BUILDING YOUR OWN DRONES

A Beginner's Guide to Drones, UAVs, and ROVs

John Baichtal
Contents at a Glance

Introduction  xiii
CHAPTER 1  A History of Drones  1
CHAPTER 2  Showcase of Cool DIY Drones  9
CHAPTER 3  Overview of Commercial Drones and Kits  21
CHAPTER 4  Building a Quadcopter I: Choosing an Airframe  35
CHAPTER 5  Rocket Drone Project  51
CHAPTER 6  Building a Quadcopter II: Motors and Props  69
CHAPTER 7  Blimp Drone Project  81
CHAPTER 8  Building a Quadcopter III: Flight Control  103
CHAPTER 9  Drone Builder's Workbench  117
CHAPTER 10  Building a Quadcopter IV: Power Systems  127
CHAPTER 11  Waterborne Drone Project  147
CHAPTER 12  Building a Quadcopter V: Accessories  173
CHAPTER 13  Making a Rover  191
CHAPTER 14  Building a Quadcopter VI: Software  221

Glossary  231
Index  237
# Table of Contents

Introduction  xiii  
Who This Book Is For  xiii  
How This Book Is Organized  xiii  

Chapter 1  A History of Drones  1  
What Is a Drone?  2  
Three Terrains  3  
Anatomy of a Drone  5  
Summary  7  

Chapter 2  Showcase of Cool DIY Drones  9  
Bicycle Rim Quadcopter  9  
3D-Printed Mini Quadcopter  9  
Clothesline Racer  11  
Vessels  11  
Radio-Controlled Blimp  12  
FPV Quadcopter  12  
Open RC Trike  14  
Foldable Quadcopter  14  
Mini-Quadcopter  15  
3D-Printed RC Boat  16  
Tricopter  17  
Mecanum Wheel Rover  18  
Summary  19  

Chapter 3  Overview of Commercial Drones and Kits  21  
Parallax ELEV-8 Quadcopter  21  
DJI Phantom 2 Vision+  24  
OpenROV  26  
Actobotics Nomad  29  
Brooklyn Aerodrome Flack  31  
Summary  34
Chapter 4  Building a Quadcopter I: Choosing an Airframe  35

Which Airframe?  35
  Choosing Between Commercial Options  37
  Making Your Own Airframe  38
Project #1: MakerBeam Airframe  41
  MakerBeam  41
  Parts  43
  Steps  44
Summary  50

Chapter 5  Rocket Drone Project  51

Amateur Model Rocketry  51
  Quick-and-Dirty Arduino Guide  54
Project #2: Data-Gathering Rocket  60
  Parts for Building the Data-Gathering Rocket  60
  Steps for Building the Data-Gathering Rocket  61
  Programming the Payload  65
Summary  67

Chapter 6  Building a Quadcopter II: Motors and Props  69

Choose Your Motors  70
  Outrunner Versus Inrunner  70
  Brushed Versus Brushless  71
  AC Versus DC  72
Choose Your Propellers  73
  Prop Adapters  74
Project #3: Attach the Props and Motors  75
  Parts  76
  Steps for Attaching the Props and Motors  77
Summary  80
Chapter 7  Blimp Drone Project  81
   Radio Control  81
   Transmitters  82
   Receivers  83
   ESC (Electronic Speed Controller)  83
Project #4: Blimp Drone  84
   Parts  85
   Arduino Parts  86
   Steps  86
   Autonomous Control with an Arduino  99
      Code  100
   Summary  102

Chapter 8  Building a Quadcopter III: Flight Control  103
   Know Your ESCs  103
      Common ESCs  105
      Programming ESCs  106
   Receiver  109
   Flight Controller  110
      Flight Controller Examples  111
   Installing the Flight Electronics  114
      Parts  114
      Installing the ESCs  114
      Installing the Flight Controller  114
      Installing the Receiver  116
   Summary  116

Chapter 9  Drone Builder's Workbench  117
   Design It  117
   Drive It  118
   Measure It  120
   Cut It  120
   Wire It  121
   Attach It  123
   CNC It  124
   Summary  126
# Chapter 10 Building a Quadcopter IV: Power Systems 127

- Choosing a Battery 128
  - Battery Types 128
- Adding Bullet Connectors 130
  - Why Bullet Connectors? 130
  - Parts List 130
  - Steps for Adding Bullet Connectors 131
- Assembling the Wiring Harness 137
  - Parts 138
  - Steps for Assembling the Wiring Harness 138
- Wiring the Flight Controller and Receiver 143
- Summary 145

# Chapter 11 Waterborne Drone Project 147

- Realities of Waterborne Electronics 148
  - Disadvantages of Waterborne Electronics 148
  - Advantages of Waterborne Electronics 148
- Waterproofing Your Electronics 149
  - Sandwich Container 150
  - Pelican 1000-Series 151
  - Sealing a Tube 152
- XBee Mesh Networking 153
- Project: Soda Bottle Boat 154
  - Parts 155
  - Building the Drone 156
  - Building the Controller 166
  - Programming the Soda Bottle Boat 170
- Summary 172

# Chapter 12 Building a Quadcopter V: Accessories 173

- Add Accessories to Your Quadcopter 174
  - Camera 174
  - First-Person Video (FPV) 175
  - Landing Gear 176
  - Parachute 176
Building Your Own Drones

Protective Plate or Dome  177
Prop Guards  178

Project: Adding Accessories to the Quadcopter  179
  Install the Camera Mount  180
  Install the Landing Gear  184
  Install the Top Plate  186

Summary  189

Chapter 13 Making a Rover  191

Advantages and Disadvantages of Rovers  192
  Advantages of Rovers  192
  Disadvantages of Rovers  192

Chassis Options  193
  3D Printed  193
  Tamiya  194
  mBot  194
  Arduino Robot  195
  Actobotics Bogie  196

Navigating with Radio Frequency Identification Tags  197

Project: RFID-Navigating Rover  199
  Parts  200
  Steps  200
  Programming the RFID-Navigating Rover  217

Summary  220
# Table of Contents

Chapter 14 Building a Quadcopter VI: Software 221

- Flight Control Software 222
  - OpenPilot 222
  - MultiWii 223
  - APM Planner 2.0 223
  - eMotion 224
  - AR.Freeflight 224
  - 3DR Solo App 226
- Configuring the MultiWii 226
- Examining the MultiWii Control Sketch 228
- Pre-Flight Checklist 229
- Summary 230

Glossary 231

Index 237
About the Author

John Baichtal has written or edited over a dozen books, including the award-winning Cult of LEGO (No Starch Press, 2011), LEGO hacker bible Make: LEGO and Arduino Projects (Maker Media, 2012) with Adam Wolf and Matthew Beckler, Robot Builder (Que, 2014), and Basic Robot Building with LEGO Mindstorms NXT 2.0 (Que, 2012). His most recent book is Maker Pro (Maker Media, 2014), a collection of essays and interviews describing life as a professional maker. John lives in Minneapolis with his wife and three children.
Dedication

This book is dedicated to my Grandma Marion, who is a couple months shy of her 98th birthday as I write this. She was in the hospital a few weeks ago with heart problems and the doctors told her to get her affairs in order, and sent her home in hospice. Grandma isn’t ready to leave the party, however, and she’s been feeling better, buoyed by the great care she’s received from my mom and aunt. Her love of life and passion for writing give me strength every day.

Acknowledgments

When thinking of my family, I am confronted by two irrefutable facts:
1) Arden, Rosemary, and Jack are the best kids anyone could ask for.
2) None of this would mean anything without my dear Elise. I love you!

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My mom, Barbara, compiled the Glossary, and I am forever indebted to her for helping out, in this and so many other things.
We Want to Hear from You!

As the reader of this book, you are our most important critic and commentator. We value your opinion and want to know what we’re doing right, what we could do better, what areas you’d like to see us publish in, and any other words of wisdom you’re willing to pass our way.

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Introduction

Drones are in the news all the time—and let’s face it, they’re likely to be an increasing part of our lives. We can throw on a tinfoil hat and look for small helicopter-shaped shadows, or we can learn as much as we can about these interesting devices. I suggest the latter—there is a lot of cool technology out there, and the best way to control it is to understand it.

Who This Book Is For

Aspiring drone-builders of all stripes will appreciate this book, as it covers many different areas of building your own drone projects, including not only electronics, but motors, airframe-building techniques, and tools.

How This Book Is Organized

This book consists of a main project, a quadcopter you’ll build over the various chapters. The alternating chapters describe a variety of projects such as a data-gathering rocket drone, a blimp, and a boat made out of soda bottles, giving you a perspective on drones beyond those quadcopters that have everyone abuzz.

- Chapter 1, “A History of Drones,” consists of a history of drones and brings you up to speed on current technological limits and terminology drone pilots use.
- Chapter 2, “Showcase of Cool DIY Drones,” describes a dozen cool drones, including UAVs (unmanned aerial vehicles), ROVs (remotely-operated underwater vehicles), and rovers built by hobbyists and amateurs alike.
- Chapter 3, “Overview of Commercial Drones and Kits,” introduces a number of commercial drones that you might care to purchase. Everything from a quadcopter packing a video camera to an undersea explorer is on the table.
- Chapter 4, “Building a Quadcopter I: Choosing an Airframe,” begins the quadcopter project as you learn about a variety of airframes and chassis products, and you begin building your quadcopter’s airframe out of a kit.
- Chapter 5, “Rocket Drone Project,” breaks from the quadcopter and has you build a rocket drone, a model rocket with a basic Arduino payload.
Chapter 6, “Building a Quadcopter II: Motors and Props,” discusses two key components of your quadcopter build. You are presented with various options for purchasing motors and propellers, and you are shown how to mount them onto your quadcopter’s airframe.

Chapter 7, “Blimp Drone Project,” shows you how to build a blimp drone, a small wooden robot hoisted aloft by helium balloons.

Chapter 8, “Building a Quadcopter III: Flight Control,” shows you how to control your robot while it’s in the air, with flight controllers and electronic speed controllers doing most of the work.

Chapter 9, “Drone Builder’s Workbench,” covers the various tools I used to build the projects in the book.

Chapter 10, “Building a Quadcopter IV: Power Systems,” introduces a very important topic: how to power your quadcopter. This includes instructions on building a power distribution system to deliver electricity to the motors.

Chapter 11, “Waterborne Drone Project,” demonstrates how to make a simple remotely-operated vehicle build out of soda bottles.

Chapter 12, “Building a Quadcopter V: Accessories,” covers the variety of accessories, such as camera mounts, available for purchase or creation.

Chapter 13, “Making a Rover,” shows you how to make a rolling robot that uses RFID tags to navigate.

Chapter 14, “Building a Quadcopter VI: Software,” profiles some flight control software and autopilot firmware and also explores the ins and outs of the control software of the autopilot we used in the copter project. With the conclusion of the book, you will complete the quadcopter build.

Finally, the Glossary explains the various terms used throughout the chapters.

If you have any questions, or want to learn more about the projects and my other books, the best way is to check out my Facebook page, www.facebook.com/baichtal. You can also email me at nerdyjb@gmail.com or follow my Twitter feed @johnbaichtal. Good luck and happy drone building!
Building a Quadcopter I: Choosing an Airframe

The main project of the book is a four-bladed helicopter (pictured in Figure 4.1) called a quadrotor or quadcopter. You’ll begin the project by choosing a chassis, which in the plane world is called an airframe.

This chapter begins by presenting you with a number of chassis options, but ultimately (spoiler alert!) I went with a set of MakerBeam aluminum girders that I bolted together into a fine airframe. I then topped this off with a handy wooden platform that will eventually house the quadcopter’s microcontroller, battery pack, and other electronics.

I’m getting ahead of myself, though! Before we get to the MakerBeam build, let’s check out a bunch of other options, including commercial products and DIY possibilities. Once we check those out, I’ll guide you through assembling your own MakerBeam airframe.

Which Airframe?

The funny thing about a drone or robot’s airframe is that it’s mostly just there to hold everything together, so consequently any reasonably rigid, strong, and lightweight material could be (and has been!) used to build a chassis. Sometimes this is done to hilarious effect, with all manner of odd things—recall some of the projects from Chapter 2, “Showcase of Cool DIY Drones.”

There are wood airframes, plastic ones, and metal ones. If it’s reasonably strong, light, and you can bolt stuff to it, chances are it will work as a chassis. That said, some airframes do offer considerable advantages.
For instance, the airframe pictured in Figure 4.2, from Parallax’s ELEV-8 quadcopter, features lightweight aluminum tubes for the motor booms, with plastic mounting lugs designed specifically to mate with the motors and other components that come with a kit. It’s to be expected, but it’s kind of nice knowing everything will fit together.

This effortless compatibility and more polished appearance are a couple of advantages offered by commercial airframes. In the next section, we’ll go over a number of features of these products to take into consideration when making a purchase.
FIGURE 4.2 The Parallax ELEV-8 features a lightweight airframe made out of plastic and aluminum.

Choosing Between Commercial Options

Let’s go over the criteria one might consider in choosing an airframe. The following list discusses some of the features to take into consideration:

- **Appearance**—Anyone can make homely. If you’re paying money for a chassis, it should look like it was designed and machined by professionals. It should look better than what you’d whip up in your basement.
- **Configuration**—How many motors will your copter feature? The number of motor booms is not the only configuration-related question to think about. Will you want to mount a camera on it? Depending on where you put the camera, you might need landing struts. The most common airframe is the now-classic quadcopter, featuring four motor booms with a central plate that supports the controller and batteries.
- **Dimensions**—How big of a quadcopter do you want? My Parallax ELEV-8 is over 2 feet across, and it’s considered only typical by quadcopter standards. Keep the overall needs of your project in mind, as well as the technical specifications of your motors and props. Don’t be hesitant to try out a smaller project first—the motors and other components may be cheaper because their technical requirements are less demanding.
CHAPTER 4: Building a Quadcopter I: Choosing an Airframe

- **Material**—As I mentioned, pretty much any reasonably lightweight and sturdy material can be used for an airframe. That said, aluminum and plastic—or a combination of the two—are the most popular.

- **Mounting hardware**—This one is huge for me. What use is a cool airframe if you can’t easily bolt your components onto it? Wanting to have motors that easily bolt onto an airframe often means having specialized plates and attachments, although this isn’t required. Many quadcopters have been built that are held together mostly with duct tape and zip ties.

- **Price**—I see a big difference in prices, but sometimes it’s not so apparent what you’re getting for the extra dough. With all hobbyist hardware, there are some categories of product that have cool screen-printing on the housing and cost twice as much, but ultimately aren’t all that impressive.

- **Strength**—The dirty secret of quadcopters is that they crash—a lot! They’re constantly plowing into the turf after batteries run out or a technical glitch occurs. How durable of a drone are you looking to build? On the other hand, with strength often comes weight, and what good will it be to have an indestructible quadcopter that can’t make it off the ground? Which brings us to...

- **Weight**—The final criteria to consider is weight. The lifting power of your motors offsets the weight of the chassis, and if you have monster motors and props, you can get away with a more robust airframe.

Making Your Own Airframe

Although buying is always an option, it’s definitely best to build an airframe if you have the time, the tools, and the materials. That way, you can have the perfect airframe for your needs, and you can take pride in having created something!

The following sections discuss the three basic ways to create your own airframe.

Building Set

With a building set, instead of designing anything, you simply build your airframe out of plastic or metal beams. Most DIY kits involve the bolting together of parts anyway—granted, custom parts rather than stock parts—but you can still see how easy it would be to build your own airframe.

In this chapter, I show you how to use a convenient and clever aluminum building set called MakerBeam to build a chassis, as seen in Figure 4.3.
Another option is to print your own airframe using a 3D printer, a tool that creates three-dimensional objects out of melted plastic. There are already a bunch of quadcopter parts on Thingiverse, a site featuring 3D-printer files that can be freely downloaded. Take, for example, the T-6 Quadcopter, pictured in Figure 4.4. Its creator, Brendan22, designed and printed the booms and enclosure, and you can download his designs on Thingiverse at http://www.thingiverse.com/Brendan22/designs.

If you aren’t content to download someone else’s work, you can use 3D-design software such as SketchUp (sketchup.com) or Tinkercad (tinkercad.com) to build the part you need for your project, and then print it out on your handy 3D printer. If this sounds a little
expensive, that’s kind of true. 3D printing is a new industry, and prices haven’t come down to the point where everyone has a 3D printer at home. Don’t worry: There are plenty of other ways to build an airframe!

**Figure 4.4** The T-6 Quadcopter has a 3D-printed body and six motors (credit: Brendan22).

**Wood**

Wood makes for a very lightweight and sturdy airframe material, especially for smaller and lighter quadcopters. A lot of model gliders use balsa, a super light and easily-shaped wood. However, quadcopters have the capability to carry a decent amount of weight, and that makes wood’s relatively unimpressive strength-to-weight ratio less of a problem.

One fun aspect of wood airframes is that you can laser-cut the frame out of thin slats of wood and then piece them together like a puzzle. Figure 4.5 shows one example of this type of creation. Called the Flone (http://www.thingiverse.com/thing:113497), it’s an airframe for a smartphone-controlled quadcopter. It looks great and is easy to make—if you have a laser cutter, that is.

Another advantage to wood is that it is a cinch to modify it on the fly—just drill a hole in it! Unlike commercial frames, or even metal and plastic ones, it’s super easy to cut or drill into a wooden chassis. If you mess up, all you have to do is laser out another one!
Project #1: MakerBeam Airframe

For my quadcopter, I decided to make my own airframe, using some cool aluminum beams I had lying around. The beams, shown in Figure 4.6, bolt together very securely and connect to multiple angle plates so that the thing won’t fly apart in midair.

MakerBeam

Called MakerBeam (www.makerbeam.eu), the beams are pretty cool, bolting together with M2.5 screws, which employ an unusual connection method—the heads of the screws are square, and they slide into grooves cut into the aluminum beams. Connector plates are added to the screws; then a hex wrench is used to tighten the nuts (see Figure 4.7).
FIGURE 4.6 The MakerBeam chassis serves as a light and flexible platform upon which to build your quadcopter.

FIGURE 4.7 MakerBeam’s threaded end-hole and clever grooves make it useful for making a quadcopter chassis.
The product has a cool idea behind it. In 2012, a crowd-funding campaign launched OpenBeam with $100,000 in development money. The idea was to create an aluminum building set that was open source, so anyone could create their accessories or expansions on the base design.

MakerBeam is an offshoot of that original project, with different connectors and slightly modified beams, but still retaining the spirit of the original. In the U.S., you can buy MakerBeam on Amazon.com (search for the ASIN of B00G3J6GDM).

You can also buy the original OpenBeam (www.openbeamusa.com) from Adafruit. It works much the same way, but uses nuts trapped in the grooves, rather than the heads of screws. It also offers downloadable designs so you can output your own 3D-printable connector parts.

Parts
You’ll need the following parts to build your airframe (shown in Figure 4.8). Note that all MakerBeam parts are found in the MakerBeam Starter Kit (P/N 01MBTBKITREG):

A. Four 150mm beams (P/N 100089).
B. Four 100mm beams (P/N 100078).
C. Four 60mm beams (P/N 100067).
D. Eight corner brackets (P/N 100315).
E. Four right-angle brackets (P/N 100326).
F. Four L-brackets (P/N 100304).
G. M3 x 6mm screws (P/N 100359), though they offer longer screws not found in the Starter Kit.
H. M3 nuts (P/N 100416). They also offer self-locking nuts (P/N 100405).
I. A piece of wood. I used a 13×13cm square of 3mm-thick (1/8th-inch-thick) Baltic Birch for the platform, with screw holes 11cm apart.
FIGURE 4.8 You’ll need these parts to build your MakerBeam airframe.

Steps
Once you have gathered all your parts together, follow along with these steps to build your airframe:

1. Make four identical assemblies, each consisting of a motor strut with a section of the central square. These sub-steps show how to make each one:
   a. Slide two screws into the groove of a 150mm beam. Secure a right-angle bracket to those two screws using the supplied nuts and hex driver, as shown in Figure 4.9. (Note that I only tightened every other screw, so I could make adjustments more quickly. I’ll go through later on and finish adding nuts once the design is the way I like.)
   b. Slide two screws into the groove of a 10cm beam. Connect it to the 15cm beam and bracket you already prepared, as shown in Figure 4.10. Secure it with two nuts.
FIGURE 4.9 Slide the heads of two M3 screws into the grooves of a 150mm beam.

FIGURE 4.10 Make a “T” with the two beams and secure with a bracket.
c. Add a corner-bracket to help secure the beams, as shown in Figure 4.11. Secure the bracket the normal way.

![Figure 4.11](image)

**FIGURE 4.11** Reinforce the “T” with another bracket.

d. Attach an L-bracket to the top of the 10cm beam, positioning it like you see in Figure 4.12.
2. Once you have all four built, connect them together using the usual hardware. It should look just like Figure 4.13.
FIGURE 4.13 Add the four segments together, and you start seeing your airframe take shape.

3. Flip over the airframe so the flat L-brackets are on the underneath. Add four 6mm beams and secure them with L-brackets. Figure 4.14 shows how it should look.

4. Now you’re ready to add the wooden platform, shown in Figure 4.15. I laser-cut the precise shape I needed, but you can use any old (thin) piece of wood and hand-drill the holes. Don’t make it too thick! Baltic Birch no thicker than 1/8” (3mm) does the trick. Screw the platform into the threaded holes in the tops of the four legs using M3 bolts, secured with a hex wrench.
Add legs!

Attach the wooden platform to the tops of the legs.
Does your quadcopter seem incomplete? It should, considering that there are no motors, props, or electronics. Be patient! In future chapters, you’ll have an opportunity to complete the build.

Summary
You’re well on your way to building your very own quadcopter—you constructed the airframe out of aluminum beams! In the following chapters, you’ll add the motors and props, battery pack, and microcontroller. But let’s mix it up! In Chapter 5, “Rocket Drone Project,” you’ll build an electronic payload that will datalog the G-forces experienced by a model rocket in flight.
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Symbols
3D-design software, 39
3D-printed chassis, 193-194
3D-Printed Mini Quadcopter, 9
3D-Printed RC Boat, 16-17
3D printers, 124-125
3D-printed airframe, 39-40
3D-printed chassis, 193-194
3D-printed mini quadcopter, 9
3D-printed RC boat, 16-17
3DRobotics, 226
3DR Solo app, 226

A
accessories (quadcopter), 173
cameras
  choosing, 174
  installing, 180-182
FPV (first-person video), 175
landing gear
  choosing, 176
  installing, 184-185
parachutes, 176-177
prop guards, 178-179
protective plates/domes
  choosing, 177-178
  installing, 186-187
AC motors, 72
Actobotics Bogie, 196-197
Actobotics Nomad, 29-31
adapters, propeller, 74
airframes, 6, 35
  building sets, 38
  choosing, 35-38
  criteria, 37-38
  laser-cutting from wood, 40
MakerBean Airframe project, 41
  overview, 41-43
  parts, 43-44
  steps, 44-50
  printing with 3D printers, 39-40
airplanes, Brooklyn Aerodrome Flack, 31-33
Alarms.cpp, 228
Alarms.h, 228
Allen wrenches, 119
amateur model rocketry, 51-53
Amazon, 2
anatomy of drones, 5-7
APM Planner 2.0, 223-224
Arduino for Beginners, 59
Arduino microcontrollers
  Arduino Robot, 195-196
  blimp drone project, 86, 99-100
  overview, 54-58
Arduino Robot, 195-196
Ardupilot, 112
AR.Freeflight, 224-225
attaching
  motors, 75-79
  propellers, 75-79
attachment tools, 123
Audry, Sofian, 11
automatic wire strippers, 122
Battery packs, 6
BenchPro BP-1562, 122
Bicycle Rim Quadcopter, 9-10
blimp drones
overview, 81
radio control, 81
   ESC (Electronic Speed Controller), 83-84
   Radio-Controlled Blimp, 12-13
   receivers, 83
   transmitters, 82
sample project
   Arduino microcontroller, 86, 99-100
   overview, 84
   parts, 85-86
   programming code, 100-102
   steps, 86-98
boats, 147
3D-Printed RC Boat, 16-17
   advantages, 148-149
   disadvantages, 148
Soda Bottle Boat project
   building controller, 166-168
   building drone, 156-166
   overview, 154
   parts, 155
   programming, 170-171
waterproofing electronics, 149
   CorrosionX, 153
   Pelican 1000-series cases, 151
   sandwich containers, 150-151
   sealed tubes, 152
   XBee mesh networking, 153-154
Bogie (Actobotics), 196-197
Brendan22, 9
   T-6 Quadcopter, 39-40
Brooklyn Aerodrome Flack, 31-33
brushed motors, 71
brushless motors, 71
building sets (airframe), 38

bullet connectors
   adding, 131-136
   overview, 130
   parts list, 130

calipers, 120
camera gimbal, 6
cameras
   choosing, 174
   first-person video cameras, 7
   installing, 180-182
cases
   Pelican 1000-series cases, 151
   sandwich containers, 150-151
   sealed tubes, 152
chassis, 193
   3D printed chassis, 193-194
   Actobotics Bogie, 196-197
   Arduino Robot, 195-196
   mBot, 194-195
   RFID-Navigating Rover project, 199-220
   RFID tags, 197-199
   Tamiya, 194
checklist, pre-flight, 229-230
choosing
   airframes, 35-38
   batteries, 128
   cameras, 174
   FPV (first-person video), 175
   landing gear, 176
   parachutes, 176-177
   propellers, 73
   prop guards, 178-179
   protective plates/domes, 177-178
Christou, Michael, 16
Clothesline Racer, 11
CNC (Computer Numerically Controlled)
   mills, 125-126
CNC (Computer Numerically Controlled) tools, 124
3D printers, 124-125
CNC mills, 125-126
laser cutters, 124
code, blimp drone, 100-102
commercial drones
Actobotics Nomad, 29-31
Brooklyn Aerodrome Flack, 31-33
DJI Phantom 2 Vision+, 24-26
OpenROV, 26-28
Parallax ELEV-8 Quadcopter, 21-24
Computer Numerically Controlled (CNC) mills, 125-126
Computer Numerically Controlled tools. See CNC tools
Config.h, 228
configuring
ESCs (electronic speed controllers), 106-109
MultiWii, 226-227
Contour ROAM, 174
controllers, Soda Bottle Boat project, 166-168
control sketch (MultiWii), 228
CorrosionX, 153
cost of commercial drones and kits
Actobotics Nomad, 31
Brooklyn Aerodrome Flack, 33
DJI Phantom 2 Vision+, 26
OpenROV, 27
Parallax ELEV-8 Quadcopter, 23
“C” rating, 128
cutting tools, 120-121

D

data-gathering rocket project
overview, 60
parts, 60-61

E

EEPROM.cpp, 228
EEPROM.h, 228
electronic speed controllers (ESCs), 5
blimp drones, 83-84
configuring, 106-109
HobbyKing 6A UBEC, 106
installing, 114
Building Your Own Drones

overview, 103-104
programming, 107
Turnigy Brushed 30A ESC, 105
wiring, 143-144
XXD HW30A, 105
electronics tools, 121-122
ELEV-8 Quadcopter (Parallax), 21-24
eMotion, 224
energy density (batteries), 128
ESCs (electronic speed controllers), 5
blimp drones, 83-84
configuring, 106-109
HobbyKing 6A UBEC, 106
installing, 114
overview, 103-104
programming, 107
Turnigy Brushed 30A ESC, 105
wiring, 143-144
XXD HW30A, 105
Estes Rockets, 51
Extech 382202, 122
FC (flight controller), 6
Ardupilot, 112
HoverflyOPEN, 111-112
installing, 114
MultiWii, 113-114
overview, 110
flight control software
3DR Solo app, 226
APM Planner 2.0, 223-224
AR.Freeflight, 224-225
eMotion, 224
MultiWii, 223, 226-228
OpenPilot, 222
overview, 221-222
overview, 103-104
quadcopters
ESCs (electronic speed controllers), 114
FC (flight controller), 114
parts, 114
receivers, 116
receivers
installing, 116
overview, 109
wiring, 143-144
flight controller (FC), 6
Ardupilot, 112
HoverflyOPEN, 111-112
installing, 114
MultiWii, 113-114
overview, 110
flight control software
3DR Solo app, 226
APM Planner 2.0, 223-224
AR.Freeflight, 224-225
eMotion, 224

F

FC (flight controller)
Ardupilot, 112
HoverflyOPEN, 111-112
installing, 114
MultiWii, 113-114
overview, 110
files, MultiWii, 228-229
fins, 53
first-person video cameras, 7
first-person video (FPV), choosing, 175
firstpersonview.co.uk, 26
Flack (Brooklyn Aerodrome), 31-33
flight control
ESCs (electronic speed controllers)
configuring, 106-109
HobbyKing 6A UBEC, 106
MultiWii
  configuring, 226-227
  control sketch, 228
  overview, 223
OpenPilot, 222
  overview, 221-222
floating drones, 147
  3D-Printed RC Boat, 16-17
  advantages, 148-149
  disadvantages, 148
Soda Bottle Boat project
  building controller, 166-168
  building drone, 156-166
  overview, 154
  parts, 155
  programming, 170-171
Vessels project, 11-12
waterproofing electronics, 149
  CorrosionX, 153
  Pelican 1000-series cases, 151
  sandwich containers, 150-151
  sealed tubes, 152
  XBee mesh networking, 153-154
Flone airframe, 40-41
Foldable Quadcopter, 14-15
food storage containers, waterproofing
  electronics with, 150-151
FPV (first-person video), 175
FPV Quadcopter, 12-13
Fritzing, 117
front indicators, 6

Game of Drones, 175
glue
  hot glue, 123
  super glue, 123
GoPro Hero, 174
government use of drones, 1

GPS.cpp, 228
GPS.h, 228
graph paper, 117

Hacksaws, 121
hardware tools
  3D printers, 124-125
  automatic wire strippers, 122
  calipers, 120
  CNC mills, 125-126
  double-sided tape, 123
  dremels, 121
  drills, 121
  Fritzing, 117
  graph paper, 117
  hacksaws, 121
  hex wrenches, 119
  hot glue, 123
  Inkscape, 117
  jeweler’s screwdrivers, 119
  laser cutters, 124
  measuring tape, 120
  multimeters, 122
  multitools, 118
  needle nose pliers, 118
  notebooks, 117
  pens/pencils, 117
  Phillips screwdrivers, 119
  power supply, 122
  protractors, 120
  rulers, 120
  SketchUp, 118
  socket sets, 119
  soldering equipment, 122
  standard screwdrivers, 119
  super glue, 123
  velcro, 123
wire cutters, 122
X-Acto knives, 121
zip ties, 123
hex wrenches, 119
HitCase, 181
HobbyKing 6A UBEC, 106
Hord, Mike, 11
hot glue, 123
HoverflyOPEN, 111-112

I

igniters, 53
IMU.cpp, 228
IMU.h, 228
IMU (inertial measurement unit), 228
inertial measurement unit (IMU), 228
Inkscape, 117
inrunner motors, 70
installing
cameras, 180-182
landing gear, 184-185
protective plates/domes, 186-187

J-K

jeweler’s screwdrivers, 119
Kelly, Stephen, 11
kits
Actobotics Nomad, 29-31
Brooklyn Aerodrome Flack, 31-33
Parallax ELEV-8 Quadcopter, 21-24

L

landing gear
choosing, 176
installing, 184-185
landing struts, 6
laser cutters, 40, 124,
laser-cutting airframes, 40
launch lug, 53
LCD.cpp, 228
LCD.h, 228
Leviathan rocket, 52
Li-ion batteries, 128-130
LiPo batteries, 128-130
lithium batteries, 128-130
Lodefink, Steve, 12, 175

M

mAH (Milli-amp hours), 128
MakerBean Airframe project
overview, 41-43
parts, 43-44
steps, 44-50
makershed.com, 33
Mars rovers, 1
mBot, 194-195
measuring tape, 120
measuring tools, 120
Mecanum Wheel Rover, 18-19
mesh networking, 153-154
Micro (Arduino), 54
microcontrollers, Arduino
Arduino Robot, 195-196
blimp drone project, 86, 99-100
overview, 54-58
Milli-amp hours (mAh), 128
mills (CNC), 125-126
Mosquito rocket, 52
motors, 5
quadcopter motors
AC versus DC, 72
attaching, 75-79
brushed versus brushless, 71
outrunner versus inrunner, 70
sample project, 75-79
rocket motors, 53
Mueller, Roger, 14
multimeters, 122
multitools, 118
MultiWii, 113-114
configuring, 226-227
control sketch, 228
overview, 223
MultiWii.cpp, 228
MultiWii.h, 228
multiwii.ino, 228

N
NASA, Mars rovers, 1
needle nose pliers, 118
nickel–metal hydride (NiMH) batteries, 128
Nomad (Acrobotics), 29-31
nose cones (rocket), 53
notebooks, 117

O
OpenBeam, 43
openbeamusa.com, 43
OpenPilot, 222
OpenPilot CopterControl, 15
Open RC Trike, 14
OpenROV, 26-28
openrov.com, 27
Output.cpp, 228
Output.h, 228
outrunner motors, 70

P
parachutes, 53, 176-177
parallax.com, 23
Parallax ELEV-8 Quadcopter, 21-24
Parrot AR.Freeflight, 224
parts lists
blimp drone project, 85-86
bullet connectors, 130
data-gathering rocket project, 60-61
MakerBean Airframe project, 43-44
quadcopter flight control project, 114
quadcopter props/motors project, 76
quadcopter wiring harness, 138
RFID-Navigating Rover project, 200
Soda Bottle Boat project, 155
Pelican 1000-series cases, 151
pencils, 117
pens, 117
Phantom 2 Vision+ (DJI), 24-26
Phillips screwdrivers, 119
photography. See cameras
pitch, 109
pliers, needle nose, 118
power supply, 122
power systems, 127
batteries
choosing, 128
lithium batteries, 128-130
NiMH batteries, 128
bullet connectors
adding, 131-136
overview, 130
parts list, 130
wiring harness assembly, 137
parts list, 138
steps, 138-142
pre-flight checklist, 229-230
printers, 3D, 124-125
3D-printed airframe, 39-40
3D-printed chassis, 193-194
3D-printed mini quadcopter, 9
3D-printed RC boat, 16-17
programming
blimp drone, 100-102
ESCs (electronic speed controllers), 107
RFID-Navigating Rover project, 217-220
Soda Bottle Boat project, 170-171

**projects**

blimp drone
- Arduino microcontroller, 86, 99-100
  - overview, 84
  - parts, 85-86
  - programming code, 100-102
  - steps, 86-98

data-gathering rocket project
- overview, 60
- parts, 60-61
- programming the payload, 65-67
- steps, 61-65

MakerBean Airframe
- overview, 41-43
- parts, 43-44
- steps, 44-50

quadcopter accessory installation
- camera, 180-182
- landing gear, 184-185
- top plate, 186-187

quadcopter bullet connectors
- adding, 131-136
- overview, 130
- parts list, 130

quadcopter flight control
- ESCs (electronic speed controllers), 114
  - FC (flight controller), 114
  - parts, 114
  - receivers, 116
- quadcopter props/motors, 75
  - parts, 76
  - steps, 77-79
- quadcopter wiring harness assembly, 137
  - parts list, 138
  - steps, 138-142

RFID-Navigating Rover
- assembly, 200-217
- overview, 199

parts, 200
programming, 217-220
Soda Bottle Boat
- building controller, 166-168
- building drone, 156-166
  - overview, 154
  - parts, 155
  - programming, 170-171

**propellers, 5**
- attaching, 75-79
- choosing, 73
- prop adapters, 74
- prop guards, choosing, 178-179
- sample project, 75
  - parts, 76
  - steps, 77-79

**prop guards, choosing, 178-179**

**protective plates/domes**
- choosing, 177-178
- installing, 186-187

Protocol.cpp, 228
Protocol.h, 228
protractors, 120
PVC piping, 152

**quadcopter flight control project**
- ESCs (electronic speed controllers), 114
- FC (flight controller), 114
- parts, 114
- receivers, 116

**quadcopter props/motors project, 75**
- parts, 76
- steps, 77-79

**quadcopters, 5**
- 3D-Printed Mini Quadcopter, 9
- accessories, 173
  - cameras, 174, 180-182
- FPV (first-person video), 175
landing gear, 176, 184-185
parachutes, 176-177
prop guards, 178-179
protective plates/domes, 177-178, 186-187
airframes, 6
building sets, 38
choosing, 35-38
criteria, 37-38
laser-cutting from wood, 40
MakerBean Airframe project, 41-50
printing with 3D printers, 39-40
battery packs, 6
Bicycle Rim Quadcopter, 9-10
camera gimbal, 6
DJI Phantom 2 Vision+, 24-26
ESCs (electronic speed controllers), 5
configuring, 106-109
HobbyKing 6A UBEC, 106
installing, 114
overview, 103-104
programming, 107
Turnigy Brushed 30A ESC, 105
wiring, 143-144
XXD HW30A, 105
FC (flight controller), 6
Ardupilot, 112
HoverflyOPEN, 111-112
installing, 114
MultiWii, 113-114
overview, 110
first-person video cameras, 7
flight control software
3DR Solo app, 226
APM Planner 2.0, 223-224
AR.Freeflight, 224-225
eMotion, 224
MultiWii, 223, 226-228
OpenPilot, 222
overview, 221-222
Foldable Quadcopter, 14-15
FPV Quadcopter, 12-13
front indicators, 6
landing struts, 6
motors, 5
AC versus DC, 72
attaching, 75-79
brushed versus brushless, 71
outrunner versus inrunner, 70
sample project, 75-79
Parallax ELEV-8 Quadcopter, 21-24
power systems, 127
battery selection, 128
battery types, 128-130
bullet connectors, 130-136
wiring harness assembly, 137-142
pre-flight checklist, 229-230
propellers, 5
attaching, 75-79
choosing, 73
prop adapters, 74
sample project, 75-79
quadcopter flight control project
ESCs (electronic speed controllers), 114
FC (flight controller), 114
parts, 114
receivers, 116
receptacles, 7
installing, 116
overview, 109
wiring, 143-144
SKITR Mini-Quadcopter, 15-16
T-6 Quadcopter, 39-40
wiring harness, 127-128
assembling, 137-142
battery selection, 128
battery types, 128-130
bullet connectors, 130-136
racers, Clothesline Racer, 11
Radio-Controlled Blimp, 12-13
radio control of blimp drones
ESC (Electronic Speed Controller), 83-84
receivers, 83
transmitters, 82
radio frequency identification (RFID) tags
explained, 197-199
RFID-Navigating Rover project
assembly, 200-217
overview, 199
parts, 200
programming, 217-220
RC (radio control) of blimp drones, 81
ESC (Electronic Speed Controller), 83-84
receivers, 83
transmitters, 82
receivers, 7
blimp drones, 83
quadcopter receivers
installing, 116
overview, 109
wiring, 143-144
recovery wadding, 53
remotely operated vehicles (ROVs)
defined, 4
OpenROV, 26-28
RFID-Navigating Nomad, 191
RFID-Navigating Rover project
assembly, 200-217
overview, 199
parts, 200
programming, 217-220
RFID (radio frequency identification) tags
explained, 197-199
RFID-Navigating Rover project
assembly, 200-217
overview, 199
rocket drones
amateur model rocketry, 51-53
Arduino microcontroller, 54-58
data-gathering rocket project
overview, 60
parts, 60-61
programming the payload, 65-67
steps, 61-65
roll, 109
routers (CNC), 125-126
rovers
Actobotics Nomad, 29-31
advantages, 192
chassis
3D printed chassis, 193-194
Actobotics Bogie, 196-197
Arduino Robot, 195-196
mBot, 194-195
Tamiya, 194
defined, 4-5
disadvantages, 192
Mars rovers, 1
Mecanum Wheel Rover, 18-19
Open RC Trike, 14
overview, 191
RFID-Navigating Nomad, 191
RFID-Navigating Rover project
assembly, 200-217
overview, 199
parts, 200
programming, 217-220
RFID tags, 197-199
ROVs (remotely operated vehicles)
defined, 4
OpenROV, 26-28
Rubbermaid containers, 150
rulers, 120
RX.cpp, 228
RX.h, 228
sandwich containers, waterproofing electronics with, 150-151
Scotch tape, 123
Scratch, 194
screwdrivers
  jeweler’s screwdrivers, 119
  Phillips screwdrivers, 119
  standard screwdrivers, 119
sealed tubes, waterproofing electronics with, 152
SenseFly eMotion, 224
Sensors.cpp, 228
Sensors.h, 228
Serial.cpp, 228
Serial.h, 228
servocity.com, 31
shock cords, 53
SketchUp, 39, 118
sketchup.com, 39
SK!TR Mini-Quadcopter, 15-16
Skycat Recovery Launchers, 177
socket sets, 119
Soda Bottle Boat project
  building controller, 166-168
  building drone, 156-166
  overview, 154
  parts, 155
  programming, 170-171
software
  flight control software
    3DR Solo app, 226
    APM Planner 2.0, 223-224
    AR.FreeFlight, 224-225
    eMotion, 224
    MultiWii, 223, 226-228
    OpenPilot, 222
    overview, 221-222
  Fritzing, 117
Inkscape, 117
SketchUp, 118
soldering equipment, 122
sparkfun.com, 31
standard screwdrivers, 119
St. Aubin, Samuel, 11
super glue, 123
T
T-6 Quadcopter, 39-40
Tamiya, 194
tape
double-sided tape, 123
Scotch tape, 123
Thingiverse, 39, 179
Tinkercad, 39
tinkercad.com, 39
tools
  3D printers, 124-125
  automatic wire strippers, 122
  calipers, 120
  CNC mills, 125-126
  double-sided tape, 123
  dremels, 121
  drills, 121
  Fritzing, 117
  graph paper, 117
  hacksaws, 121
  hex wrenches, 119
  hot glue, 123
  Inkscape, 117
  jeweler’s screwdrivers, 119
  laser cutters, 124
  measuring tape, 120
  multimeters, 122
  multitools, 118
  needle nose pliers, 118
  notebooks, 117
  pens/pencils, 117
Phillips screwdrivers, 119
power supply, 122
protractors, 120
rulers, 120
SketchUp, 118
socket sets, 119
soldering equipment, 122
standard screwdrivers, 119
super glue, 123
velcro, 123
wire cutters, 122
X-Acto knives, 121
zip ties, 123
transmitters (blimp drones), 82
Tricopter, 17-18
Turnigy Brushed 30A ESC, 105
Types library, 228

U

UAVs (unmanned aerial vehicles), 1-4
UBEC (universal battery eliminator circuit), 106
universal battery eliminator circuit (UBEC), 106
unmanned aerial vehicles (UAVs), 1-4

V

velcro, 123
Vessels project, 11-12
Vice Grip wire cutter/stripper, 122
video cameras, 7
voltage ratings, 128

W

waterborne drones, 147
3D-Printed RC Boat, 16-17
advantages, 148-149
disadvantages, 148
Soda Bottle Boat project
building controller, 166-168
building drone, 156-166
overview, 154
parts, 155
programming, 170-171
Vessels project, 11-12
waterproofing electronics, 149
CorrosionX, 153
Pelican 1000-series cases, 151
sandwich containers, 150-151
sealed tubes, 152
XBee mesh networking, 153-154
waterproofing electronics, 149
CorrosionX, 153
Pelican 1000-series cases, 151
sandwich containers, 150-151
sealed tubes, 152
water-repelling enamel, 153
websites
3DRobotics, 226
APM Planner 2.0, 224
Ardupilot, 112
brooklynaerodrome.com, 33
firstpersonview.co.uk, 26
Game of Drones, 175
HitCase, 174, 181
Hoverfly, 112
makershed.com, 33
mBot, 194
MultiWii, 223
openbeamusa.com, 43
OpenPilot, 222
openrov.com, 27
parallax.com, 23
Parrot, 224
Scratch, 194
SenseFly, 224
servocity.com, 31
sketchup.com, 39
Skycat Recovery Launchers, 177
sparkfun.com, 31
Thingiverse, 39, 179
tinkercad.com, 39
Vessels project, 11
wire cutters, 122
wire strippers, 122
wiring harness, 127-128
assembling, 137
parts list, 138
steps, 138-142
battery selection, 128
battery types
lithium batteries, 128-130
NiMH batteries, 128
bullet connectors
overview, 130
parts list, 130-136
wood airframes, laser-cutting, 40
workbench tools
3D printers, 124-125
automatic wire strippers, 122
calipers, 120
CNC mills, 125-126
double-sided tape, 123
dremels, 121
drills, 121
Fritzing, 117
graph paper, 117
hacksaws, 121
hex wrenches, 119
hot glue, 123
Inkscape, 117
jeweler’s screwdrivers, 119
laser cutters, 124
measuring tape, 120
multimeters, 122
multitools, 118
needle nose pliers, 118
notebooks, 117
pens/pencils, 117
Phillips screwdrivers, 119
power supply, 122
protractors, 120
rulers, 120
SketchUp, 118
socket sets, 119
soldering equipment, 122
standard screwdrivers, 119
super glue, 123
velcro, 123
wire cutters, 122
X-Acto knives, 121
zip ties, 123
wrenches, hex, 119

X-Y-Z
X-Acto knives, 121
XBee mesh networking, 153-154
XXD HW30A, 105

yaw, 109

zip ties, 123