing a range of tasks. This increase in capabilities and utilities has resulted in more common use of UAS, with them oftentimes sharing airspace with manned aircraft. Thus it is necessary for UAS operators, or remote pilots, to be aware of the various requirements, regulations, and operational principles associated with manned aircraft so as to safely and responsibly operate in the airspace above the United States (referred to as the National Airspace System or NAS).

For many of you, this may be the first time you have been exposed to the sometimes confusing and complex nature of aviation and piloting knowledge. Even if you are a manned aircraft pilot, you may be unfamiliar with the intricacies associated with UAS operations and how they fit in with manned aircraft. Reading this book is your first step in the path to become a competent, knowledgeable, responsible, and safe remote pilot as well as prepare for the Federal Aviation Administration (FAA) written knowledge test.

The first step is to collect some information that is readily available from the FAA. Since UAS operations are covered by FAA regulations, it is a good idea to get your hands on a copy of these important documents. Since these rules have been fairly dynamic, I would suggest you visit the Electronic Code of Federal Regulations website (eCFR) at www.ecfr.gov and peruse Title 14, which covers everything aviation-related. In particular, you will want to read through 14 CFR Parts 91 and 107. Part 91 covers general operations requirements for aircraft and pilots, while Part 107 is specific to UAS. It is also recommended that you read FAA Advisory Circular (AC) 107-2, *Small Unmanned Aircraft Systems (sUAS)*, which expands upon the various requirements for sUAS operations in the United States.

For those of you who are seeking to fly only recreationally, you technically do not need a Remote Pilot certificate, but it is wise to familiarize yourself with the aforementioned information. Additionally, you will want to get a copy of FAA Advisory Circular 91-57, *Model Aircraft Operating Standards*. You may also want to join the Academy of Model Aeronautics (AMA), which provides tremendous resources for hobbyist pilots.

While the FAA provides some free online training and documents for aspiring remote pilots (including those who already hold a manned pilot certificate), a more comprehensive reference is necessary to gain a full understanding of UAS and how to safely use them in U.S. airspace. Thus, this book was written to help guide you through the process to become an educated, responsible, and safe remote pilot.

REMOTE PILOT CERTIFICATE

There are two primary pathways to becoming a certificated Remote Pilot. First, if you are not a current manned aircraft pilot (e.g., Private Pilot, Commercial Pilot, or ATP with a current flight review), you will need to successfully pass the FAA Remote Pilot knowledge exam. (Note that a Student Pilot certificate does not suffice.) This exam covers a range of topics, many of which are likely to be unfamiliar to both manned and unmanned pilots. Therefore, you will need to do some studying before attempting the exam. Studying is critical to success. At a cost of more than $100 for each attempt, you do not want to have to take the exam more than once; moreover, the FAA requires you to wait 14 days to retest if you fail. In order to take the Remote Pilot exam, you must be at least 16 years of age, and you must receive a score of at least 70 percent to pass. Prior to taking the exam, you should create an Integrated Airman Certification and Rating Application (IACRA) account by visiting iacra.faa.gov. After passing the exam, you will complete your IACRA application for the Remote Pilot certificate with an sUAS rating. A temporary certificate, good for 120 days, will be issued. Once your application has been officially processed, you will receive a permanent certificate in the mail.

The second pathway applies to certificated manned aircraft pilots (excluding Student Pilots) who are current per 14 CFR §61.56. Additionally, you will need to complete the FAA's online Part 107 training course which, upon completion, will provide you with a certificate as evidence of the achievement. You will then need to apply via a Flight Standards District Office (FSDO), designated pilot examiner, airman certification representative, certificated flight instructor, or other person authorized by the FAA administrator. You will be issued a temporary certificate that is valid for 120 days, after which you will receive a permanent certificate in the mail.

WHAT WILL THIS BOOK DO FOR YOU?

A quick search of the Internet and popular online retailers will display almost endless numbers of resources to study for the Remote Pilot exam and to prepare for flying UAS recreationally or for business. Unfortunately, most miss many of the nuances associated with aeronautical knowledge and often simply regurgitate, in overly terse text or outline form, what the FAA has released. These resources don't provide the most efficacious or efficient way to become a competent remote pilot. This text is designed to not only prepare you for the exam, but also to help you learn how UAS fly, how to intelligently talk about them and their components, and to be well-versed in the aeronautical knowledge required to fly these systems in the same airspace as large commercial jets.

Our goal is to provide important details in down-to-earth language. Whether or not you already know a thing or two about flying, this book will bring things into perspective specifically for the remote pilot. Aviation has its own language, much of which remote pilots need to know to understand the intricacies associated with flying. Sometimes the terms, maps, and reports available to the manned aircraft world are somewhat complex and confusing. That's what this book is for—to guide you through this unfamiliar territory (or refresh your memory about it) so you never have to feel lost.

Here are some examples of things you need to know, but may not yet be prepared to perform:

- Did you know that you should not typically fly UAS within 5 nautical miles of an airport with a control tower?
- How do you know you're within 5 nautical miles?
- What is a nautical mile?
- How do you know if an airport has a control tower?

These are just a few examples of questions you will be able to answer with the help of this book. And this is just one tiny bit of aviation knowledge from the plethora of information with which you must be familiar. Fear not, however, because we'll guide you through it all. Best of all, each lesson has review questions to ensure you understand the material, as well as to help prepare you for your written exam. You may also want to purchase ASA's *Remote Pilot Test Prep* book to focus in on the exam itself, and refer to the reader resource page for that book: **www.asa2fly.com/reader/tpuas**.

Well, let's get started!

LESSON 1

Unmanned Aircraft Systems: Learning the Language of Drones

A VERY BRIEF HISTORY OF UNMANNED AIRCRAFT SYSTEMS (UAS)

Here is a question to get us started: when was the first drone (which we will refer to as UAS) flown? What's your guess? Would you believe that it was in August of 1849? While the Austrians were laying siege to the city of Venice, Italy, they concocted a plan to send balloons with attached explosives to bombard the city. While one could argue that these were not UAS as we imagine them, they were one of the first uses of an aerial system to complete a mission of sorts. Similar tactics were employed during the U.S. Civil War but were not entirely effective. In 1896, Samuel Langley launched an unmanned aircraft, the Aerodrome, off of a catapult housed on his floating barge. It wasn't until World War I that a guided, pilotless winged aircraft was flown. Between 1916 and 1917, the first of these types of aircraft were flown—some to serve as targets and others to deliver bombs, the latter which were referred to as aerial torpedoes, guided by rudimentary autopilots.

World War II brought forth a slew of UAS from both Axis and Allied forces. Germany's V-1 "buzz bomb" had a simplistic guidance system that would cut the engine when assumed to be in the target area. The United States also experimented with remote control technologies to convert existing manned aircraft into UAS. One example was Project Aphrodite, in which B-17 bombers were made into flying bombs. Pilots were on board to take off and to arm the warhead. After remote control was engaged, the pilots would parachute out. Probably the most prolific use of UAS during this period was as targets, with more than 12,000 target drones used to assist aerial gunners and pilots practice their shooting skills.

Most of the UAS activity from World War II to Vietnam continued to be in the form of target flights or flying bombs. Eventually, the latter evolved into the modern-day cruise missile. UAS were later used for reconnaissance, typically launched from an airborne platform such as a Lockheed C-130 Hercules. Following the Vietnam War, the United States dramatically slowed its drone research and production, but other countries, notably Israel, made leaps and bounds, paving the way for the UAS age as we know it.

Around 1990, the United States became increasingly interested in using UAS to perform missions that would typically be too boring or dangerous for manned pilots. Thanks to the Global Positioning System (GPS) and advances in sensors, computational power, and other components, UAS could be accurately guided to precise target locations and perform a range of missions from reconnaissance to attack. By 1994, companies were producing unmanned war machines. UAS such as the now-familiar Predator and Global Hawk came to fruition. Since 2000, the U.S. military has rapidly increased its use of UAS to perform tactical missions across the globe. Today, headlines frequently highlight the U.S. military's use of UAS. However, these types of UAS are not commonly seen in the United States (although they do fly here—for training, special missions, and border protection purposes), and they do not resemble the types of systems most remote pilots will operate.

While militaries were figuring out how to utilize UAS for war, radio-controlled aircraft as we know them today were concurrently being developed. In fact, the technologies went hand in hand. The ability to control an object via radio came about in 1898, thanks to Nikola Tesla. A more sophisticated control system was tested in 1903, using radio waves to execute specific commands on a robot. By 1917, such technologies were being used in UAS. Throughout the period of the World Wars, remote control aircraft became more sophisticated and popular. In the 1950s, gas- and battery-powered, remote control aircraft truly sparked the hobby flying market. By 1968, there were even remote-controlled helicopters. As batteries have improved, computers and other components have shrunk, and as prices of these items have become more reasonable, the world of remote control flying has become more accessible to a wider audience. While much of the remote control flying done before the early 2000s was for recreation or as a hobby, it quickly became apparent that UAS has much more capability and potential. Fast-forward to today, and UAS are technologically advanced tools that can be used to perform a very wide range of functions, from simple photography to assisting farmers through the use of precision agricultural sensors. There is no limit to what modern UAS can do. The only limit is your imagination. Of course, a UAS is only as good as its pilot, so let's start digging into the details on how to become one.

TERMS AND ABBREVIATIONS

Both the manned and unmanned aircraft worlds have their own set of terms and abbreviations. Wouldn't you be a little nervous if you asked a doctor, "Hey doc, what are the results of my thoracic CT scan?" and he looked at you puzzled, responding "A what kind of scan? What is a CT?" Similarly, you want to be able to use and understand the UAS/aviation talk. This is essential to being a knowledgeable remote pilot, but it can also be a critical part of communication with other UAS operators and personnel as well as conversations you may need to have with pilots and air traffic controllers.

Below are some of the most common UAS and aviation-related terms and abbreviations that will be important for you to know.

AC — Advisory Circular—an advisory document released by the FAA to provide additional guidance on important subjects that goes beyond the explanations in the regulations and other documents.

AGL — Above ground level—the height, in feet, of an object (e.g., tower or UAS) above the underlying local area terrain.

AIM — *Aeronautical Information Manual*—An FAA publication applicable to all types of aviation/aerospace operations. Provides detailed information on topics such as air traffic control, weather, airports, and other subjects critical to remote pilots.

AIRMET — Airman's Meteorological Information—a current and forecast weather warning covering a specific area that is applicable to small aircraft and UAS (e.g., for windy conditions, turbulence, low visibilities).

AOA — Angle of attack—the angle between the middle of an airfoil (i.e., wing or rotor blade), referred to as the chord line, and the relative wind. Relative wind is opposite to the direction the aircraft/wing/rotor is moving.

ATC — Air traffic control—a service provided by ground-based personnel in charge of separating aircraft in controlled airspace. Remote pilots may have to contact ATC in specific situations.

ATCT — Air traffic control tower—a facility responsible for handling departures, arrivals, and ground operations at an airport (or airports).

ATIS — Automatic Terminal Information Service—a continuous broadcast of non-control aeronautical information. Provides weather information for the transmitting airport.

CFI — Certificated Flight Instructor—an individual who is licensed to provide flight and ground instruction.

CFR — Code of Federal Regulations—the codification of the general and permanent rules and regulations published in the *Federal Register*. Title 14 of the CFR applies to areas of operation and certification of UAS and other aviation/aerospace vehicles.

COA Certificate of Waiver or Authorization—a special waiver or authorization by the FAA to allow operations beyond those defined by Part 107. Operators with COAs are allowed to continue to operate under them until they expire.

CT Control tower—*see* ATCT.

DPE Designated Pilot Examiner—a person designated by the FAA to represent the administration in the issuance of pilot certificates and to conduct practical exams.

FAA Federal Aviation Administration—government entity charged with regulation, enforcement, and promotion of the aviation/aerospace industry in the United States. Also charged with ensuring safe operations in the NAS.

FPV First-person view—the ability of a remote pilot to utilize a camera onboard a UAS to see from the perspective of the UAS in flight. The view is displayed on a screen that is part of the controller, on a tablet/smartphone, and/or in FPV goggles worn by the remote pilot.

FSDO Flight Standards District Office—a local field office serving as a representative of the FAA, providing services and handling compliance relating to aviation/aerospace for a specific geographic area.

FSS Flight Service Station—the provider of flight and weather services to pilots. FSS can be accessed via the Internet or phone.

GCS Ground control station—the ground-based means of controlling a UAS. Also known as the controller.

GPS Global Positioning System—a U.S.-based network of satellites that provides very accurate position information to aircraft and some UAS. GPS is one of several Global Navigation Satellite Systems (GNSS). For example, Russia has its own system called GLONASS.

IFR Instrument flight rules—the set of FAA rules that applies to aircraft flying on IFR flight plans and that allows aircraft to fly in poor weather (less than 3 SM visibility and cloud heights below 1,000 AGL; referred to as instrument meteorological conditions, or IMC). IFR aircraft primarily navigate with sophisticated instruments and navigation systems, such as GPS.

KTS Knots—nautical miles per hour.

METAR Aviation Routine Weather Report—a weather report, usually distributed each hour, from airports with weather observation capabilities.

MOA Military Operations Area— a type of special use airspace, designed to separate military aircraft training and activities occurring in the designated area from non-military air traffic. sUAS typically should avoid operating in MOAs.

NAS National Airspace System—the various types of airspace as well as the airports, ATC facilities, technology, and related rules and regulations that exist in the United States.

NM Nautical mile—a distance of 6,076 feet or approximately 1.15 statute miles. NMs are used for most aviation navigation distance measurements.

NOTAM Notice to Airmen—a notification of a change to expected or documented procedures or operations. Examples may include if a control tower frequency has changed or airspace is restricted due to the President being in the area. Be sure to check for NOTAMs before each flight to avoid unwanted attention from the FAA or law enforcement.

NTSB National Transportation Safety Board—the government agency in charge of investigating transportation accidents in the United States.

PIC Pilot-in-command—the person in charge of the operation of an aircraft. In the case of UAS, they are referred to as the remote PIC. Note that the remote PIC does not necessarily have to be at the controls of the UAS.

RPAS Remotely piloted aircraft system—the term used by many countries outside the United States to describe UA or UAS. RPAS is generally synonymous with UAS.

RPIC — Remote pilot-in-command—the person in charge of the operation of a UAS. Note that the remote PIC does not necessarily have to be at the controls of the UAS.

RWY — Runway—pavement used by manned aircraft for takeoff and landing.

sUAS — Small unmanned aircraft system—a UAS that weighs less than 55 pounds (25 kg).

SIGMET — Significant Meteorological Information—a weather warning covering a specific area and that is applicable to all types of aircraft and UAS (e.g., for extreme and dangerous conditions).

SM — Statute mile—a distance of 5,280 feet. Commonly referred to as miles in non-aviation contexts. SM are sometimes used for distances in aviation, such as in aviation weather reports (METARs and TAFs).

TAF — Terminal Area Forecast—an aviation weather forecast for a specific airport.

TFR — Temporary Flight Restriction—a restriction to flight operations issued via NOTAM. Flight into a TFR can have dramatic consequences usually involving law enforcement or government agencies. Be careful to avoid these.

TSA — Transportation Security Administration—the government entity charged with the safety of transportation in the United States. The TSA will vet potential remote pilots prior to the FAA issuing permanent certificates.

TWY — Taxiway—pavement used by manned aircraft to taxi to and from runways.

UA — Unmanned aircraft—term used to describe the actual aircraft that is part of a UAS (i.e., excludes the ground station/controller).

UAS — Unmanned aircraft system—the total system associated with an unmanned aircraft, including the ground station/controller, sensors, processors, and other components. UAS is also used generically to refer to a drone or remote-controlled aircraft. Previously referred to as unmanned aerial vehicles (UAV).

UTC — Universal Time Coordinated—a standard time used in aviation operations based upon the time in Greenwich, United Kingdom, uncorrected for daylight saving time. Given in 24-hour (military) format. Also referred to as Zulu time. UTC is used in communications, NOTAMs, and weather forecasts.

VFR — Visual flight rules—the set of FAA regulations that dictate operations by aircraft not flying under IFR. VFR flight requires good weather conditions (i.e., more than 3 SM visibility and cloud ceiling heights above 1,000 feet). VFR aircraft navigate with the assistance of visual cues.

VLOS — Visual line-of-sight—the ability of the remote pilot to see the UAS without any aids to vision (such as using FPV or binoculars).

VOR — Very High Frequency Omnidirectional Range—a navigational aid used by aircraft, often to define aircraft routes or position.

WX — Weather—a common abbreviation used when referring to aviation weather conditions.

TYPES OF UAS

Just as there is a cornucopia of manned aircraft, UAS come in various sizes, shapes, and configurations. With few exceptions, at least in the near-term, most civilian UAS remote pilots will be operating small UAS (sUAS), which are defined as those weighing less than 55 pounds. This text will focus on sUAS operations, though most of the details outlined are also applicable to larger UAS.

UAS are divided into two primary categories: fixed-wing and rotor-wing. Fixed-wing UAS generate the lift necessary to fly from a wing, just like a conventional aircraft. Rotor-wing UAS generate the lift needed to go aloft through rotors (essentially propellers oriented horizontally to provide lift vertically), just like a helicopter. Rotor-wing UAS are classified by the number(s) of rotors that they utilize for flight; for example, a UAS with a single rotor is considered a helicopter, while one with several rotors is referred to as a multicopter. A common configuration of four vertical propellers/rotors is referred to as a quadcopter. Figure 1-1 shows typical UAS configurations.

UAS use one of two types of engines to produce power to fly—internal combustion or electric. Internal combustion engines are typically used in larger UAS as well as in hobby/model aircraft, while electric seems to be the power source of choice for sUAS, particularly for multicopters. Obviously, internal combustion engines require some kind of fuel, a means to store it, and a way to induce combustion. Electric engines require a fuel of sorts, as well, in the form of batteries (or even solar panels). Because most of the various components needed for sophisticated sUAS use electricity, and conserving size as well as weight is important, batteries are the ideal choice for powering sUAS.

UAS COMPONENTS

Just like manned aircraft, UAS are comprised of numerous subsystems that allow for controlled flight as well as more utilitarian functions such as providing navigation and position information, speed and altitude measurements, and the ability to take pictures and videos. Figure 1-2 shows the "guts" of a typical quadcopter. While internal components of sUAS vary in regards to size and capability, in general the innards of UAS are very similar. For example, all UAS have flight controllers, systems to manipulate the engine(s), a power source (battery or fuel), and a means to communicate with the ground station/controller, which is used by the remote pilot to fly the UAS.

/ Flight Controller

The brain of the UAS is the flight controller. This device interprets the inputs from sensors and the remote pilot's controller commands. Onboard sensors often include GPS, an inertial measurement unit (IMU), an altimeter, and a magnetometer (i.e., a fancy compass). Additionally, some UAS have autopilots to allow for autonomous navigation, which can be programmed to fly pre-planned routes, circle objects, or follow the remote pilot. The flight controller manipulates the speed of the motor(s) to execute the commands of the remote pilot or autopilot. It also is used to manipulate other sensors, such as the onboard camera.

If installed, a GPS module can provide extremely accurate position information that can be used to superimpose the UAS position on a map (such as on a controller display or in FPV). GPS is available just about anywhere on Earth as long as the UAS has a clear "view" of the sky, thanks to the constellation of satellites that constantly transmit the data needed for

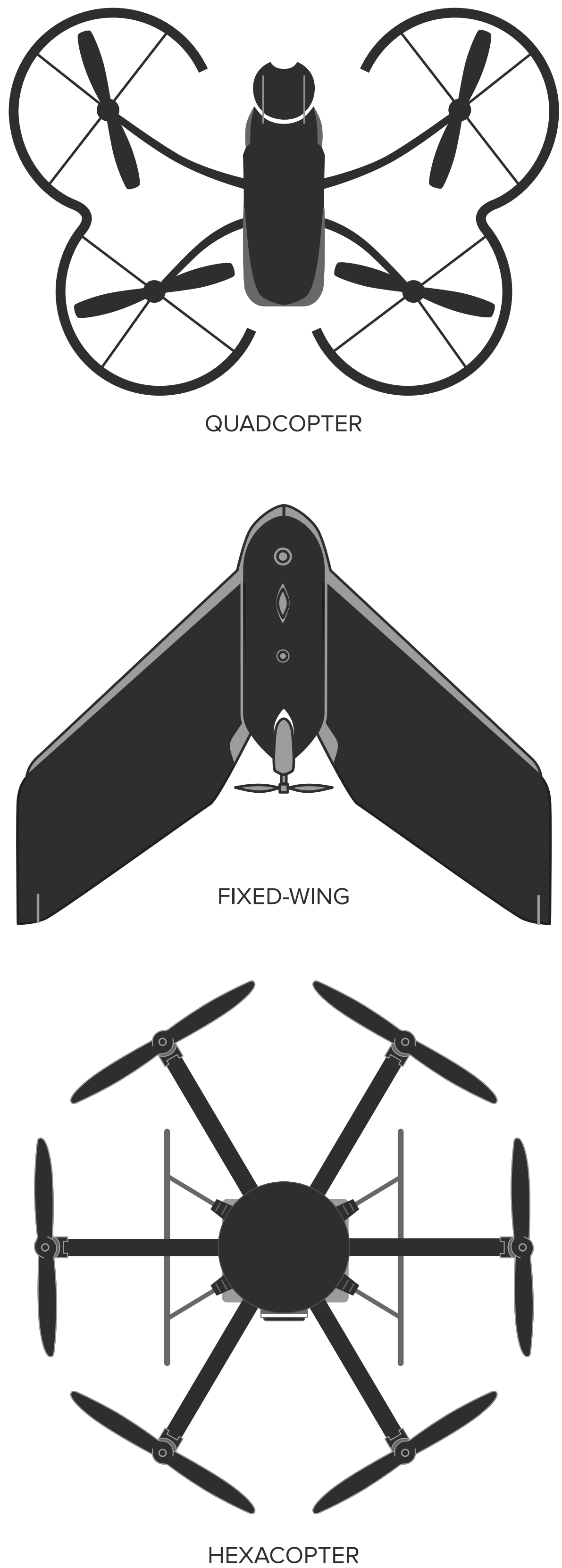

Figure 1-1. Typical UAS configurations.

the GPS module to determine its location. Obviously, GPS will not work indoors, so remote pilots should familiarize themselves with any limitations to UAS use when GPS is not available. Many UAS use GPS to stabilize their positions, making it very simple to fly and essentially allowing for "hands off" loitering. Some UAS can become less stable when GPS is unavailable. Another useful feature of GPS is that it allows a UAS to note the position where it launched and automatically return to this "home" location if commanded to do so or in abnormal situations (such as controller signal loss or getting too far from the controller transmitter). One caveat is that the Return to Home function of most UAS is not aware of trees or buildings that may exist between the UAS's current position and the remote pilot. You do not need much imagination to understand how that could ruin your day. When beyond visual line-of-sight (BVLOS) operations are

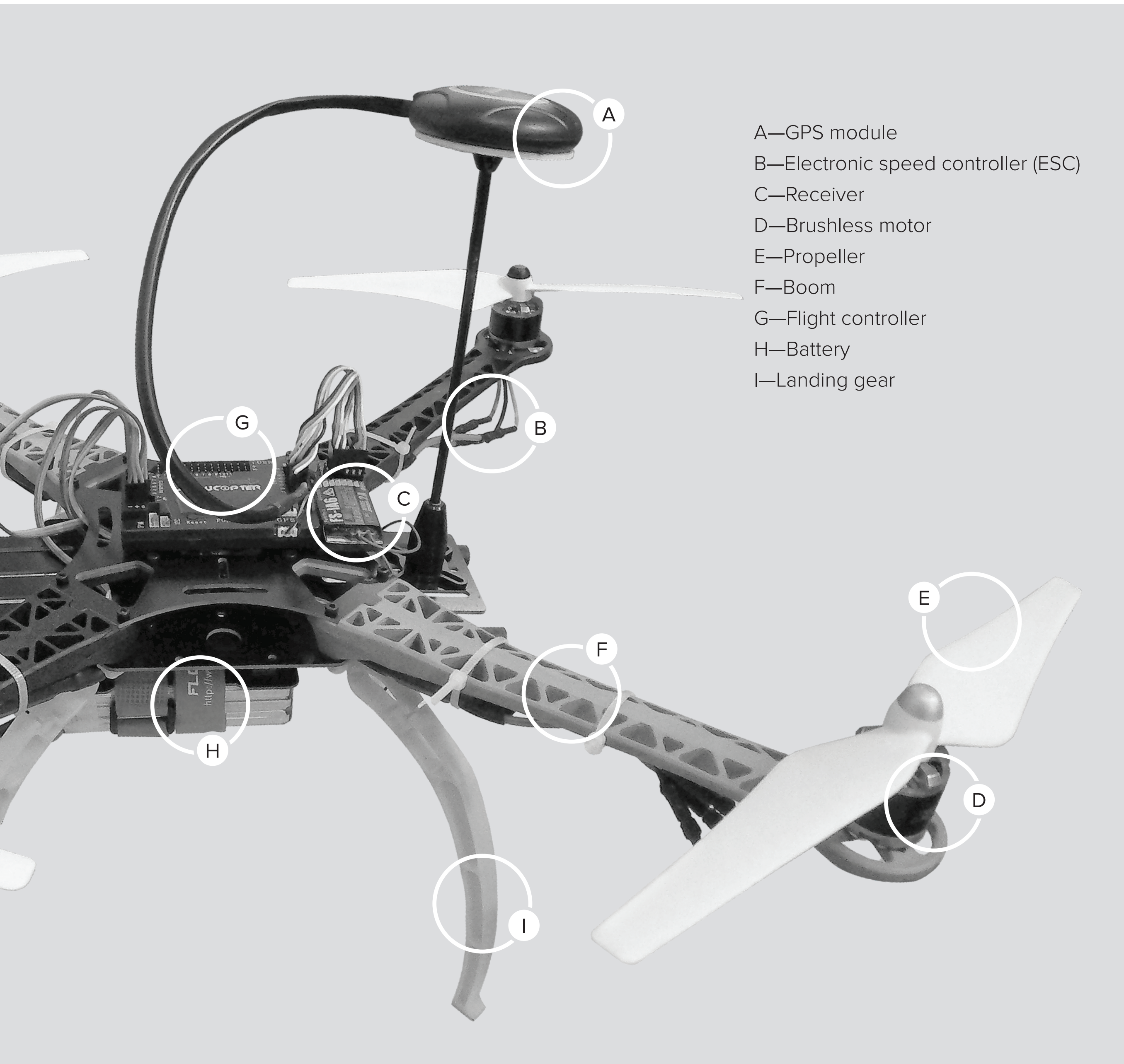

Figure 1-2. Typical quadcopter components.
(Halftermeyer; https://commons.wikimedia.org/wiki/File:Parrot_fleet_of_Drones.jpg; CC BY-SA 4.0)

THE COMPLETE REMOTE PILOT

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This textbook is for anyone interested in pursuing and obtaining a Remote Pilot certificate, which is required in order to operate drones for commercial use. With a friendly and readable style, the authors cover all of the details involved in becoming a competent, responsible, and safe remote pilot, opening up tremendous opportunities for flying increasingly affordable and sophisticated small unmanned aircraft systems (sUAS).

An FAA Knowledge Exam is a requirement for earning a Remote Pilot certificate. *The Complete Remote Pilot* is designed to not only prepare you for the exam but to teach you about how UAS fly, their components and systems, and the aeronautical knowledge required to fly these systems in the same airspace as large commercial jets. This book covers specifics on the language of drones, regulations, airspace and navigation, airport and off-airport operations, radio communication procedures, weather, aerodynamics and aircraft performance, emergency procedures, human factors, maintenance, and preflight inspection procedures.

The required aeronautical knowledge is augmented with specific tips and techniques, checklists and mnemonic devices, and sound advice from personal experience. You'll benefit from the review questions for each chapter similar to the type found on the FAA test, a comprehensive glossary, and index. This practical application of the knowledge needed to pass the FAA Exam is not available in any other book! You will gain the knowledge needed to pass the test and understand how to operate safely as a remote pilot in the U.S. National Airspace System.

BOB GARDNER began his flying career in Alaska in the U.S. Coast Guard. Over the next 50+ years, he earned his ATP and Instructor certificates, flew commercially, and operated as a designated examiner, Director of ASA Ground Schools, author, journalist, and airshow lecturer.

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