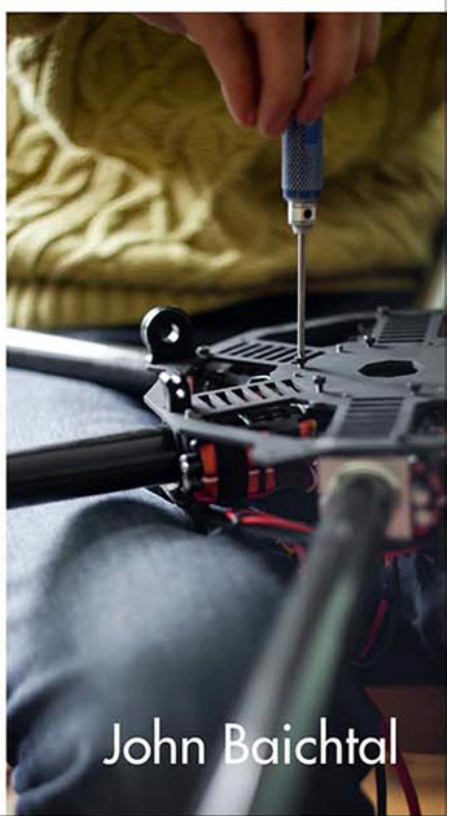
BUILDING YOUR OWN DRONES

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



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John Baichtal

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BUILDING YOUR OWN DRONES

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

John Baichtal

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800 East 96th Street,
Indianapolis, Indiana 46240 USA

Building Your Own Drones: A Beginners' Guide to Drones, UAVs, and ROVs

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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!

Workwise, thanks for the inspiration and assistance to Windell H. Oskay, Johngineer, Matthew Beckler, Riley Harrison, David Lang, Trammell Hudson, AnnMarie Thomas, Pete Prodoehl, Bruce Shapiro, Alex Allmont, John Edgar Park, Dexter Industries, Miguel Valenzuela, Pete McKenna, Steve Norris, Steven Anderson, MakerBeam, Jude Dornisch, SparkFun Engineering, Brooklyn Aerodrome, Adam Wolf, Michael Freiert, Sophi Kravitz, Christina Zhang, Lenore Edman, Rick Kughen, Sean Michael Ragan, John Wilson, Susan Solarz, Akiba, Mark Frauenfelder, Chris Berger, Michael Krumpus, Alex Dyba, Brian Jepson, Becca Steffen, Dave Bryan, Actobotics, Mike Hord, Makeblock, Pat Arneson, and Erin Kennedy. Apologies to anyone I forgot!

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 the 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 its 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!

4

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.

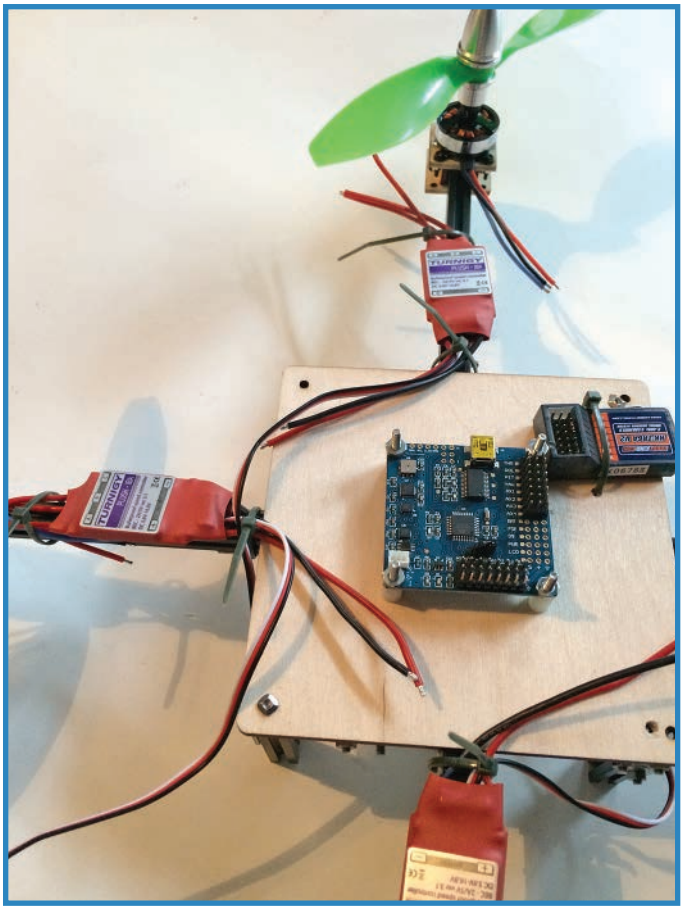

FIGURE 4.1 Build this quadcopter yourself!

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.

- **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 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.

FIGURE 4.3 Build an airframe just like this with the steps shown later in this chapter.

3D Printer

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!

FIGURE 4.5 The Flone airframe is easily laser-cut out of a piece of wood (credit: Lot Amoros).

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.

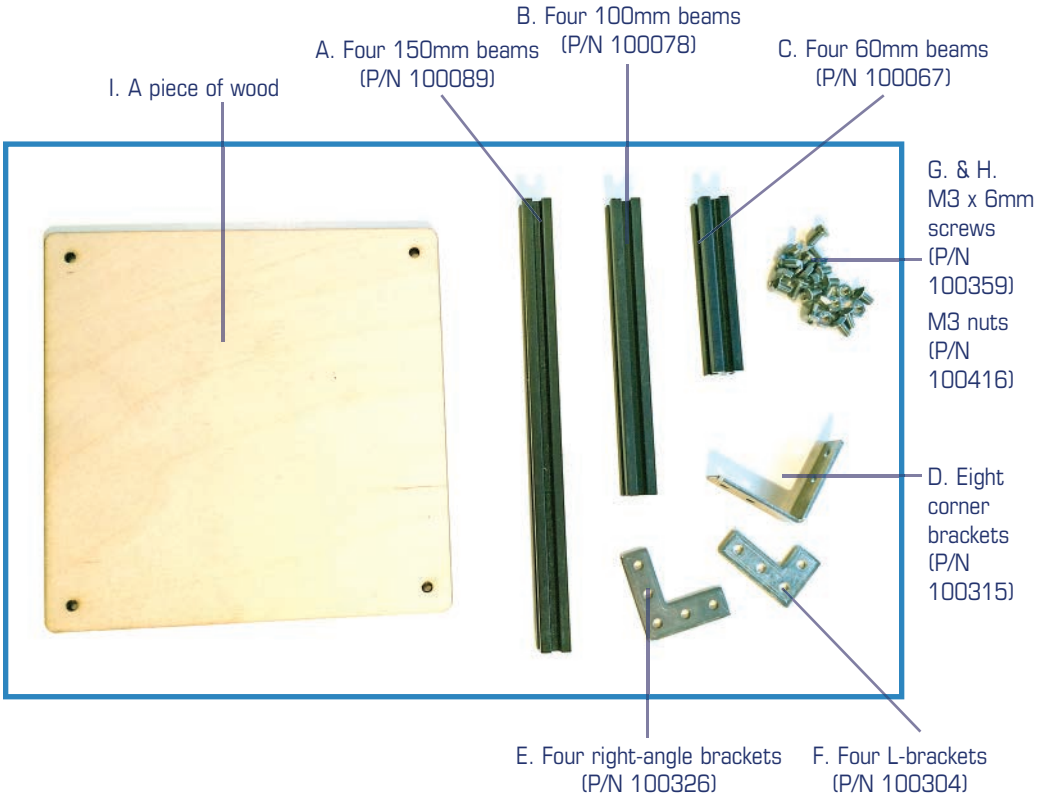

FIGURE 4.8 You'll need these parts to build your MakerBeam airframe.

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.

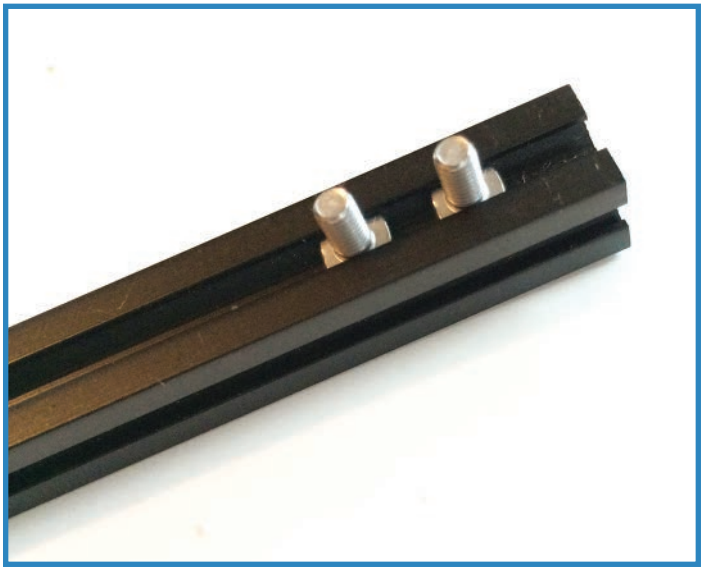

FIGURE 4.9 Slide the heads of two M3 screws into the grooves of a 150mm beam.

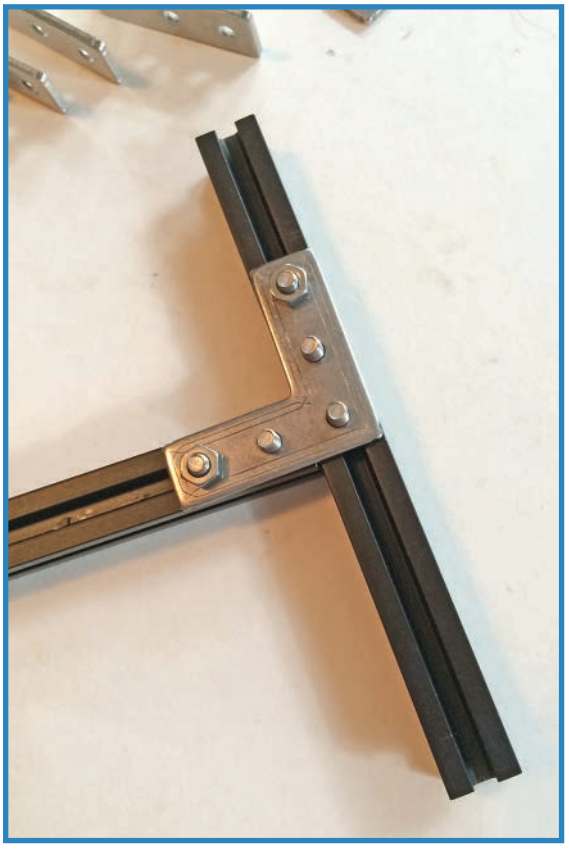

FIGURE 4.10 Make a "T" with the two beams and secure with a bracket.

c. Add a corner-bracket to help secure the beams, as shown in Figure 4.11. Secure the bracket the normal way.

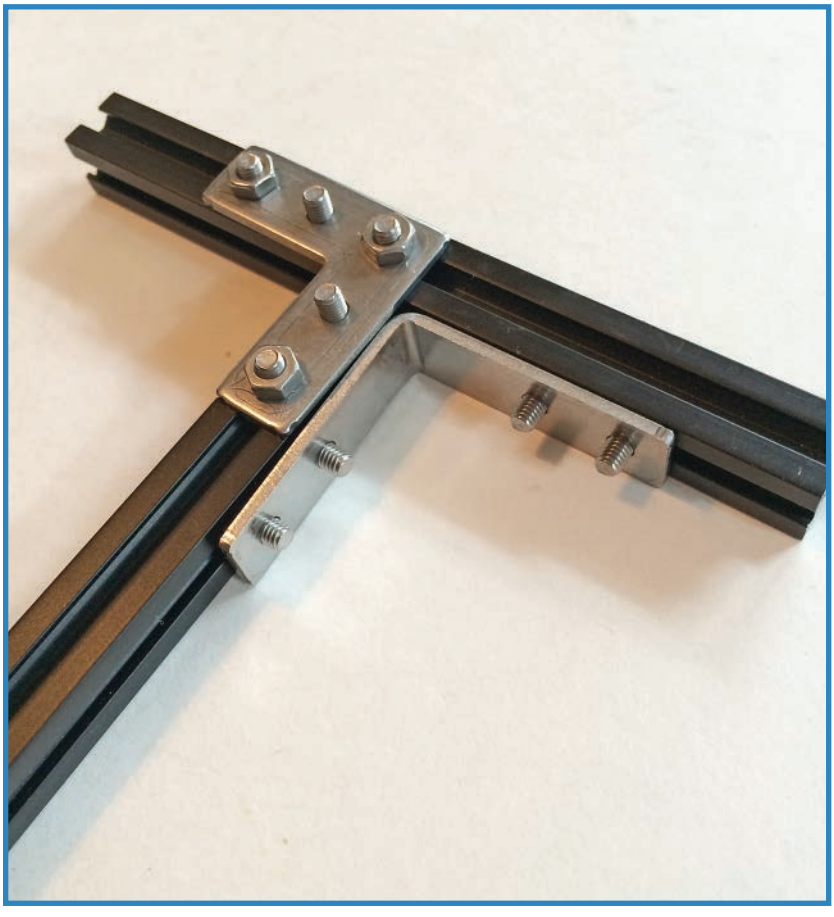

FIGURE 4.11 Reinforce the "T" with another bracket.

d. Attach an L-bracket to the top of the 10cm beam, positioning it like you see in Figure 4.12.

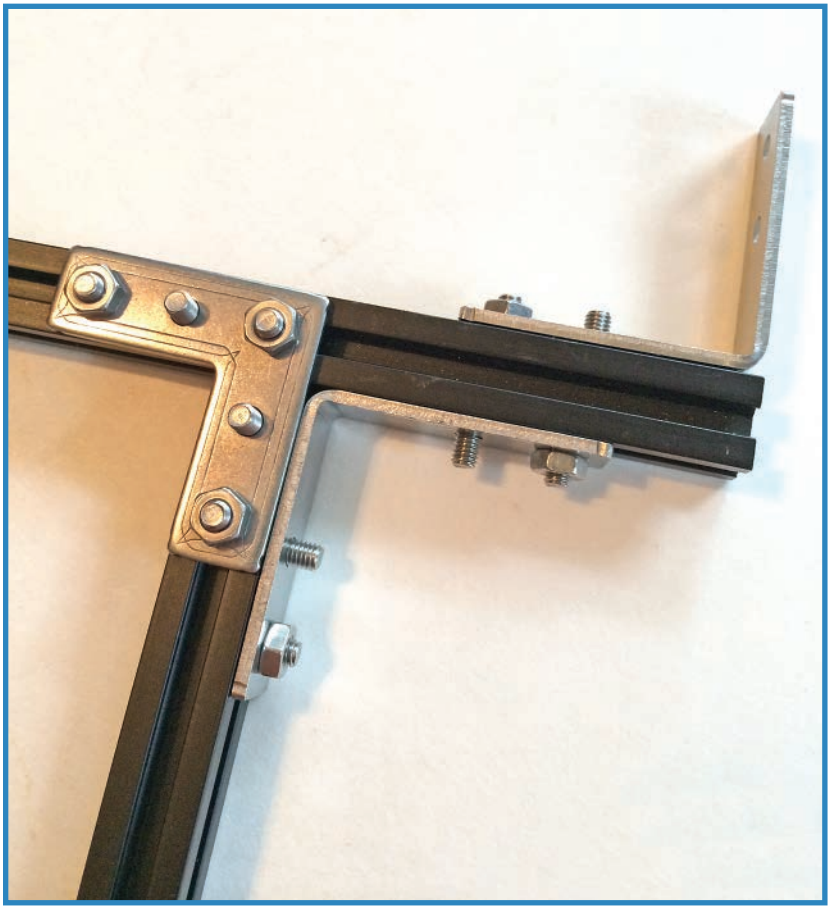

FIGURE 4.12 Add another bracket.

2. Once you have all four built, connect them together using the usual hardware. It should look just like Figure 4.13.

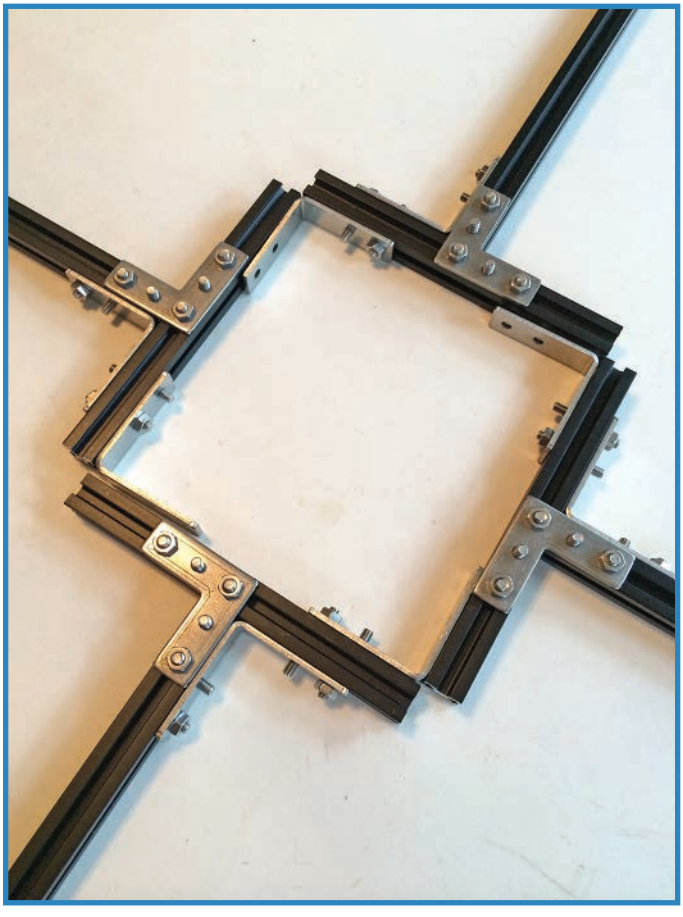

FIGURE 4.13 Add the four segments together, and you start seeing your airframe take shape.

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.

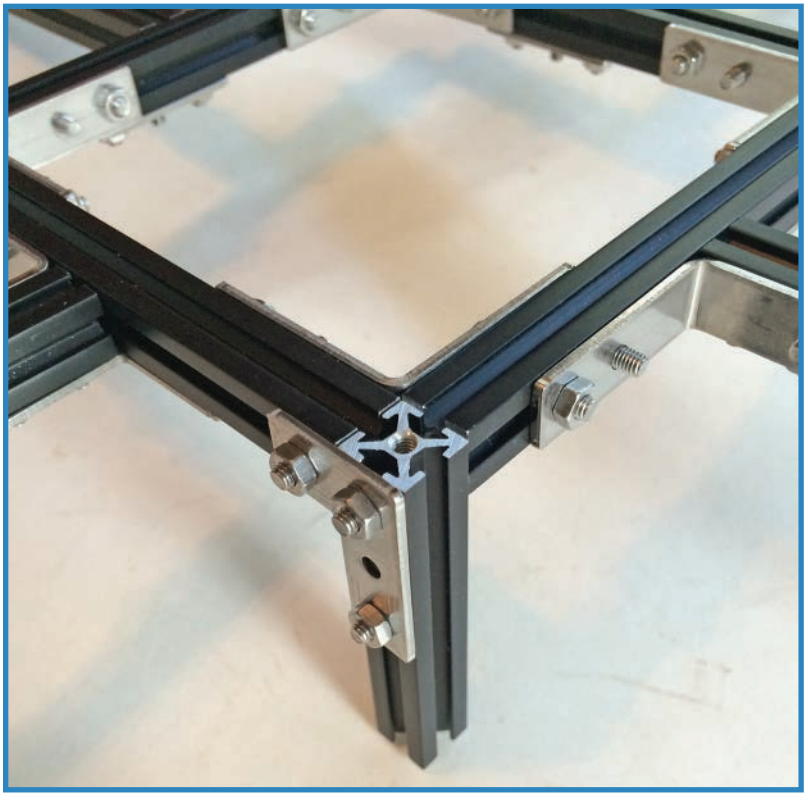

FIGURE 4.14 Add legs!

FIGURE 4.15 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 fight.

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