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Make:

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THE COMMUNITY ISSUE

Building Planes, Trains, and DIY Robocars Together

MEGABOTS

Readying the Beast for Battle

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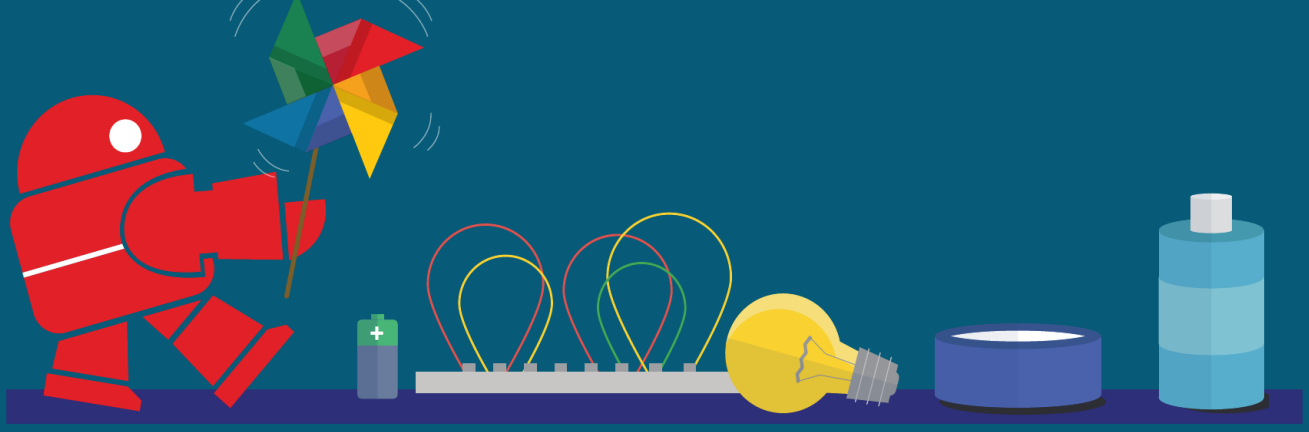

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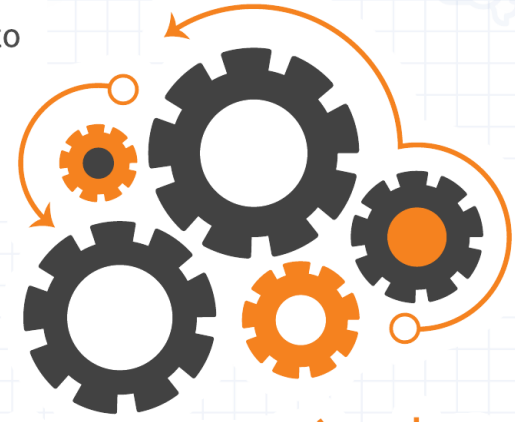

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ON THE COVER: The MegaBots Mk.III weighs in before entering the arena. Photo: Hep Svadja.

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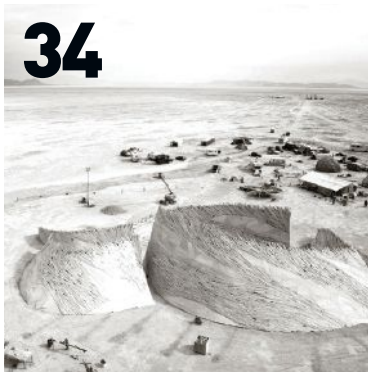

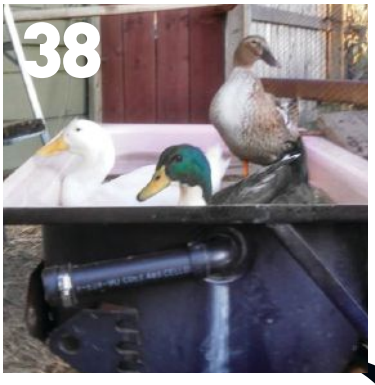

Joel Reid, Hep Svadja, Curley, Cole Novotny, Will Atwood, The McKenty Brothers, Charles Platt

Origami

Make:®

"One man alone can be pretty dumb sometimes, but for real bona fide stupidity, there ain't nothin' can beat teamwork." — Edward Abbey

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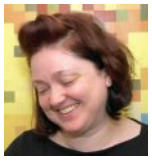
CONTRIBUTORS

What's your super-sized team-built dream project?



Mandy Stultz
Warwick, RI
Hamming It Up

I've been dreaming up a wall-sized aquaponics system for our hackerspace (Ocean State Maker Mill), to share the harvest with our whole building. Salads and fruit for all!

Jess Hobbs
San Francisco, CA
Building Burning Man

One dream project is to build a park for large-scale interactive sculpture on the West Coast to call home. Sadly, most of it lingers in 40-foot containers in and around the SF Bay Area.

The McKenty Brothers
Cortes Island, BC, Canada, Covert Communication

An autonomous garbage barge that roams the ocean, scooping up, sorting, and recycling plastic. Eventually it'd make us rich and fund even bigger and better garbage barges!

Cintia Gonzalez-Pell
Melbourne, Australia
Scrap Fabric Twine

I'd love to work on a large rug or tapestry with a team of fibre artists, preparing, spinning and dying yarn, then working together to weave or hook a finished design.

Taylor Callery
Baltimore, MD
Come Together illustration

The dream is to create studio spaces and living quarters that artists, creatives, and like-minded people can flourish in by working together to maintain the community.

Making a Difference

HOW *MAKE:* CHANGED MY LIFE

From the time I was very young, I identified as an outsider and though I didn't have a word for it, a maker. As a third generation entrepreneur, son of a machinist, making is in my blood. I picked up *Make:* Volume 01 in Barnes & Noble, an act that changed the course of my life. Eight years later I had joined a makerspace and then created my own as a business with my best friend, Dustin Smith. Quickly, C4 Labs transformed into a makerspace with a product-design focus and through a chance encounter with Intel's Jay Melican at Portland Mini Maker Faire, ended up selling custom cases to Intel for the Galileo, which were inspired by an article in *Make:*.

Recently I was brought on as director of MakerLab at Portland Community College. It's been a huge dream come true to be in the lives of young people empowering thought, innovation, and creativity. I can trace that success directly back to the influence *Make:* had in my life with Volume 01. *–Ed Ivory, Portland, Oregon*

GETTING STARTED WITH ELECTRONICS

I would like to say "thank you" to Charles Platt! 1.5 months ago I knew nothing about electronics. And I had a task to build a device, which you can control with your brain (through brain-computer interface). I'm a game designer with some background in programming, but working with offline stuff and electricity was new to me.

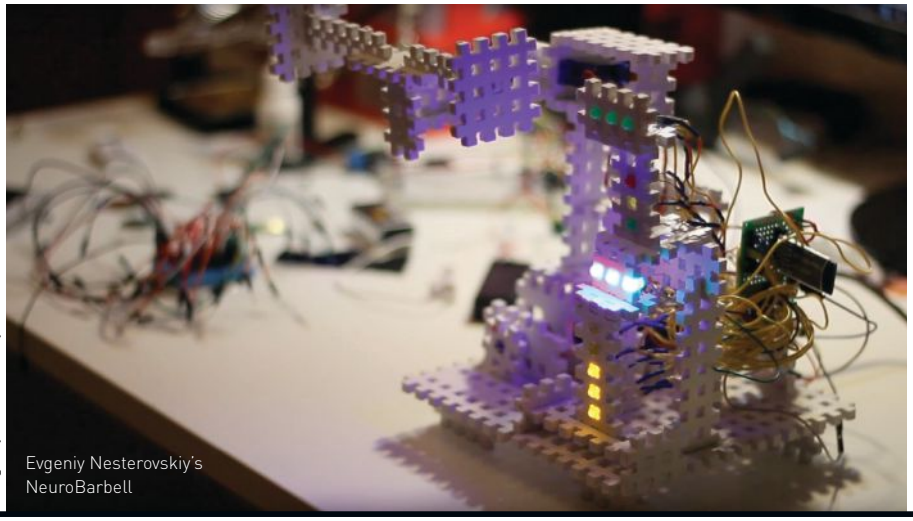
So, I bought *Make: Electronics* (first edition, I think) and it's one of the best self-study books I've ever read. Sometimes it was a little bit hard, but I kept reading and practicing.

Here is a video of my working device: youtube.com/watch?v=Sb7LZMBaYNw. It mostly uses Arduino, but I couldn't make it without the strong theoretical base I've got from *Make: Electronics*.

Thank you, Mr. Platt! You're my hero.
–Evgeniy Nesterovskiy, Moscow, Russia

Make: Amends

In *Make:* Volume 55, we misspelled one of the makers' names of the Canyonero project (pg. 96). His correct name is Juan Pedro López. Our apologies.

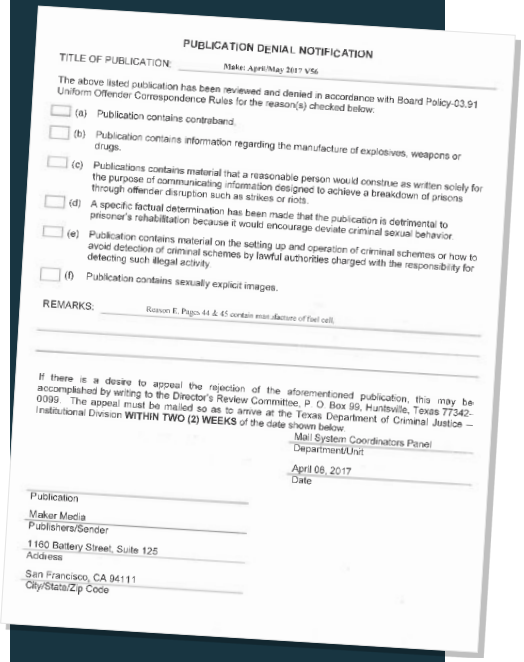


Evgeniy Nesterovskiy's NeuroBarbell

Evgeniy Nesterovskiy

Prison Ban of the Month

- **LOCATION:** Texas Department of Criminal Justice
- **TITLE:** *Make:* Volume 56
- **REASON:** Publication contains material on the setting up and operation of criminal schemes or how to avoid detection of criminal schemes by lawful authorities charged with the responsibility for detecting such illegal activity. Pages 44–45 contain manufacture of a fuel cell ["Microbial Fuel Cell"].



PUBLICATION DENIAL NOTIFICATION

TITLE OF PUBLICATION: Make: April/May 2017 V56

The above listed publication has been reviewed and denied in accordance with Board Policy-03.91 Uniform Offender Correspondence Rules for the reason(s) checked below:

(a) Publication contains contraband.
(b) Publication contains information regarding the manufacture of explosives, weapons or drugs.
(c) Publications contains material that a reasonable person would construe as written solely for the purpose of communicating information designed to achieve a breakdown of prisons through offender disruption such as strikes or riots.
(d) A specific factual determination has been made that the publication is detrimental to prisoner's rehabilitation because it would encourage deviate criminal sexual behavior.
(e) Publication contains material on the setting up and operation of criminal schemes or how to avoid detection of criminal schemes by lawful authorities charged with the responsibility for detecting such illegal activity.
(f) Publication contains sexually explicit images.

REMARKS: Reason E. Pages 44 & 45 contain manufacture of fuel cell.

If there is a desire to appeal the rejection of the aforementioned publication, this may be accomplished by writing to the Director's Review Committee, P. O. Box 99, Huntsville, Texas 77342-0099. The appeal must be mailed so as to arrive at the Texas Department of Criminal Justice – Institutional Division **WITHIN TWO (2) WEEKS** of the date shown below.

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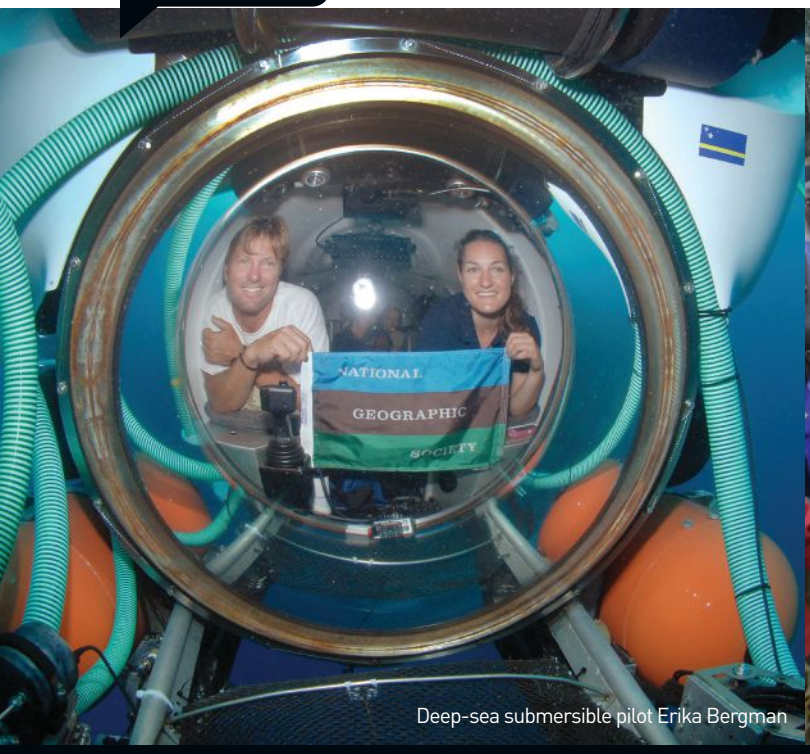


Deep-sea submersible pilot Erika Bergman


Chukudu scooter building in the Kiziba refugee camp

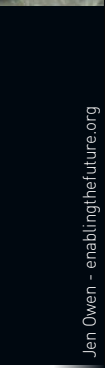
Mission Possible

Create open communities to solve problems of greater sophistication and significance

by Dale Dougherty


Public Lab prepares to do balloon-mapping


Syria Airlift aims to deliver humanitarian aid



GEECs.com, Doug Bradbury, Public Lab, Hep Svadja, SeaCharger, SpiroEdge, Donna Sanchez, Jen Owen - enablingthefuture.org

I HAVE ALWAYS ENJOYED GETTING TO KNOW MAKERS and their stories. I enjoy learning about what they make and how they make it, but I find especially fascinating why makers make what they do. Many projects start from a personal interest or passion, but then go beyond what the maker might have imagined. Makers explore and experiment; they create and innovate. Collectively, as a community, makers are having an impact by defining personal and social missions.

Ideas into Action

In our January issue's "The Little Boat That Could," Damon McMillan told us about his project to build an eight-foot boat, a solar-powered autonomous craft. It was a project that started in his garage and he saw it as a personal challenge — not one done for a competition or to make money. He simply wondered if he could build this boat and if it would work. In May of 2016, he showed his boat at Maker Faire Bay Area and got lots of feedback on his design, and some skepticism on whether or not it would work. Later that same month, Damon took the boat to Half Moon Bay and launched the SeaCharger, setting it off on a 2,400-mile mission to Hawaii. The boat was able to inform him where it was on the journey via satellite. Some 41 days after launch, Damon and his family gathered in a harbor on the Big Island of Hawaii and watched his boat come to shore. Damon had built a boat and proved to himself and others what could be done with cheap electronics and basic fabrication techniques. He had completed a mission to demonstrate that his boat could sail on its own over that distance.

Designing and building the boat is just part of the story, and it didn't end in Hawaii either. Because he is a maker, and didn't want to pay to crate and ship his boat back to California, he put the boat back in the ocean and programmed it to go to New Zealand. SeaCharger traveled an additional 6,480 miles before its rudder broke. It was eventually picked up by a container ship and brought to New Zealand, and placed on display in the New Zealand Maritime Museum.

Hannah Edge is a 15-year-old high school student in Dublin, California who showed me a device she had designed and 3D printed. She called it a "spirometer" and I had to stop and ask her to explain what a spirometer is. She said that it measures breathing, specifically intake and outflow of your lungs. I asked her why she designed a spirometer and she said that she has asthma. She goes to the doctor's office where they have a spirometer but she wondered if she could design a device that would be affordable for personal use. Not many asthma attacks happen in a doctor's office. Her device, which she named "SpiroEdge," is now a product and connects with a smartphone to collect data and produce reports. She rightly believes that others share her problem and would benefit from using SpiroEdge.

The DIY ethos behind the maker movement encourages more people to figure out things for themselves — that you can learn to do anything if you want to do it. Not everybody knows how to solve the problems they encounter. Yet more people are aware that it is possible that such a problem could be solved, even if they can't figure it out by themselves.

Donna Sanchez wondered if some kind of device could help her 11-year-old daughter, Malia, who has cerebral palsy. She thought there could be a tool to assist Malia to express herself more clearly so that others could understand her, as her mother does. Donna had in mind a name for the device — an "Articulator" — that would recognize Malia's speech and convert it into plain spoken English. Malia could wear the articulator around her neck or on her wrist. Donna had the idea for a device but she wrote us, asking if there were makers who might figure out how to build it. I know there are makers who would be interested.

Leveraging the Maker Community

Open communities of practice have grown up in the maker movement that help to organize makers who can do things as well as people they might serve. One example is the e-Nable community that brings together makers who contribute designs for prosthetic hands and makers with expertise in 3D printing. E-Nable helps people share expertise and learn to solve problems together. I recall meeting a parent at a Maker Faire who exclaimed that he knew nothing about 3D printing a year ago. When he discovered that he could use one to create a prosthetic hand for his son, he became part of the community and learned to do so. When I heard his story, he was standing next to his son who held up a bright-red hand and flipped it over to show me the black Batman logo. Both of them were beaming with pride.

As the maker movement grows, we can pursue two

Damon McMillan and the SeaCharger

Hannah Edge's SpiroEdge

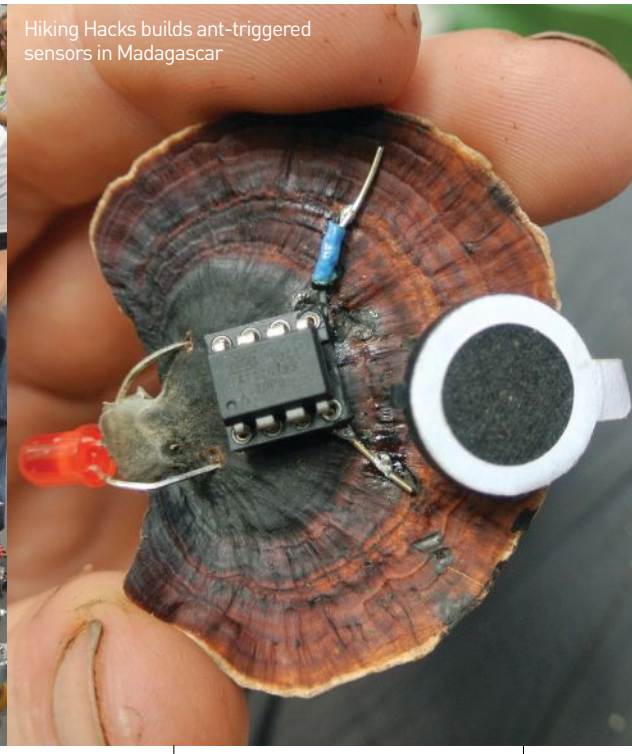
Malia Sanchez

A Thor-inspired E-Nable build

Iron Man-style E-Nable hand

Topher White's devices detect the sounds of illegal logging

The global Tikkun Olam Makers network helps a girl with mobility needs in Buenos Aires



Hiking Hacks builds ant-triggered sensors in Madagascar

large goals. First is to broaden participation in the maker movement so that more people from diverse backgrounds get access to tools and develop skills and mindset as makers. Second is to create open communities that have a mission to combine the range of abilities of many makers to solve problems of greater sophistication and significance. We can leverage the maker community for research, collaborative production, and open innovation, solving problems that many of our institutions struggle to solve and serve people who are not well served today.

Missions for Makers

This summer, we are launching a new online platform called Maker Share. Much like Maker Faire, we want to enable makers to share their projects, which show their interests and demonstrate their capabilities. On Maker Share, you can create a maker portfolio. You can tell your own story, share a show-and-tell video for each project that explains what you made and why you made it. We developed Maker Share with Intel as a partner to promote collaboration and innovation in the maker community. Maker Share will also host missions and invite makers to participate by solving important problems and helping other people. You'll find the Malia Project as a mission on Maker Share. I expect that we will see all kinds of missions presented on Maker Share — humanitarian, conservation, energy innovation, healthcare, and more. Sharing a mission with other makers can be a rewarding experience personally. By documenting these missions, the maker movement can demonstrate tangible benefits to society and justify investment in makerspaces, microfactories, and innovation labs that support makers.

Consider defining a mission for yourself as a maker. Many artists have a mission statement that shapes what they do and helps them explain why they make a number of choices. Consider joining missions or leading one of your own. One might even think that learning to become a maker is training to become part of an important mission.

Maker Share

To create a portfolio, visit makershare.com

Rainforest Connection, TOM, Hannah Perner-Wilson, Tribhuvan University, Field Ready

Radio Mala sets up communications in post-earthquake Kathmandu

The Field Ready team 3D prints in Nepal

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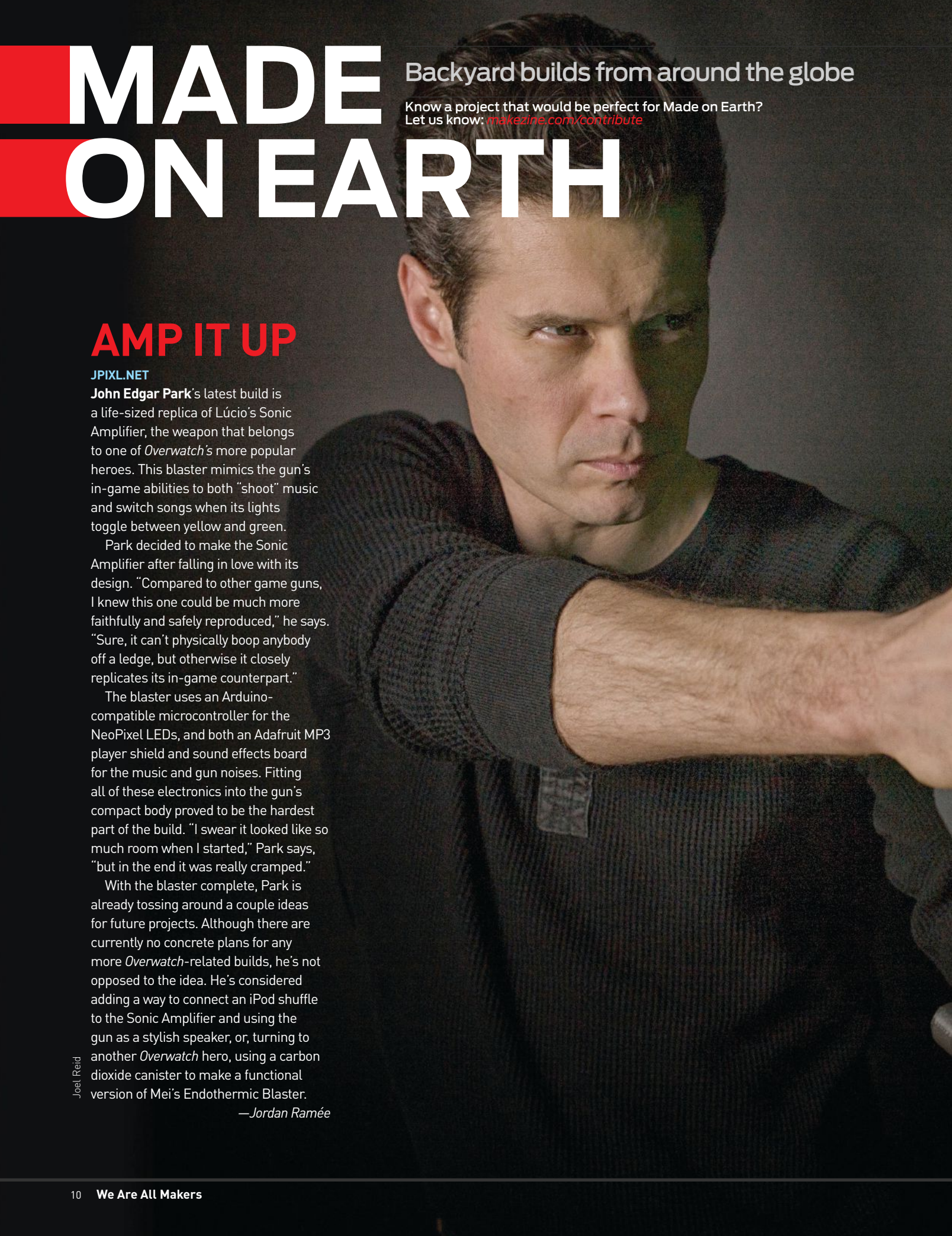


Joel Reid

AMP IT UP

JPIXL.NET

John Edgar Park's latest build is a life-sized replica of Lúcio's Sonic Amplifier, the weapon that belongs to one of *Overwatch's* more popular heroes. This blaster mimics the gun's in-game abilities to both "shoot" music and switch songs when its lights toggle between yellow and green.

Park decided to make the Sonic Amplifier after falling in love with its design. "Compared to other game guns, I knew this one could be much more faithfully and safely reproduced," he says. "Sure, it can't physically boop anybody off a ledge, but otherwise it closely replicates its in-game counterpart."

The blaster uses an Arduino-compatible microcontroller for the NeoPixel LEDs, and both an Adafruit MP3 player shield and sound effects board for the music and gun noises. Fitting all of these electronics into the gun's compact body proved to be the hardest part of the build. "I swear it looked like so much room when I started," Park says, "but in the end it was really cramped."

With the blaster complete, Park is already tossing around a couple ideas for future projects. Although there are currently no concrete plans for any more *Overwatch*-related builds, he's not opposed to the idea. He's considered adding a way to connect an iPod shuffle to the Sonic Amplifier and using the gun as a stylish speaker, or, turning to another *Overwatch* hero, using a carbon dioxide canister to make a functional version of Mei's Endothermic Blaster.

—Jordan Ramée

METICULOUS MEDIUM

BEHANCE.NET/WILLATWOOD

When you're staring straight at them, **Will Atwood**'s three-dimensional resin paintings appear at first glance to be just that — paintings. Look a little closer at one and you'll see the drop shadow. Approach it from an angle and the separated layers will reveal themselves.

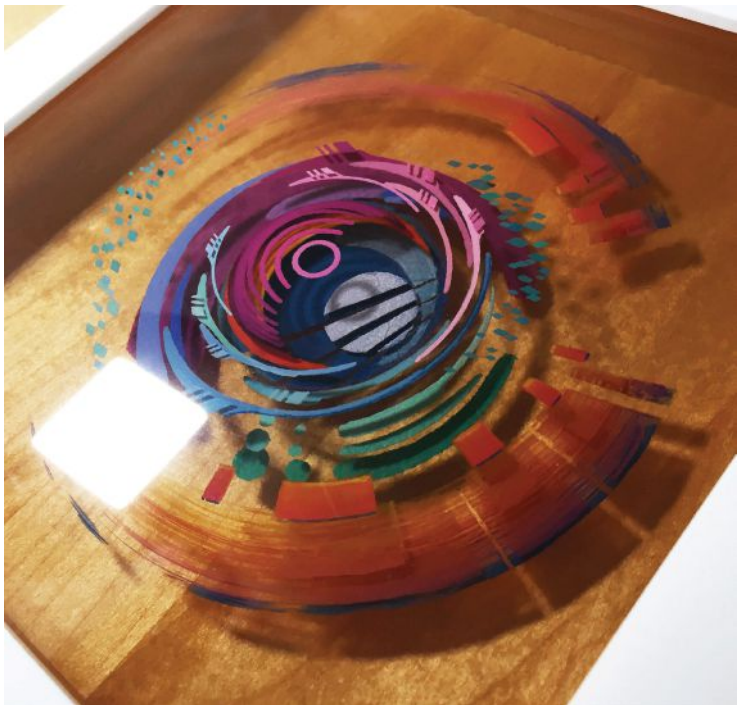
Atwood's pieces average about 20 layers. He works on several simultaneously to optimize time spent mixing resin and waiting for layers to cure. "If I'm working nonstop," he says, "I can make a few pieces from start to finish over the course of a few weeks."

To plan out his pieces, Atwood uses design software like Illustrator and Photoshop, as well as Blender, Rhino, and Fusion 360. "Resin makes it easy to erase the layer you're working on, but if I want to prototype something that would unfold over multiple layers, I'll turn to digital tools to make mock-ups to see how the idea might work," he explains. "I'm inspired by the technical aspect of merging the analog and the digital, using a vast array of tools to help realize a novel idea and create something new."

The medium of resin itself often complicates his planning, though. He says the most difficult part is just the finicky nature of the material itself. It's impossible to cure it with absolute pristine clarity — hairs, smudges, and bubbles are inevitable hiccups. When unsightly imperfections happen, Atwood has to change course. "Sometimes these adjustments to unexpected problems can yield a more interesting final product than what I'd planned!" he says.

Atwood is now experimenting with unframed pieces so that the layers can be admired from all angles, such as the piece featured to the left, *Second Law*.

—Sophia Smith



Will Atwood

LAND PHIL

MAKEZINE.COM/GO/LAND-PHIL

It all started with a wooden left hand. Once finished I decided to build the hand a body.

The ensuing sculpture, dubbed Phillip, is an amalgamation of useless items accumulated through years of collecting, tinkering, and repurposing. I'm a tall guy, but he's seven foot and broad shouldered. Everything down to his plywood skeleton was found or salvaged and repurposed, ranging from shells to old game consoles.

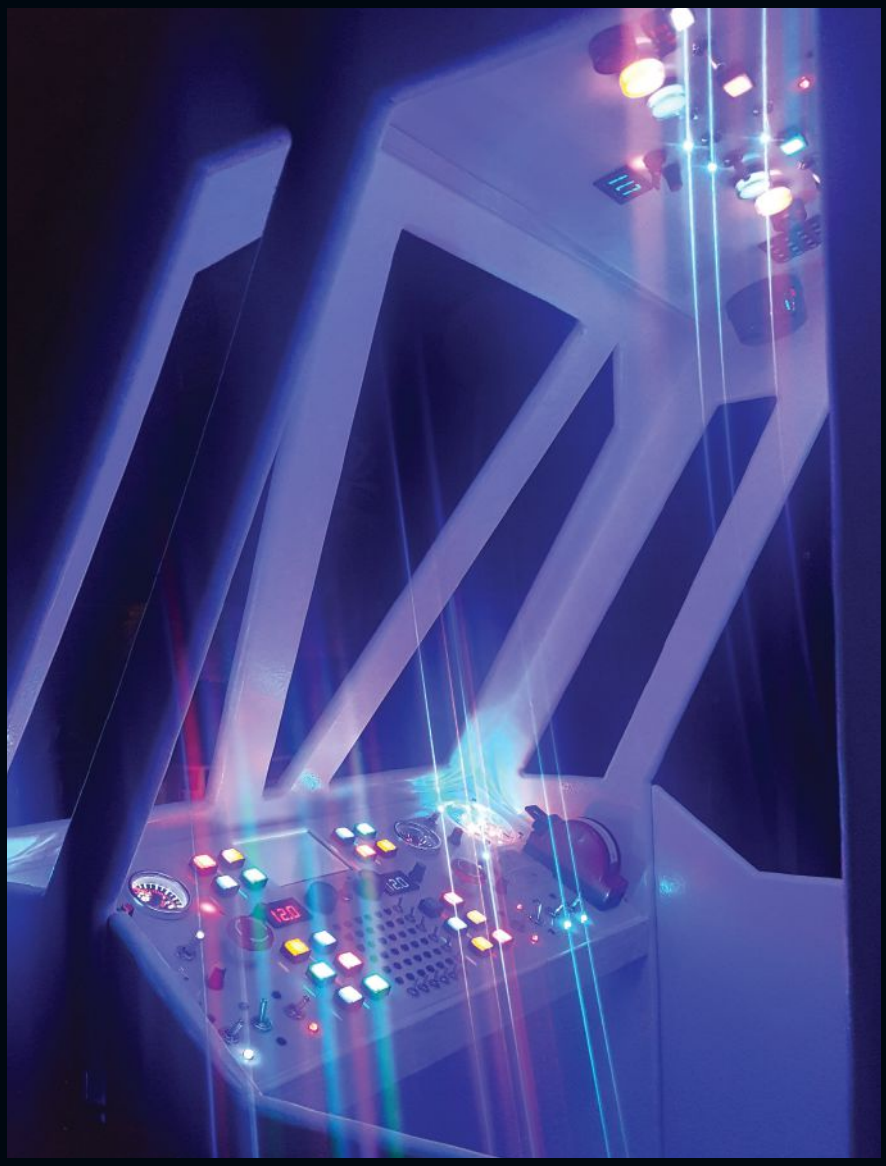
The various areas of his body and their corresponding materials were decidedly thematic. I tried to use more "intestinal" materials in the abdomen and branch out into larger, more robust materials in appendages. In the tradition of makers, many Altoids tins were adapted to his frame. His skeleton is composed of plywood cookies shaped and fitted together with the band saw.

Most of his appendages are opposable. His shoulders rotate like ours, head turns, knees bend. I measured nothing on him; everything was eyeballed. This made creating Phil a flow. Once I had frames for each body part built I simply diced up materials which possessed textures I wanted. Using materials in this way, only utilizing what I had and not planning anything, let the material influence the build as much as my vision. This is a large part of what makes Phil himself.

In all honesty, the most difficult part of the build was designing and implementing a viable stand. He's a big boy. Currently he resides in a workspace in Willmar, Minnesota, called Workup. I've always wanted to make him a companion, something like a parrot for his shoulder. Emulating the texture of feathers with junk would be fun. —*Ben Noeldner*

Wyatt Allen

BLAST OFF TO BEDTIME



Pete Dearing

MAKEZINE.COM/GO/SPACE-BUNK-BEDS

Pete Dearing is undoubtedly winning the maker dad of the year award for the interactive cockpit in these spaceship bunk beds.

He'd noticed how much his kids adored buttons; "Elevators, remote controls, mobile phones, they just loved them," he says. He first made a basic control panel out of some switches and buttons mounted on top of an old toolbox with a power source inside. The boys kept asking him to add more buttons. So, Dearing decided to build something more permanent. With no real experience in electronics or woodwork, Dearing sought inspiration online, and purchased plans for a rocket ship bunk bed (playhousedesigns.com/product/space-shuttle-bunk-bed-plans).

The build took roughly 100 hours. After adjusting the plans and converting to metric, Dearing was ready to roll. He cut sheets of MDF using large printouts of the plans, and began gluing and laying out pieces to visualize spacing for the control panel. The boys helped, and even had some creative input: "The 'hidden' room under the slide was actually my 5-year-old's idea. He asked if we could cut a door so he could hide his toys!"

After setting up the control panel, Dearing says one main oversight was planning the layout based only on the front. Since most of the pieces were bigger on the back, the inside was rather cramped when it came to wiring.

The electronics run on 12V power, and "the whole bed runs though a timer that cuts power at night, but it's also only turned on when they are actively playing," says Dearing. The system also has big, red emergency stop buttons that the kids love incorporating into their games.

Most of the buttons control real lights, sounds, fans, meters, and headlights. All the sounds are controlled via Raspberry Pi. Plus, Dearing wired in a couple sets of headphones with mics, so that the kids can communicate with each other just like real space explorers!

Even though it's a rocket ship, the bunk bed has transformed into everything from a bus to a submarine during playtime. When asked if he gets to help pilot the ship, Dearing says, "Of course! I can't fit into the cockpit easily, but I still get to wear headphones and join in."

—Sarah Vitak

THE MAGIC OF MAKER FAIRE

GLIMPSE SOME OF THE FANTASTIC PROJECTS THAT CONVERGED AT OUR BIG EVENT THIS MAY

Written by Hep Svadja

Maker Faire is one of the most exciting events in the world to photograph, and each year our photo team captures the spirit of the event as it happens. Here are some of the amazing projects featured at our Bay Area flagship show this past May.

1 ***Le Attrata*** is a glorious installation that combines a moth's fascination with light and heat, and human fascination with elaborate works of fire. Towering above the grounds, these three metal moths spit colored fire effects and a cacophony of loud noises. [Photo: Sydney Palmer]

2 ***Tobor the Gigantic Dinosaur*** is capable of picking up objects when guided by a hacked Wi-Fi glove. Tobor was built by a multidiscipline, 14-person team from the **Northampton Community College's Fab Lab**. [Hep Svadja]

3 The giant, inflatable ***Jack*** by **Chromaforms** was a favorite with kids. Weighing only 140lbs, it was easy for groups of children to roll it or even pick it up. [Hep Svadja]

4 The centerpiece of the Dark Room this year was ***Deeper*** by **Peter Hudson**, a large-scale moving, illuminated zoetrope that depicts a man diving down into the floor. [Becca Henry]

5 The victors of **The Power Racing Series Endurance Race**. From left to right: Nimby Ferrari, Kitty Grabs Back, and MarioKart. [Hep Svadja]

6 **The Exploratorium's Tinkerlab** offered illuminated expression for artists of all ages. Full of light-bending experimentation, cardboard movie-scene construction, and a gallery of illuminated shadowbox sculptures, the lab had something to please everyone. [Jun Shéna]

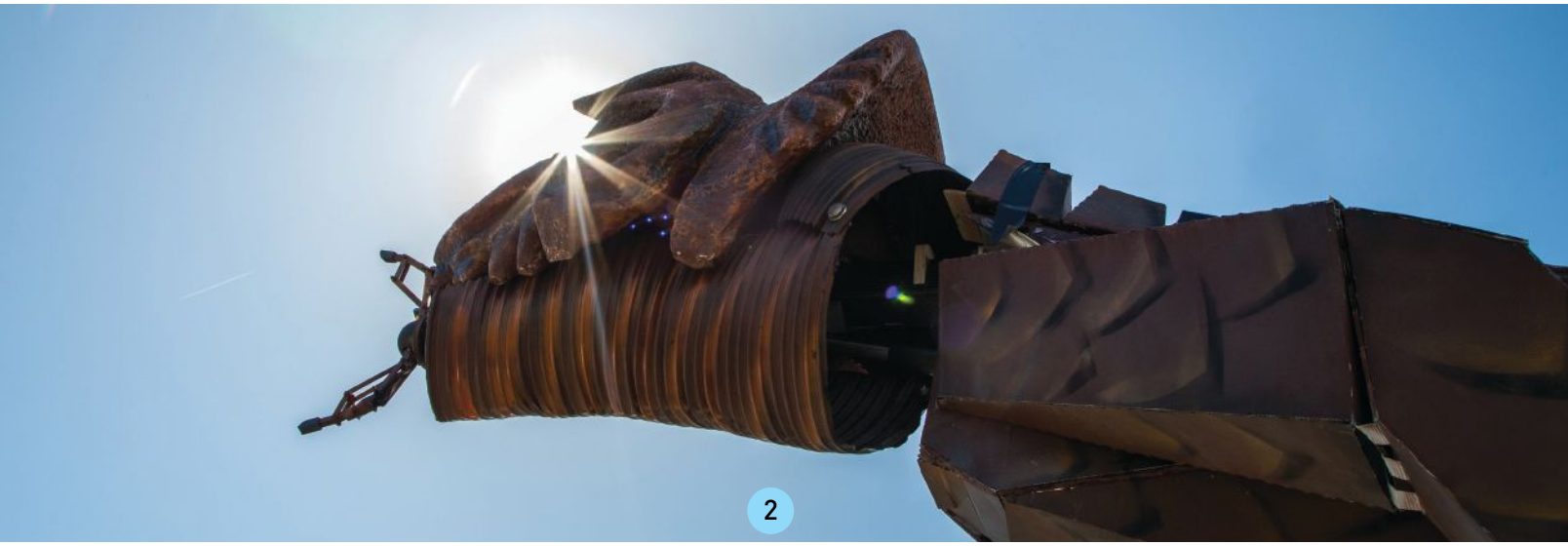
7 **Adam Savage** rides to his "Sunday Sermon" on **La Machine's *Ant***. La Machine is a French street theatre group lead by **François Delarozière** that builds elaborate and fantastic mechanical creatures. They let Maker Faire patrons pilot the *Ant* all weekend. [Jun Shéna]

8 **Aerial Sports League** provided an action-packed weekend of first-person-view drone racing on their multilevel, illuminated course. Fairegoers could fly along in FPV with competing pilots in an area set aside for passive co-pilots. [Becca Henry]

9 **The Crucible** was working throughout the sweltering weekend, teaching a variety of hot arts including blacksmithing and glassblowing. [Hep Svadja]

10 When Maker Faire got a little too overwhelming, you could kick back inside the **AZoth Pyramid** for a meditative experience using biofeedback, binaural beats, and rhythmic light technology. [Hep Svadja]

11 ***Odo***, the beautiful art deco dragonfly by **Chris Merrick**, was spotted gracefully wending its way across the grounds. It's constructed with multiple sets of metal filigree segments backed by opaque panels filled with LEDs. [Jun Shéna]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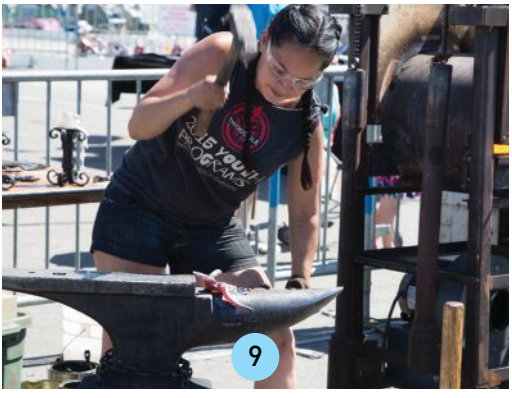
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STANDING ♀UT

Written and photographed by **MIKE SENESE**

Female engineers shine at the inaugural Maker Faire Kuwait

MIKE SENESE is the executive editor of **Make:**.

SITTING BETWEEN IRAQ AND SAUDI ARABIA ALONG THE NORTHWEST CORNER OF THE PERSIAN GULF (regionally called the Arabian Gulf), Kuwait is a tiny, triangle-shaped country, about the size of Connecticut and Rhode Island. Historically, it was a boat-building and trade leader for the Arabian peninsula. The discovery of large oil reserves in the 1930s helped Kuwait develop a strong focus on science and engineering and turned it into one of the richest countries in the world.

I wasn't too familiar with these aspects as I traveled to Kuwait for its first Maker Faire this past February. Approaching at night over the Gulf by plane, the tall, modern downtown glowed below, each building brightly lit up with flashing lights along the waterfront. The roads appeared empty compared to Western cities — I later learned this is due, in part, to it being an alcohol-free country with little proper nightlife, but also because the country rises for 5am daily prayer, followed by a workday lasting from 7am until 3pm. (Kuwaitis also pay no taxes, another perk of their lofty economic position — Porsche Cayenne SUVs abound like Honda Civics do in the United States.)

In the daylight, the desert's grit offset some of the nighttime gleam, with dusty construction revealing a rapid transition between the country's past and today's glossy downtown skyscrapers and towers.

A SHOWCASE OF HIGH-TECH ENGINEERS

The next morning, I arrived at the shiny, metal-and-glass Kuwait International Fairgrounds, which is located in a quickly growing area about half an hour from downtown. There I met Hala Montague, the senior PR officer of Kuwait Investment Company (KIC), the Faire's main supporter and organizer. Energetic and in charge (and a wonderful tour guide over the next three days), she quickly introduced me to many of the exhibitors, including a cheerful local artist who hand carves intricate designs into all types of bird eggs, ranging in size from small marbles to ostrich eggs the size of a Nerf football — he told me those ones in particular are not easy to come by. I noticed many groups of schoolchildren touring the space, eagerly listening to the makers

explain their projects, participating actively in the 3D Pen Workshop, and throwing balls at a wall to pop virtual balloons and unlock a prize. Youth was on display not only at the Faire, but also throughout Kuwait in general, where 70% of the population is under age 30.

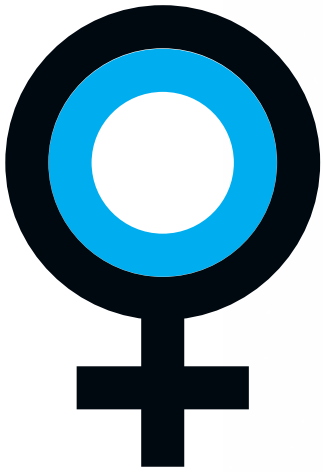
The other group helping organize the Faire was Creative Bits Solutions, a Kuwaiti-based business that distributes tools and electronics for makers in the Middle East. Ahmad Alsaleh and his family founded and run the business. He and his friend Nasser Alkhaldi brought the maker movement into Kuwait by launching the country's first FabLab; they also design and sell an educational robotics hardware platform called Ebot. In 2014, they participated as makers at World Maker Faire New York and brought home the idea of organizing their own faire.

The Kuwait producers split their show into two sections: artist projects on one side of the hall and tech projects on the other. Altogether there were 67 local makers sharing projects ranging from high-tech inventions to handmade regional crafts. Many of the tech groups came from engineering programs at local universities or were recent graduates showing their capstone projects.

As I met the makers in the tech area, I began to notice that the majority were proud young women who were electrical engineers, mechanical engineers, computer science engineers, and IT professionals. The proportion of female makers outweighed what I see at Maker Faires in the United States or Europe.

This female prominence can be traced back to the country's historic and more recent engineering and science needs. Kuwait's massive resources have always been offset by a relatively small population, which has provided employment opportunities for women. Countries with a strong travel culture also tend to move toward modern ideals. And despite both a massive stock market crash in the early '80s and turmoil from the Iraqi invasion of 1990, Kuwait has maintained a progressive position in the region for arts, media, government, and gender. Women even outnumber men in their workforce, according to an official report from February 2016.

WOMEN EVEN OUTNUMBER MEN IN THEIR WORKFORCE



That's not to say that women in Kuwait experience perfect parity overall — the right to vote was only granted to women 12 years ago, there are still strict rules enforcing modest attire, and men are allowed by law to practice polygamy. At the Faire, it was also difficult to find teams of makers that contained both men and women, although this did not elicit a strong reaction when I asked about it.

Many of the women's projects at the Faire focused on assistance: One group had built an attachment to motorize ordinary wheelchairs affordably. Another group created a camera tool that could translate sign language gestures into spoken words. Four women showed their diabetic wound detection device that could help diagnose foot injuries caused by the disease. Another female duo built an app to provide social reminders and tools for people experiencing the onset of Alzheimer's. One woman built a robotic "nose," designed, among other uses, to help impaired people determine if their produce is fresh. There was also a tracked robot designed to detect and pick ripe fruit ("No one else's robot has an arm like ours," explained one of the makers, showing me the appendage they made for it), a homebrew CNC PCB mill, a modular digital fabrication machine, a "connected home" house model ("I just started learning Arduino," the maker, Fatima, told me), a heat-resistant drone for firefighters, and more — all from women, humble but happy about their work.

The men too brought creative and engaging projects. Two high school–aged brothers, Mohammed and Yousef, built Gate Game — a device powered and controlled by a Raspberry Pi in which you try to illuminate a virtual LED by activating onscreen logic gates using physical toggle switches. It was fun, frustrating, and subversively educational. I asked Mohammed what gave him the idea for the project, and he replied with a shrug, "Honestly? Minecraft."

One group's self-erasing whiteboard project used one of Ahmad and Nasser's Ebot controllers to drive a mechanical wiper. Another, called Kuwait 1951, presented a virtual-reality re-creation of old Kuwait 66 years ago, experienced through an HTC Vive virtual reality headset. Some groups had traveled from neighboring countries, including Saudi Arabia and Qatar. The Qatar Scientific Club brought their robot camel jockeys. This group has been refining camel racing in the region, moving away from child jockeys to small, lightweight remote-controlled robots that strap to a camel's back and spin a whip to make it run. Youns and Nasef, two other Qatari makers, brought the Sanea Bus, a mobile workshop inside a retrofitted bus that contained workbenches, a huge assortment of littleBits, a laser cutter, an Ultimaker 3D

1. Maker Faire Kuwait organizer Ahmad Alsaleh and KIC's Hala Montague during the first day of the event.
2. The Ability Wheelchair, a powered conversion for standard wheelchairs, built by Fatimah, Fatimah, and Deyar.
3. My Voice, a sign-language translation device, by Anfal and Sara.
4. Alzheimer's assistance app Rico's designers, Anaf and Rawan.
5. The ladies from Scrollsaw Arts work on their pieces during the Faire.
6. Fatima's connected, sensor-driven model home is powered by Arduino.
7. Marwa explains the AnyMaker, a modular digital fabrication tool designed and built by the FabLab UAE.
8. Auxilio, a firefighting drone, built by Aya Al-toukhy.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Wood Working
Workshop


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GILGAMESH


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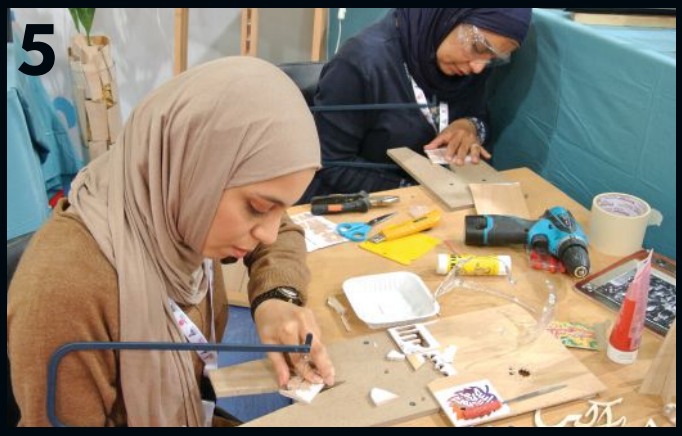
KFAS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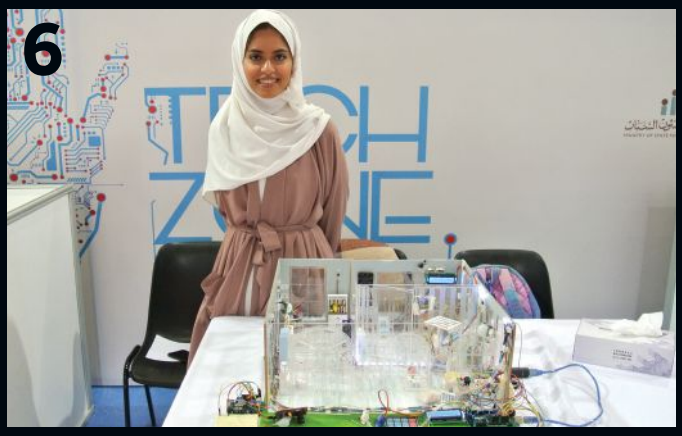
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printer, and an Inventables Carvey. "If you take a picture, make sure to show [Inventables founder] Zach Kaplan," they told me.

Because the maker movement is new to Kuwait, a lot of the exhibitors wanted validation that they were on the right track with their projects. "What do you think — is it OK?" was a common question men and women alike asked me throughout the weekend. There were a few Arduino-based projects, but not as many as I typically see at a Maker Faire. The Gate Game and a magic mirror were the only two projects I saw with a Raspberry Pi. Instead, the makers tended to use more conventional electronic components, relays, and drivers. I told them all their projects were great, because they were. Some asked, "Then you'll vote for me?" Ahmad later explained that the Faire's organizers were putting on a competition for all exhibitors via Instagram, with five winning projects for each of the two categories (art and tech) — the top in each winning 2,000 KD (about $6,500).

> "WE'RE STILL NOT BACK TO NORMAL"
>
> —Hala Montague, on the 1990 invasion

WEST MEETS MIDDLE EAST

Ahmad took me to lunch in downtown Kuwait City, a wood-fired pizza place I had looked up before I left on the trip. It was quite good. Most of Kuwait shows a mix of well-known international companies and Western concepts. We discussed the impact of the 1990 invasion — he was 12 years old at the time — and he told me that it was pretty terrifying, leveling the country in just seven months. ("We're still not back to normal," Hala later told me.) After high school, Ahmad moved to Southern California to study engineering at Cal State Fullerton. He started his first company there with a roommate refurbishing computers and stayed for 10 years before moving back and starting a new business in Kuwait. "It's nice to raise a family here," he told me. Most of the Kuwaitis I asked had been to the United States — more than a few to study — and all seemed to travel regularly.

The middle section of the Faire was partitioned off into activity zones: a robotics arm workshop, a woodworking workshop, fighting robots, and a giant, assembled, CNC-routed bird that kids were free to paint throughout the event. A 3D printing area provided visitors with an opportunity to design objects on Tinkercad and print them out. In the center of it all, Ahmad Awadh showed off his Big Bike, a huge bicycle with wheels that alone stand about 6 feet tall. He'd periodically let someone ride it slowly through the expo hall, which gathered a spontaneous procession as the rider would honk the loud electronic horn. It was a great centerpiece to the show.

I experienced one of the cultural differences of the region halfway through a presentation I was giving during the first night. The stage manager stopped me while

I was speaking to tell me I had to pause because it was almost time for prayer, and immediately after that, they had to do the daily televised national giveaway, which was a weekend shopping trip to Dubai on a private jet. I stepped off the stage and took photos with exhibitors while one volunteer flew a DJI Mavic drone around us. About 20 minutes later, I resumed my presentation.

Each night people stayed at the Faire until after 10pm, despite the show officially ending at 9pm. The enthusiasm from all involved — attendees, makers, volunteers, and organizers — was infectious.

PICKING THE WINNERS

The content in the arts area was varied, but one theme popped up regularly. Throughout the region (and across Kuwait in general), models of traditional sailing vessels reinforced the historic importance of both water and travel to the country. Artists brought and worked on gorgeous wooden boat models, flanked by anime sculptors, knife makers, and traditional craftsmen. There was a strong presence of both men and women showing projects in this area; but while crafts tend to be more female focused in the United States, the Faire's arts area had a higher proportion of male makers compared to the prominently female tech area.

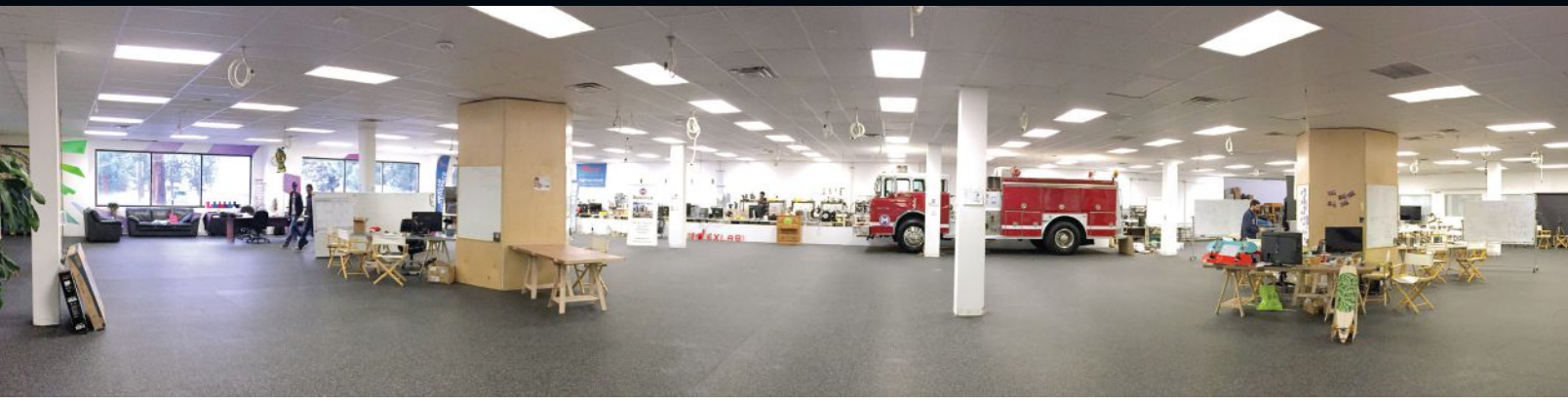
On the last night of the show, the organizers took the stage to announce the 10 winners of their Instagram competition. The top spot in the arts segment went to Nawaf Hussine, who makes endearing touch-sensitive lamps out of plumbing pipes. His friends whooped and hollered when his name was called, throwing their *ogals* (twisted black headbands) onto the stage, and then lifting him up and throwing him in the air over and over.

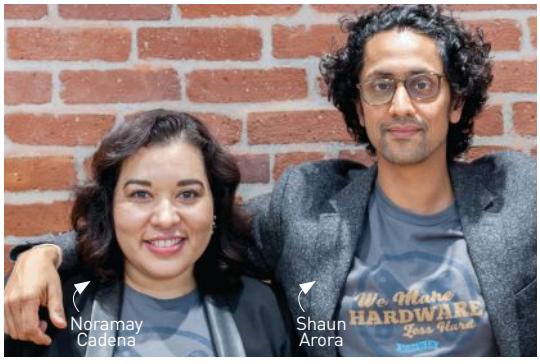
The organizers then called up the winners of the tech category, from fifth place to first. The runner-ups included the electric wheelchair, the Alzheimer's app, the firefighting drone, and the fruit-picking robot. The top selection went to the team that created the diabetic wound detector. What did they all have in common? All five winners from the tech category were female teams — a point that the organizers proudly brought up to me after the award ceremony. Beder Alsubaie, the CEO of KIC, summed it up succinctly: "We love women. They're smarter than men."

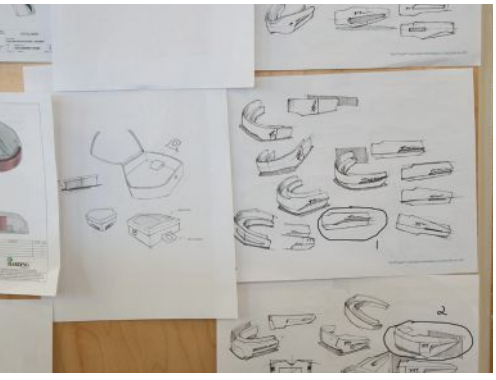
1. The Diabetic Wound Detector team: Noura, Esraa, Anwar, Shaika, and Amira (not pictured).
2. Fatima AlKhayat shows E-nose, "a device mimicking the human olfaction system using sensor arrays and pattern recognition system."
3. A custom PCB milling machine, by engineer Afrah Abdulaziz AlMutairi.
4. Heba, Fatma, and Fatima, engineers from the American University of Kuwait, show off their Harvesting Robot.
5. Thekrayat AlShamiry uses clay and reclaimed elements to make her art.
6. Zain AlSabah, the Under Secretary of Kuwait's Ministry of Youth Affairs, participated in the first day of activities.
7. Maker Faire Kuwait's organizers and volunteers relax after the final night of their three-day event.
8. Downtown Kuwait City, a beautiful contrast of gleaming skyscrapers and sandy, sun-bleached dwellings.

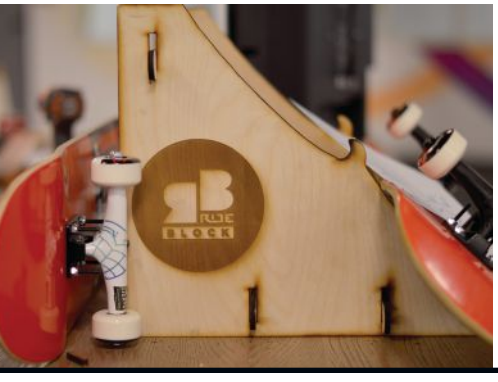
Zero to Sixty

Written by DC Denison









How **Make in LA** jump-starts your startup through mentorship

DC DENISON is the co-editor of the *Maker Pro Newsletter*, which covers the intersection of makers and business, and is the senior editor, technology at Acquia.

Read more from Arora and Cadena online at makezine.com/go/make-in-la.

Shaun Arora and Noramay Cadena are the co-founders of Make in LA, an early stage hardware accelerator and venture capital seed fund at the center of a growing community of hardware startups in Los Angeles. Since 2015, Make in LA has funded, mentored, and graduated three cohorts of hardware startups, each one completing an intensive four-month program designed to help hardware startups turn their ideas into working products. Since Arora and Cadena see thousands of early stage projects, we asked for their take on the accelerator landscape.

Q. What's the difference between an accelerator and incubator?

A. Incubators are great if you're doing something that's highly regulated, takes a long time to get to market, or if you're still exploring your options. An accelerator is great if you want to learn quickly and attack a key market. People who do well in accelerators are often looking for a large market, and are comfortable with the speed, accountability culture, and high standards that come with an accelerator.

Q. Why choose an accelerator in LA?

A. We have a mix of capital and hardware unlike any city. There are numerous early stage options like angels, angel networks, accelerators, incubators, venture, and even super angels and celebrities. We have 200+ languages spoken within our city limits, allowing for customer discovery on a global scale. Our local port handles 46% of all U.S. imports, so our ecosystem includes best-in-class logistics and packaging. We graduate more Ph.D.s and engineers than the Bay Area. We have the largest manufacturing workforce in the U.S. That ecosystem makes it a great place to grow new hardware companies like SpaceX, Ring, Hyperloop, Daqri, Neural Analytics, and uBeam. We're watching 170+ hardware companies moving through the local ecosystem right now.

Make in LA

Make in LA's 6 Tips for Hardware Startups

1. DON'T WORK IN ISOLATION

During the early stages of building a company, a founder will build the solution that works for them. If they're working away in a garage without the benefit of constant input, they could end up with a product that is loved by one instead of by many. Don't be afraid to share. We see a lot of makers who are overprotective about their idea; too often entrepreneurs worry about someone stealing it. But there have been many cases where a team went out there, talked to the world, and they received uncomfortable, but valuable, feedback. They realized a critical flaw early on and were able to correct it before going to manufacturing.

2. FOCUS ON MANUFACTURING

Making a prototype is very different than mass manufacturing. A lot of times, a founder's sweat equity in the prototype isn't factored into the assembly cost, nor with how to scale production.

The ability to establish a supply chain, and to perform quality checks throughout the process, and all the intricacies of machine setups — that's all very important. It's easy for makers to take for granted the availability of parts, or the quality of incoming material as one transitions to manufacturing. One thing that we help our entrepreneurs do is prototype on mass manufacturing equipment. The more they know about the process, the better their ability to troubleshoot future problems. They also develop an understanding of which design features can make manufacturing easier or harder.

3. FRONTLOAD YOUR MISTAKES

We remind entrepreneurs to stay ugly for as long as possible. We're helping our founders make mistakes in a safe space. They learn from flaws in their product or their approach. If they put time into making it pretty, two things happen: they have less time to test, and are less open to feedback.

4. HAVE STRONG BELIEFS, BUT HOLD THEM LOOSELY

This is a way to trigger debate without being a bully. We may believe umbrellas are poorly designed. However, if you had a strong reason why your umbrella needed to be shaped that way, we wouldn't dig in our heels — you can persuade us, and we're open to playing around with it.

5. DUMB DOWN YOUR IDEA

When you design and engineer a product, it's easy to discuss how superior your features are, and then the jargon starts. I was explaining to someone about our hardware for blockchain program. And then he asked, "*What is* blockchain?" When forced to explain it, I had to find a new language that would get the other person excited. I had to think through fundamental questions like "Why are we doing this?" and "What does that mean?"

6. "MAKE EVERY DETAIL PERFECT AND LIMIT THE NUMBER OF DETAILS TO PERFECT"

That's a quote from Jack Dorsey (of Twitter and Square). In hardware, you can run into the issue where, as you make your product better, you add complexity and cost. Do you ever say things like, "If we only added this one feature the product would be better." Examine how much margin it increases and then how long it will take to repay the upfront costs to execute that scope change. We have to pause and ask, "Is this the right thing for the business as a whole?" The answer is often yes, but sometimes we add features merely because of a perceived advantage. And it's not just development costs and timelines that get moved. Is the audience going to be the same audience when you start adding new features?

Illustrated by Taylor Callery

Come Together

Written by Louise Glasgow

BUILDING WITH OTHERS LETS YOU DO GREAT THINGS. BUT FIRST, MAKE A PLAN.

It all starts with "I have an idea!" When someone likes another person's idea, the process of doing a project together starts. However, the path can be rocky without incorporating some basic planning principles so everyone can band together, contribute, and enjoy the process.

Some tips from my toolbox to help you lead a group project:

The Idea

Break it down into small attainable tasks. What areas need to be researched, what supplies need to be gathered, what skills need to be tapped into? Create little steps so that these can be distributed and everyone can feel included.

Assemble Your Group

Seek talent with a variety of skill sets and a "can-do attitude." Remember that each person brings a different perspective, and having different viewpoints is important.

Create a Positive Environment

Be supportive and encourage a sense of pride by acknowledging contributions. Build a solid foundation for effective communication with a clear understanding of what needs to be accomplished. Task management tools can help provide this open platform to document process and provide information sharing. The art of listening is key and it helps to understand the opportunity of a question. Create a solution-based environment and handle mistakes wisely: no blame, only resolutions.

Time Is Valuable

Understanding the time involved will help structure the project and gain commitments. It can be a simple list of all the tasks in the order in which they need to be accomplished. Some tasks will be contingent on others; a list will help clarify that. Creating a basic timeline will keep the project on track.

Make meetings matter. Start with your agenda and outline what needs to be accomplished, review these items, identify action items with owners, and document everything. I often use the timeline to set the meeting agendas. A trick is to agree on the topics for the next meeting before you finish the current meeting — this saves time and helps everyone come prepared.

Now turn those great ideas into amazing group projects!

Louise Glasgow is the executive producer of Maker Faire, successfully collaborating with artists and makers to create the award-winning event. She has over 30 years of production experience, including the International AIDS Conference, the 2002 Winter Olympic Games, and Dwell on Design.

The brash MegaBots team is gambling on a bigger, better mech

Written by Mike Senese

Mike Senese is the executive editor of *Make:*. Find him on Twitter at @msenese.

MegaBet

THE MEGABOTS SHOP IS LOCATED in an easily overlooked industrial area one exit before the bridge that takes you from the suburban East Bay into the gleam of Silicon Valley. There are no visible windows, just a building with a solid door and a rolling metal gate that leads to a work yard. A "Press the gray button for MegaBots" note is the only external indicator of what's inside.

Everything through that door is oversized. The interior of the shop is long and tall. The workspaces are stocked with giant tools and parts. A huge MegaBots logo on the back wall faces three towering bay doors. And in the center is the star of the show: a massive, black, partially built robot. Even kneeling and with its arms and panels removed it's impressive, its size accentuated by the team members climbing on top of it to adjust the wiring and hydraulic hookups.

This is MegaBots' Mk.III, a $2.5 million dollar fighting robot that, its creators hope, will kick off a new form of live entertainment, a wild mix of UFC bouts and monster truck rallies. And after nearly two years of hype, the Mk.III is slated to make its first public appearance in just over a week — yet the shop seems awfully calm for something so bold.

Kickstarting a league

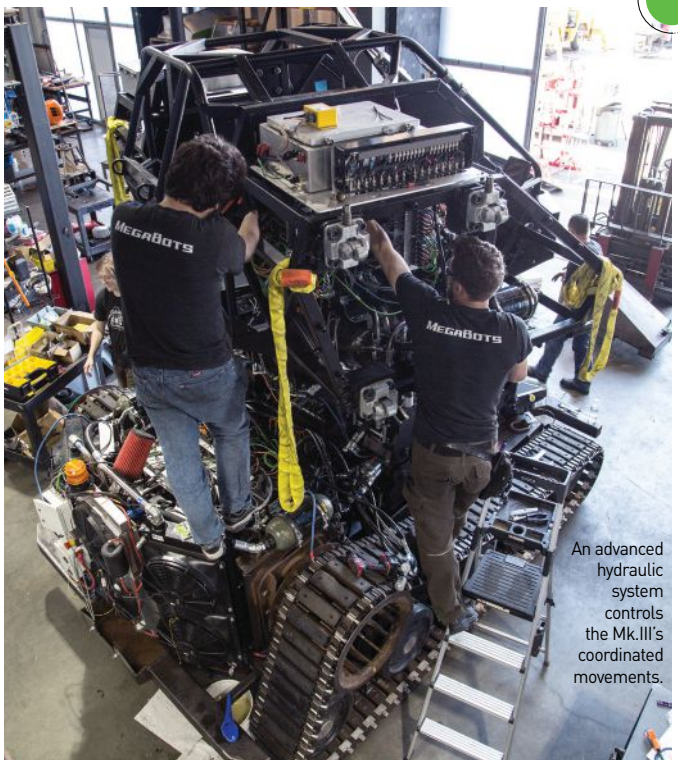
MegaBots began in 2014, a collaboration between the heads of two large makerspaces, Gui Cavalcanti from Boston's Artisan's Asylum and Matt Oehrlein from i3 Detroit. Their shared experience of bringing oversized group projects to life with their communities led to an assignment to build a robot, with the intention of launching a new sporting league.

"We had got a small amount of angel funding," Oehrlein says about MegaBots' inception. "The investor said 'Take this money and build as much of a robot as you can, run a Kickstarter, and see what happens.' So we built as much of a robot as we could with the funding, which was like half a robot, and dragged it to New York Comic Con."

"Some people didn't get it," he continues, describing the reaction to the seven-ton, cockpit-and-cannon-arm contraption that appeared in the concourse of the Javits Center. "There were a good amount of people who were like, 'what is it? What video game is this from? What movie is this from? What comic book is this from?' But there was a small percentage of people, maybe like 20% of people there, 15% of people there, that did get it. And the people who got it, their minds were blown. That was probably the first little 'Hmm, OK, there's something here people are connecting with.'"

That first Kickstarter, seeking $1.8 million to build two fighting robots that would riddle each other with giant paintball cannons shooting at 120mph, ended

The MegaBots team readies the Mk.III a week and a half before its debut.



An advanced hydraulic system controls the Mk.III's coordinated movements.

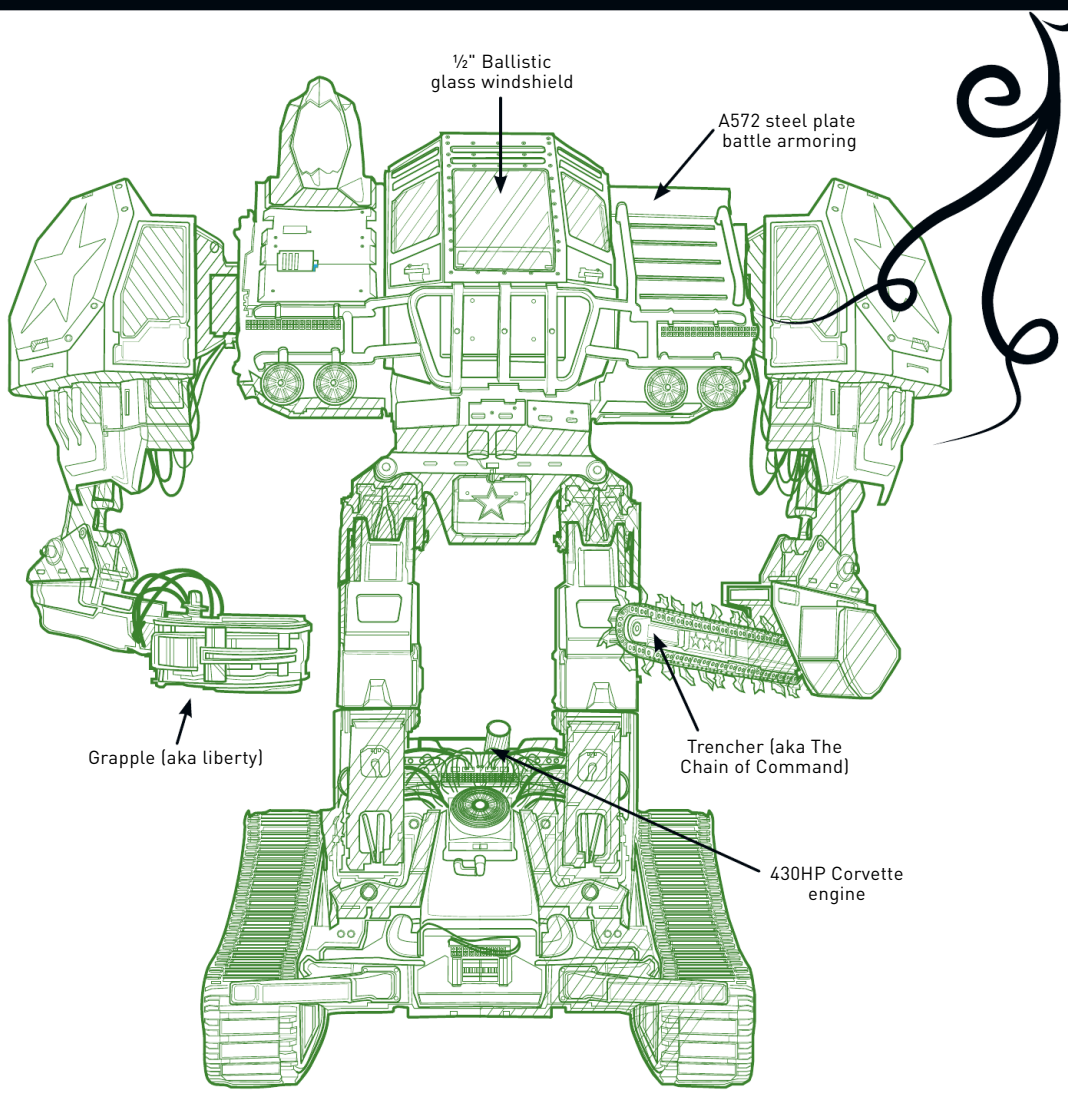
How Did You Design This Thing?

"Gui used to work at Boston Dynamics, so that's an obvious crossover there, they build super dynamic, responsive robots. I used to work at Eaton Corporation on hydraulic systems for construction equipment. So, if you take our backgrounds in visual form, and you put a Boston Dynamics robot next to a giant excavator and you put a plus symbol next to them and an equals, it's that robot out there — that's the equation." —Matt Oehrlein

Hep Svadja

Mk.III Stats:

- **WEIGHT:** 14 tons
- **HEIGHT:** 16 feet (18 with the eagle)
- **CAPACITY:** Seats two pilots
- **OS:** Realtime Linux Kernel and Ubuntu
- **ELECTRONICS:** 650+ cables, 300+ devices
- **SOUND SYSTEM:** 4x500W coaxial speakers
- **VIDEO:** 14 HD (1080p) weatherproof cameras with 10x IP65+ display screens connected to 16 in/16 out video matrix
- **HYDRAULICS:** Up to 140 gallons per minute of hydraulic flow at 4000 psi
- **DEGREES OF FREEDOM:** 21
- **ACCUMULATORS:** Steelhead Composites BattleMax, Kevlar Jacket, 7.8 gallon total capacity
- **COMPUTER:** Logic Supply Neousys Rugged
- **IMU:** XSens MTi Series
- **VALVES:** Parker Hannifin high-speed proportional valves
- **HOSES:** Parker Hannifin 4000 psi, Tough Cover and Super Tough Cover
- **COCKPIT CONTROLS:** 2x 5-DOF Joysticks, 2 foot pedals, 40+ momentary/toggle switches, for each pilot
- **RADIATORS:** 6 radiators, 2x hydraulic oil, engine coolant, transmission oil, engine oil, pump case drain
- **GALLONS OF HYDRAULIC OIL:** 100
- **GALLONS OF GASOLINE:** 17
- **GALLONS OF ENGINE OIL:** 1.5
- **GALLONS OF ENGINE COOLANT:** 4
- **TOTAL LENGTH OF CABLING:** 1 mile
- **TYPES OF CONNECTORS:** M12 A-Code, M12 D-Code, M12 T-Code, M8, BNC, 350A power couples, and many others



James Burke

Howe & Howe Technologies tank treads

"It's not hard to get people excited about building giant fighting robots, as you can imagine."
—Matt Oehrlein

unsuccessfully. The duo pushed on regardless, moving construction from Boston to San Francisco, where they built a complete second iteration of the robot, Mk.II. It debuted at the Maker Faire Bay Area in May 2015. Weathered to look like a seasoned combat vet, the green and yellow machine rolled around on treads, lifted up on two legs, and launched three-pound, paint-filled ballistics at a donor car. It was loud, messy fun. The crowd loved it.

Bring on Japan

At the end of June 2015, MegaBots popped up in the news again as Cavalcanti and Oehrlein released a video challenge to fight a similarly sized robot from Japan: Kuratas by Suidobashi Heavy Industry. The video, featuring the duo in American flag capes and aviator glasses, is heavy with exaggerated patriotism and robotic destruction, highlighting their flair for theatrics. Media outlets all over picked it up — the video now has nearly 8 million views — and a few days later, the creator of Kuratas posted his own video (complete with a Japanese flag cape) with the response "WE ACCEPT."

The team actually knew about Kuratas before they started MegaBots, but the initial idea wasn't to fight it. "We essentially got to a point where we were like 'we need to start a sports league, we only have one robot, and we don't have enough money to build a second robot,'" Oehrlein says. "How do you start a sports league with only one robot? Well, you find someone else who already has a robot."

With the buzz that generated, MegaBots launched their second Kickstarter to revamp their robot for melee combat (a requirement from the Japanese team). This time they ended successfully, accumulating over $550,000 from nearly 8,000 backers. They even offered to let the top backers drive the robot (31 pledges) and punch a Toyota Prius with it (3 pledges). Although they posted the estimated delivery as June 2016, this was to be a big part of their performance at Maker Faire, nearly a year later.

Building a team

From their Kickstarter, MegaBots continued accumulating financing, raising an additional $3.85 million in venture capital, plus revenue from appearances, sponsorships, and merchandise sales. This would go into building a new robot, but first they had to build a team.

"Having money to pay people helps a lot," Oehrlein says, somewhat sheepishly, about how his group came together, "but it's not hard to get people excited about building giant fighting robots, as you can imagine. It's legitimately one of the coolest jobs in the world. I feel like I can kind of say that without exaggerating."

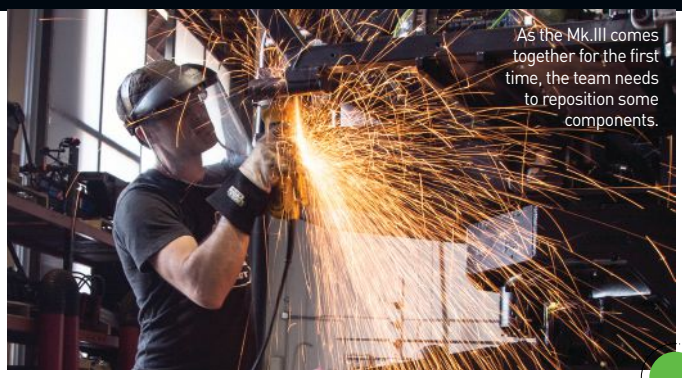
Oehrlein then admits, "I remember thinking it would be way easier than it actually was. I imagined we'd put something on LinkedIn, or just post something on the MegaBots Facebook page, and we would just get thousands of resumes. We set our requirements pretty high, pretty aggressively for who we wanted to hire and that's resulted in a really amazing team."

As the 18 full-time staff settled together, they initiated their plans for Mk.III, a bigger, badder MegaBot than the Mk.II. "Massive upgrades," Oehrlein says of the differences between the two. "The Mk.II was about 24HP, the Mk.III is a 430HP Corvette engine. It's super loud. It's a little more than double the weight of the Mk.II. It's about a foot taller when it stands up. It has melee weapons on it. It is way more responsive; the hydraulic system is orders of magnitude more responsive. Complex, compound movements are a breeze to do in this thing — where the Mk.II was literally levers attached to the valves, your hands are now on joysticks that talk to a computer and calculate where you are moving the robot's hand in space, and all of the joint positions just fall into place automatically. The whole control system is decades of technology improvement built into that thing."

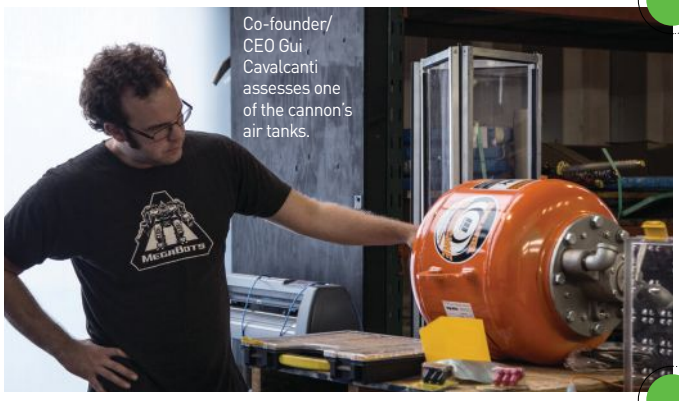
They didn't just assemble a team to build a robot, either. The goal from the beginning has always been entertainment, both live and televised, which has been a large part of the financing they've attracted and the partnerships they've built — their advisors include Greg Munson and Trey Roski, founders of *BattleBots*, Grant Imahara from *MythBusters*, and others with ample robotics (and television) cred. The team is discussing broadcast options for the duel with Kuratas, and in the meantime has assembled an on-site production company and produced a web-cast series of Mk.III build-up episodes over the past year.

Two days to go

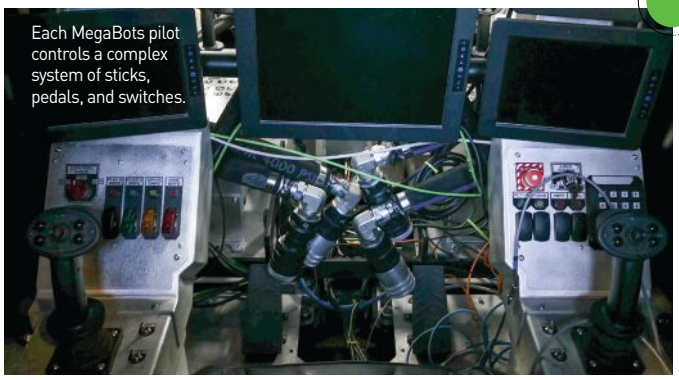
On our stop at their shop a week after the first visit, the MegaBots team has made considerable progress on the robot, attaching its arms and canopy, and has driven it into their outdoor test area. The space is a concrete slab surrounded by shipping containers that have been converted to additional workspaces, including one for the programming team, a prestigious group of roboticists from the Institute for Human & Machine Cognition — 2nd-place finishers in the DARPA robot challenge. They're using a custom, open source code that is written in Java and is faster than ROS, which is uploaded via Ethernet to an onboard Intel i7 computer running Linux.



As the Mk.III comes together for the first time, the team needs to reposition some components.



Co-founder/ CEO Gui Cavalcanti assesses one of the cannon's air tanks.



Each MegaBots pilot controls a complex system of sticks, pedals, and switches.

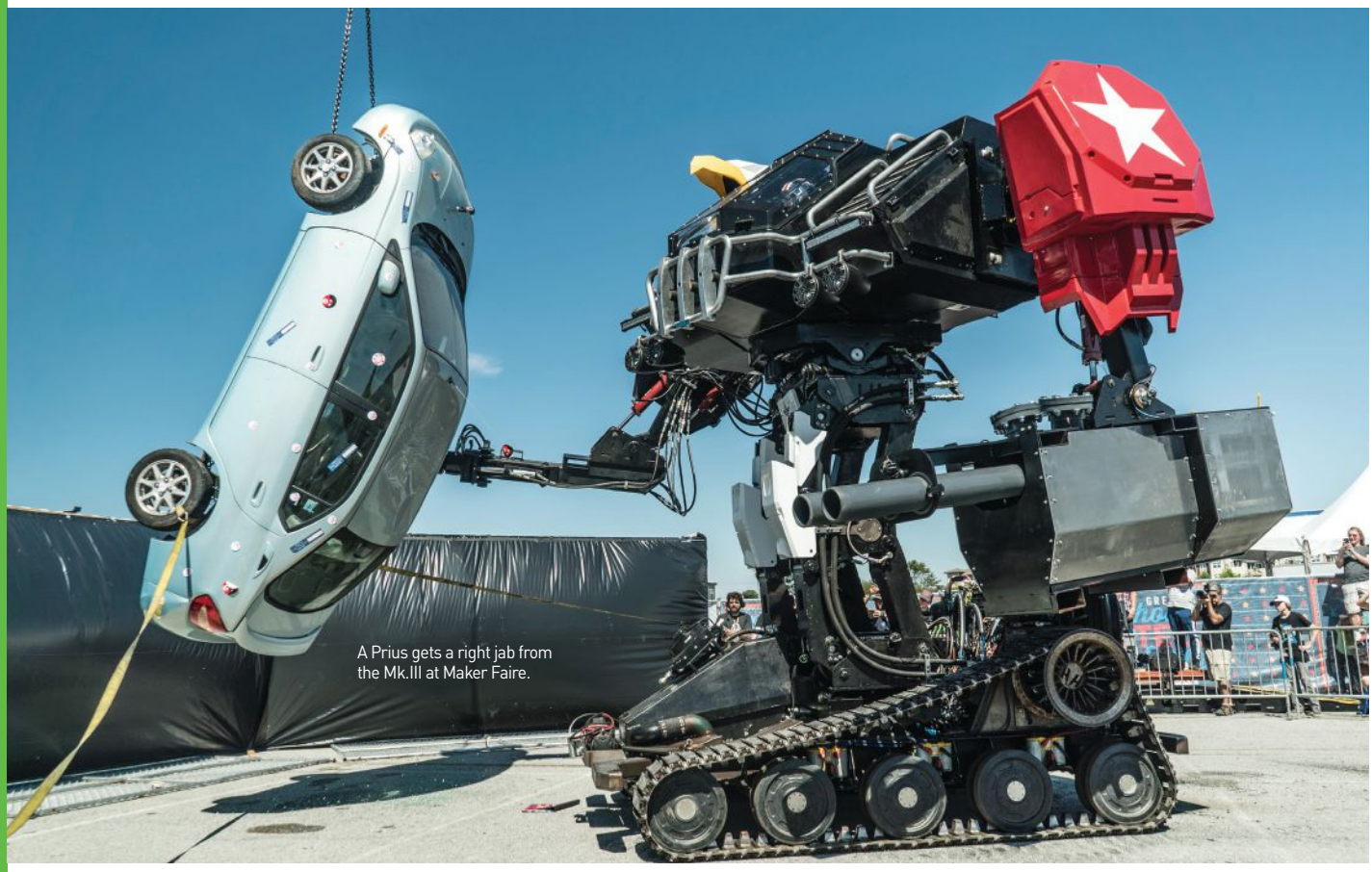
The Mk.III, standing tall, looks even more impressive than a week ago, and the team looks a lot tenser as well, with two days to go before their Friday debut at Maker Faire.

"The thing I'm most afraid of is a hydraulic failure in the robot," Oehrlein tells us. "If a hose blows and the robot sits down very rapidly, or maybe one leg fails and the whole robot tilts off to the side … ." He explains that both legs move independently and says he's not sure if there's a hard stop in it. "I'm more afraid of failures in the robot rather than 'If I punch this car, will it swing into the cockpit and kill me?'" he says.

The IHMC team echoes his concern. "The part that is hard is the scale," their leader Peter Neuhaus says. "It's hard to not make it tear itself apart. This thing can move fast." The group tells me it has a 35-foot wingspan, and each arm can move, outstretched, from the side of the robot to its front in a half second.

The team grinds away as the day turns to night. Their plan is to drive it over the bridge to San Mateo, where Maker Faire is located, at 3pm the next day. "It's going to be a late night tonight," Oehrlein says.

Hep Svadja, MegaBots



A Prius gets a right jab from the Mk.III at Maker Faire.

Jun Shéna, MegaBots

"I'm more afraid of failures in the robot rather than 'If I punch this car, will it swing into the cockpit and kill me?'"

—Matt Oehrlein

Showtime

Thursday comes and goes with the Faire team putting the finishing touches on the event, but MegaBots is nowhere to be seen. They've updated their arrival time to the following morning. Friday, a flatbed truck shows up just after noon with the robot loaded aboard, tucked sideways in an attempt to fit within the legal highway width constraints. They unload inside the front gate as the crowd begins to gather for the 1pm Faire opening. Cavalcanti climbs into the Mk.III, fires up the engine, and slowly drives down a ramp and to their location 50 feet away. Even crouched, it jiggles a bit as it moves off the truck. The crowd applauds. The MegaBots team spends the rest of the afternoon working on the robot, adding the external armor pieces, and placing a giant eagle's head on its shoulder that, they tell us, will be equipped with additional weaponry in the future.

The first official showtime is slated for 10:30 Saturday morning. That day, the team has a Prius hanging by a truck-mounted crane stashed behind a safety barrier. Crowds fill the too-small bleachers and overflow 20 people deep around the fencing that surrounds the MegaBots demo space. Cavalcanti is on the microphone, giving details about the Mk.III, explaining its transmission (it's from a boat), what the hydraulic accumulators do ("they're like capacitors"), and how, fully pressurized, the robot should throw a washing machine 75–80 feet. He also mentions that the hydraulics on the robot have been limited to 25% of their capacity, as they have only just fully assembled it for the first time and don't want to hurt the robot, much less any of the attendees.

Oehrlein and one of the engineers are inside the robot as the programmers, seated under a canopy, send code to its computers. The pilots fire up the engine, but the first three attempts to pressurize the hydraulic system result in it stalling and the crew running the Ethernet cable back inside the cockpit to load code adjustments. Cavalcanti jokes with the crowd that this is now a live engineering show. The robot rumbles alive again with its grid of radiator fans sending dust flying, and then rises to its legs. But shortly afterward, the team pauses to work out a few more kinks in the code that are keeping it from retracting its right arm, tipped with a grappling hook "fist" from a large logging machine, and then swiveling it forward — the motion that allows it to stretch outward to smash the automobile punching bag in front of it.

By 1:30pm, the first punches have been thrown, and while they aren't impressively fast, the mass behind the 14-ton, steel robot easily shatters the windows and leaves large dents in the car's sheet metal on each impact. As the day continues, between periodic hydraulic seal-failure repairs, the team proceeds to adjust the punch sequence. Toward the end of the

The Team

From left to right:

- **Max Maruszewski** - machinist
- **Robert Masek** - facilities manager
- **Kelsey Mohland** - office manager
- **Andrew Dresner** - electrical engineer
- **Gui Cavalcanti** - CEO
- **David Isaacs** - lead business development
- **Miles Pekala** - senior electrical engineer
- **Jon Gulko** - senior mechanical engineer
- **Lyra Levin** - senior mechanical engineer
- **Nathan Mertins** - IHMC control system
- **Matt Oehrlein** - COO
- **Micah Leibowitz** - machinist
- **Tim Bogdanof** - fabricator
- **Zachary Wetzel** - fabrication manager
- **Stephen McCrory** - IHMC control system
- **Doug Stephen** - IHMC control system
- **Jan Ochoa** - camera op/editor
- **Dan Pederson** - senior mechanical engineer (not pictured)

day, Cavalcanti excitedly tells us they've really got it dialed in, doing a couple swings toward the crowd before rotating to the car and slamming it twice. It's the first time we see him smile.

The performances continue through the afternoon and Sunday, each drawing massive crowds that now stretch 100 people deep. Some still gripe about its slow movement, but the group lingers with anticipation regardless, camera phones extended overhead like at a rock concert.

The final show ends with the robot on one knee, piloted by senior electrical engineer Miles Pekala as he proposes to his girlfriend, Baltimore Hackerspace President Jen Herchenroeder, with a supersized 60-pound engagement ring attached to the Mk.III's hand. After she says yes, the plan is for her to pull a rope that will drop the ring through the windshield of the now-battered Prius below. But as the Mk.III turns into position, it breaks another seal and begins to spew hydraulic fluid. The team powers it down before any damage results.

Looking forward

A few days later, the mood at the MegaBots shop is decidedly lighter — goofy even, with the weight of the show lifted off their shoulders. "It was stressful at first," Oehrlein says, recapping the weekend, "but then it turned out to be cool because the people that come to Maker Faire, they really like to geek out on how things get made, how they go together, and how projects are built. So they actually got to see some of the process that we go through as we fix things on the robot, wake it up for the first time. On one hand, the robot didn't perform up to our expectations on Friday and Saturday, but we were able to offer people a sneak-peek behind the scenes and turn that around into a positive. On Sunday by one o'clock, we had all those problems buttoned up, and we were able to hit our stride and put on great shows."

That still leaves the bigger objective looming, however — the duel with Kuratas, slated to happen this summer. The MegaBots team hasn't forgotten that, and by the end of the week, have already pulled the robot apart to get it in its final fighting form.

"The cockpit is taken off, and we're updating the cooling even more on the track base," Oehrlein says. "We're re-wiring a few things to make it more reliable, and we'll be putting it back together late next week. And then we have a number of weeks of tuning the controls on it and getting it tuned up, and unlocking those speed improvements.

"If there was one thing that we had more time to do," he continues, still reflecting on Maker Faire, "it would be trying to get the robot moving faster. Our valves were seriously artificially limited in how much fluid they could push. That's probably the biggest difference between how the robot performed and audience expectations inspired by science fiction."

With the machine updated, its speed maximized, and with time to learn how to use it to its fullest, Oehrlein is expecting a bright future. "You have my word, the robot will move much faster. Maker Faire was the robot's first baby steps. We're just starting to see what this robot is capable of."

Building Burning Man

Collaborative art is more than just projects – it builds up community

Written by Jess Hobbs

I FIRST ATTENDED BURNING MAN IN THE LATE '90S. In the early years of the festival, most projects were still being built during the event, so I was able to participate with a group of people building and burning art. Collaborative art was something I explored before, but discovering a whole culture and festival focused on it changed my art practice entirely. The process of making artwork together was beyond something I alone could envision. It took the group to complete the process. I was hooked.

Fast-Growing Network

As Burning Man grew in scale and complexity, so did the artwork. More groups formed and more spaces dedicated to supporting this work grew. California spaces like The Shipyard (Berkeley), The Box Shop (San Francisco), NIMBY (Oakland), American Steel Studios (Oakland), m0xy (Oakland), Obtainium Works (Vallejo), and The Generator in Reno, Nevada, evolved, usually taking over formerly industrial buildings to make a place for big art to be built. Groups also formed such as Flaming Lotus Girls, Therm, Neverwas Haul, Five-Ton Crane, Cyclicide, and Ardent Heavy Industries.

Loving the Process

I came to a deeper understanding and appreciation of the collaborative group process when I began working with the Flaming Lotus Girls, a women-driven group started in 2000 that continues to welcome both women and men to build with them. I along with my co-founders, believed so strongly in this inclusive, collaborative, and community-building process that we formed our nonprofit Flux Foundation in 2010 while we built the Temple for Burning Man. We have been building projects and community out of American Steel, following the idea that art can create community.

Art making at Burning Man evolved as an inclusive group process and the artists and art groups surrounding it share this as a core tenant. Most projects created for Burning Man, or now projects "beyond the playa," are built by large groups, and most invite people to join their build process. The best way to participate in a build is to look at the latest Honorarium projects on the Burning Man website to see which ones are in your area or an area you'd like to visit. Then look on the project site and reach out. You can also reach out or visit spaces like American Steel Studios, NIMBY, or The Generator.

Over 250 volunteers helped create the Temple of Flux. From the designers to the chefs that feed the crew, all were integral to the success of the project.

Joe Dacanay, Brendan Jones, Marc Hertlein

Jess Hobbs is an idea generator, maker, and social sculptor. Collaboration is her magic ingredient for success. She has co-founded and directed Flux Foundation, All Power Labs and Flaming Lotus Girls. She also helps make Maker Faire.

Tips

- Sometimes projects reach a volunteer capacity and don't have space for more. Be respectful.
- Be patient. Some parts of a project require expertise you might not have. What else do they need help with?
- Remember, sometimes sweeping the floor or grinding a pile of parts is the most important thing that needs to be done.

Find a Group

San Francisco:
- boxshopsf.org

Oakland:
- nimbyspace.org
- facebook.com/AmericanSteelStudios
- m0xy.com

Vallejo:
- obtainiumworks.net

Reno:
- therenogenerator.com

Elsewhere: search for Burning Man Honoraria near you!

A Global Party Game

1. M-LAB in Vilnius, Lithuania, designed this *Sound Branch* as an offshoot of the iterative design.

2. This *Tree of Making* was the first iteration that kicked off the game, designed at The Gate 510 in San Leandro, California.

3. Lighted appendages attach to the tree's branches in this render from MakerPlace in San Diego, California.

MakeItGo brings together different makerspaces to create an iterative project

Written by Will Chase

Will Chase is a Bay Area-based writer, communications executive, and art curator, who has dedicated his skills to supporting artists and creators in realizing their dreams.

MAKEITGO IS A COLLABORATIVE GAME THAT FACILITATES CONNECTIONS ACROSS THE MAKER COMMUNITY. The idea is simple: invite a series of makerspaces to co-create an iterative project in which each makerspace builds on the cumulative design of the previous teams' work. Think of it as an "Exquisite Corpse" game for makers.

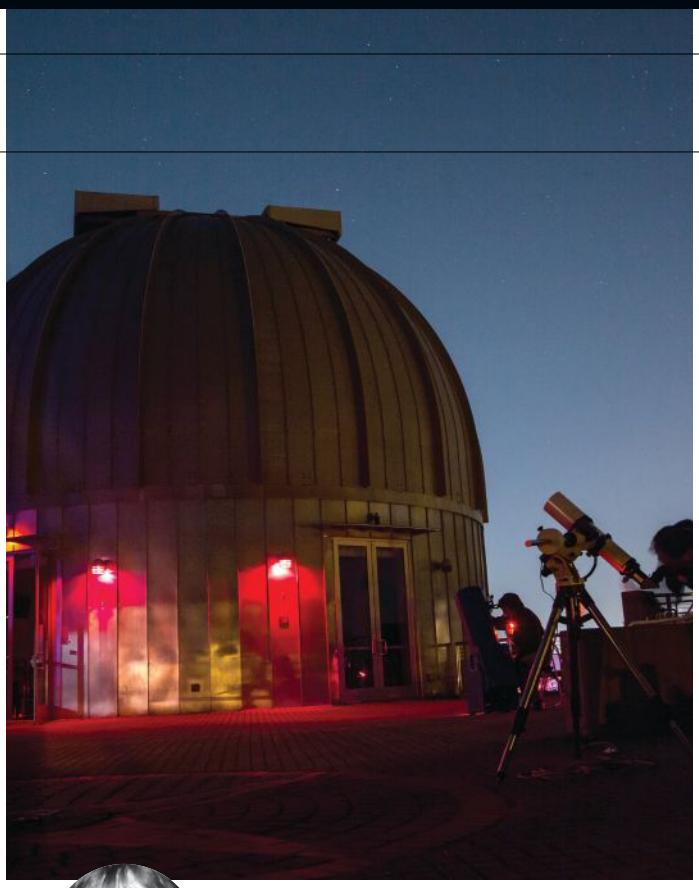
The first MakeItGo project, which centered around building a kinetic sculpture, launched in June, 2016. Eleven different makerspace teams from around the world, including California, Oregon, Tennessee, New York, Spain, Belgium, and Lithuania participated over the course of eight weeks. Each team was given 24 hours to modify and reimagine the sculpture using CAD software, and then one team would actually produce the final piece for presentation at World Maker Faire in New York City.

Rather than building something with a specific functional intent, the objective to build a kinetic sculpture gave the participants significantly more creative leeway, allowing them to dive headlong into whimsy without being hampered by the practicality of their contribution. Plus, it made it more fun to work on.

However, as MakeItGo founder Nathan Parker notes, "This process yields more than mere art. We're forming friendships and collaborations that create an active network through which these spaces can share resources and expertise. We're not only bringing value to each other, but we're taking on the challenges of the world in new and effective ways."

The MakeItGo organizers were careful to design the game to offer just enough time for teams to engage in a meaningful way on the artwork, but not so much that they'd get bogged down in an intensive creative process. It was also important to establish guidelines and boundaries (such as "kinetic sculpture") so teams didn't run off into the weeds or get confounded by a lack of direction. Lastly, it definitely helped to start with a design seed that would create an extensible foundation on which other teams could build.

Neat idea, right? It's easy enough to do it yourself. Gather some makers, come up with a plan, a schedule, and a way for everybody to communicate, and have at it. Scale it as big as your ambition. Most importantly though, enjoy the process as much as the final product — have fun making!

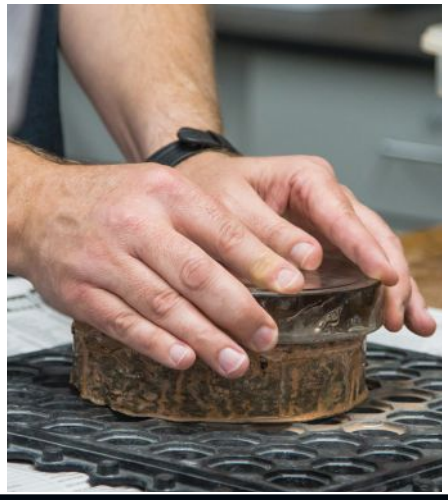


Skylab

Telescope-making workshops let you share the thrill of peering through the cosmos

Written by Richard Ozer

Richard Ozer co-directs the Chabot Telescope Makers' Workshop with Dave Barosso. He is also president of the Eastbay Astronomical Society, the workshop's sponsor.



Hep Svadja

More Telescope Workshops

Look online for a telescope workshop near you — standouts include the Springfield Telescope Makers in Stellafane, Vermont (stellafane.org), the National Capitol Astronomers in Washington, DC, led by Guy Brandenburg (home.earthlink.net/~gfbranden/GFB_Home_Page.html), and Dave Frey's workshops with the San Francisco Amateur Astronomers (sfaa-astronomy.org).

CLEARING DISINFORMATION IS OUR FIRST JOB AT THE TELESCOPE MAKERS' WORKSHOP. "So you're grinding a lens!" No, we're grinding a mirror. "How do you put the coating on the back?" The aluminum coating actually goes on the front. In that sense, it's not really a mirror, it's a mirror holder! "That mirror you're making; what power magnification is it?" The mirror doesn't magnify anything. The magnification is done by the eyepiece; the mirror just gathers enough light to make the view worth looking at. "Will it save me money?" Well, probably not; but amateur astronomy is rarely about saving money or time.

Make Your Own Masterpiece

Held every Friday night at Oakland, California's Chabot Space and Science Center, the Telescope Makers' Workshop is an informal gathering where you can learn how to grind and polish a high-quality Newtonian telescope mirror and, hopefully, turn it into your own masterpiece of optics, woodcraft, and design. We have helped build thousands of telescopes over the workshop's 70+ years of existence. A typical project takes a year; the largest we've seen someone build is 22 inches. Every person's telescope is different, albeit they all work according to the same optical and mechanical principles. The accuracy of your work is measured in millionths of an inch!

Building a telescope involves a unique combination of physics, mathematics, astronomy, and craft. You don't have to be a rocket scientist, but you might just imagine you're flying in a rocket as you look through your home-built scope and see galaxies, clusters, and nebula invisible to the naked eye, inhabiting regions of space thousands or even millions of light years from planet Earth.

Aim for the Stars

The workshop is free to the public, and funded by the Eastbay Astronomical Society. Students have to purchase some materials and scavenge the rest, but the Society provides grinding and polishing compounds as well as instruction and measurement. Visit chabotspace.org/telescope-makers-workshop.htm for more information about getting started, and eastbayastro.org to learn about the Eastbay Astronomical Society.


OAKHELLA

Growing Grass Roots

Written by Sophia Smith

Hep Svadja

Bottom's Up Garden cultivates more than produce — it's a local hub for cultural events, personal initiative, and communal autonomy

SOPHIA SMITH likes to eat a lot of plants. She also loves learning from community organizers. Especially organizers who grow plants. Sophia is online managing editor for *Make:*. She lives in Oakland and tweets @sophiuhcamille.

CHICKENS ARE CLUCKING, DUCKS QUACKING, AND A GROUP OF KIDS ARE KICKING A BALL AROUND on the schoolyard across the street. It's almost easy to forget that Bottom's Up Community Garden is in the middle of a major metropolitan area, nestled on a street corner in the Lower Bottoms neighborhood of West Oakland, California.

In San Francisco Bay Area's patchwork of both affluent and disadvantaged neighborhoods, West Oakland is the latter. Jason Byrnes, one of the garden's founders, says that in terms of food availability, the Lower Bottoms is a desert. There's no grocery store. Even the 99 Cents Only store, which did have some produce, is no longer there. Seneca Scott, an organizer for the garden, explains that in West Oakland, "theft is rampant. You'll see car windows that have been busted out, you'll see tape over people's windows."

It's not just food and community that the garden provides — it's a haven. "I like to think we've added a lot to this neighborhood," says Scott. "People tell us all the time that they feel safer."

Plants with Purpose

Byrnes founded Bottom's Up three years ago. He started with a few abandoned plant beds, now overflowing with produce on the roughly 3,500-square-foot plot. He also runs a few other community lots, with goats, chickens, and ducks (the animals will eat anything people don't want to), and a beehive. They sell weekly batches of produce to a few local restaurants — The Cook and Her Farmer, Swan's Market, Desco, and Flora — all in Oakland.

He says he had to do it. "I don't really have a choice. If I'm not growing something I won't feel right about myself." Byrnes grew up gardening, but often felt like the "community" of community gardens was absent. "There were a lot of isolated beds — it was like the opposite of a community garden." He would give his neighbors extra produce from his personal garden while living in Santa Rosa. "After a year or two, all the neighbors had small gardens and we all knew each other by name. I realized it could be a lot more than just a garden," he says. "Every farm becomes a community farm if you're in a strong community."


Oakhella Festival, April 30, 2017

"I like to think we've added a lot to this neighborhood," says Scott. "People tell us all the time that they feel safer."

Scott, on the other hand, used to be the East Bay director for the SEIU 1021, a labor union. He doesn't have an agricultural background. He just likes to cook and wanted to get involved. "One of our philosophies" says Scott, "is to plant yourself and grow your roots." It's about consistently dedicating your time, about weathering yourself against the storm. That won't happen overnight, but it will happen.

Cultivating Culture

Scott and Byrnes have few rules for the garden, if any. There's no org chart; it's not hierarchical. But they do have different levels of involvement — they're the main organizers, they have about half a dozen regular volunteers, and 317 members on their Facebook page. Plus the neighborhood benefits from their work directly and indirectly.

"If you grew something, we will protect your investments and make sure you get something for your work, but it's not yours. This is ours. No one has any excuse that their 'ownership' of this place supersedes the community," Scott explains.

What you do at the garden is for the common good. Sometimes they conduct workshops, or volunteers will, if they have knowledge to share. It doesn't have to be about gardening. That's the totally inclusive, "sky's the limit" model that Byrnes and Scott are following — anyone can come and get involved and initiate anything they want: yoga workshops, poetry readings, you name it.

For a brief stint, there was a café operating out of the garden that opened every single day at 7am. Scott pinpoints this as the tipping point that got the entire neighborhood involved. "People started coming as customers, we started throwing parties, and it became a community hub," he says.

It got so popular, you can now search for the Bottom's Up Café as a geotag, even though it doesn't officially exist anymore — the city gave a warning due to lack of permits. After that came Oakhella, a recurring DIY hip-hop music festival put on right there between the planter beds. They've thrown five so far since the beginning of 2016.

"I think what's great about this place is that it acts as a magnifier for anyone's talent," says Byrnes. "We couldn't have started the café in a random abandoned lot. Oakhella wouldn't have worked." Not without the energy and vision that came from the group of people involved at Bottom's Up. Scott remarks how special it is that everyone benefits from everyone else, that everyone adds value. "But we also hold each other accountable," he says, "It's not for the faint of heart. Don't disrespect anyone, but we don't always have to agree."

And dissent can be good — productive, even. Byrnes and Scott are highly opinionated, and they're thinking far beyond their plot of land. Scott says Bottom's Up is very old school, but also futuristic in their philosophies. He mentions *The Jetsons* and *The Flinstones*: taking technology that's valuable to us, and looking at what's sustainable. He explains that the technological landscape is changing the way we work, and the way we view work. "Technology's gonna move. It doesn't have a soul or any empathy. We're responsible for that. So if the path we're headed is that people don't work anymore because there's no work to do ... What do you do? You spend more time on

Eddie by the Bay, Zenaida Sengo, Jason Byrnes, Hep Svadja, Sarah Seamstress

Grace Spangler, Jason Byrnes, and Seneca Scott

your community. On your art. On your personal expression. We do that all day." He says "the goal isn't profit so much as showing people how localized agricultural systems work." Right, agricultural systems. It must mean more to Scott than just growing plants, because they're accomplishing so much more than that.

Organizing Organically

Sitting in the garden on a quiet Wednesday afternoon, under the baking sun on this tiny plot of land, it's hard to imagine 500 people squeezed in here around a ramshackle stage for Oakhella on April 30th. (The Oakhella tag on Instagram proves it, though.) There was virtually no damage to the plant beds, a nod to the communal respect that governs this space.

"As an organizer, we help enhance what a community garden can be by bringing a music festival," says Scott. "It

"Have parties. Invest in your neighbors. Celebrate. Live life. Grow some veggies."

really pushes the boundaries of what people consider as a community garden."

Scott says he's just sort of learned along the way — how to grow plants, how to build a table, how to organize. The organizing came from simply getting involved, and from observing other failed and successful attempts at social programs. He mentions "The Village," a grassroots homeless camp at Grove Shafter Park that greatly benefited the homeless population — until the city of Oakland cited violations and tore it down at the beginning of the year. The city then backed its own homeless camp, which promptly burned down May 1. It's a stark indication that sometimes what communities need aren't administrative measures, but organizers from their own ranks.

Oakland, of course, has a long history of political and administrative clashes with community organizers. The Black Panthers and their Free Breakfast Program were highly influential in establishing West Oakland's history of urban agriculture. "As long as [the government] controls a commodity," says Scott, "they control the people. Anything that you can get to take control over your commodity is worthwhile. When the Black Panthers formed, this neighborhood was in the exact same place it's in now."

So what do Scott and Byrnes want next, exactly? "Getting organized will help, and involving more people, but what we really want people to do," says Scott, "is go start your own garden." "So we can come to your Oakhella," chimes in Byrnes. "We'll help you out," says Scott, "but you gotta take the ownership. First of all, what is your 'Why'? What are you doing, and why? Next," he says, "you need to take a skills inventory. [Jason and I] can take a dozen people and figure out what everybody's best at. When I first came here, you know how I contributed? I cleaned up. I brought water. I sweep up. Just get together and figure out what you're good at and drop the ego." He mentions, "we both have big egos. We've had some big fights here, cause we care about it."

Byrnes and Scott are plenty aware of injustice, from the smashed windshield in their neighborhood all the way to the global consolidation of wealth. It's all connected. The world is a scary place, and there's a lot of uncertainty about what will happen next. "Until then," Scott says, "this is what you do. Have parties. Invest in your neighbors. Celebrate. Live life. Grow some veggies."

After all, everybody's gotta eat.

Build It...

Makerspaces are the social soul of the maker community — and are perfect for big projects

Written by Matt Stultz

Joachim Hall

IN 2009 I HAD A CRAZY IDEA. My town at the time, Pittsburgh, Pennsylvania, needed a hackerspace. I teamed up with a bunch of other makers who thought the same, and it's been a wild ride ever since. I love being a hackerspace/makerspace member; tool sharing is great, but the real key to it all is the people. We all come from diverse backgrounds with even more diverse interests and skills. When you bring this all together, bigger, more creative, and more challenging projects can be accomplished than most anything you'd do on your own.

Here are a few of the great projects that some of these spaces have created or are currently working on — get inspired, and then make your way to your local makerspace to find out what you can help with.

Matt Stultz is the 3D printing and digital fabrication lead for *Make:*. He is also the founder and organizer of 3DPPVD and Ocean State Maker Mill, where he spends his time tinkering in Rhode Island.

...Together

Andrew Coy, Christopher Drew, Spencer Zawasky

1 The Roaming Tardis

HackPittsburgh, Pittsburgh, PA
hackpittsburgh.org

When local distillery Wiggle Whisky decided to hold a competition for a creative way to move their barrels of whisky through the streets of Pittsburgh, my good friends at HackPittsburgh answered the call with an out-of-this-world project — a motorized Tardis replica from *Dr. Who*.

They started with wood-working plans to make the iconic, blue police box, but member Bob Burger created a custom circuit to make the light on top pulse like its TV counterpart. They made use of the shop's laser cutter and vinyl cutter to create the other accoutrements necessary to make it a true Tardis.

HackPGH president Chad Elish and member Joachim Hall motorized it with a discarded electric wheelchair base. Now in parades and events across Pittsburgh, you will often find a blue British police box zipping down the street entertaining all those who see it.

2 Fat Cat Hot Shot

Fat Cat Fab Lab, New York, NY
fatcatfablab.org

Two days before World Maker Faire last fall, I noticed hurried activity at Fat Cat Fab Lab in New York City. The team was feeling that familiar Maker Faire crunch as they attempted to complete their massive pingpong-ball-shooting *Space Invaders* game. I fell in love with this project as it hit so many of my favorite Maker Faire project criteria: big, cool-looking, interactive, and pointlessly fun.

Dreamed up by Fat Cat member Zack Freedman, seven members of the lab worked on the Hot Shot for four months to make it come to life. The team used every tool in the maker toolbox: laser cutters, CNC machines, multiple microcontrollers, LEDs, and even tossed in their shop-vac to help power it.

Hot Shot was a huge success at the Faire. Kids and adults alike were lining up to have their turn blasting little laser-cut aliens with the air-powered pingpong balls.

3 SXSL Sign

Digital Harbor Foundation, Baltimore, MD
digitalharbor.org

Last fall as one of the final hurrahs of the Obama administration, the White House held a South by Southwest (SXSW)-inspired bash that they named South by South Lawn (SXSL). One invited attendee was Maker Faire regular and *MythBuster* extraordinaire, Adam Savage. Being a nonstop maker, he teamed up with the amazing youth-focused makerspace, Digital Harbor Foundation (DHF), to build an interactive sign heralding the event: the SXSL letters.

The letters, designed by Jen Schachter, came out to around 7-feet tall. The front of each letter had frosted acrylic and the inner boxes had strips of RGB LEDs, programmed by Shawn Grimes to change colors, responding to tweets sent out by attendees as they stood in line for their turn taking selfies with the colorful masterpiece. DHF made sure that even their youngest members had a chance to join in the fun working with Adam, and set them to task with rollers in hand to paint the letters. Those letters now dominate the search results for "SXSL."

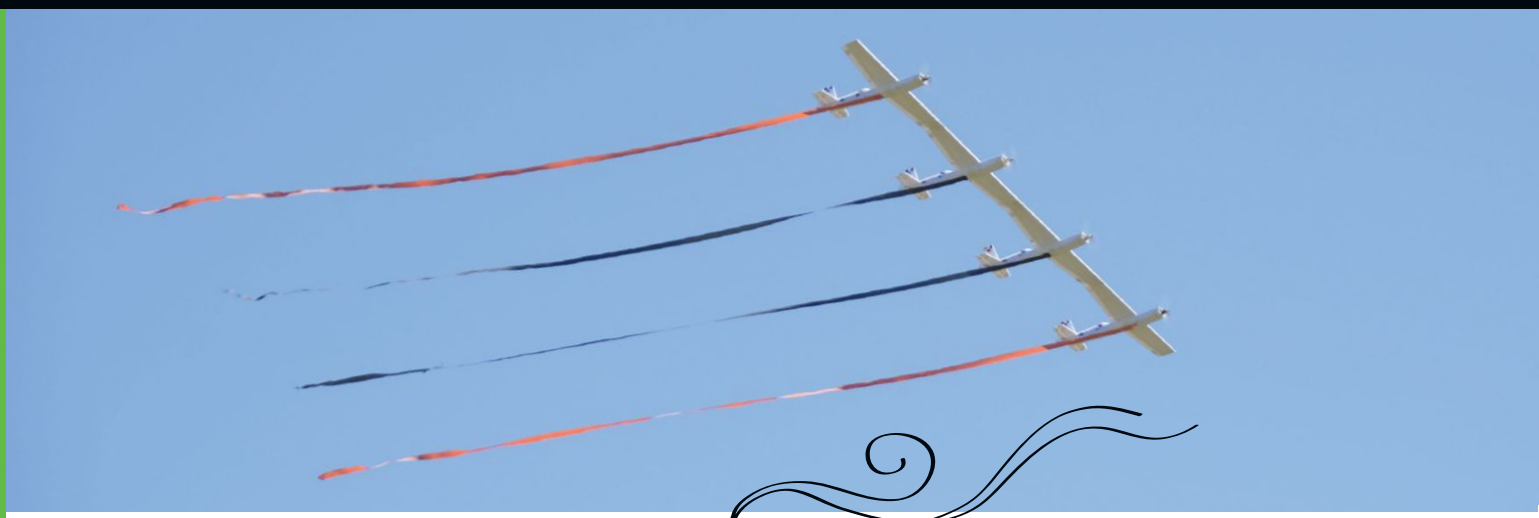
4 Moat Boat Paddle Battle

Ocean State Maker Mill, Pawtucket, RI
oceanstatemakermill.org

A few years ago, my wife and I were talking about what to bring to Maker Faire that could show 3D printing's potential. She remembered racing paddleboats in 7th grade, and the idea took off from there. We went to the other members of our hackerspace, Ocean State Maker Mill in Pawtucket, RI, to discuss the idea. Moat Boat Paddle Battle was born.

Setting racers against each other in a drag-race-style competition down a 12-foot trough, the Moat Boat Paddle Battle has two major rules: Your boat must be 3D printed, and it can only be powered by elastic. With the race sponsor, SeeMeCNC, offering a 3D printer, competition has been intense. Our first races separated the entrants into different classes so adults wouldn't dominate the younger competitors. However, it was the adults who needed the protection as the kids brought their A game. Last year's winner at World Maker Faire in New York, Luke, was only 12 years old. Luke was a veteran racer though, coming in second place the year before and redesigning his boat himself, determined to take the win.

We have now brought the race coast to coast, featuring it at both Maker Faire Bay Area and World Maker Faire. We will be back at World Maker Faire in September, so fire up your CAD and heat up your extruder — it's race time.



Taking Off

A proliferation of pilot communities have made **R/C flight** more approachable

Written by Austin Furey

Austin Furey is the marketing manager for FliteTest.com, a community dedicated to entertaining, educating, and elevating the world of flight. Find him on Twitter as @austinfurey.

RADIO CONTROL FLIGHT CAN SEEM A BIT INTIMIDATING, complicated, and full of nuance. Perhaps you or someone you know spent months on a balsa wood model only to see it explode into splinters just seconds into the first flight. If you don't already know someone in the hobby, it might feel like a long road ahead of you. This is starting to change with the growth of the internet, dramatic innovations in electronics, and overall growth of the industry.

Plug In

Though R/C flight can be a solo activity, it is best enjoyed with others. There are thousands of model flying groups and fields, so there's likely one in your area. In the United States, you can use the Academy of Model Aeronautics (modelaircraft.org) to find local flying sites. People who are interested in newer aspects such as first-person-view (FPV) flying can find local companions through Multi GP for racing (multigp.com) or Drone Squad for social flying (dronesquad.com).

Getting plugged into a community such as Flite Test (flitetest.com) is also a great way to find cool projects, fun content, answers to technical questions, and flying buddies. Flite Test has been around for close to seven years and a big reason for our average growth of 100,000 members a year is due to how our community makes flight so approachable, affordable, and achievable. Just about anyone can get building and flying, even if you don't have a vast base of technical ability or hundreds of dollars.

Party On

Along with getting plugged into a local group or field, you can also keep an eye out for one of our Flite Fest events. They are exactly what they sound like: "a festival of flight." These events are perhaps the perfect indoctrination and exposure to the R/C flying hobby. At Flite Fest you'll find foam flying in every shape imaginable, the smell of solder in the build tents, the whirr of a 3D printer making spare parts, and an incredibly helpful group of people who want you to succeed.

With cheap DIY materials, affordable ready-to-fly models, FPV drones, and increasingly reliable electronics, the model flying industry is experiencing a resurgence! If you have ever had an interest in defying the laws of gravity as a hobby, there has never been a better time to start.

Mike Senese

Hamming It Up

Hep Svadja

Connect with the global community of amateur radio enthusiasts

Written by Mandy Stultz

Mandy Stultz is a founding member of Ocean State Maker Mill. She favors fiber arts, but explores digifab tools to help in these ventures.

I FIRST GOT INVOLVED IN AMATEUR RADIO (ALSO CALLED HAM RADIO) IN 2010, mostly to prove a point that "girls can be amateur radio operators too" — and discovered I was joining a fun community by doing so. Ham radio dates back to the late 1800s as a means of communication. And communicate we have! There are over 743,000 active licenses in the United States.

From the start, I was welcomed to group study sessions for license test prep at HackPittsburgh. Once I had my Tech license (the U.S. entry-level license is known as the Technician Class) and my call sign (I'm KB3UGX), I could start communicating by radio, which made attending group events even more fun.

Field Day, established in 1933, is a great example of sharing ham radio with the community, by setting up temporary stations to demonstrate the science of ham radio, as well as technical skills and emergency preparedness. You can find out more about Field Day, which happens every fourth weekend in June, at arrl.org/field-day.

Hamvention (hamvention.org), the world's largest amateur radio gathering, is held in May every year. You'll find everything from license tests, seminars, radio and radio parts vendors, and the largest flea market you'll ever see.

For any ladies looking for a tribe of their own, the Young Ladies' Radio League (ylrl.org) is an organization for women of all ages all over the world who hold amateur radio licenses.

Possibly the most fun ham radio group project I have had the pleasure of working on was the LEAD Balloon Project with HackPittsburgh —read more about one of our adventures at hackpittsburgh.org/our-day-in-space. We utilized Ham Radio twofold — to track the balloon on its path, as well as communication between all the chase vehicles.

Join the amateur radio community! A Tech license is easy to study for. You can get involved and find more info on the American Radio Relay League's website, arrl.org.

All Aboard

Explore the multifaceted, century-old world of model railroads

Written by Neil Besougloff

MODEL RAILROADING DATES TO THE EARLY YEARS OF THE 20TH CENTURY; artisans in Europe were building handcrafted metal toy trains even earlier. Today, more than 250,000 people in North America declare themselves model railroaders, and more can be found in Europe, Australia, and elsewhere. Far from the image of a lone-wolf hobbyist slaving away in a dank basement, many model railroaders today embrace groups as a way to share skills and companionship by jointly building, operating, and enjoying scale model train layouts.

Model railroads are built in different shapes, scales, and sizes, from exact-detailed copies of railroad locales as they looked on a specific date in the past, to more fanciful railroads designed chiefly to please their builders. Some railroads are large enough to fill an auditorium while others fit on a bookshelf. Skills are shared, including carpentry, wiring, electronics, programming of digitally controlled trains, and of course scenery building and model making.

Construction begins with saws and hammers, and advanced hobbyists today turn to software programs, laser cutters, Arduinos, and 3D printers to improve their models. Model trains can even be the board pieces for a role-playing game that mimics actual railroad freight and passenger operations.

Some groups are formal organizations that construct and operate large permanent layouts. Others are informal round-robin groups, whose members jointly build each other's home layouts. Still other hobbyists construct freestanding modules that are designed to connect with one another. You likely have seen these at public events and hobby shows. The newest spin on these modular railroads are the "Free-Mo" groups, who have jettisoned rectangles for free-form modules that have no rules other than the ability to pair up for public events.

For more about model railroading, check out World's Greatest Hobby (greatesthobby.com), *Model Railroader* magazine (modelrailroader.com), or the National Model Railroad Association (NMRA.org).

Neil Besougloff has been a model railroad magazine editor for 20 years, the past 10 at *Model Railroader* magazine. Before that, he was a newspaper editor in Florida. He and his wife, Susy, live in Oconomowoc, Wisconsin. In addition to model railroading, Neil spends his free time learning Spanish and tinkering with slot cars and a 1931 Ford Model A.

Hep Svadja

TIME REQUIRED: 2 HOURS **COST:** $200

Hands-Free Racing

Build a $200 **Raspberry Pi car** that uses machine-learning software to drive autonomously

Written by Adam Conway and William Roscoe

IN MAY OF 2016, THE SELF RACING CARS GROUP HELD THEIR INAUGURAL AUTONOMOUS TRACK DAY FOR FULL-SIZE CARS at Thunderhill Raceway Park in Northern California. Will and I both attended, but wouldn't actually meet until a few months later. We were intrigued by the event, but we knew that full-sized autonomous racing cars were not for hobbyists like ourselves.

Then in November, Chris Anderson announced a hackathon for scaled-down cars (later named DIYRobocars), and we both showed up excitedly. The new mini series included a league for 1/10th scale R/C cars, which is a perfect scale for a low-cost car. I brought an R/C car, a Raspberry Pi, and some hastily 3D-printed and laser-cut parts. While I was assembling my vehicle, Will introduced himself to me and asked if he could help — thus beginning the partnership that has led to the creation of the Donkey Self Racing Car.

Initially I had modest goals of using computer vision line-following techniques with OpenCV, but Will was more ambitious. He wanted to leverage machine-learning techniques used in self-driving cars like those made by Google and Tesla, but the challenge was where to start.

The event ended with a race featuring all running cars. There were about six cars being hacked on through the day, but only three were up and moving by the time the race began. One of those was the one Will and I worked on, and although it required manual control via a terminal connection, it demonstrated motion and control with our basic hardware setup. One of the other cars, built by Otavio Good and Matt Ball, wowed the crowd with its high speed and ability to learn and autonomously emulate Otavio's remote control driving. The open source code for their car, dubbed the "Carputer" (github.com/otaviogood/carputer), gave Will the machine-learning starting point he needed as we moved forward with the project after the event. I helped refine the hardware and "Team Donkey" is now competing and finishing races in the DIYRobocars monthly events. Even better, there are now about 10 Donkey vehicles up and running in the world — maybe after this article there will be more!

Why Donkey?

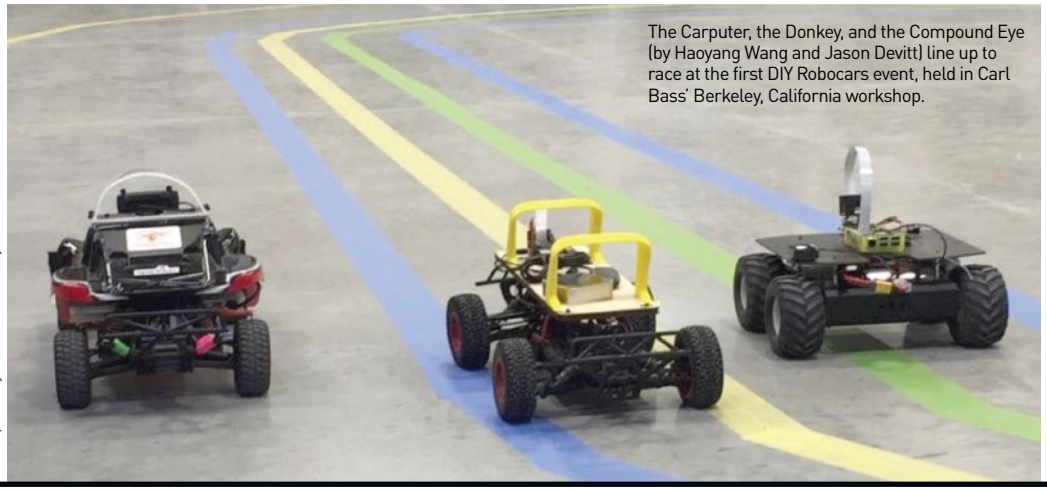
- Donkeys are one of the earliest domesticated pack animals.
- They're safe for kids.
- They occasionally don't follow their master's commands.
- The word donkey has a negative or ugly connotation, so expectations are super low!

Will and Adam work on the first iteration of the Donkey vehicle.

Donkey Car Overview

The Donkey autonomous car is a very simple car. It's based on a Raspberry Pi computer, a camera, and a servo shield (or "hat") board to interface with the R/C car. You drive the vehicle around a lined track to capture images and steering angles, which trains a neural-network autopilot to drive itself around the track. Top speeds around corners are about 4–6mph.

While collecting training data, the car itself doesn't do all that much. It basically takes pictures and sends them to an Amazon server and gets servo commands in return. The server is where the magic happens. First it collects the images and



The Carputer, the Donkey, and the Compound Eye (by Haoyang Wang and Jason Devitt) line up to race at the first DIY Robocars event, held in Carl Bass' Berkeley, California workshop.

Hep Svadja, Adam Conway

Adam Conway is a Silicon Valley techie by day, but by night makes robots, 3D printers, and even satellites. Adam has contributed to *Make:* magazine in the past on drones and Wi-Fi (Vol 37) and has spoken on drones twice at MakerCon.

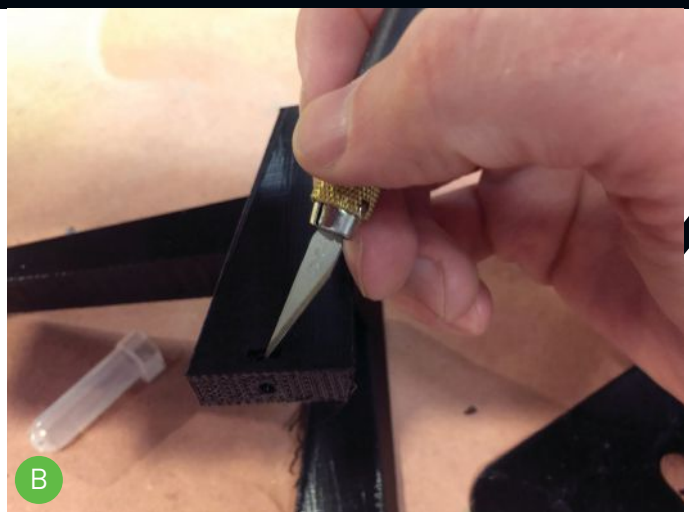
William Roscoe works to scale operations at Ceres Imaging in Oakland. When not building cars he advocates for safe bike routes and campaigns to build a Bay Area subway that uses self-driving mini-vans.

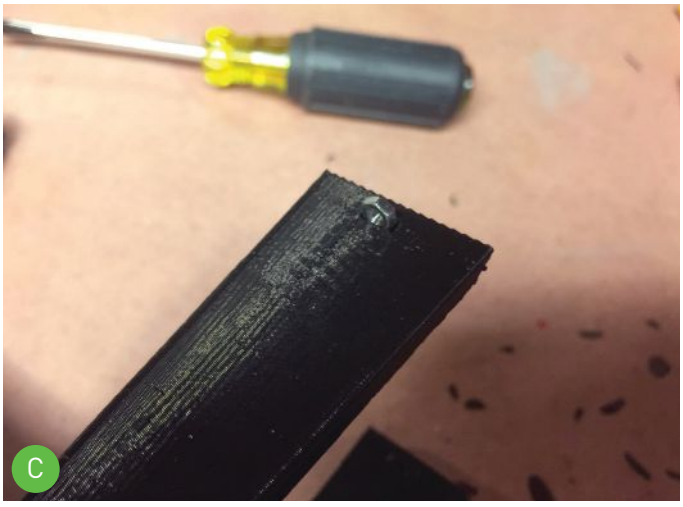
MATERIALS

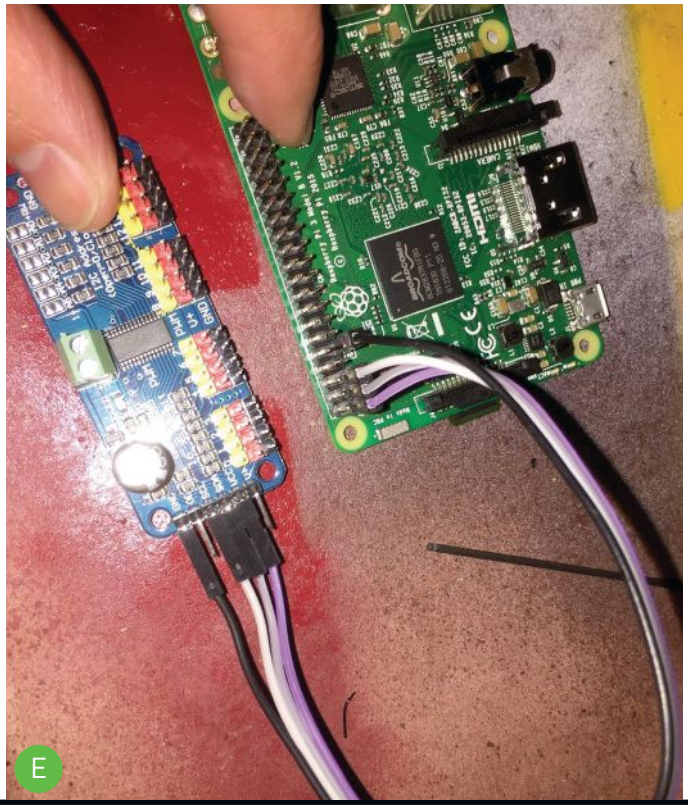
- **R/C truck, 1/16 scale** Exceed Magnet monster truck, NitroRCX #51C853-SavaRed-24-Ghz, nitrorcx.com with RC-380 motor, electronic speed control (ESC), and 7.2V 1100mAh Ni-MH rechargeable battery
- **Battery, USB with micro-USB cable** such as Amazon #B00P7N0320, but any battery capable of 2A 5V output is sufficient
- **Raspberry Pi 3 single board computer**
- **MicroSD Card, 32GB** Many will work, I like Amazon #B00P7N0320 because it boots quickly.
- **Raspberry Pi Camera, wide angle** such as Amazon #B00N1YJKFS
- **Jumper wires, female to female (4)**
- **Servo driver shield, PCA 9685** I used Amazon #B014KTSMLA.
- **3D-printed roll cage and top plate** Get the CAD files at a360.co/2pf3Dam or the STL files for printing at thingiverse.com/thing:2260575.
- **Screws, M2×6mm (4)** for the camera
- **Screws, M2.5×12mm (12)** 3 for the frame, 4 for the Pi, 4 for the motor controller, and 1 spare
- **Nuts, M2.5 (8)**
- **Washers, M2.5 (8)**

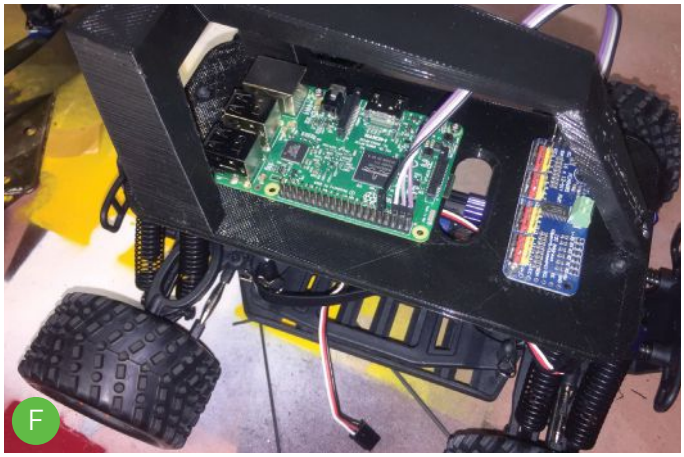
TOOLS

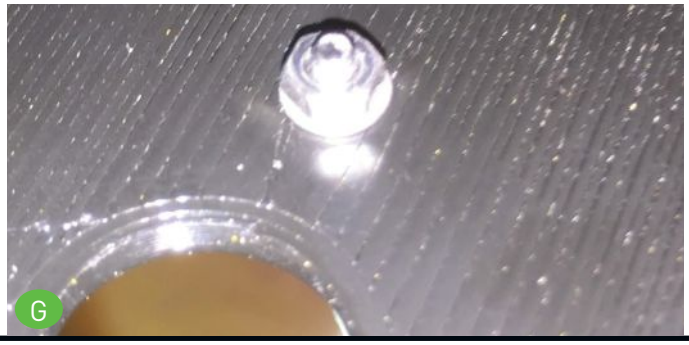
- **3D printer (optional)** with at minimum a 200mm×200mm bed
- **Hex wrenches, metric** I recommend this Bondhus set, Amazon #B00012Y38W.
- **Soldering iron (optional)**
- **X-Acto-style knife**
- **Screwdriver, slotted, small**
- **Drill and bits**











Adam Conway

driving information from the user manually driving the car around the track. The default way to do this on the Donkey is via the mobile-friendly web page delivered by the server.

The mobile web page even has a live video view of what the car sees and a virtual joystick. The server records data from a person driving the car, then uses those images and joystick positions to train a Keras/TensorFlow neural network model in software. This happens quickly — full trip latency (car > server > car) takes about 1/10 second.

Once trained, the model can be loaded on the car and the car should be able to drive like you. This how-to will teach you to get a car up and going.

How to Build a Donkey V2

While you can use these instructions to modify most hobby-grade R/C cars, these directions focus on modifying the Exceed Magnet 1/16th scale truck. Get an invite to our Slack channel to ask questions and post pictures: donkeycar.com/community.html.

Hardware

1. PRINT AND CLEAN THE PARTS

Download the 2 files, for the top plate and the roll cage, from thingiverse.com/thing:2260575 and print them. I used black PLA, with 2mm layer height and no supports. The roll cage prints upside down. If you don't have a 3D printer, you can order parts from Shapeways.

Almost all 3D-printed parts will need cleanup. Re-drill the holes where needed, and clean up excess plastic (Figure A). In particular, clean up the slots in the side of the roll cage, as shown in Figure B.

2. ASSEMBLE TOP PLATE AND ROLL CAGE

Slide the M2.5×12mm screw into the slot in the side of the roll cage. This is not particularly easy. You may need to clean out the hole again and use a small screwdriver to push the nut in such that it lines up with the hole in the bottom of the roll cage (Figure C).

Once you have the nut in, you can attach the bottom plate (Figure D). Once again, this may be tricky. I use a small screwdriver to push against the nut to keep it from spinning in the slot. Good news: You should never have to do this again.

3. CONNECT SERVO SHIELD TO RASPBERRY PI

You could do this after attaching the Raspberry Pi to the bottom plate, but it is easier to see the parts when they are lying on the workbench. Connect the parts as you see in Figure E. We connect to 3.3V, the two I2C pins (SDA and SCL), and ground.

> **Note:** While it is possible to have the Raspberry Pi provide power to the servo shield, you should never set up the shield this way. Steering servos pull too much power and create too much noise for the Raspberry Pi.

4. ATTACH RASPBERRY PI TO BOTTOM PLATE

Before you start, now is a good time to insert the already flashed SD card and bench-test the electronics. Once that is done, attaching the Raspberry Pi and servo is as simple as running 4 screws through the board into the screw bosses on the top plate (Figure F). The M2.5×12mm screws should be the perfect length to go through the board and the plate, and still have room for a washer. The "cap" part of the screw should be facing up and the nut should be on the bottom of the top plate (Figure G). The Ethernet and USB ports should face forward. This is important as it gives you access to the SD card and makes the camera ribbon cable line up properly.

5. ATTACH CAMERA

Attaching the camera is a little tricky; the four M2 screws can be screwed into the plastic but it is a little hard. I recommend drilling the holes out with a 1.5mm bit (1/16" in imperial land) then pre-threading them with the screws before putting the camera on. It is only necessary to use 2 screws (Figure H). Before using the car, remove the plastic film from the camera lens.

The camera's cable will drape down such that it does not need to be twisted before being plugged into the Raspberry Pi board. It is easy to put the camera cable in the wrong way so look at Figures H and I to make sure you do it properly.

6. PUT IT ALL TOGETHER

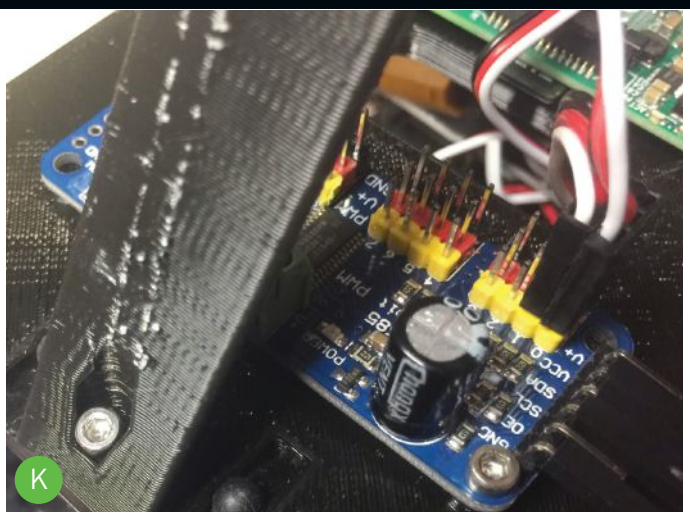
The final steps are straightforward. First, attach the roll bar assembly to the car. This is done using the same cotter pins (R-clips) that came with the vehicle's original body (Figure J).

Second, run the servo cables up to the car. The throttle

H


I


J



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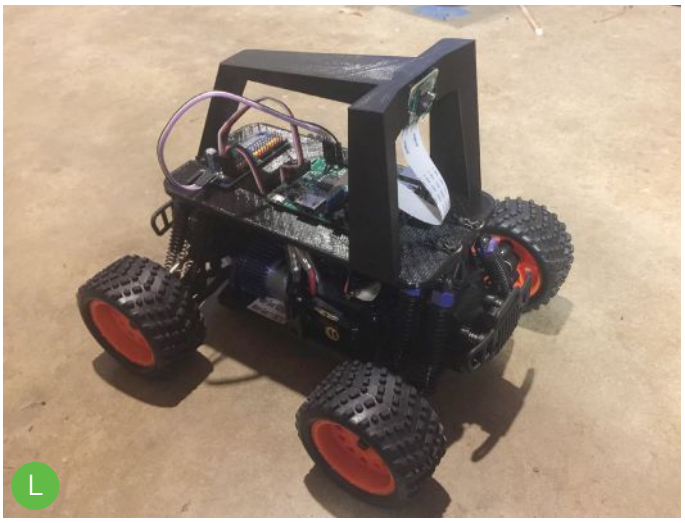

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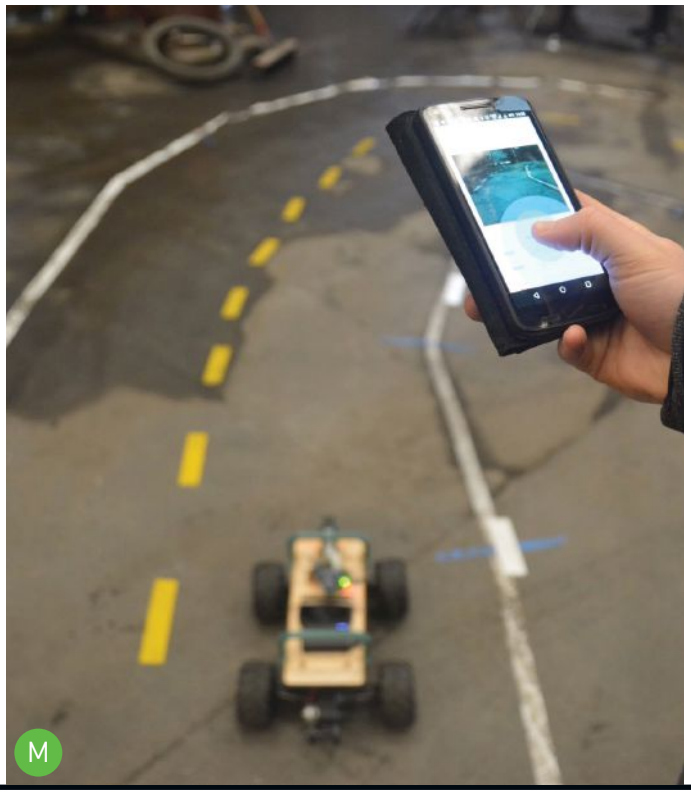


M

Adam Conway, William Roscoe

cable runs to channel 0 on the servo controller and steering is channel 1 (Figure K).

Now you're done with the hardware! (Figure L)

Software

1. GET RASPBERRY PI RUNNING

Download the zipped disk image from https://s3.amazonaws.com/donkey_resources/donkey.img.zip (2.5GB). See our FAQ for instructions at donkeycar.com/faq to install the required packages manually. Unzip the disk image (8GB).

Insert your SD card into your computer and use a disk creator utility to create a disk image. Eject the SD card from your computer and put it in the Raspberry Pi. Plug a monitor, keyboard, and mouse into your Pi, then turn it on by plugging in the battery. Finally, connect to Wi-Fi.

2. START A PILOT SERVER

A Donkey vehicle uses a separately hosted web server to route communications and perform autopilot calculations. To begin driving your vehicle from your phone you need to first start a Donkey control server on your laptop or a remote server.

Install Docker (docs.docker.com/engine/installation) if you don't have it already. Then type in the following from a command-line tool:

```
git clone http://github.com/wroscoe/donkey.git
cd donkey
bash start-server.sh
```

(This will take about 10 minutes the first time to create the Docker container.)

Now you can go to `localhost:8887` to view the web interface.

Drive the Vehicle

CONNECT TO THE PI VIA SSH

You can't have the Raspberry Pi attached to the monitor while you drive, so first you must connect to the Pi remotely via SSH. Then you'll simply start the drive loop and the Pi will start requesting directions from the server.

Find your Raspberry Pi's IP address. Assuming your Pi is connected to the same local network as your computer, you can find the IP address of your Pi by running this command on your computer:

```
python scripts/find_car.py
```

SSH into your Raspberry Pi using:

```
ssh pi@<your raspberry pi ip address>
```

ACTIVATE THE VIRTUAL ENVIRONMENT

Still in the command line, type:

```
cd donkey
source env/bin/activate
```

START THE VEHICLE

Connect your car to the server:

```
python scripts/drive.py --remote http://<your server ip>:8887
```

> **Note:** If you're using a different car, see donkeycar.com/faq to learn how to update the PMW settings in *drive.py*.

Now turn on the power to your car. You should first see the ESC blink red, then hear a beep indicating that the ESC has been calibrated.

COLLECT TRAINING DATA

Go to <your server ip>:8887 in your web browser. Then go to the vehicles tab and select "mycar." To start driving your car, use the virtual joystick (Figure M).

TRAIN AN AUTOPILOT

After you've driven for about 10 minutes around a track and collected over 1,000 training images and steering angles, you can train an autopilot by entering this command:

```
python scripts/train.py
--sessions <your session
name(s)> --name <name
your autopilot>
```

After that, refresh your control screen and you'll see the autopilot in your Pilot dropdown. Select your autopilot here. Press "Start Vehicle" to make it begin. Try increasing your throttle to see how the pilot steers!

Go Forth and Experiment

This is a work-in-progress, open source project. It will be refined as people continue to contribute improvements to the Donkey platform. Get creative and make your car do amazing things. (With only a few changes the same Donkey setup can be used to make a differential drive vehicle, for example.) The faster we innovate, the faster we'll see a self-driving world.

How to Run Donkey on Amazon EC2

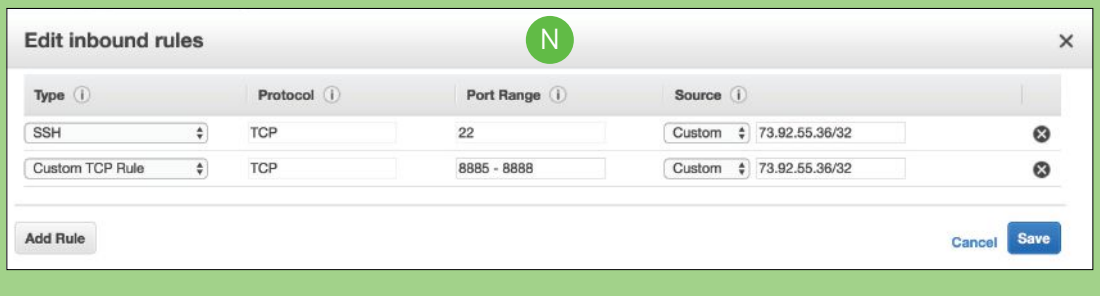
Amazon Elastic Compute Cloud (Amazon EC2) is a web service that provides secure, scalable computing capacity in the Amazon Web Services (AWS) cloud. Users rent virtual computers on which to run their own computer applications.

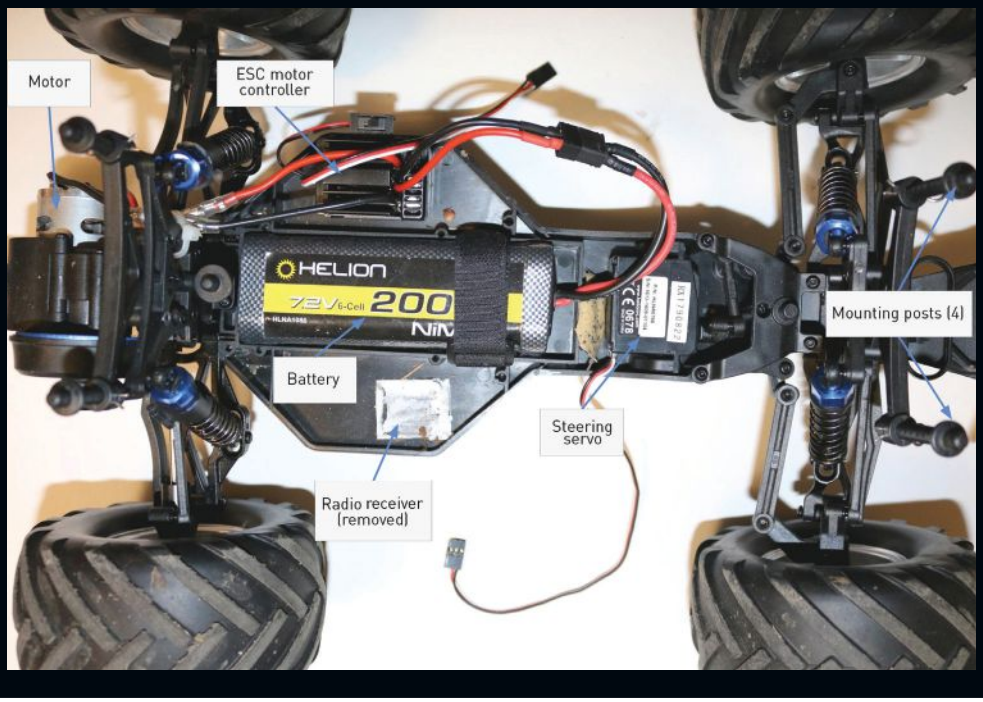
1. Log in to Amazon EC2.
2. Click Launch Instance.
3. Make sure you're using the N. California region (recommend g2.2xlarge).
4. Click Community AMI's.
5. Search for "donkey" to find the instance. Pick the one with the highest number next to it. As of this writing it was ami-df5e07bf.
6. When you launch, your Security Groups should look something like Figure N, but with the source IP changed to your IP. One note — we are not using a secure protocol or login, so this is the only thing protecting you from the internet.
7. Once you launch the server, either SSH to it or use the AWS console to get terminal access:

```
cd donkey
git pull origin master
source env/bin/activate
```

8. Start the server:

```
python scripts/serve.py
```





Donkify Your Own R/C Cars!

Almost any R/C car where the receiver is not integrated into the ESC motor controller can be made into a Donkey autonomous vehicle. Here's what to look for:

- The servo should use a 3-wire connector. ESCs have 2 wires on one side to connect to the battery; on the other side, they'll have 3 wires if they're for brushless motors, or 2 wires for brushed motors.
- Brushed motors are easier to use because they don't need calibration and handle lower speeds better.
- An ESC with a BEC (battery elimination circuit) or UBEC makes integration much simpler. A BEC provides 0 and 5 volts from the ESC through the 3-wire cable, which can be used to power the servo shield. This is important because the servo shield does not get power from the Raspberry Pi by default.

Build a balloon arch to elevate your next event

Written by Larry Moss

Learn more balloon techniques at makezine.com/go/airigami.

A Little History on Balloons

Balloons have been around since at least 1824, when Michael Faraday used rubber balloons in his hydrogen experiments at the Royal Institution in London. Rubber manufacturer Thomas Hancock fabricated balloons as toys the following year, in a DIY kit containing a bottle of rubber solution and a condensing syringe. These versions were affected by temperature, but J.G Ingram's vulcanized toy balloons in 1847 were not, and are considered the precursor to modern toy balloons.

Super Pumped

TIME REQUIRED: AN AFTERNOON **COST:** $20–$40

MATERIALS

- **Balloons**
- **Tent pole** Bamboo or fishing line can also be used, depending on how much stability or flexibility you need in the inner structure.
- **Clamps**

TOOLS

- **Air pump**

Larry Moss and his partner Kelly Cheatle are the masterminds and lead artists behind Airigami. They travel the world, designing and constructing massive artistic balloon installations of all kinds.

AT AIRIGAMI WE DON'T DEAL WITH TINY BALLOON DOGGIES, OR EVEN A FEW BALLOONS FORMING HATS. We're a team that builds massive artistic installations involving up to 100,000 balloons. The crew that brings these to life ranges anywhere from a handful of people up to a team of 60.

Since our building material is a far cry from traditional elements like bricks or 2×4s, endeavors this large come with specific difficulties. But while our pieces each pose unique challenges for us, we've worked out some basic, foundational techniques that you and your friends can use to start building your own balloon formations for your next event.

Build an Arch

Here's a good starting project to make and put over the entrance to your party, place atop your parade float, or use as a jumping-off point for your own custom balloon-scape.

Building anything large requires some basic understanding of how to make simple structures. The basic balloon arch is first of these. The traditional balloon arch uses some non-balloon material as an inner framework. (Not all balloon structures need that inner framing material. This is just an easy way to start.)

You can use a couple bags of 5" round balloons and an 11' flexible pole for a smaller arch that's about 6' wide at the base. For larger arches, opt for 11" or 12" round balloons.

Depending on the project, balloons are most often filled with air, helium, or nitrogen. Most Airigami projects use air. You can use anything from small hand pumps (such as pumps for sport balls and bike tires) to large air compressors.

Sizing Your Balloons

Round balloons aren't perfectly round. Size is determined by diameter across the shorter dimension (Figure A).

For a smooth-looking arch, it's important that all balloons are inflated exactly the same. You can set up a template, like a hole in a cardboard box, in order to inflate all your balloons to a uniform size.

Sizing Your Arch

You could do precise arc length calculations but to simplify, we use some basic guidelines that the balloon industry uses for quick estimates. There are three possible relations of the height and width (Figure B):

A. The arch is wider than it is tall. We estimate that the total length l is equal to $h + w$.
B. The arch is roughly the same height as width. We estimate that $l = 1.5h + w$.
C. The arch is taller than it is wide. We estimate $l = 2h + w$.

Assemble the Arch

1. TIE TWO BALLOONS

Fully inflate both, then tie their necks together (Figure C).

2. CREATE A QUAD

Repeat Step 1 so you have two pairs of balloons tied together (Figure D). Twist them together at their necks to create a quad (Figure E).

3. ATTACH TO POLE

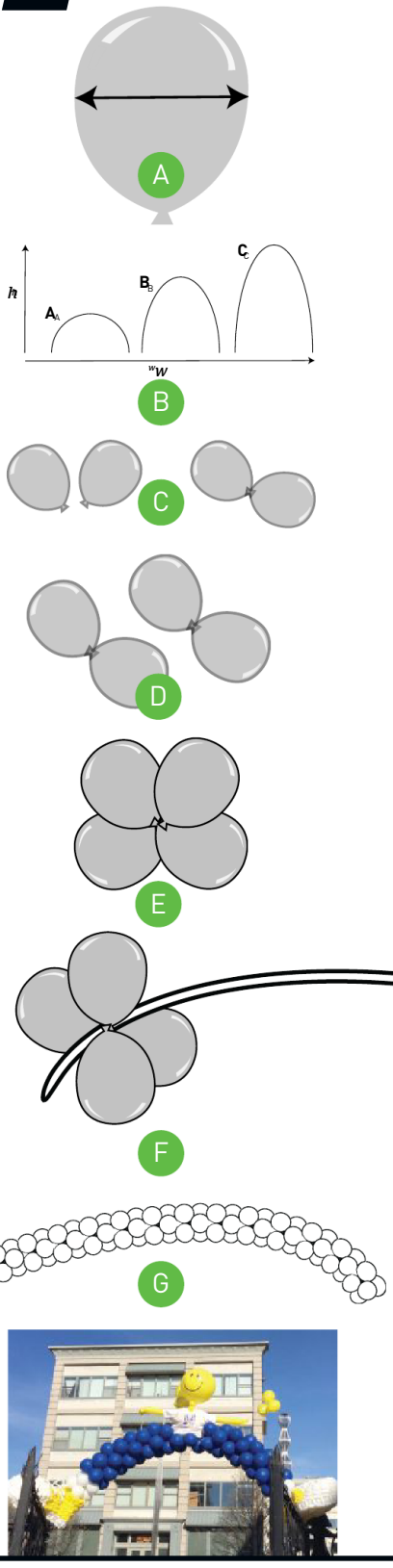
Slide the quad onto your pole and lock it in place by twisting two balloons around each other to trap the pole in between (Figure F).

4. BUILD OUT THE ARCH

Continue to create quads and add them to the pole, placing each successive quad as close to the previous one as possible (Figure G).

Going Further

You can probably already see how the inner framework can be any shape imaginable, allowing us to not just build arches, but letters or other complex shapes. Several of these can be joined together to form any kind of massive sculpture you can image. The rigid pole in the center can be replaced by string or fishing line to make a more flexible creation.



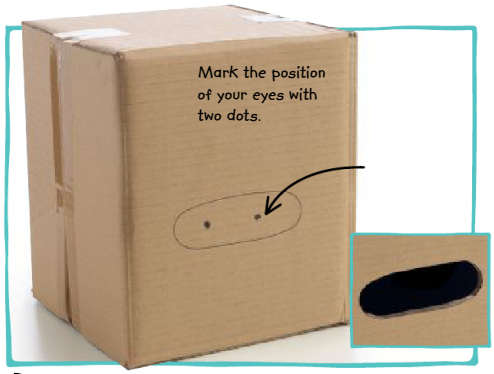
Larry Moss

HOW TO MAKE
BOX ROBOTS

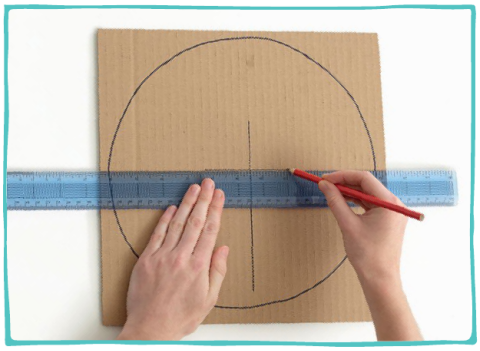
To make this fantastic robot costume, you'll need a big box for the robot's body, a square box for its head, and two smaller boxes for its hands. Make sure the boxes are big enough for you to wear. You'll be using cardboard circles and cups to add the robot's ears and eyes.

YOU WILL NEED

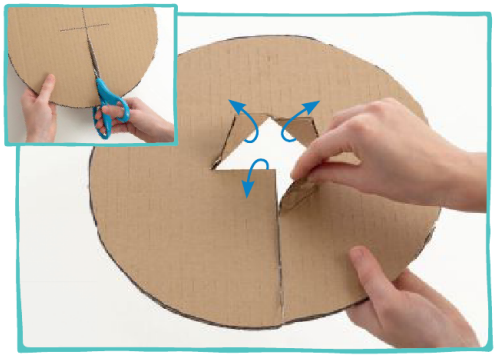
You'll need cardboard sheets, a large box for the body, a smaller square box for the head, and two small boxes for the hands.



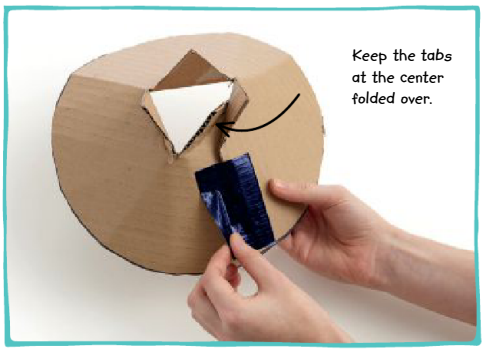
1 Place the square box over your head and mark the position of your eyes. Then remove the box and draw around the dots. Cut this shape out to make a slot for you to see through.



2 To create the **ears**, trace around a large plate on a piece of cardboard. Mark the center of the circle with a cross, then cut the circle out.



3 Cut along one arm of the cross from the outside of the circle to the center. Cut short slits across the other arms of the cross and fold them upward to make tabs.



4 Pull the circle into a cone shape. Secure the overlapping edges of the cone with strong tape. **Repeat steps 2–4** to make a second ear.

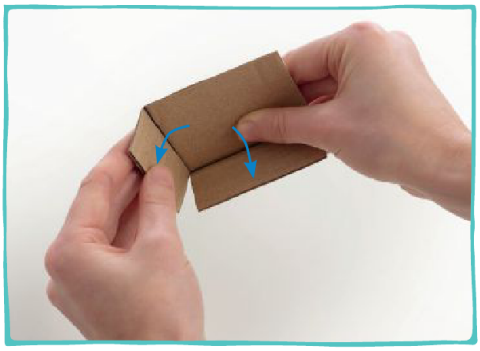
5 To attach the ears, tape the tabs at the center of each cone to the sides of the box.

6 Now, make the **eyes**. Cut the base off two paper cups, cutting slightly above the base of the cups. Make slits around the bottom of each cup to create tabs.

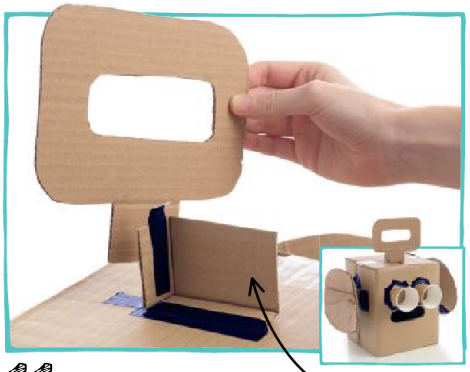
7 Fold the tabs outward so that you can easily stick the eyes to the robot's head.

8 Stick the eyes to the head by taping the tabs down.

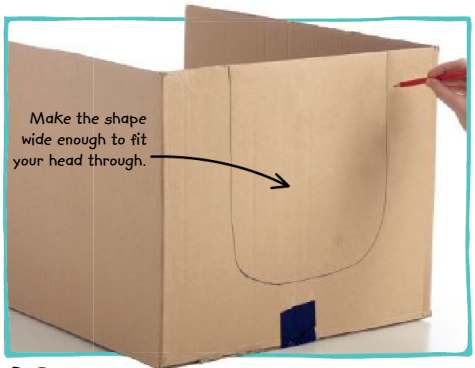
9 Draw an **antenna** shape on cardboard. You can use the picture above as a guide if you like. Cut the shape out.



10 Make a **support** for the robot antenna. Cut out a small rectangle with tabs on two of the sides as shown, and fold the tabs up.

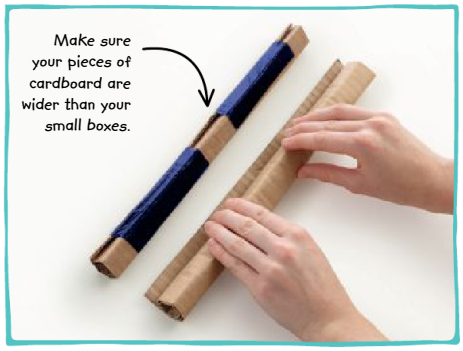


11 Tape the support in place on top of the robot's head, then tape the antenna to the support.



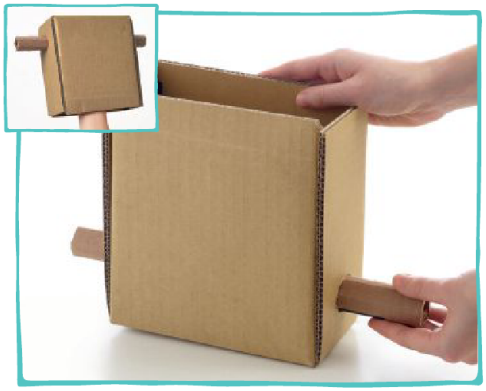
12 Now make the robot's **body**. Cut off one of the sides of the large box. Then draw a U shape on the opposite side and cut it out.

13 Use a large plate to draw circles on the other two sides of the box. Cut the circles out to make holes for your arms.



14 Next, make the robot's **hands**. Cut out two rectangular pieces of cardboard, roll them into tubes, and secure them with strong tape.

15 Take one of the small boxes and draw around the tube on each shorter side near the bottom. Then cut holes where you have drawn.



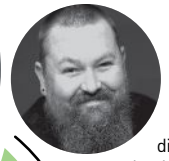
16 Push a tube through the two holes to make handles you can hold when you wear them. **Repeat steps 15 and 16** to make the other hand.

17 Finally, decorate each part of your robot. Paint a base coat first and let it dry. Then paint on futuristic designs in bright colors.

It's a Family Affair

These builds are great to make and use with your **nearest and dearest**

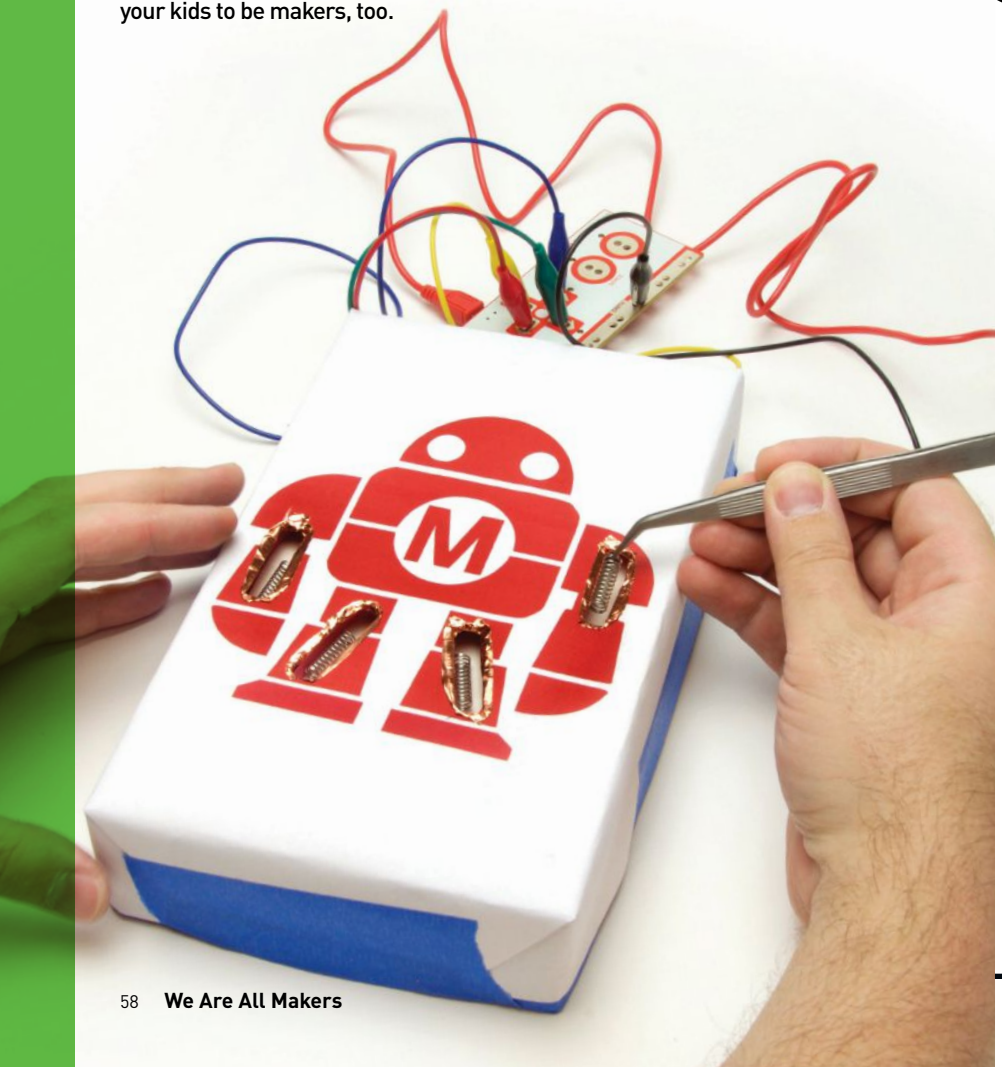
Written by Matt Stultz



Matt Stultz is the 3D printing and digital fabrication lead for *Make:*. He is also the founder and organizer of 3DPPVD and Ocean State Maker Mill, where he spends his time tinkering in Rhode Island.

WHEN IT COMES TO GROUP PROJECTS, there is one group that is more fun to make things with than any other — your family! I grew up remodeling our house with my mother and waxing skis with my father, activities that instilled my love for tools and creating. Now my wife and I help run a hackerspace and create projects together that you will often find at Maker Faires around the country. Making together is one of the things that makes us both happy and always keeps our relationship from getting dull.

Here are some project ideas your family will have fun collaborating on, and that will help inspire your kids to be makers, too.



Matt Stultz, Mark Frauenfelder, Sydney Palmer

Makey Makey Operation Game

I created this project last year as part of our 2016 Maker Camp program (makercamp.com). We included a Makey Makey controller board as part of the kit sent to the participants, which gave me the basis for recreating the classic operation game. Construction is pretty easy with not much more needed than a pair of scissors. The real fun comes by trying to find the items to remove from Makey; I started with springs but any metallic object will work. As a bonus the Makey Makey opens a whole cornucopia of potential projects.

TIME REQUIRED: ABOUT 30 MINUTES

FULL PROJECT: makercamp.com/projects/makey-makey-makey-operation

TOOLS AND MATERIALS:

- Shipping box, small
- Makey Makey kit
- Cardstock (1 sheet)
- Tape, copper
- Tape
- Springs, ⅛"×1" (4)
- Tweezers, metal
- Printed template
- Scissors

Simple Longboard Skateboard

This project comes from *Make:*'s first editor-in-chief, Mark Frauenfelder. If you or your kids enjoy carving the concrete waves, this build will set you sidewalk surfing in a couple of days. The project teaches a simple way to laminate your plywood to give your board extra strength to support kids and parents alike.

TIME REQUIRED: 2 DAYS

FULL PROJECT: makezine.com/projects/simple-longboard

TOOLS AND MATERIALS:
- **Plywood, Baltic birch, ¼" thick, 4'×8' (2)**
- **Glue, wood** such as Gorilla Glue
- **Tape**
- **Skateboard wheels**
- **Skate trucks**
- **Grip tape**
- **Band saw**
- **Paintbrush**
- **Pencil**
- **Scissors**

Rideable Hovercraft

I grew up seeing the ads in the back pages of comic books and *Boys' Life* magazine for instructions to build your own hovercraft and always dreamed of gliding along on a cushion of air anywhere my adventure-seeking heart would lead me. Of course, I now know that while those hovercraft plans had more validity to them than some of the other projects, they were still not going to get me where I wanted. Later when I saw a friend fashion a hovercraft out of common materials, I knew it would be fun to create and turned it into another Maker Camp project. Build a couple and let your family race!

TIME REQUIRED: 2 HOURS

FULL PROJECT: makercamp.com/projects/rideable-hovercraft

TOOLS AND MATERIALS:
- **Plywood, ½"×4'×4' sheet**
- **Tarp, heavy-duty, larger than 4'×4'**
- **Leaf blower**
- **Bucket lid**
- **Tape, duct, heavy-duty**
- **Screws, ½" long**
- **Drill**
- **Jigsaw**
- **Scissors**
- **Yardstick**
- **String**

Vortex Cannon

This classic project is sure to be a blast with your family. A vortex cannon is nothing more than a bucket with a hole in the bottom, a plastic diaphragm instead of a lid, and an elastic cord to pull the diaphragm in. When you pull the plastic back and let it go, a strong gust of air is shot from the back of the cannon, strong enough to knock down plastic cups or throw back your hair. A few power tools will be needed to construct this one but it's easy enough to make three or four for the whole family to run around with, harmlessly blasting each other. Bonus, scoop some mist from a party fog machine into the bucket before firing and watch a smoke ring shoot out.

TIME REQUIRED: ABOUT 45 MINUTES

FULL PROJECT: makercamp.com/projects/vortex-cannon

TOOLS AND MATERIALS:
- **Bucket**
- **Bungee cords (2)**
- **Tape, duct**
- **Zip ties**
- **Trash bag, heavy-duty**
- **Drill**
- **Jigsaw**

Stomp Rockets

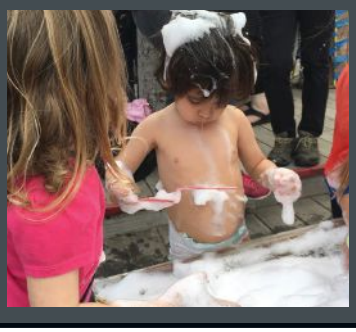
Who didn't have dreams of rocketing to the stars as a kid? Growing up, shuttle missions sparked my imagination and made me love science and technology. Making model rockets with combustible motors is fun, but finding a safe place to launch them is tricky. Stomp rockets give you a chance to both design rockets and safely shoot them to the heavens (or 20'–30' high) in any backyard or cul-de-sac. A few bits of PVC pipe and a soda bottle will create your launch pad and set your family's eyes to the skies.

TIME REQUIRED: ABOUT 30 MINUTES

FULL PROJECT: makercamp.com/projects/stomp-rockets

TOOLS AND MATERIALS:

- Pipe, PVC, ½"×5'
- End caps, PVC, ½" (2)
- L-fitting, PVC, ½" (1)
- Cross-tee, PVC, ½" (1)
- Pipe, PVC, ½"×1' (optional)
- Soda bottle, 2-litre
- Sheets of paper
- Tape, scotch
- PVC cutter or saw



Messy Art Day

Another great way to get the whole family — or neighborhood, even — working on a fun project is to organize a messy art day. This is exactly what the El Cerrito Preschool Coop in California has been doing as an annual event since 2010, transforming their classrooms and playground into a variety of hands-on art activities that promote the art-making process over the finished product. The real goal, more than anything else, is to get absolutely messy.

I attended this year's event in March with my wife and young son, and was totally thrilled with the experience, coming home with a lot of ideas I'd like to reproduce. Some of the standout activities included:

- **Human Spin Art:** A repurposing of the playground's tire swing into a pendulum art maker; a child lays on the tire with a paint-filled squirt bottle, then gets a push to create large looping designs on the material below.
- **Wind Tunnel:** A cone of cardboard is taped to the outside of a box fan, placed on its side, and raised off the ground to allow for airflow. Kids toss buckets of tissue confetti into the high-speed wind over the fan to fill the room. You might want to encircle the space with curtains to keep the little paper pieces from going absolutely everywhere.
- **Shaving Cream Mountain:** As fun as it is simple, you just need to unload numerous cans of shaving cream into an oversized container. Bring in garden utensils to help shape and sculpt the growing mass of foam. Food coloring adds a fun element too.

All of the activities at ECPC incorporated everyday items, such as paint-soaked tennis balls and a maze made from flattened cardboard boxes. The utility of the pieces used only enhances the fun and reinforces the notion that being resourceful is a key to making.

— Mike Senese

Sydney Palmer, Dana and Scott Mitchell - ECPC, Mike Senese

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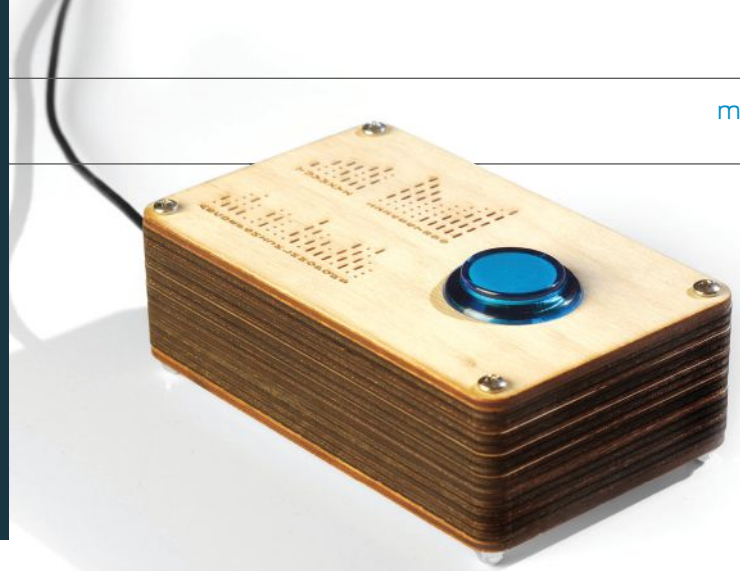
Covert Communication

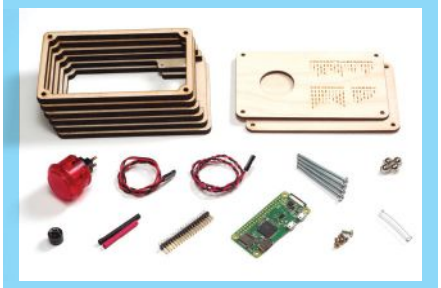
Trade secret messages in Morse code with a button, a buzzer, and a Pi Zero

Written and photographed by Adam, Immanuel, and Isa McKenty

ADAM, **IMMANUEL**, and **ISA MCKENTY** are three thing-building, self-educating, voraciously reading, computer-tinkering, music-playing brothers who hail from Cortes Island on Canada's west coast, where the weather is wet and the post office is open three days a week. They occasionally post the results of their experiments at autodidacts.io.



Time Required:
2-4 Hours
Cost:
$30-$60



MATERIALS

- **Raspberry Pi Zero W, with a microSD card and power source** Adafruit #3400, #2767, and #1995, adafruit.com
- **Male pin header for Raspberry Pi GPIO, 40-pin 20×2** Adafruit #2822
  NOTE: All of the Pi-related components can be had in Adafruit's Raspberry Pi Zero W Budget Pack, Adafruit #3410
- **Buzzer, 3V** Adafruit #1536
- **Arcade button, 30mm** Adafruit #473
- **JST connector leads, 12" female 2-pin (2)** Adafruit #1003
- **Machine screws, #6-32 × 1¾" (4)**
- **Acorn nuts, #6-32 (4)**
- **Pan head screws, #3 × ½" (4)**
- **Heat-shrink tubing**
- **Plastic tubing, ¼", 1" length, or 4 small plastic washers** for Pi standoffs
- **Laser-cut enclosure (optional)** You'll need 1 square foot of ¼" plywood, ½ square foot of ⅛" paneling, and access to a laser cutter or CNC machine. For alternate box options, see "Get Outside the Box."
- **Code and design files** from github.com/TheAutodidacts/InternetTelegraph
- **Micro USB to Ethernet adapter (optional)** such as Adafruit #2992

TOOLS

- **Phillips screwdriver, small**
- **Soldering iron and solder**
- **Hobby knife**
- **Glue gun**
- **MicroSD card reader**

MORSE CODE IS A SUPER SIMPLE COMMUNICATION PROTOCOL THAT CAN BE USED IN ALL KINDS OF WAYS — from secret signals tapped out by hand, to lights, whistles, radio beacons, you name it. It was humanity's first means of long-distance electronic communication, and appearances in fictional (and sometimes factual) tales of adventure and intrigue have been propping up its vintage mystique ever since.

Like many youngsters, we were intrigued by codes and ciphers, especially Morse. We sent Morse coded letters to our friends, and used flashlights to transmit Morse messages between the shore and our family's sailboat. Our first Morse telegraph system was made of two hand-wound electromagnets connected by a salvaged telephone wire. An AC transformer powered the magnets, which rattled against strips of scrap metal with an ear-wrenching 60Hz buzz with each dot and dash.

Luckily, our technical skills have improved since then. What would happen, we wondered, if we took the bare-bones simplicity of a physical Morse key and connected it to the internet? When the Raspberry Pi Zero W came along, offering a web-connectable board that would fit in a project box for $10, we decided to find out.

Several prototypes and programming languages later, we had a tidy laser-cut 3"×5" box with the Pi, buzzer, and one large button. Push the button, and a Golang client on the Pi sends a signal through a WebSocket server, turning on the buzzer in all the other connected telegraphs. The Pi's configuration lets you set the channel to which your telegraph connects, allowing open channels that anyone can listen and talk on (like amateur radio Morse bands) and private ones for you and your cohorts. Both server and client code are open source, so you can hack and modify at will.

1. LOAD THE PI

The simplest way to get the telegraph code set up on your Pi is to use the pre-packed disk image. Download and unzip the disk image from github.com/TheAutodidacts/InternetTelegraph/releases. The disk image includes the Raspbian operating system, so it will take a few minutes to download. (For advanced options, or to install the telegraph client manually, check the instructions in the GitHub repo).

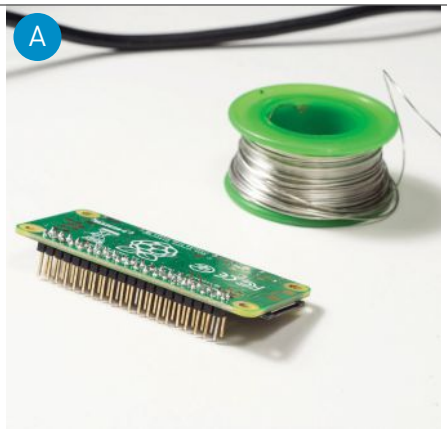
If you don't already have a tool for burning disk images, Etcher (etcher.io) is a good option. Insert a blank microSD card into your card reader. Launch Etcher, click "Select Image," and select the Internet Telegraph disk image (*internet-telegraph.img*). Click

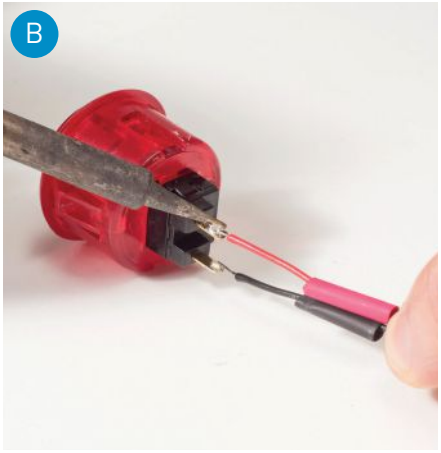
All Systems Golang!

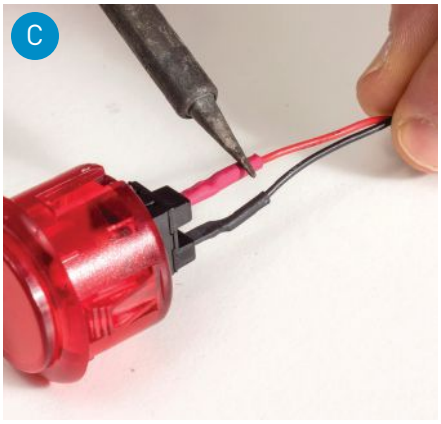
Sending Morse over the internet requires a real-time communication protocol — you wouldn't want to wait for an HTTP request to complete every time you tried to send a dot or dash! Luckily, there is a protocol for that: WebSockets.

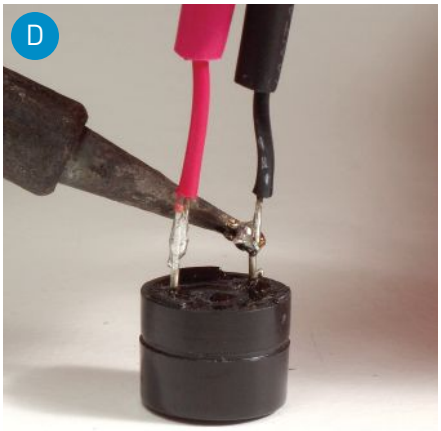
We went through several different technology stacks in the quest for a simple client-server WebSocket implementation for the telegraph. These included Node.js, which is equipped with a nice WebSocket library but is complex to implement on the Pi, and Python, which works nicely on the Pi but not so nicely, we found, on the server end.

We settled on Go. Go, or "Golang," is a relatively new open source programming language originally developed by Google. It combines features of some high-level languages like Python or JavaScript (such as online package management and relatively compact syntax) with features of low-level languages like C++ (static types, compiles to machine code), and then adds some special sauce of its own, like the ability to add threads easily through "goroutines."









"Select Drive" and select your microSD card (be careful with this one — you don't want to write the image to your hard drive!). Click "Flash" and wait for Etcher to do its work. Eject the SD card and pull it out of your card reader, then put it back in. It should mount as a disk that's accessible through your file manager.

2. CONFIGURE YOUR TELEGRAPH

SET THE WIRELESS NETWORK INFO

The telegraph can be run over Ethernet (using a micro USB to Ethernet adapter such as Adafruit #2992), or connected to a wireless network. To connect it to a wireless network, open */etc/wpa_supplicant/wpa_supplicant.conf* from the SD card, and update the network info at the bottom of the file with your network's SSID and Wi-Fi password.

SET TELEGRAPH CHANNEL AND SERVER

Open *config.json* in the root directory of your SD card. There are two configuration options you can set: The "channel" determines who else you'll be communicating with. To send private Morse messages with your friends or relations, set this to an obscure series of words or string of characters that only you and your buddies know. The default channel is the "lobby." Anyone with a telegraph who doesn't change their channel will be in the lobby.

By default, telegraph messages go through our server at morse.autodidacts.io. You can also grab the server code from GitHub and set up your own server either on the web or on your local network. If you're running your own server, change the "server" value from morse.autodidacts.io to the URL or IP address of your server.

Once you've saved the updated config, eject your SD card and pop it into the Pi Zero.

3. WIRE IT UP!

The first step for connecting things to your Pi Zero is to solder on the GPIO pin header. Put the header in from the top, then flip the Pi over and solder a pin in at each end to hold the header in place. Solder the rest of the pins, taking care to avoid bridging the gaps between pins with any errant solder blobs (Figure A). (For more detailed instructions, see this short tutorial from Adafruit: learn.adafruit.com/pigrrl-zero/pi-zero.)

Slip a couple of sections of heat-shrink tubing over the leads of one of the JST connectors, and then solder the leads onto the terminals of the arcade button (Figure B). It doesn't matter which wire goes to which terminal on the button. When you're done, slide the heat-shrink tubing over the joint and shrink it on with your soldering iron (Figure C).

Solder the other JST lead onto the buzzer. This one is polarity-specific: Make sure you connect the black or dashed negative wire onto the longer pin (Figure D).

4. CUT THE PIECES

If you have access to a laser cutter, cut the top and bottom panels (*InternetTelegraph-top-and-bottom.svg*) from ⅛" plywood paneling, and optionally laser-engrave the Morse alphabet on top.

Cut the box sides (*InternetTelegraph-enclosure-sides.svg*) from 6 layers of ¼" plywood. If your cutter can handle it, these can alternatively be made from 3 layers of ½" plywood.

You can also order the plywood parts from a laser cutting service. Talk to local makers about the best cutting service in your area or check out makezine.com/where-to-get-digital-fabrication-tool-access.

5. ASSEMBLE THE TELEGRAPH

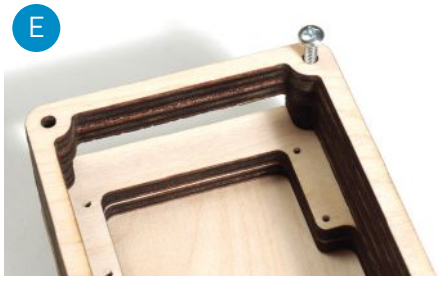
Stack the plywood layers, leaving off the top panel, and drop the machine screws into their holes temporarily to keep the layers lined up (Figure E).

Cut four 2mm (0.078") slices of the plastic tubing (Figure F). Place one of these over each of the pilot holes in the enclosure (Figure G), and then place the Pi on top with the ports facing toward the edge of the enclosure (Figure H). Secure the Pi with four #3×½" screws.

Plug the buzzer lead into GPIO pin 19 and ground (Figure I), making sure the negative side is toward the edge of the Pi, and glue the buzzer down with a dot of hot glue to prevent it from knocking around in the box like a poltergeist (Figure J).

Thread the arcade button's wire through the hole in the top plate, and press the button into the hole. Plug the button's lead into GPIO pins 26 and ground (Figure K). This one can be oriented either way.

Remove the machine screws. Add the laser-engraved top panel to the top of

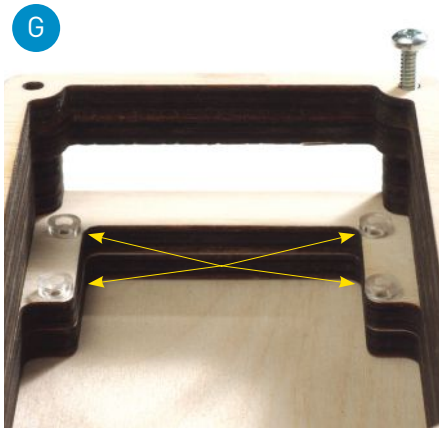


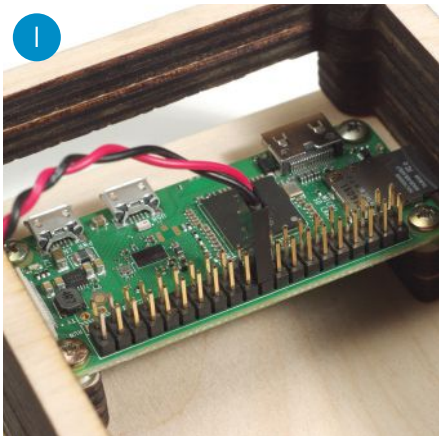
Get Outside the Box

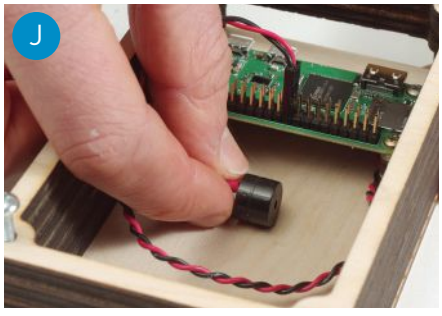
We've used stacked laser-cut plywood for the enclosure. This is a convenient and attractive approach, but it's only one of many options for housing your telegraph. Our first prototype was sawn out of a solid 2×4. You could use clear acrylic, 3D print your enclosure, or even install the telegraph in a cottage cheese tub, like many of our early electronics experiments. Let your creativity, available materials, and aesthetic preferences lead the way.

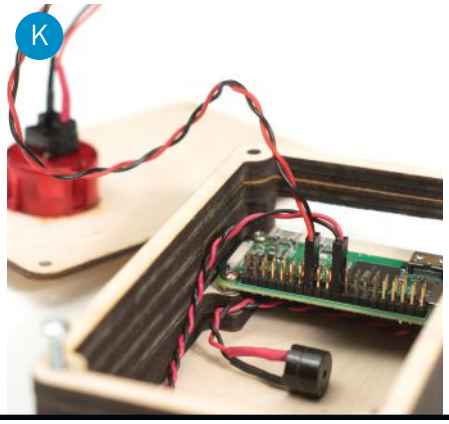
Standoff-ish Behavior

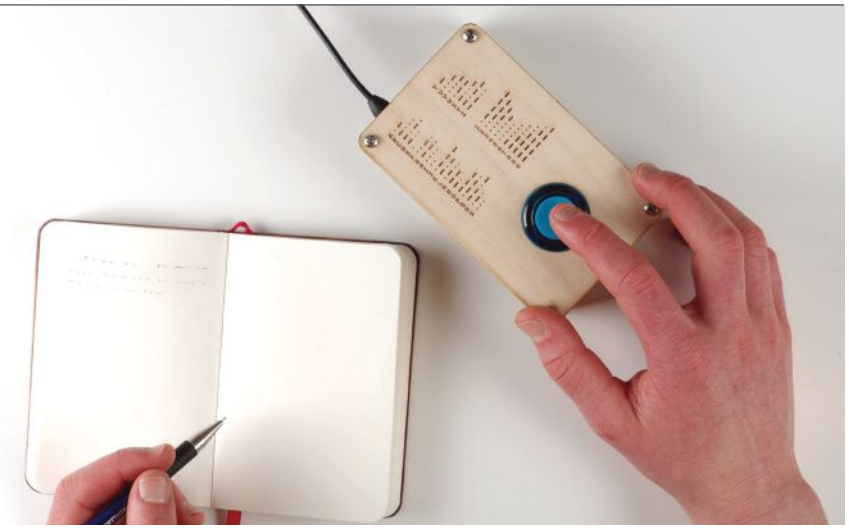
We've found that most electronics projects require standoffs: small spacers, ideally non-conductive, to separate circuit boards from surfaces above or below. These often need to be a precise length in order to make things fit into unexpectedly tight spaces, and finding the right standoff for a job — especially if you live in a remote area — can be a problem. Our solution is to make our own standoffs by slicing sections off of a length of acrylic tubing. This means we can instantly create a standoff of an arbitrary length, and experiment as needed until we get the size just right.











the sandwich, oriented so the button is at the opposite end from the Pi (Figure L, previous page). Put the screws back in, and secure them with 4 acorn nuts (Figure M).

6. POWER UP

Plug in the USB power and wait about 30 seconds for the Pi to boot up. When the Pi is booted up and connected to the Morse server, it will beep out "ready" in Morse code (.-. . .- -.. -.--).

To test your connection, push the button on your telegraph. If you hear a beep, your telegraph is talking to the server. All systems go!

MAY THE MORSE BE WITH YOU!

The standard Morse alphabet includes letters, numbers, and a variety of punctuation symbols. The numbers and letters are shown in the engraving on the top of the telegraph for easy reference. For a more complete set, as well as some tips on learning Morse, print out a copy of *InternetTelegraph/Docs/translate-morse.pdf* from the GitHub repo. You'll want to have a notebook handy for transcribing incoming messages.

Morse is made up of dots, dashes, and spaces (gaps). Each of these has a specific length in relation to the other symbols. Keeping these lengths in mind will help you send well-formed messages that are easy to decode, at whatever speed you're punching them out. A *dash* is 3 times as long as a *dot*. Gaps between symbols within a letter are as long as one dot. Gaps between letters are 3 dots long, and gaps between words are 7 times as long as a dot.

Once you (and any other telegraph operators on your channel) are ready to go, it's time to send a message!

We suggest something short and sweet, like "hi." In Morse, that's 4 dots, a space, and then 2 dots: dit-dit-dit-dit dit-dit. (As it happens, "hi" was also the output sample that came just before the first ever use of "hello world" in a 1972 programming tutorial by Brian Kernighan. We're sticking with historical precedent here.)

Try going very slowly at first, and sending simple messages. You might want to jot down the Morse as it comes in, and then decode it after the transmission. The same works for sending: write out the Morse first, and then key it into the telegraph.

Less Is Morse

Morse code, and the telegraphs to send and receive it, were invented by painter and tinkerer Samuel Morse and machinist Alfred Vail around 1840. For a century, Morse code was the primary means of long-distance communication, both over wires and by radio.

The original Morse telegraph used a solenoid-actuated stylus to press dots and dashes into a moving sheet of paper. Eventually, telegraph operators discovered they could hear the code in the solenoid movements and do away with the stylus system altogether.

Morse code has also found some more arcane uses. Thomas Edison famously proposed to his wife in Morse code, and the two would send surreptitious messages to each other by tapping out the code silently with their fingers (a trick that we've tried on several occasions as well, though not with marriage proposals). U.S. Navy commander and POW Jeremiah Denton rose to celebrity status after using Morse-coded eyeblinks during a television interview to sneak a message out from under the nose of his North Vietnamese captors in 1966.

Because of its simplicity, Morse can be transmitted by sounds, light beams, radio, touch, telegraph wires, or just about any other medium that can be varied or turned on and off. Morse radio transmissions are less susceptible to weak signals and interference than voice communications, which makes it a popular mode for long-distance amateur radio operators.

TROUBLESHOOTING

If the telegraph runs into an error connecting to the Morse server, it will give out a string of 8 short beeps when the button is pressed. This means it's time to check that the Pi's internet connection is working and the telegraph client is configured correctly.

The easiest way of troubleshooting is to attach a monitor, mouse, and keyboard to your Pi. Once you've got these peripherals hooked up, first make sure that the Pi is connected to the internet. Second, try running the telegraph client from the command line by opening up a terminal and typing **`cd / && ./internet-telegraph`**. Then try pressing the telegraph button. Check to make sure the terminal is logging key presses, shows the client is connected to the server, and hasn't thrown any errors.

If you're feeling 1337, you can do all this through SSH rather than plugging in a monitor. Use nmap to obtain your Pi's IP address (or try **`ssh pi@raspberrypi.local`**), SSH into your Pi, and start debugging.

If any problematic issues show up, we're happy to help. Just open an issue on the GitHub repo, or shoot us an email at info@autodidacts.io.

1+2+3 Scrap Fabric Twine

Written and photographed by Cintia Gonzalez-Pell

IF YOU'RE DROWNING IN FABRIC SCRAPS AND OFFCUTS, this is the perfect project to upcycle them into something practical.

It's an idea that came to me while I was in the process of tidying up my sewing space. I tend to keep all my fabric scraps (just in case!) and all those really long, thin pieces were tangling together and making a big mess. After doing a bit of online research on rope making, I found a video showing how to hand-twist rope from tree bark. I adapted the same technique with fabric and it works a treat.

1. START THE TWINE

Tie two fabric strips together with a small knot.

TIP: To avoid tangles, use one long strip and one short strip.

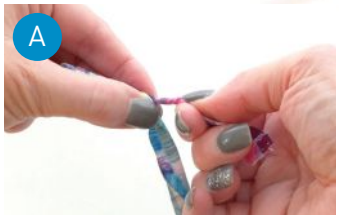
2. TWIST AWAY

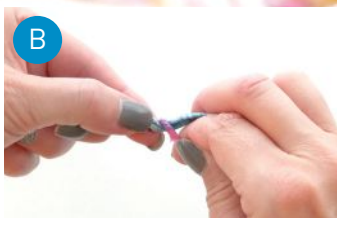
Working with the strip at the rear, twist the strip several times away from you (Figure A). Then pull that twisted strip over the other strip and toward you (Figure B). Repeat this until you reach your desired length (Figure C). To join strips in order to lengthen your twine, leave a tail of about 1"–2" and wrap it around the new fabric strip (Figure D). Continue twisting as before. Stagger your joins to avoid weak points.

TIP: The tighter you twist, the firmer your twine will be.

3. TIE IT OFF

Tie a small knot on the end of the twine to secure it and prevent unraveling (Figure E).





Time Required: 1-2 Hours

Cost: $0-$10

MATERIALS

» **Fabric scraps in assorted lengths, cut to 1" wide**

TOOLS

» **Fabric scissors**

CINTIA GONZALEZ-PELL runs mypoppet.com.au, a craft blog that recognizes possibility in the ordinary. A desire to create, and an ability to see potential in an unloved object and give it new life, is the driving force behind Cintia's inspirational craft tutorials. She lives in Melbourne, Australia.

USE IT

This twine can be used as an upcycled alternative to rope and cord in weaving and craft activities:

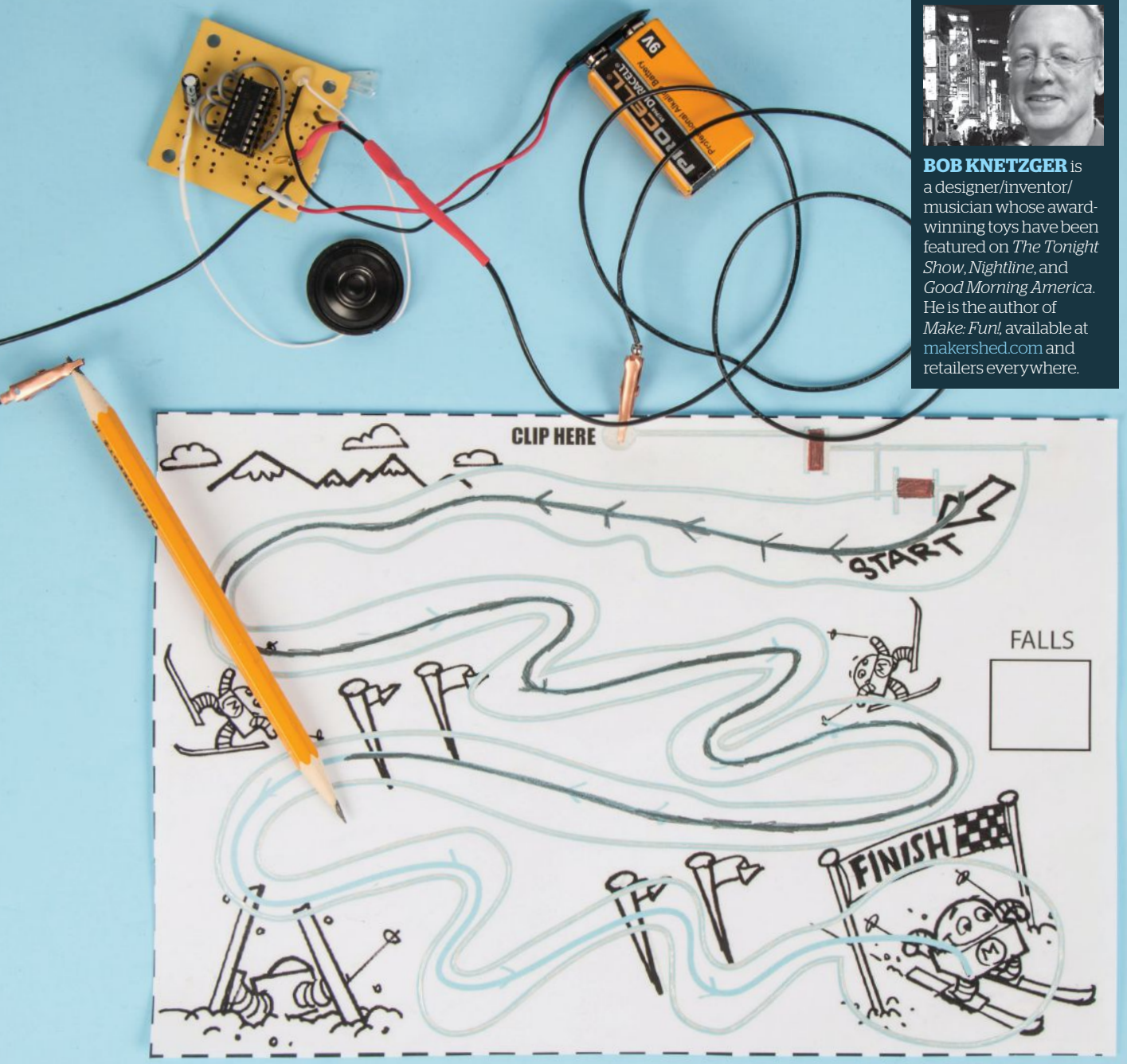
» A brightly woven doormat

» Woven chair seat cover, in place of sea grass cord

» Incorporated into jewelry or sewing projects

» A decorative ribbon around brown paper wrapped parcels

Watch a video how-to: youtu.be/-XfpFhnh8xg.



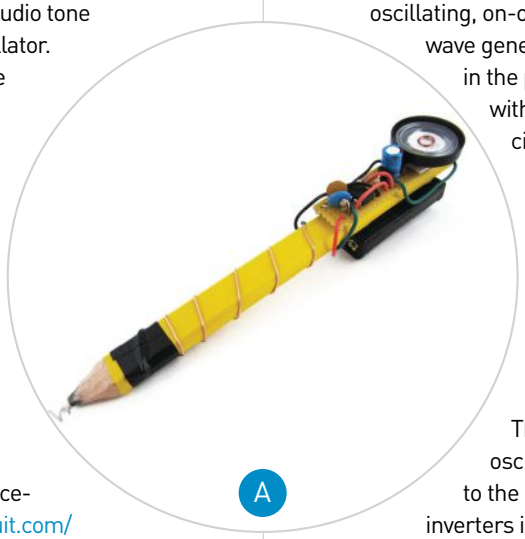
BOB KNETZGER is a designer/inventor/musician whose award-winning toys have been featured on *The Tonight Show*, *Nightline*, and *Good Morning America*. He is the author of *Make: Fun!*, available at makershed.com and retailers everywhere.

Sounds Like Fun

Written by Bob Knetzger

Play electronic audio games by creating a circuit and conductive ink cards

OVER THE YEARS THERE HAVE BEEN MANY ELECTRONIC TOYS THAT LET YOU PLAY WITH AND LEARN ABOUT ELECTRICITY. Jay Silver's Drawdio (Figure A) from 2008 combines a simple 555 timer circuit with a pencil to make squeals, beeps, and musical tones. When you draw, the graphite (carbon!) in the pencil conducts an electrical signal — you're literally drawing a circuit! The longer and skinnier the pencil lines, the higher the electrical resistance and the lower the audio tone created by the oscillator. Short, fat lines have more conductive carbon, giving a lower resistance and making higher-pitched tones. (Adafruit sells a Drawdio kit with a clever 2-sided circuit board — one side for wired components, the other side for surface-mount! — at adafruit.com/products/124.)


A

Thirty years earlier Mattel produced The Electronic Connection toy (Figure B), which included game cards printed with conductive ink: drawing with the electronic pencil let you solve squealing mazes, play beeping games, and create music! The silk-screened and heat-cured conductive inks on the game cards were formulated with real silver, expensive even then!

Now, new developments in conductive ink pens let you draw your own circuits: quick, easy, and (relatively) cheap! For my recommendations, see "Closer Look: Conductive Pen Reviews" on page 71.

Here's a simple DIY project that combines all three: Build a simple sound-making circuit with an electric pencil stylus. Then draw with conductive ink pens to make and play electronic sound games. You can use the included print-and-use card designs, or create your own.

WIRE THE CIRCUIT

This simple circuit uses a minimum of components. You can assemble it on a protoboard or easily solder it up with point-to-point wiring on a perf board. I used a DIP socket for the 4049 chip, but you don't have to. Make each connection, one-by-one, following the circuit diagram (Figure C).

How does it work? Usually used for decoders and multiplexers, the lowly 4049 was re-imagined by Mattel's engineers to create musical tones in The Electronic Connection toy. Three of the six inverters are linked head-to-tail with a resistor and capacitor to create a simple, self-oscillating, on-off-on-off square wave generator. The "lead" in the pencil, together with the marks and circuits on the paper, act as a feedback resistor: the greater the resistance, the faster the circuit oscillates, and the higher the pitch of the tones. The output of this oscillator is hooked up to the remaining three inverters in parallel, and their combined output is enough to directly drive a dynamic speaker — no audio amplifier needed!

Once you've built the circuit, attach or solder an 18"-long wire with an alligator clip to the connection marked "A" and another 18" wire with alligator clip to the connection from pin 2 on the 4049 hex inverter chip.

TRY IT OUT!

Sharpen both ends of a 2B (not 2H!) or softer pencil and attach one of the alligator clips to the pencil. An ordinary No. 2 pencil is too hard and won't leave enough carbon on the paper to complete the circuit. Look for drawing pencils marked 2B or 4B or even 6B at an art supply store. Staedtler Mars Lumograph 6B pencils work great!

Draw a thick, fat patch of pencil marking near the edge of a piece of paper. Connect the free alligator clip directly on that mark. When you touch the pencil tip to the pencil mark, you complete the circuit and hear an audio tone: *BEEEEEP!* Make crazy sound effects from a low growl to a high squeal as you draw with the pencil and add more and more conductive carbon lines to the

Time Required:
1-2 Hours
Cost:
$30

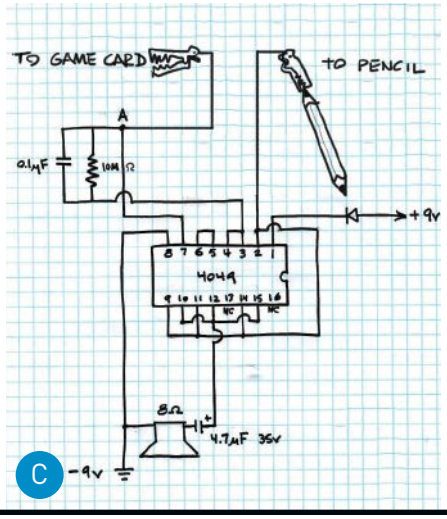
MATERIALS

- **Hex inverter IC chip, 4049** plus an optional DIP socket, as the CMOS part is static sensitive
- **Capacitor, 0.1µF**
- **Resistor, 10MΩ**
- **Power diode**
- **Capacitor, 4.7µF, 12V**
- **Battery, 9V**
- **Battery clip, 9V, with leads**
- **Alligator clips (2)**
- **PCB protoboard or perf board**
- **Multi-strand wire**
- **Speaker, small, 8Ω**
- **Solder**
- **Graphite pencil, soft**
- **Vinyl eraser, soft white**

TOOLS

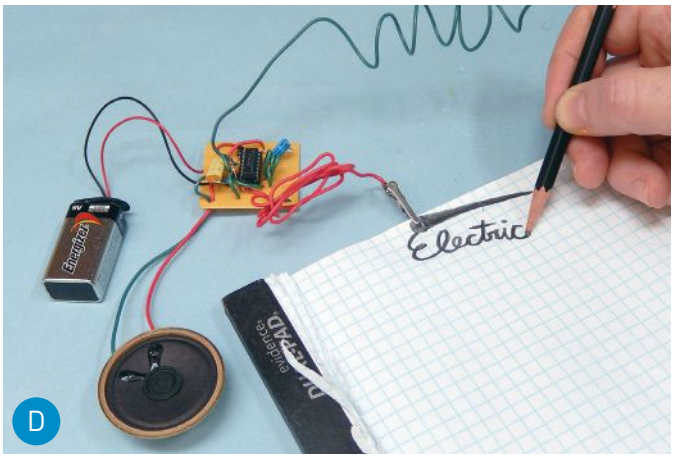
- **Soldering iron**
- **Conductive ink pens** see "Closer Look: Conductive Pen Reviews," page 71
- **Wire stripper**
- **Side cutters**
- **File folder (optional)**
- **Glue or double-back tape (optional)**

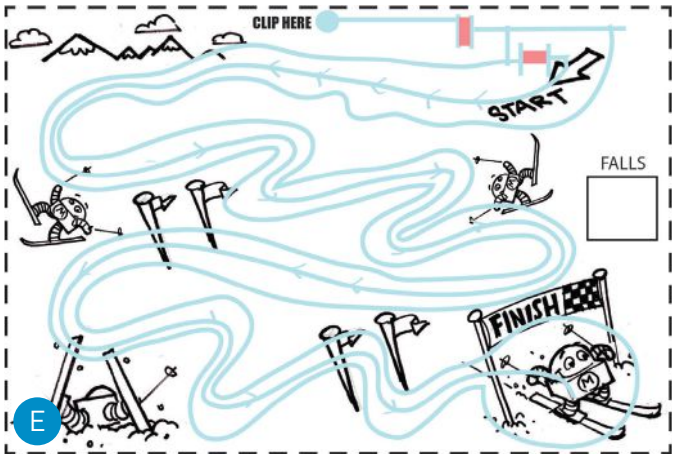
B

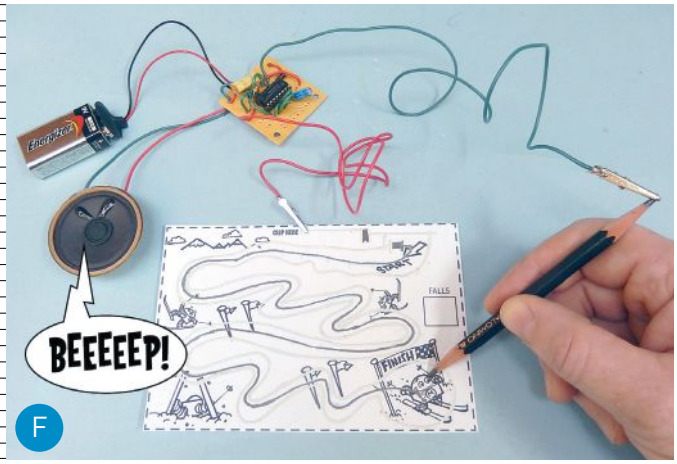


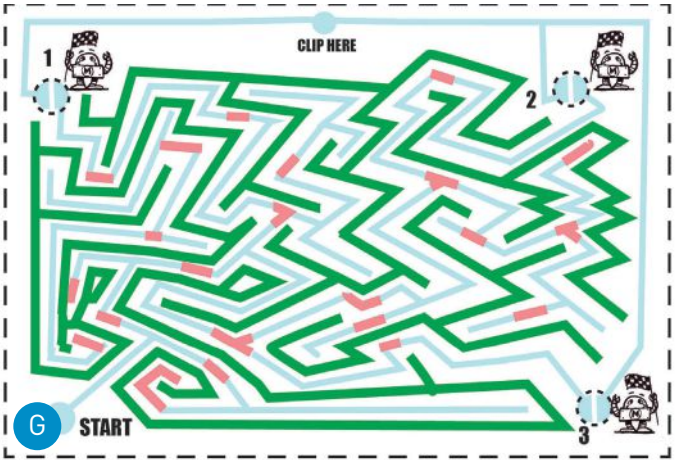
C

Sydney Palmer, Bob Knetzger









circuit: *ggrrrreeeEEEEEE!* (Figure D). Have fun making sounds and drawing paths and pictures. You can also use your fingers to touch and complete the circuit. Hold the pencil tip in one hand and touch the pencil marks on the paper. Just making sounds with the circuit is fun by itself — but there's more.

MORE FUN WITH GAME CARDS!

The next step is to create game cards using conductive ink pens to draw circuits. You can create your own original game circuits using the conductive pen lines as traces together with pencil lines for resistors. To get you started, try these fun electronic circuit game cards, updated from the original Electronic Connection toy. Go online to makerfunbook.com/portfolio.html to print out the game card layouts (they're the 3rd, 4th, 5th and 6th "Print" buttons on the top row.) For a longer-lasting card, laminate the paper onto thin cardboard (like a file folder) with some glue or double-back tape, then cut out.

Color in the solid blue lines, shown in Figures E – J, with conductive ink. Let the ink dry completely, then use the soft 2B pencil and press firmly to fill in the resistance values, as shown in red, with a nice, thick layer of pencil. Press down hard for a dark pencil line. Hook up the alligator clips and use the pencil stylus to check the continuity of each of the lines as you draw. You may need to go back and fill in any nonconductive gaps or thin spots.

Let the games begin!

DEXTERITY SKI RUN

Here's how to play this easy skill game: Start your pencil probe on the center line at the START. You'll hear a low tone — that's good. Now trace the path of the center line toward the FINISH (Figure F). Don't press or draw, just touch lightly with the pencil tip to keep the tone playing. Be careful! If you stray or lift the pencil, the tone stops: that's a "fall." Make a tick mark in the FALL box and go back to the start and go again. If you really stray you'll hear a high-pitched tone: that's a double fall. Make 2 marks in the score box and go back to the start and try again. What's the fewest number of falls you can make to get to the finish? Can you do a perfect run? Think it's too easy? Hold the pencil in your other hand!

3-IN-1 SOUND MAZE

This game (Figure G) is a maze that magically changes sound to direct you to one of three different goals. First, use the pencil to completely fill in one of the three goal circles to make an electronic connection. Go to the START and lightly touch the pencil tip as you trace a path through the maze. Listen to the buzzing tone. As long as the tone you hear keeps getting higher, you're going the right way. If the tone you hear starts to fall, that means you're going the wrong way. Retrace your path and keep going, following the rising tones until you get to the finish. Then, erase and color in a different goal circle: The maze changes sounds as you trace to the new goal.

TWO-PLAYER BASEBALL

Here's a baseball game for two players with hits, outs, and innings (Figure H).

At the start of the inning one player secretly chooses five of the "hit" baseballs

Bob Knetzger

and colors in their five red squares with pencil. Each filled-in ball will make a "buzz" sound when touched with the pencil. Then fold the paper over to hide the colored-in choices. The second player "bats" by choosing a ball and touches it with the probe. If there is no tone, it's a hit! Mark the base runners on the diamond lightly with the pencil and bat again by choosing a different ball. But if you hear a buzzing sound, that's an out! Update the scoreboard and keep playing. Keep tallying base, runs, and outs just like in real baseball. After three outs, players switch sides: Now the first player will bat after the second player erases and colors in five red squares. Will he fake out his opponent and keep some of the previously colored hits as outs again? That's up to you ... play ball! You can play nine whole innings of conductive ink fun.

MAKEY BOT MUSIC

Three Makey bots are playing some music (Figure I): a low-pitched bass, a sliding trombone, and a high wailin' sax!

Hook up the alligator clip to the card. Touch the pencil tip to the spots on the various instruments. The bass plays low notes. The sax plays high notes. Slide the tip along the trombone to make a sliding trombone sound! Slide your way across the trombone to play a melody.

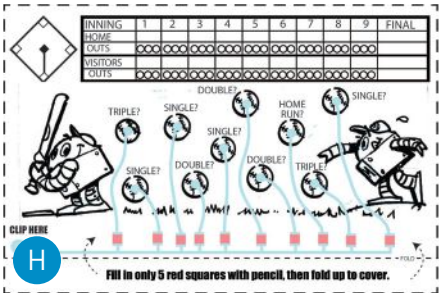
CROSS GRID STRATEGY GAME

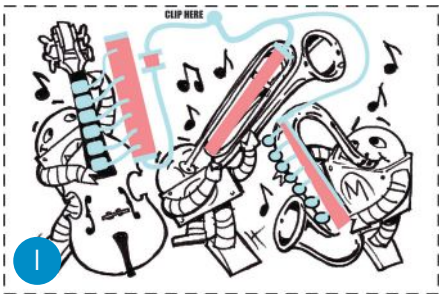
A strategy game for two players: First player to complete a continuous line that connects all the way across the grid and sounds the buzzer is the winner! (Figure J)

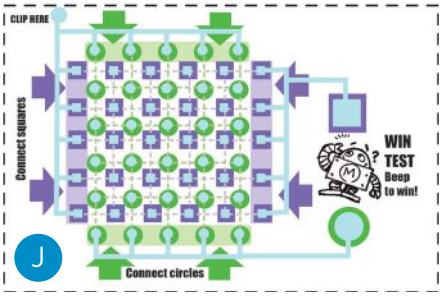
On their turn, each player draws a line connecting two of their shapes. (Press firmly to draw solid pencil marks along the dotted lines.) The "circle" player draws on the dotted lines connecting any two adjacent circles. The other player, playing "squares," draws on the dotted lines connecting any two adjacent squares. No diagonal lines are allowed. Players cannot cross their opponent's lines. Keep taking turns coloring in lines until one player has drawn a continuous line connecting all the way across the grid.

To claim a win, touch the pencil tip to your shape's WIN TEST spot. If you hear a beep, buzz, or growl tone (no matter how low-pitched), you win!

Carefully erase all lines to play again.







This project, along with 40 more, appears in Knetzger's book ***Make: Fun!*** *Create Your Toys Games and Amusements*, makerfunbook.com.

To print out the conductive game cards, go to makerfunbook.com/portfolio.html.

Closer Look: Conductive Pen Reviews

I found several different kinds of conductive ink pens that will work well with this project. Look for these in electronic stores or online. Here they are, starting with the best:

CIRCUIT SCRIBE BY ELECTRONINKS

These roller ball pens lay down a very controlled and fine line of silver-based ink. Dries really fast and conducts well. They're also sold with kits that include magnetic electronic modules, like LEDs and switches. Even though they can cost more, you'll get more electronic parts to play with. **Cost: $20**

TIP: Store these pens vertically with the tips down for best ink flow.

SILVER CONDUCTIVE PEN BY MG CHEMICALS, CAIG, AND CIRCUITWORKS

These paint-pen type markers leave a thicker, painted line. They're a little harder to use, and tricky to keep clog-free, but they give great results on almost any surface. They can be a little messy (clean up with nail polish remover) and take more time to dry, but the end result works really well. You might find two versions with different sized tips: The larger 1mm tip is easier to use. Expensive — made with real silver! **Cost: $30–$50**

TIP: You must shake these pens really well before and during use. If they clog up you can remove the tip for cleaning but note: the caps twist off backward with a left-handed thread!

NICKEL CONDUCTIVE PEN BY MG CHEMICALS

A lower-cost version that uses nickel instead of silver. Similar application: squeeze to draw a thick, paint-like line. Not quite as conductive as the silver but costs a lot less! **Cost: $10–$15**

TIP: Remember to shake — there's a small ball inside (like in a can of spray paint) to help mix the nickel paint and solvent.

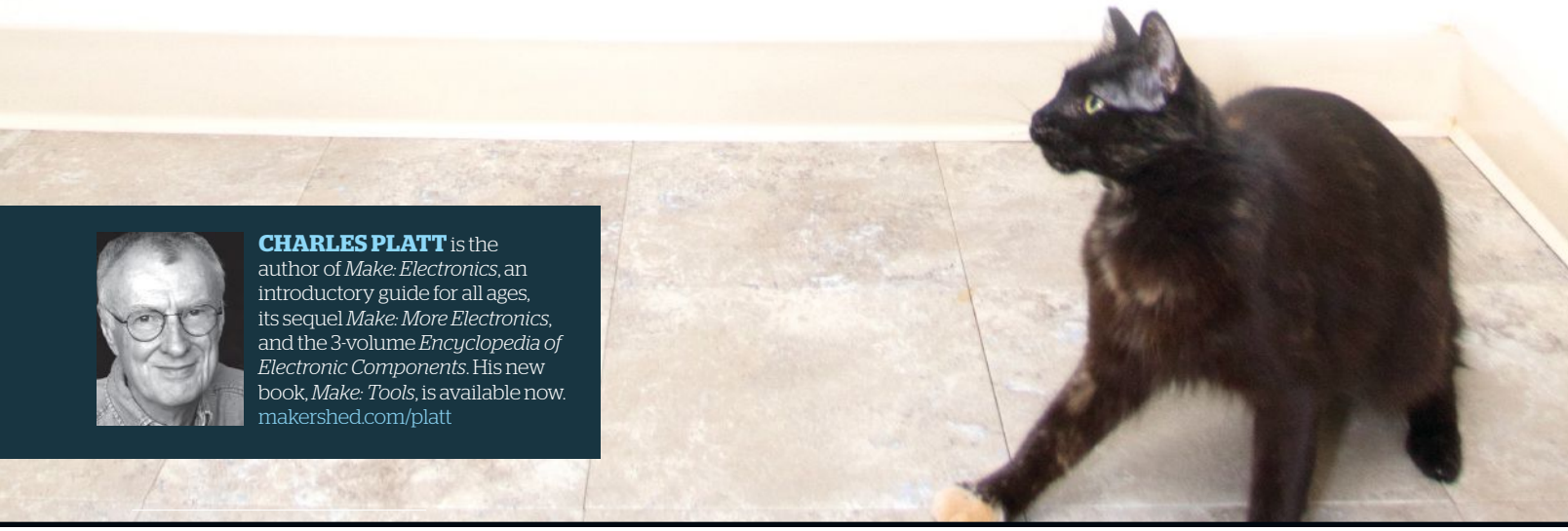
ELECTRIC PAINT FROM BARE CONDUCTIVE

This product uses carbon in a black, water-based, paste-like paint. Not as conductive as the silver or nickel pens, but not smelly and cleans up easily with water. Comes in a small squeeze tube so if you can't manage the tiny squeeze tip, try a fine brush to draw lines. **Cost: $10**

Chaotic Cat Toy

Written by Charles Platt

Build an unpredictable compound pendulum with two weights, a piece of string, and a mouse



CHARLES PLATT is the author of *Make: Electronics*, an introductory guide for all ages, its sequel *Make: More Electronics*, and the 3-volume *Encyclopedia of Electronic Components*. His new book, *Make: Tools*, is available now. makershed.com/platt

DRAGGING A TOY ON A PIECE OF STRING IS A TIME-HONORED WAY TO ENTERTAIN A CAT. The problem is, it may be less fun for you than it is for the cat.

Can the process be automated? After rigorous, exhaustive testing, I have determined that a compound pendulum is the simplest way to do it. Compound-pendulum projects have been published previously in *Make:* (makezine.com/projects/double-pendulum in Volume 22, and makezine.com/projects/double-pendulum-2 in Volume 50), but they used motor-driven levers and created their output with LEDs. My version just needs two weights, a piece of string, and an output device commonly known as a "mousie" (see Figure A).

The length of a pendulum determines how quickly it oscillates. Consequently, when you have two weights that are linked together but are hanging at different heights, the movement of the higher weight interferes with the movement of the lower weight, and the result is a series of chaotic movements that cats find interesting.

To keep the pendulum swinging for as long a time as possible, the weights should be as heavy as possible. However, this is a potential hazard: If you build this project, be sure to suspend the weights securely, so that they don't fall on top of your cat. I cannot take responsibility for feline injuries caused by substandard pendulum construction.

BUILD THE PENDULUM

Each weight can consist of a plastic container such as a medium-large vitamin bottle. Drill a hole through the base of the bottle and its cap, and thread some string through the holes. Fill the bottle with small stones, sand, or scrap hardware, then screw the cap on, and tie a large knot under the bottle to hold it securely, as shown in Figure B. Nylon string is stronger, more flexible, and more durable than polyester or natural twine, although knots in nylon are more likely to loosen with time.

I used a piece of fishing line for the bottom section of the pendulum, because this only carries a small load, and fishing line is difficult to see. I figured it would create the illusion of the mousie moving around under its own power, although I'm not really sure that my cat finds this important.

HANG IT UP

An easy place to hang the toy is in the opening of a door. Most interior door frames are made of wood, providing a secure location for a #10 pan-head screw at least 1" long. Use a fender washer under the screw head, to make sure the string doesn't slip off. And if you don't want to violate your door frame, you can make a clamp using pieces of hardwood as shown in Figure C, although this will prevent the door from closing.

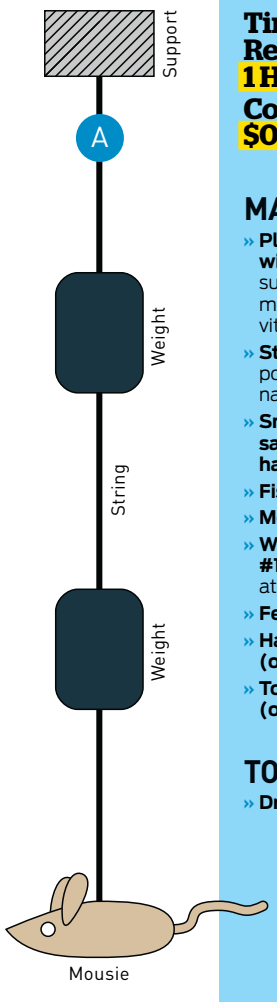
If you're more ambitious, you can suspend the toy from the ceiling. A toggle bolt is a reliable way to do this. You can learn more about toggle bolts, anchors, and other devices for insertion in drywall if you take a look in my book *Make: Tools*, which has a whole chapter on the subject.

MANAGE THE MOTION

Once you've suspended your pendulum, you can fine-tune it to make the motion unpredictable. The upper weight should have more momentum than the lower weight, to swing it around. This means the upper weight should be twice as heavy as the lower weight. Experiment by removing some of the mass from inside the lower container till they oscillate in an interesting way.

Your cat may respond most actively when the mousie is close to the floor, like a real mouse. When the cat pounces on the toy and drags it, this renews the motion of the pendulum, so that when the mousie is released, it starts moving again. The interaction can sustain feline interest for 15 minutes or more, and is entertaining to watch. Indeed, you may finally have a cat toy that is almost as much fun for you as it is for your cat.

To see the pendulum cat toy in action, visit makezine.com/go/pendulum-cat-toy.



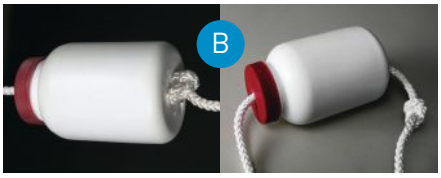
Time Required: 1 Hour
Cost: $0–$10

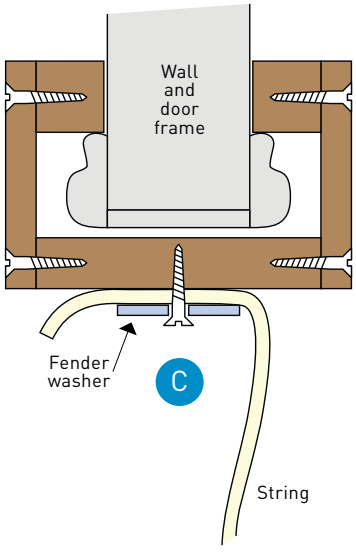
MATERIALS

- **Plastic container with cap (1 or 2)** such as a medium-large vitamin bottle
- **String** nylon, polyester, or natural twine
- **Small stones, sand, or scrap hardware**
- **Fishing line**
- **Mouse toy**
- **Wood screw, #10 pan-head** at least 1" long
- **Fender washer**
- **Hardwood (optional)**
- **Toggle bolt (optional)**

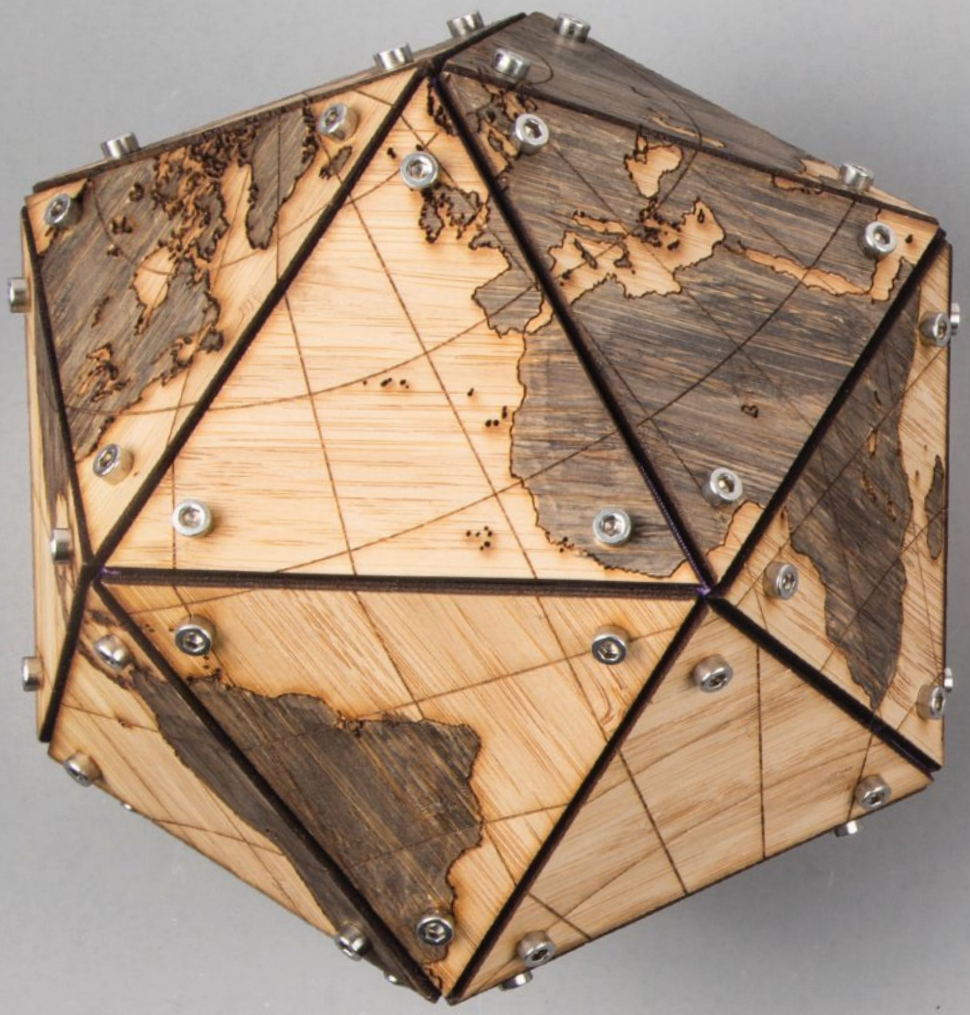
TOOLS

- **Drill**





Tyler Winegarner, Charles Platt



Bucky's World

Laser-cut a map that goes from 2D to 3D with very little distortion

Written by Gavin Smith

I WAS PLAYING AROUND WITH MAP PROJECTIONS ONE DAY AND BECAME A TAD SMITTEN WITH BUCKMINSTER FULLER'S "DYMAXION" PROJECTION. It's able to unwrap a spherical map of the Earth onto a flat plane with surprisingly little distortion. The flat Dymaxion map can then be divided up into triangles and folded back into a three-dimensional figure. I started this project because I wanted to make my own 3D version of Fuller's globe.

TRIAL AND ERROR

My first thought was to laser-cut miter joints into the panels and glue them together, but this led to big seam lines on the map, and it was hard to hold all the pieces together while gluing. Next, I decided to make a row of holes and tried sewing the faces together. The stitching was a bit time consuming, and it was difficult to retighten the stitches if the thread came loose.

Finally, I had the idea of using 3D-printed vertices, and using screws to hold the tiles (Figure A). I printed the vertices in ordinary PLA and sized them to let M3 screws self-tap nicely into the plastic. With a bit of playing around with angles and parametric design, I made vertices for all five Platonic solids, including a tetrahedron (4 faces), cube (6 faces), octahedron (8 faces), dodecahedron (12 faces), and an icosahedron (20 faces) for the Dymaxion globe (Figure B). You can download the files at thingiverse.com/thing:1862570.

HOORAY FOR TECHNOLOGY

I downloaded the Dymaxion map as an SVG from Wikipedia (Figure C), and it took about an hour's work to get something suitable for laser cutting (Figure D). It wasn't perfect, but it was *way* better than tracing manually with a pencil and paper. You can download my DXF file at thingiverse.com/thing:1871829. I made it in a hurry, and you may notice I didn't bother to fix the broken triangles in the file, and instead glued them together after cutting. Thingiverse user Kim Stroman ("kbst") remixed my version and stitched together the triangles, so you may want

to start with her version (thingiverse.com/thing:1995457).

There's a bit of a dark art to my laser cutter, so when I imported the DXF file all the lines came in as black. I had to select the lines by hand in the laser software and chose whether to cut or engrave. This was time consuming, but once done you can save the file in your laser cutter's format and use it again easily. Other laser cutters are hopefully much smarter than the one I used. You should experiment and see which (if any) works for you.

GET CREATIVE

I used 2mm–3mm bamboo ply for the triangle panels and a Copic marker to color in the continents by hand (Figure E). This was mostly because I was in a hurry and didn't want to edit the file too much. However, you could also engrave a solid fill with the laser and save time. Alternatively, you could also get creative and paint both the lands and waters in much bolder colors, or water down the paint to create a subtle wash on the wood, which preserves the original grain.

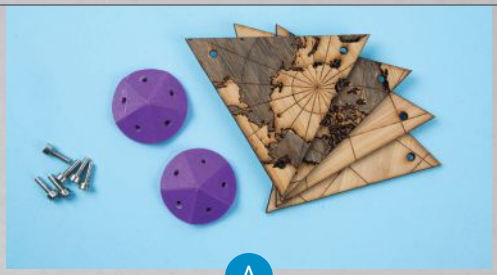
I'm pretty happy with the construction method. Sure, it's not exactly light on screws, but I rather like the aesthetic of the cap heads, compared to countersunk or dome heads. Plus, it's extremely strong. I can stand on the map, and it takes my weight with no problem!

Also, the nice thing about this approach is that the vertices work for any tile that has the hole 15mm from the edge. To make a larger object, all you need to do is recut the wooden parts and the 3D-printed vertices can stay the same.

I'm not sold on the Dymaxion being *the* default map projection for humanity, but it has some interesting properties, and it was certainly a fun build.

GOING FURTHER

To more easily show off the transition from flat map to globe, consider using magnets to hold it all together. A chap called Stefan Daschek got in touch and let me know he made a magnetic foldable version. Check out Stefan's globe at makezine.com/go/magnetic-dymaxion-globe.



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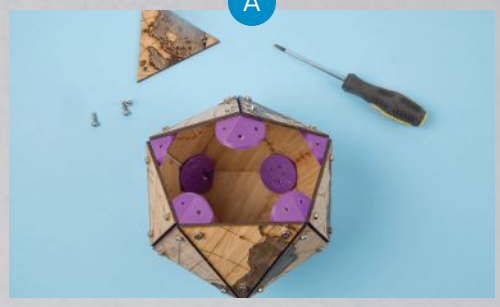

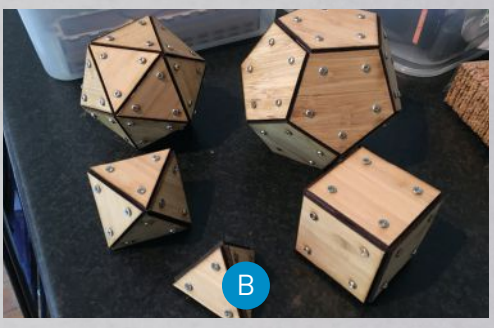

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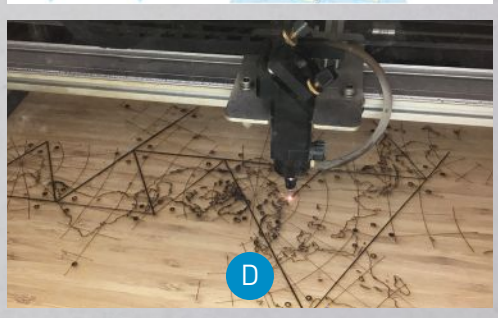

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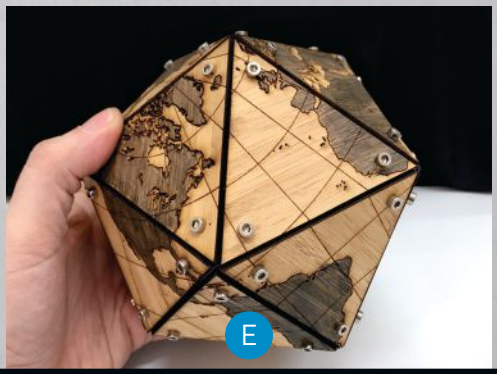


E

Time Required:
1-2 Hours
Cost:
$5–$30

MATERIALS

- **Screws** I used M3 self-tapping screws because I liked the look, but any similar screw is fine.
- **PLA filament**
- **Wood** I used bamboo ply, 2mm–3mm thick.
- **Markers (optional)** I used a Copic marker to color the continents by hand.

TOOLS

- **Laser cutter**
- **3D printer**
- **Computer with internet access**

What's a Dymaxion globe, anyway?

When you think of a conventional flat depiction of the world, you're probably imagining the classroom-mainstay Mercator projection, which dates way back to 1569: a flat grid with the Americas on the left and Europe, Asia, and Africa on the right. Its grid structure was a boon for navigation, but flattening out the map introduced massive distortion, to the point where Greenland is almost the size of Africa and Antarctica is a thin line at the bottom. The Dymaxion projection, as developed by Buckminster Fuller, creates a flat map of the Earth with less distortion to the size and shape of landmasses. The map also doesn't have a traditional up and down, and the flat sections can be shifted around to show various configurations of the continents that are all accurate.

GAVIN SMITH is a longtime tinkerer and a founder of Robots and Dinosaurs, the first Makerspace in Sydney. He's a robotics engineer, and helped build the Australian Synchrotron, a particle accelerator in Melbourne.

Hep Svadja, Gavin Smith, Made by Eric Gaba – Wikimedia Commons user: Sting

Vintage Ventilation

Written by Phil Bowie

Build a custom car-window scoop and let the fresh air in

Time Required: A Weekend
Cost: $20–$30

MATERIALS

- Cardboard
- Craft plywood, lightweight, ¼"×12"×24"
- Wood filler or body putty
- Sandpaper, coarse and fine
- Primer
- Paint
- Velcro, self-stick

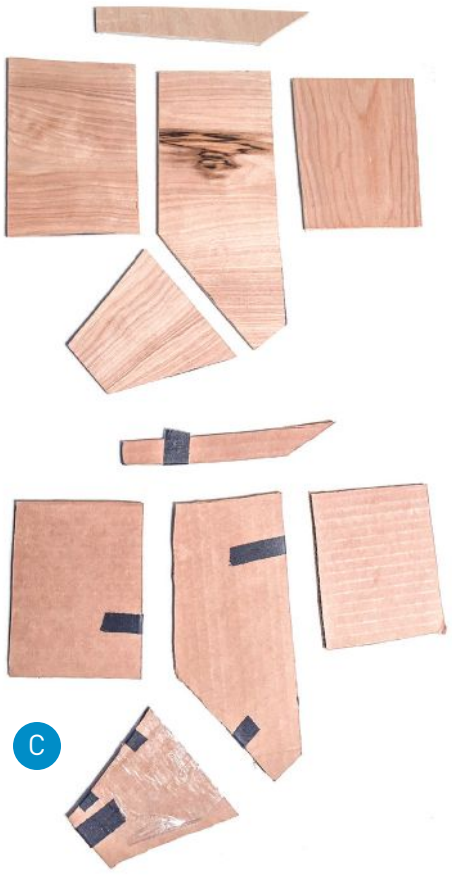
TOOLS

- Measuring tape or ruler
- X-Acto knife or scissors
- Masking tape
- Quick-set epoxy
- Saw

PHIL BOWIE is a lifelong freelancer with 300 published articles and short stories. He has an acclaimed series of suspense novels out. Visit him at philbowie.com


A


B


C

MY FIRST CAR HAD NO AIR CONDITIONING. IN THOSE DAYS NOT MANY CARS DID. What we did have, though, were small triangular vent windows (Figure A) that pivoted outward to scoop buffeting gales of fresh air into the car, which cooled us by evaporation. It worked much better than you might think. It also allowed us to smell fresh-cut hay or yard grass, or fragrant flowers, or fall leaves, and it let us sense pleasant temperature changes while driving through shady valleys or climbing New England hills. I miss all that.

Cars these days — some even equipped with ultimately pampering filtered and zoned AC — cut us off from the outside world, and opening the windows on a fine spring or autumn day or a warm summer evening doesn't let in much air.

To experience a whiff of those bygone days, make your own air scoop. Almost every car has a convenient space between the front plastic triangle of side-window filler and the side mirror housing. It's the perfect place to mount a scoop, but each vehicle is a little different, so you'll need to tailor yours to fit.

MEASURE THE SPACE

Start by taking rough measurements — height, width, length, and any slope angle of the vehicle filler panel. (The exhaust of my scoop measures about 2"×3".)

PROTOTYPE IN CARDBOARD

Rough out the scoop panels in cardboard with an X-Acto knife or scissors. Use masking tape to hold the panels together for trial fitting (Figure B). You may have to recut the panels a time or two to get the mock-up scoop just right.


D

BUILD AND MOUNT YOUR SCOOP

When you're happy with the mock-up, use the cardboard pieces as templates to cut final panels out of lightweight ¼" craft plywood from Lowe's or elsewhere (Figure C). Glue the panels together with quick-set epoxy (Figure D). Fill any joint imperfections with wood filler or body putty. Sand, prime, fine-sand, and apply topcoat. I chose flat black to be inconspicuous (Figure E). Apply a generous rectangular patch of self-stick velcro to hold the scoop securely in place so it will be removable in inclement weather, or quickly mountable on a nice day. To regulate airflow, simply raise or lower the side window a bit (Figure F).

Now go enjoy one of the simple pleasures motorists of the past knew well.

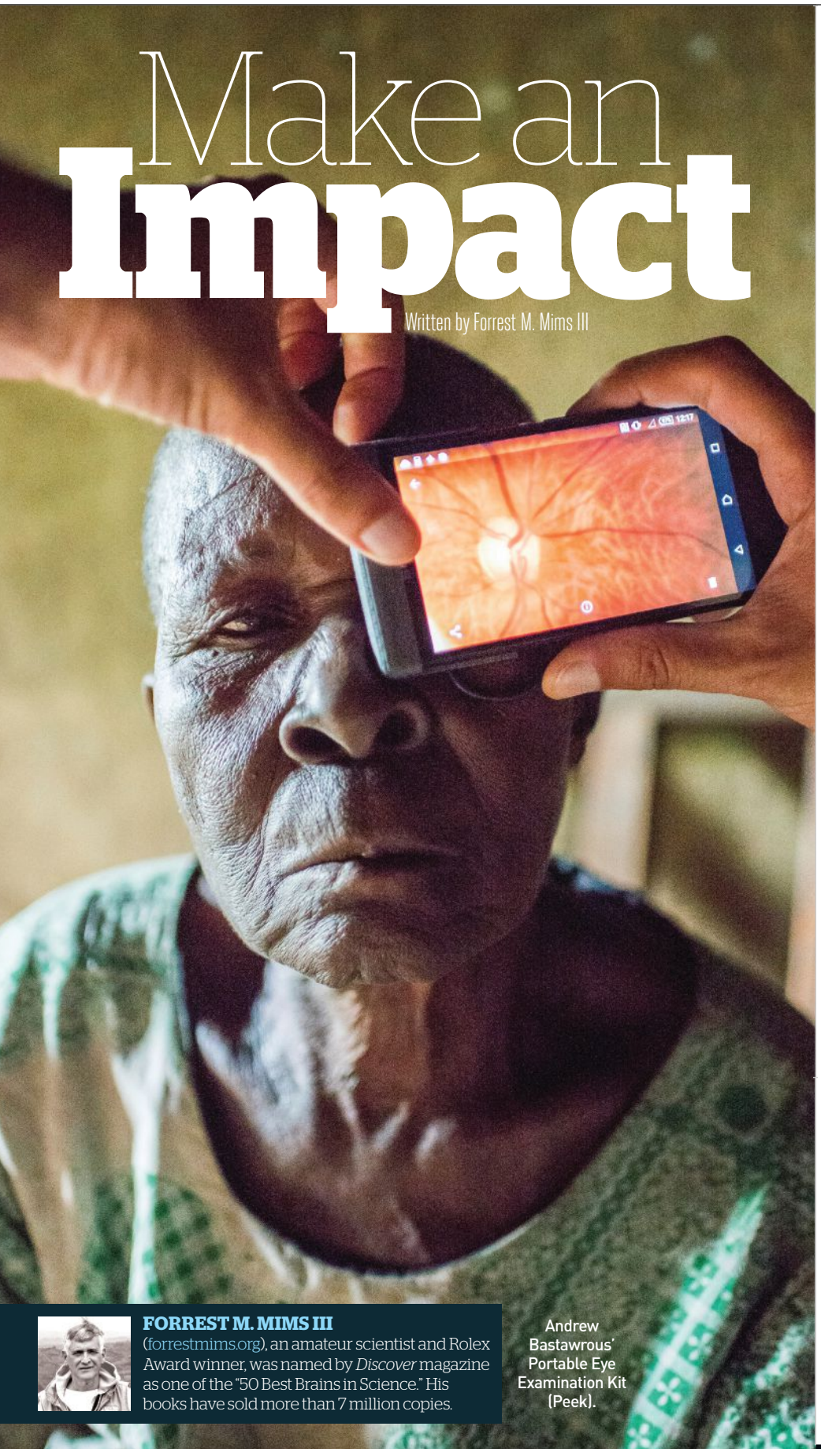

E


F

Hep Svadja, Phil Bowie, Sydney Palmer

Make an Impact

Written by Forrest M. Mims III



Andrew Bastawrous' Portable Eye Examination Kit (Peek).

FORREST M. MIMS III (forrestmims.org), an amateur scientist and Rolex Award winner, was named by *Discover* magazine as one of the "50 Best Brains in Science." His books have sold more than 7 million copies.

Your pioneering project, significantly expanding knowledge or improving the quality of life, could help you earn a Rolex Award for Enterprise

THE PAGES OF *MAKE:* ARE CONSISTENTLY FILLED WITH CREATIVE PROJECTS provided by the magazine's contributors. Many have practical applications, and some might lead directly or even indirectly to a project that could earn a prestigious Rolex Award for Enterprise (Figure A).

A Rolex Award provides a huge opportunity for individuals with the right project. Rolex has summarized its awards program in 22 words:

Empowering exceptional individuals. The Rolex Awards for Enterprise support inspiring individuals who carry out innovative projects that advance human knowledge or well-being.

Empower is certainly appropriate, for the award comes with 100,000 Swiss francs (about $102,650) that the recipient, the laureate, can apply to the project. All winners are also given an inscribed Rolex chronometer and, significantly, benefit from an international media campaign and exposure, including on the Rolex Awards website, rolexawards.com. They also gain access to the network of former laureates and jury members, the independent experts who select the winners.

THE RANGE OF WINNING PROJECTS

Over the past 40 years, the Rolex Awards have supported pioneering work in applied technology, cultural heritage, environment, exploration and discovery, and science and health. This broad range of areas provides for projects involving education, ecology, archaeology, medicine, agriculture and many other topics.

The competition is very tight; only 140 awards have been received by the 33,000 applicants from 190 countries since 1976. That's only 0.4%. Yet some winning Rolex projects are surprisingly simple. Food spoils rapidly in the northern Nigeria desert. Mohammed Bah Abba received a 2000 Rolex Award for developing a simple method for keeping food fresh (Figure B). A pot made

Courtesy of Rolex, Forrest M. Mims III

from clay is inserted inside a slightly larger pot. Sand is then poured into the space between the two pots. Water is poured over the sand and food is placed in the central pot, where it is cooled by the evaporation of the water. Bah Abba sold more than 100,000 of his cooling pots for $2 each before he died in 2010.

Some projects use modern technology, like Andrew McGonigle's 2008 award for his use of instrumented, remote-controlled miniature helicopters to survey the gases emitted by active volcanoes (Figure C). McGonigle's system now includes using ultraviolet cameras to allow scientists to study volcanic plumes from a safe distance and possibly predict new eruptions.

2016 Rolex Award laureate Andrew Bastawrous was employed by the National Health Service in the United Kingdom until he moved to Kenya in 2011. There he soon learned that the country has widespread mobile phone service but a severe shortage of trained eye-care professionals. This combination led Bastawrous and his collaborators to develop the Portable Eye Examination Kit (Peek) for smartphones. The Peek system (peekvision.org) enables nonmedical users to give visual acuity tests and, when coupled with an adapter, provide high-quality fundus photographs (see facing page). These are images of the eye's retina that provide important diagnostic information. Rural people with no prior eye-care training can quickly learn to use the Peek system. In a trial, Bastawrous and his team trained 25 schoolteachers to use Peek and more than 20,000 students were screened in nine days.

Then there's Arthur Zang's 2014 award for a mobile heart monitor for use in remote areas. Zang, an electronics engineer from Cameroon, designed the Cardio Pad (Figure D), a sophisticated medical tablet that monitors the heart and transmits the results to heart specialists in larger cities. The Cardio Pad (himore-medical.com) is an invaluable medical asset for rural regions in countries like Cameroon, where fewer than 50 cardiologists serve its 22 million people.

You can learn much more about these four laureates and the 136 other winners at the Rolex Awards website, rolexawards.com/people. Some of these awards just may suggest a project or an idea you might want to pursue.

A

ROLEX

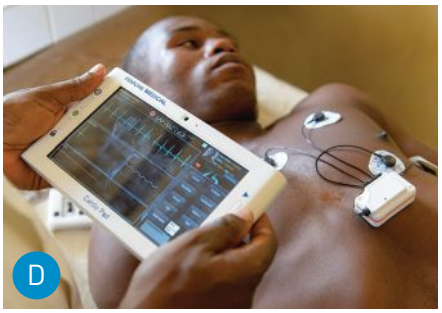
The famous Rolex logo.

B

Mohammed Bah Abba's clever solution for keeping food fresh.

C

Andrew McGonigle and his remotely controlled copter for sampling the air over active volcanoes.



D

Arthur Zang's Cardio Pad medical tablet.

E

The author's TOPS ozone instrument alongside his Rolex Award certificate.

WHY APPLY FOR A ROLEX AWARD

The Rolex Award has dramatically impacted the lives of many of its winners, and that certainly occurred after I received a 1993 award (Figure E). Second only to the award itself was being hosted at the ceremonies by my childhood hero, Rolex Award jury member Sir Edmund Hillary. In 1953 Hillary and Tenzing Norgay became global celebrities when they became the first men to climb Mount Everest.

My vocation as an electronics projects developer and writer was instantly transformed into a science career by the Rolex Award. My project was to establish a global network to monitor the ozone layer. In 1989, I had developed TOPS (Total Ozone Portable Spectrometer), a handheld instrument that accurately measures the thickness of the ozone layer when pointed at the sun. The Rolex Award provided the money to hire Scott Hagerup, an electrical engineer friend, to develop MicroTOPS, a microprocessor-controlled version of TOPS.

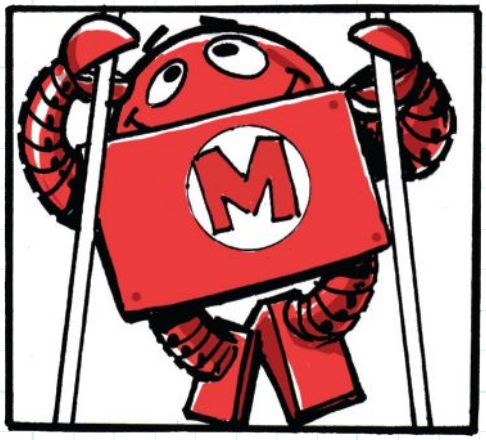
My goal of establishing a global ozone network failed, for the optical filters in MicroTOPS degraded after only a few years. Fortunately, the Solar Light Company acquired rights to MicroTOPS and then developed the more sophisticated MicroTOPS II that uses very expensive, high-quality filters. Today more than 1,000 MicroTOPS IIs are in use by scientists and researchers around the world, and their findings have been described or cited in 352 scientific publications. These results are much more significant than my original plan, which would have merely duplicated a small part of the existing global ozone network.

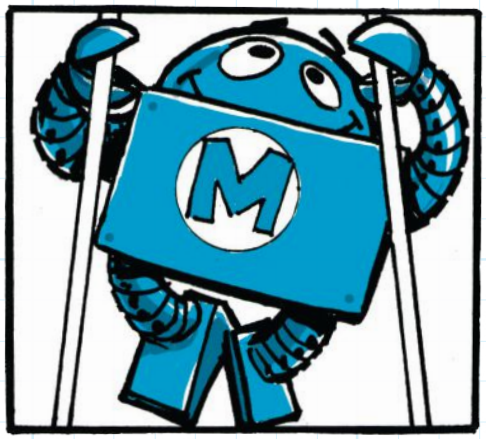
PREPARING TO APPLY

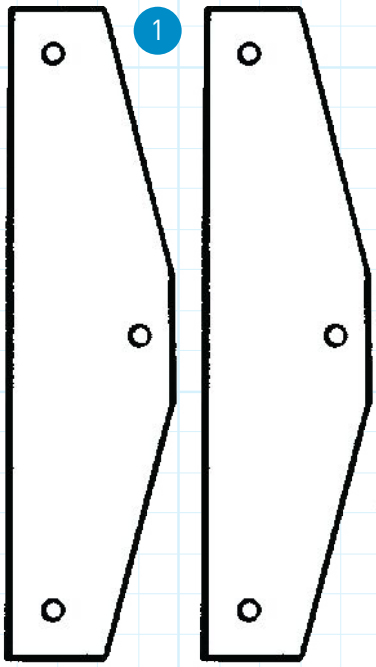
Now is the time to begin work on a future Rolex Award application, for considerable preparation is vitally important, three years in my case. Rolex and its awards jury want to see significant evidence that your proposal can succeed should it be selected. Therefore, before selecting a project, be sure to carefully review the Rolex Awards website to see if a project you are considering measures up to prior winners. Even if you don't win an award, you will learn much from the preparation process, which might culminate in a project in the pages of *Make:* and make a major contribution on its own.

Toy Inventor's Notebook

STRING CLIMBING RACERS First one to the top wins!







Time Required: 30 Minutes
Cost: $2

MATERIALS

- **Plastic or wood, thin piece**
- **String, 17'** or more
- **Drinking straws, cut into 2½" pieces (4)**
- **Beads or dowels**

TOOLS

- **Saw, utility knife, or scissors** depending on material used
- **Drill**
- **Spray adhesive, double-sided contact paper, or glue stick**
- **Cyanoacrylate glue** aka crazy glue or super glue
- **Nails (2)**
- **Hammer**

Find the parts to print at makezine.com/go/string-climbing-racers.

Invented and drawn by Bob Knetzger

THESE SIMPLE-BUT-FUN STRING-CLIMBING MAKEY BOTS are based on an old folk toy. They climb up strings by using friction and alternating tension/slack. Make two bots and have a race!

1 CUT OUT YOUR MAKEY BOTS

Paste the facing page onto a piece of thin plastic or wood, then cut out the robot racers and the swivel shapes on the solid black line (or if you'd rather keep your ish of *Make:* intact, go online to makezine.com/go/string-climbing-racers to download and print out the parts).

2 DRILL HOLES AND ADD STRING

Drill the holes in the swivels. Tie a short loop of string to each of the top center holes. Tie long pieces of string (4 feet or even longer!) to each of the bottom holes.

3 ADD STRAWS AND HANDLES

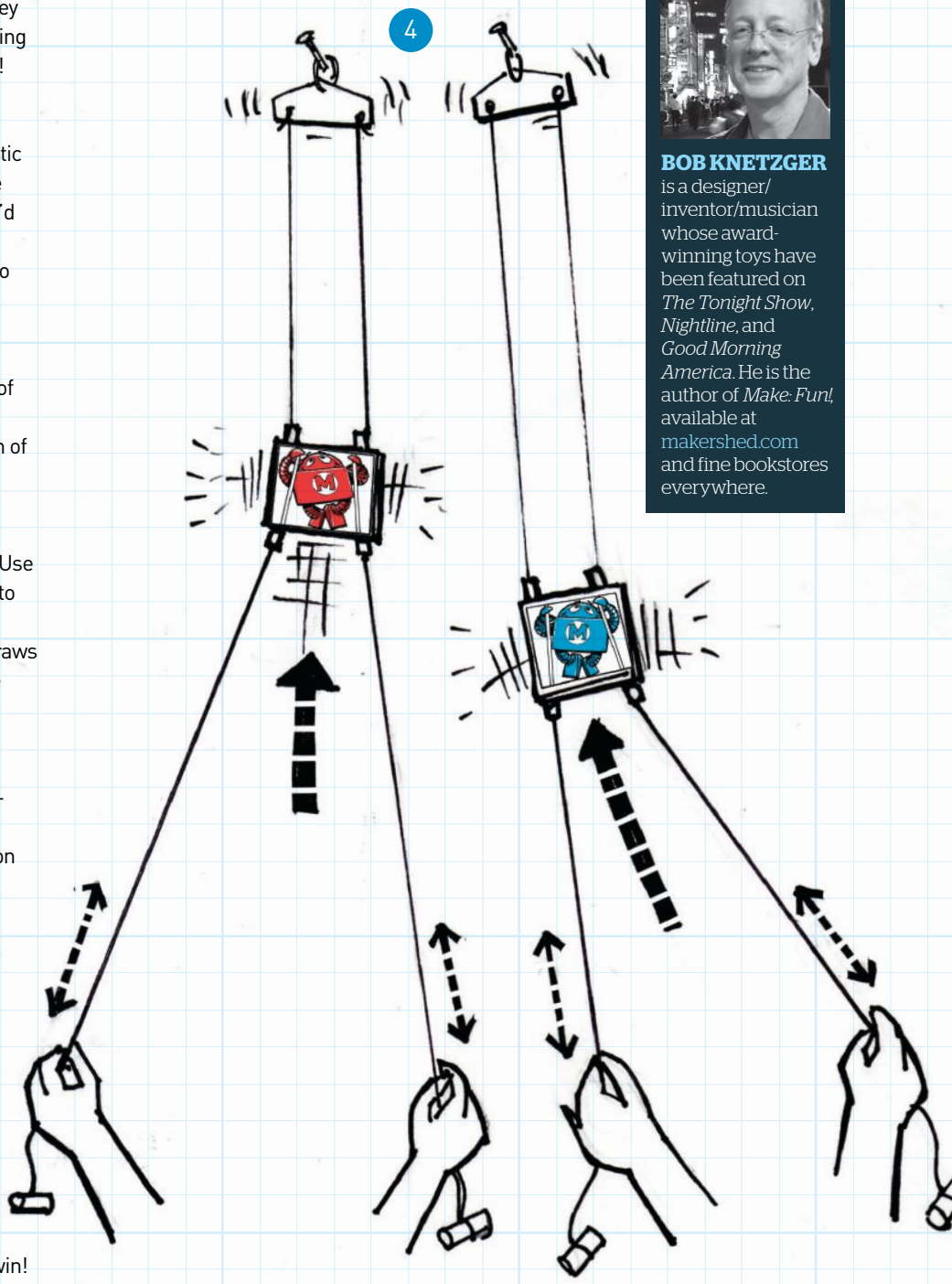
Cut four 2½" pieces of plastic drinking straw. Use cyanoacrylate (super glue) to attach 2 straws to the back of each racer. Angle them slightly as shown. Thread the long strings though the straws and tie a bead or dowel at the end as a handle stop.

4 ON YOUR MARK, GET SET, GO!

To race, hang the loops up on a wall on 2 side-by-side nails. Hold the strings apart, one in each hand, and while keeping a light tension on both, gently pull on one string, then the other. With alternating left-right-left-right tugs, the racer will slide up the strings in little jumps. Quick, keep going: first one to the top wins! (But don't tug *too* fast; the climber will stall!) Release tension and the climber falls back down, ready for another race.

FOR MORE FUN TRY THESE:

- Have a race of multiple "laps": first to complete 10 up-and-back trips wins!
- Team up with partners: one person tugs one string, their partner tugs the other. It'll take coordinated teamwork to go fast and win!
- If you have a really high space, like over a stairwell or loft, try stringing up the racers with super l-o-n-g strings!)



BOB KNETZGER is a designer/inventor/musician whose award-winning toys have been featured on *The Tonight Show*, *Nightline*, and *Good Morning America*. He is the author of *Make: Fun!*, available at makershed.com and fine bookstores everywhere.

Don't SLIP

Here's the lowdown on how to hold down your workpiece for CNC

Written by Tim Deagan

ONCE UPON A TIME, THE MOVEMENTS OF MASTER MACHINISTS WERE MEASURED, RECORDED, AND STORED ON CARDS AND PAPER TAPE. The stored numbers were used to control motors that moved mills, lathes, and other machines exactly the way the machinists had. This was referred to as numeric control (NC). After World War II, computers found their way into manufacturing and were used to control the machines, which is called computer numeric control (CNC). Broadly, computers controlling motors that move tools includes modern 3D printers, laser engravers, stencil cutters, and the target of this skill builder: CNC devices using routers (Figure A) or motor spindles.

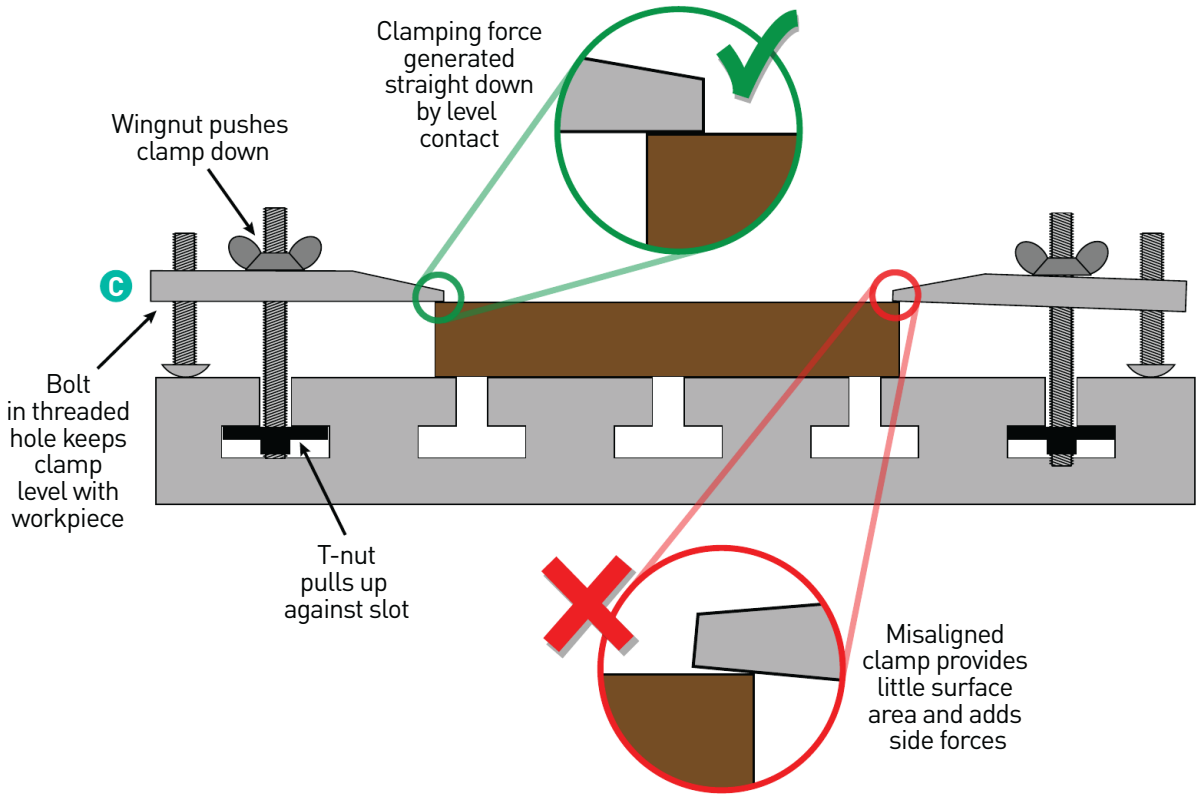
In general, we use the term CNC to refer to subtractive manufacturing techniques. Subtractive manufacturing removes material with cutting bits, end mills, or other tooling — the opposite approach is additive techniques like 3D printing, where the part is constructed by building up material. 3D printers rely on plastic adhesion to keep the print from moving during production. CNC machines that grind, cut, and drill, however, are much more aggressive — unless the piece is firmly held in place during these operations, the part is ruined and expensive bits are broken.

CNC workholding is a topic that can, and has, filled books, but we'll take a look at the basics of how to hold parts in place. Which method you choose depends to some degree on the table or work surface on which the part is mounted, and the material being held, but ultimately a few techniques cover the important ideas.

ANCHORING ESSENTIALS

On a CNC machine, the work surface can be unbroken, or have built-in methods to hold items, such as T-slots. A T-slot is a T-shaped cutout (Figure B), where the crossbar of the T is on the underside of the table or inside the table itself. A nut fits into the slot to provide a movable location for inserting a bolt or clamp for workholding.

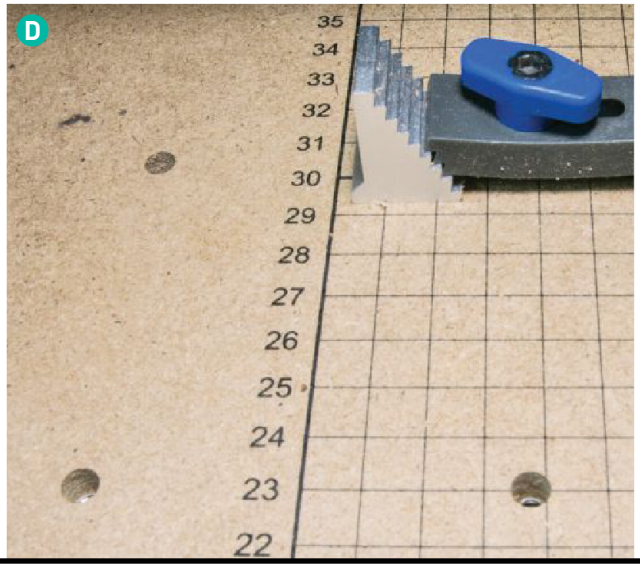
There are many types of clamps that can be used. The different designs offer various advantages and disadvantages. It's surprising how much holding power



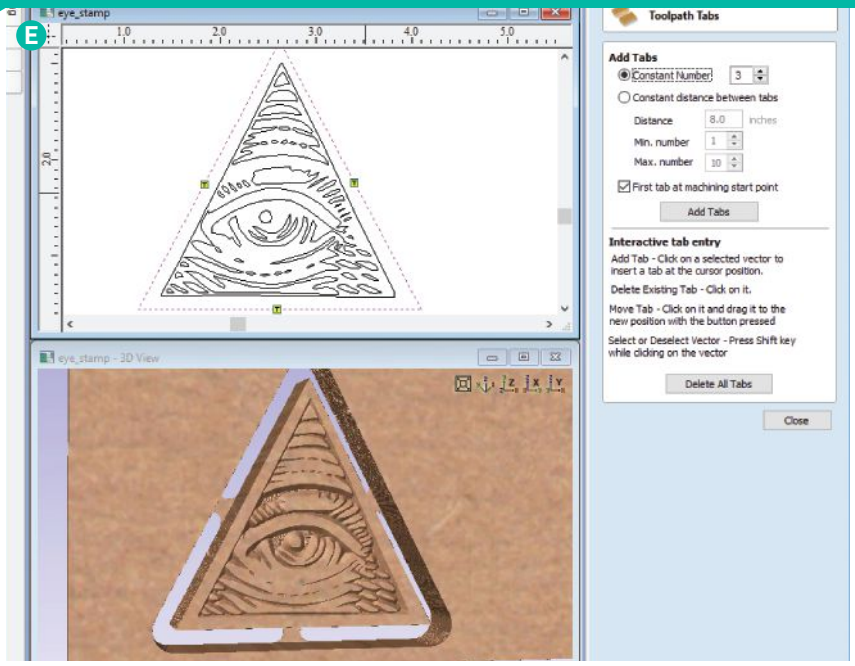
a small clamping area can provide. But misaligned clamps (Figure C) can cause trouble when they fail to hold. Clamps that have a flat surface need to be placed level to the workpiece. If they hold at an angle, especially against the edge of the work, the holding force is less than intended, and may even contribute to the piece moving when under pressure. A bolt or other support at the back of the clamp is adjusted so that the clamp is horizontal under load.

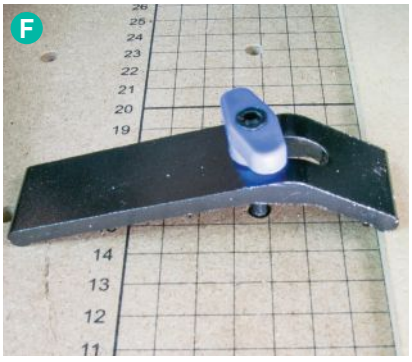
Many work surfaces that don't have T-slots will have thread inserts mounted at regular locations (Figure D). Bolts can be threaded into the inserts to hold clamps of various designs.

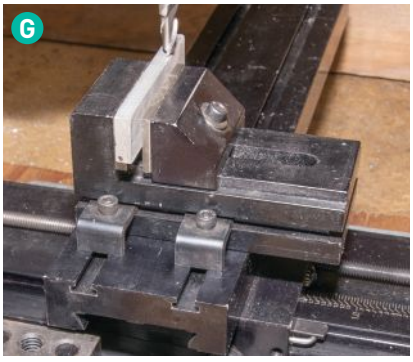
TIM DEAGAN (@TimDeagan) casts, prints, screens, welds, brazes, bends, screws, glues, nails, and dreams in his Austin, Texas shop. A career trouble-shooter, he designs, writes, and debugs code to pay the bills. He's the author of *Make: Fire*, and has written for *Make:*, *Nuts & Volts*, Lotus Notes Advisor, and Database Advisor.

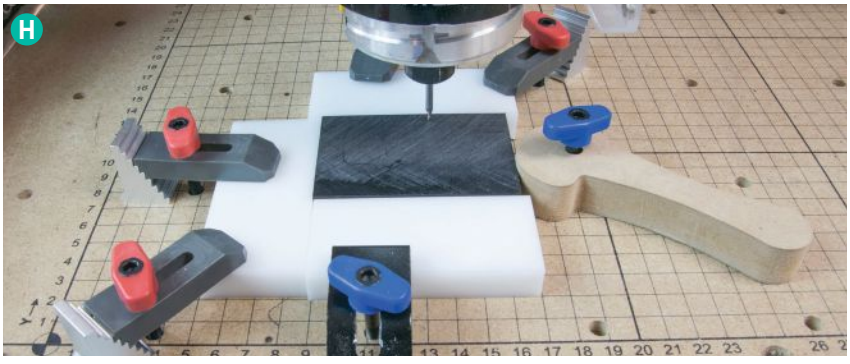


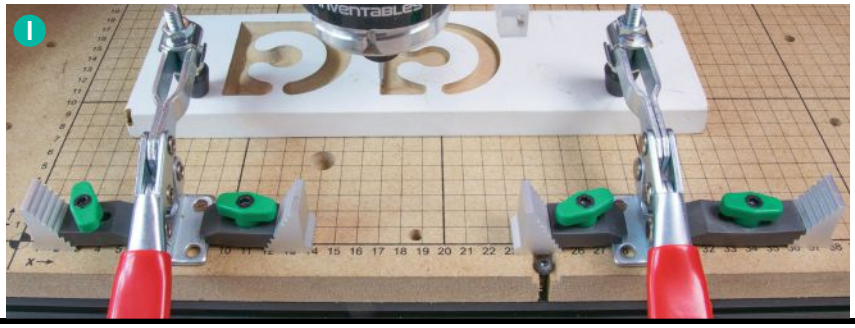
Istockphoto.com/Craig Couden, Tim Deagan











Tim Deagan

When cutting parts, your workholding strategy must take into account whether you're cutting all the way through a piece or just cutting on the surface. If you're cutting all the way through, it's common to use a "spoilboard" under the workpiece so that the bit doesn't cut into the table. It's also important to consider if the part being cut out might move once there is no more support and get thrashed by the bit. Many CAD programs will provide a feature to add tabs to the design (Figure E). Tabs are small, uncut regions left at the base of the part, just large enough to keep it in place during the remaining operations.

Some clamps are designed to hold with an edge, rather than flat (Figure F). These are usable at an angle and are supported on the back by the worktable.

For many operations, a vise clamped to the table holds the workpiece (Figure G). This allows quick swapping of workpieces but only registers the piece in one direction.

WHEN CLAMPS WON'T CUT IT

When absolute positioning is necessary, the concept is taken to another level with the creation of a jig. A jig is a structure that correctly positions the workpiece in all dimensions. The piece is slid or dropped into the jig and held in place with one or two quick clamps. Cam clamps (Figure H) that rotate to lock a piece into place with horizontal force are common in jigs, as are toggle clamps (Figure I) that clamp things in place vertically.

Clamps can have the disadvantage of getting in the way while cutting. Running a $30 bit into a metal clamp is a distressing (but not uncommon) experience. Many of my clamps bear the mark of shame (Figure J) that motivates me to take extra care.

Many operations need the workpiece to be fully exposed without clamps sticking up. In these cases there are three basic approaches. The first is to screw or nail the piece directly to the table. This requires careful planning so that the cutting bit doesn't run into a screw. It also doesn't serve to hold the entire piece down; If sections without tabs are cut away from the screws, the piece can move.

The second approach is common on many large CNC routers used in cabinet and woodworking shops. The worktable will have small holes in the surface and channels underneath through which a vacuum is drawn, like an air-hockey table in reverse. This pins the workpiece in place for the duration of the cut and quickly releases it

afterwards. Smaller vacuum clamps are available and can be used like vises (Figure K).

The third approach is to mount the workpiece in place with double-sided tape. This is easy with small pieces, but difficult with larger ones. Be careful when positioning tape so that it doesn't leave some areas without support. Even a hundredth of an inch difference in height between supported and unsupported areas can be a problem with many materials. Unfortunately, double-sided tape in quantity is expensive and frustrating to work with. Worse, many varieties have very weak holding power.

TENACIOUS, TAILOR-MADE TAPE

Ben Crowe, a master luthier at Crimson Guitars (crimsonguitars.com) has come up with a popular variation on the double-sided tape approach. He uses regular masking tape (generally the very wide variety) on both the table and the workpiece, then applies thin squiggles of cyanoacrylate (super glue) to one side of the tape and, optionally, cyanoacrylate accelerator to the other side. When placed together, this creates a wonderfully strong, homemade double-sided tape that's actually affordable. When the work is completed, the workpiece peels off the tape and the tape peels off the table.

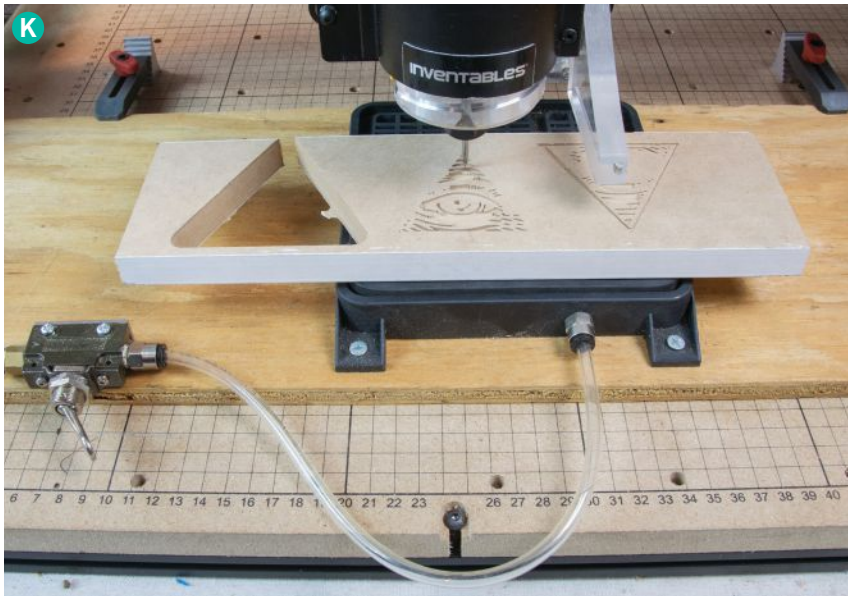
I've been using my own variation on this method for even larger pieces. Rather than using masking tape, I've been using 12"- or 24"-wide adhesive shelf lining paper (sometimes called contact paper) and adhesive spray (Figure L).

This has allowed me to adhere large pieces of leather to my worktable very solidly and very cheaply without having to carefully apply multiple strips of tape. This is much easier than aligning tape strips and hoping I didn't overlap them, creating bumps, leaving gaps, or getting glue on the table and workpiece. I use newspaper to cover any areas that I don't want to get adhesive spray on (like the motors or rails of my CNC). The spray gives me even coverage of adhesive and the shelf paper easily peels off the surfaces without problems when done, but holds firmly while in place (Figure M).

This article only scratches the surface of a gripping topic, so I hope you'll experiment and research more ideas for holding your work successfully!

J

K



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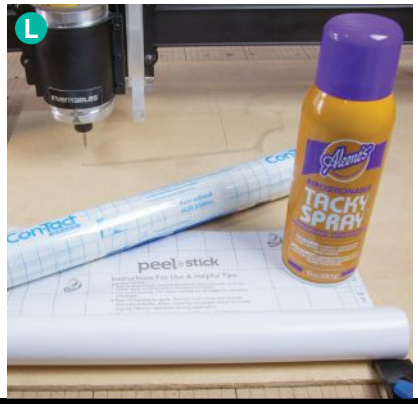

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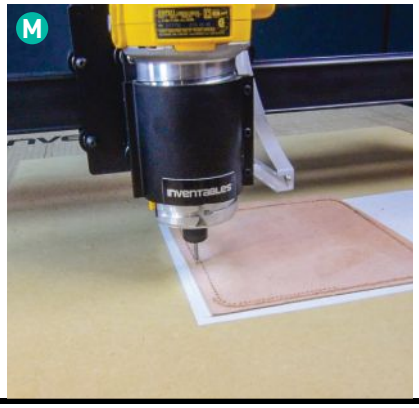


CALEB KRAFT has been sewing since junior high, but never got that good at it. Cheap robotic machines have changed his world and now there's thread everywhere! He's also senior editor for *Make:*.

Learn the Lingo:

MACHINE EMBROIDERY

Written by Caleb Kraft

Embellish clothing, make patches, and customize all your textile projects

"MACHINE EMBROIDERY CAN BE MISLEADING," says Erich Campbell, a veteran embroidery digitizer, and the in-house designer at Black Duck Embroidery and Screen Printing in Albuquerque, New Mexico. "The level of automation seems to promise a hands-off experience. While stock designs can be relatively simple, creating your own designs takes specialized software, and requires a great deal of understanding both of the media and the way the machines work." He warns that "well-executed embroidery is never a scan-and-convert process; creating designs requires art to be reinterpreted, using skills that combine vector drawing with the added difficulty of understanding how fabric distorts, and what can and can't be done with a needle — and using that artistically to render the design."

Want to give embroidery a try? "Mix art, math, craft, and a healthy dose of visualizing things that you can't see until needle hits fabric; if that sounds more exiting than frustrating," says Campbell, "machine embroidery may be for you."

Machine embroidery is an enjoyable and creative outlet, but one with its own vocabulary. To familiarize yourself with the practice, get comfy with the following terms:

HOOP: The nested set of rings that hold fabric at tension (Figure A). Machine embroidery hoops are designed to push the fabric and stabilizer to the bottom of the inner ring and hold it against the bed of the machine. They have fixtures that attach to the pantograph.

PANTOGRAPH: Moves the hoop in the X- and Y-axes in order to produce stitches. It's important to note that in machine embroidery, the pantograph moves the material under the stationary needle.

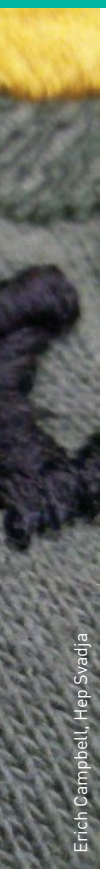
STABILIZER: Material added under the workpiece, spanning the hoop from edge to edge in order to combat distortion and sometimes to provide added strength to the finished piece (Figure B). Common varieties are made of wet-laid fibers to create a nondirectional fabric, allowing it to maintain its shape. Varieties include cut-away, tear-away, and water-soluble stabilizers.

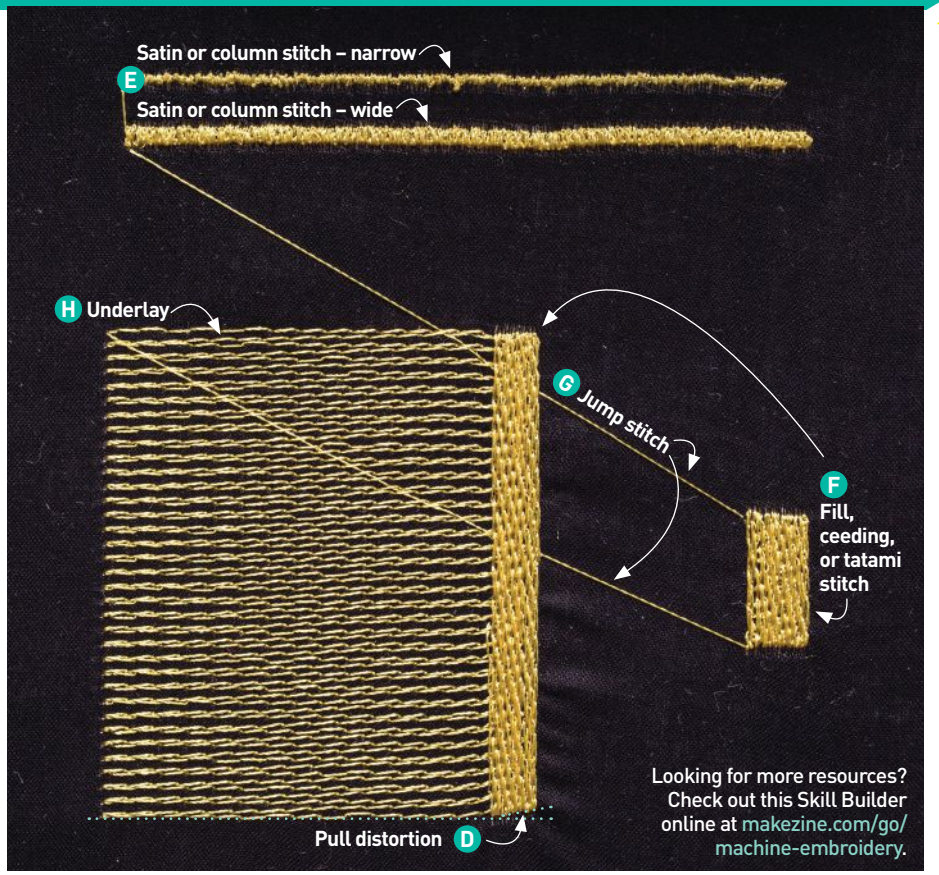
BOBBIN: Interlock sewing and machine embroidery stitches are formed by wrapping the top thread around thread coming from a small spool of thread under the workpiece called the bobbin (Figure C). You can use manually wound or prewound bobbins.

TENSION: The amount of friction placed on thread as it runs through the machine; adjustable for both the top and bottom thread paths. Proper tension allows some of the top thread to pass under the workpiece, ensuring that only the decorative thread shows on the fabric's surface.

DIGITIZING: The process of creating files containing commands that dictate the movement of an embroidery machine's pantograph and needles. The initial art is like vector drawing, and then shapes are filled with stitches programmatically based on specified variables like stitch length and density. Automatic options exist, but some digitizing requires manual placement for certain effects.

DENSITY: The amount of space between stitches or rows of stitching, used to determine how much coverage an embroidered element achieves. Measured in stitches per inch (SPI), metric spacing, or embroidery points (1 embroidery point = 0.1mm). Standard machine embroidery thread is roughly 0.4mm thick, so complete coverage is achieved at 0.4mm or 4-point density. More than full coverage builds mass or cuts an underlying material. Lighter densities allow internal elements to show through.





PULL DISTORTION/COMPENSATION: Stitches are under tension, and "pull" toward their center, shortening as they run. A column of satin stitches will be slightly narrower than is shown on-screen (Figure D). You can add width to the column so that it appears as intended, which helps elements like outlines and borders to maintain registration.

PUSH DISTORTION/COMPENSATION: When placed side by side at full coverage densities, areas of stitching tend to expand or "push" toward the edges of the stitch: a satin stitch column will be taller stitched than it is on-screen. Compensate by slightly reducing the height of the column — particularly in lettering, you'll see that a perfectly aligned stitched word must be very uneven on-screen.

PATHING: The sequence and direction of travel in a design that reduces unnecessary movements, color changes, and running time. It can also affect the surface of the workpiece; poorly pathed designs may cause rippling, puckering, and may lose registration.

STRAIGHT STITCH: A line of stitching, like those on a standard sewing machine. They're used to create detail, shading, fine outlines, and small text elements.

SATIN OR COLUMN STITCH: The most common for lettering, this high-sheen stitch is a tightly spaced zigzag wherein every other stitch lies perpendicular to the edges of the defined area. It can be used for elements from 1mm to 12mm, though most embroiderers will limit them to 10mm (Figure E).

FILL, CEEDING, OR TATAMI STITCH: Used to fill larger areas, this stitch usually consists of a field of tightly spaced rows of straight stitching of a uniform length, though the stitch penetrations or their endpoints are usually offset row-to-row to avoid them lining up and causing breaks in the surface (Figure F). The way those penetrations line up, as well as the randomness of their placement, can be used intentionally to create texture.

JUMP STITCH: When the needle is kept up and the pantograph moves to the next location in a design without stitching. Unless a machine uses automatic trimmers, this leaves a thread that must be trimmed away after the design is finished running (Figure G).

LOCK STITCH OR TIE-IN/OUT STITCHES: A set of small stitches, usually three at 1mm length at the beginning or end of an element or sequence that are meant to keep the thread from unraveling. These are necessary before and after any jump stitch that will be removed, and before or after changing color.

UNDERLAY: Stitching that runs previous to the topstitching in order to support it or otherwise mitigate texture in the underlying fabric. Underlay can provide a platform on which topstitching rests above the fabric, edges that topstitching can track, and/or holds down the nap or pile of the fabric. In all instances, it helps cover the base fabric, or to create a higher profile or texture to the decorative stitching (Figure H).

STITCH-OUT: A sample, or the act of running a sample of any new design or design and fabric combination. As various materials react differently to being stitched, you should test the combination of material and stabilizer that you want to embroider to allow for any necessary adjustments.

TOPPING: A material used on top of a textured fabric to temporarily prevent the texture from interfering with the embroidery process. Most are water-soluble films that are later removed.

TOOLBOX

GADGETS AND GEAR FOR MAKERS

Tell us about your faves: **editor@makezine.com**

$265 gearbest.com

GEARBEST DIY VIOLET LASER ENGRAVER

Despite warnings and inconsistent information online, some friends and I recently purchased a DIY laser engraver kit. These tools, originating in China, are available from multiple vendors. They seem to come in a variety of configurations, based on either acrylic or aluminum T-slot gantry designs and sporting either a 500, 2500, or 5500mW laser. We chose a 2500mW, 300mm×400mm T-slot (similar to 80/20, MakerBeam, or OpenBeam) design from GearBest. The laser is a blue-violet 455nm unit that could be easily switched out for an upgrade.

Seven weeks later the device arrived unassembled, with no instructions. Assembly wasn't particularly difficult, but less foolhardy buyers will want to read one of the excellent maker-written sets of instructions at Instructables.com (search for "gearbest laser engraver") or notice GearBest's links to downloadable assembly instruction.

The parts were all well made and all the necessary tools (e.g. hex wrenches) were provided. The EleksMaker controller has an Arduino Nano and two Pololu-style stepper driver boards. The controller doesn't have inputs for limit switches, which means the unit doesn't have absolute positioning. This isn't a huge issue, but it's frustrating when setting up projects. No software was included, but considerable searching led us to the intended Benbox software (the Baidu download link seems to disappear from time to time and occasionally points to malware infested software, so be careful and virus check your download). It's a very basic, but functional, tool that will flash the Nano with an old version of Grbl. Later versions of Grbl provide PWM capability for driving the laser, which allows it to provide a grayscale mode instead of just on and off.

Ultimately, I consider the laser engraver a fantastic purchase, even though considerable amount of tuning was required to get good results. The X-carriage needed some tweaking, the drive belts all had to be carefully tightened, and the software will drive you to drink. But for under $300, this tool is tremendous fun. I'm using it primarily for leather burning and cutting and getting incredible results. Don't let the haters scare you off. For makers with some kit building experience and reasonable patience, this is a tool that can do amazing things. —*Tim Deagan*

Tim Deagan

Fluke

FLUKE SCOPEMETER OSCILLOSCOPE 190-204

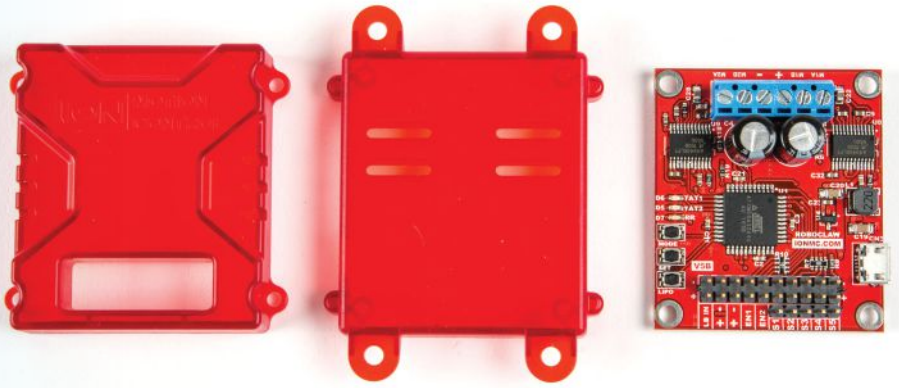
$4,800 en-us.fluke.com

When I needed to analyze some high-powered voltage signals, I reached out to a contact at Fluke who loaned me a ScopeMeter oscilloscope. It's designed for industrial applications and features a 2.5 GS/s sampling rate, 200MHz bandwidth, 4 input channels, 10,000 samples per channel memory, built-in multimeter, IP51 dust and "drip" resistance rating, and Li-ion battery pack. Here's an important part — it has four electrically isolated inputs, making it safer for making floating measurements. Even though my projects don't involve much fieldwork, the ScopeMeter's isolated inputs allowed me to measure voltages and signals that would have been dangerous, if not deadly, with a typical benchtop oscilloscope. Using the scope on lower power signals, I found the ScopeMeter to be intuitive to use, with crisp and clear signal display. My experiences have left me open-minded and optimistic about Fluke's other (and less expensive) ScopeMeters. Should the need arrive for a rugged oscilloscope for use away from my test bench, I wouldn't hesitate to buy one. —*Stuart Deutsch*

ROBOCLAW 2X7A MOTOR CONTROLLER

$70 ionmc.com

Ion Motion Control has come out with new versions of all their RoboClaw motor controllers. The 2x7A RoboClaw is the smallest amperage model, but can handle powering two standard-sized motors for robotics projects or your other mechanical creations. The new RoboClaw has some appealing features, such as a higher-powered BEC (battery eliminator circuit), regenerative battery charging, support for dual quadrature encoders and other sensor inputs, and built-in commands for controlling motor behavior. It can be controlled by USB, radio control, PWM, TTL serial, analog, and microcontroller input. What I like most is the new mini enclosure they give you, which offers good protection and an easier way to get started. — *SD*



HOWTOONS PROJECT KITS

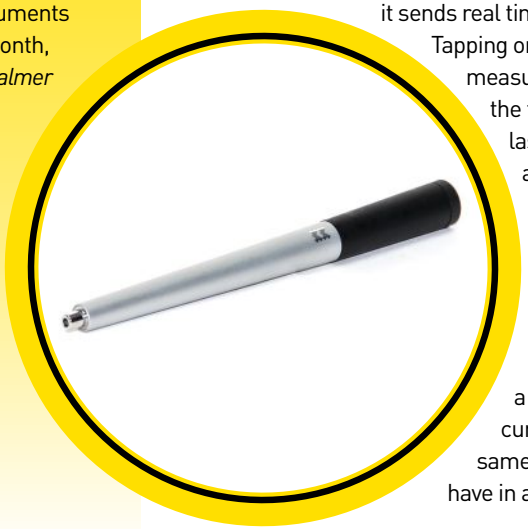
$25/month subscription howtoons.com

The ukulele kit from the company's project subscription service, was easy — and a lot of fun — to assemble. In Howtoons' kid-friendly style, instructional comic illustrations walk you through the steps. I loved that the kit came with pretty much everything I needed, and the laser-cut pieces make putting it together a breeze. I think this kit is great for a young maker (ages 7–12) interested in music or learning about how instruments are constructed. With a new kit coming every month, I'm excited to see what they do next. —*Sydney Palmer*

INSTRUMMENTS 01

$150 instrumments.com

The 01 from InstruMMents is an interesting take on how to keep a measuring device on you at all times. Rather than the bulk of a tape measure, a ruler, or worse, a yardstick, the 01 is the size of a pen — actually it *is* a pen. The front tip is a standard roller ball pen while the back holds the magic. The 01 connects to your phone over Bluetooth and when the back of the pen is rolled along a surface, it sends real time measurements to your phone. Tapping on the back will change to the next measurement, allowing you to capture the full dimension of an object. A laser line helps line up your object and keep your measurements straight. I found a little practice produced accurate results and the device was useful enough and small enough that I didn't mind keeping it in my pocket. InstruMMents has promised a secondary app that will allow curves to be captured with the same device, which could be a must-have in a designer's toolbox. —*Matt Stultz*

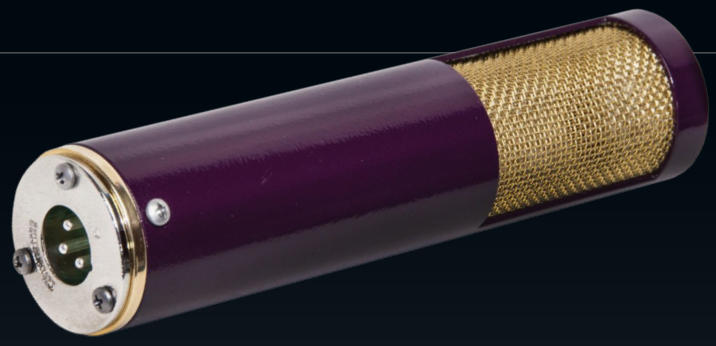


ROSIES WORKWEAR COVERALLS

$82 rosiesworkwear.com

I struggled my entire life to find decent, hard-wearing workwear that fit — until I found Rosies Workwear for Women. If you run into the same problems with universal sizing that I do (sleeves too long even rolled up, pockets hitting your knees and preventing kneeling work), Rosies coveralls will solve them, without sacrificing things like pocket volume or fabric strength. And far from just copying the men's version and making it pink, these coveralls are specifically tailored for women, to be both protective and flattering.

Featuring plenty of colors and fabric choices, including lighter-weight, durable fabrics for painting or gardening, they offer tons of choice for style and fit. And for those under 5' tall, there's short sizing. No longer will you find me swimming in an oversized jumpsuit like a toddler in Dad's clothing. I can finally be the Ripley I want to be in the workshop. —*Hep Svadja*

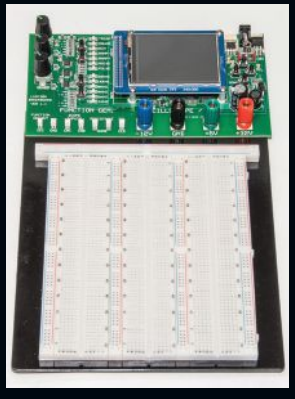


AUSTIN RIBBON MICROPHONE

$249 diyribbonmic.com

High-end recording gear comes with high-end prices. If you're interested in saving some cash by putting in some work, the Austin Ribbon Microphone kit is for you. A ribbon microphone converts sound into an electric signal by placing a thin sheet of metal film between two fixed magnets. As sound waves make the metal film vibrate, the magnets produce a small current. This is an old and classic style of microphone that is well known for capturing an even frequency response across a broad spectrum of audio.

The Austin Ribbon Mic kits come with all the parts you need to create the microphone at home, but be sure to read the directions thoroughly and watch the videos before sitting down to create the kits (you will need some tools and parts that you might not have laying around, like a 1" dowel). While fairly straightforward in process, the heart of the ribbon mic is an incredibly thin piece of aluminum leaf that is extremely fragile and takes a couple tries to master placing. Thankfully plenty of extra foil is supplied. *—MS*



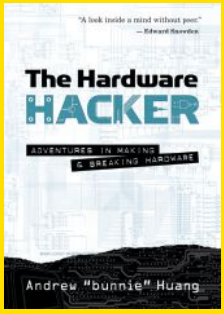
BAKERBOARD

$249 www.lumidax.com/products.html

Analog electronics are often considered an almost magical art. Audiophiles and musicians quest for the cleanest tone while ham radio operators attempt to filter the cleanest signal possible. Knowing what components to use is often not enough, you also have to know what position and orientation of the components will affect the signal in the end. The Bakerboard from Lumidax Electronics is an attempt to provide those interested in learning this art with a toolkit that will make the process easier.

The Bakerboard gives you three full-sized breadboards to prototype with, plus a workbench's worth of connected tools. The PCB on the Bakerboard is the heart of the system, and a built-in power supply outputs -12V, 12V, and 5V for all of your projects' power needs. There's also an audio frequency range oscilloscope and function generator built-in to test your circuit and make debugging easy. If you want to test circuits on the go or don't have the space or budget for a full bench of tools, the Bakerboard is a powerful combo of features and portability. *—MS*

BOOKS



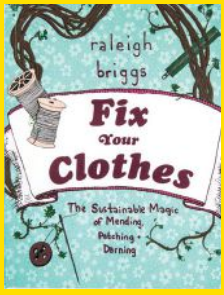
THE HARDWARE HACKER: ADVENTURES IN MAKING AND BREAKING HARDWARE

by Andrew "bunnie" Huang

$30 No Starch Press

Part memoir, part interview, this book reads like a real-life William Gibson novel, complete with quasi-legal tech exploration, and even things like creating entirely new coding languages to avoid accidental plagiarism. He explores manufacturing facilities in China, learns the ins and outs of data law, and is constantly pushing boundaries. The most astonishing part of this book is that it is completely factual.

Bunnie is best known to the rest of the world as the amateur engineer who was sued for hacking into his own Xbox, but he's also an open hardware activist, going so far as to create and sell a completely open source laptop, "just to show it could be done." He's worked on projects such as the Chumby, which many regard to be the precursor to the BeagleBone and Raspberry Pi. The stories are enthralling, even if you don't know the exact engineering terms he's referring to, and the pictures are often detailed views of rarely seen internal components. *—Caleb Kraft*



FIX YOUR CLOTHES: THE SUSTAINABLE MAGIC OF MENDING, PATCHING + DARNING

by Raleigh Briggs

$7 Microcosm Publishing

Raleigh Briggs gives solid, simple overviews of everything from stitches and buttons to zippers and waterproofing. Each section is accompanied by zine-style, hand-drawn illustrations, and a conversational tone that feels like you're chatting with a knowledgeable friend. My favorite tip thus far is the tying off stitch, which is easier and lays flatter than tying a bunch of knots. This quick pocket reference is a lifesaver for the amateur seamstress! *—Sophia Smith*

BCN3D SIGMA 2017

Much improved in quality and performance, this machine shows great promise

Written by Matt Stultz

DURING LAST YEAR'S 3D PRINTING SHOOTOUT WE TESTED THE BCN3D SIGMA and were let down by poor build quality and a system that didn't seem fully fleshed out. Now BCN3D has come back with a 2017 revision of the Sigma, and you can tell they've been listening to their customers and reviewers.

TWICE THE CONTROL

MatterHackers, the U.S. reseller for the Barcelona, Spain-based company, arranged for me to test the updated machine. BCN3D has greatly improved on the one really compelling feature of the Sigma that I hoped they would: the independent dual extruder or IDEX system. While most dual extrusion systems tie two extruders together on the same carriage, IDEX uses two motors to control two separate carriages. This allows each extruder to be calibrated to each other and the bed, preventing an extruder that is lower than the other from bumping into a print and knocking it loose. When one of the extruders is not in use, it is parked over a container to collect any filament leaking from the heated extruder.

This new revision of the Sigma feels far more solid than its predecessor and boasts a newly designed hot end that can be swapped for different nozzle sizes easily. I would still love to see the base plate of the Sigma replaced with a metal panel like the rest of the machine, but the current plastic is leaps and bounds better than the previous version.

SMOOTH PRINTING

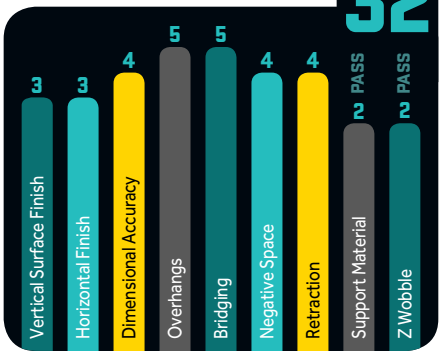
Printing on the Sigma is easy with its Cura integration and the intuitive control panel. You can tell the interface wasn't designed for primarily English speakers, but the adaptation to English is well done and the graphics are more than enough to explain operation. Dual extrusion setup is done through Cura, and while the instructions require the extruders to be set by the model import order, newer versions of Cura will allow you to select a model and set the extruder within the program.

The prints turned out great and really clean. If I had any complaint, it would be that I would like to see nicer vertical surfaces and better stitched together top surfaces. These are both things that could be easily tweaked in the printing profiles though.

ONE TO WATCH

BCN3D is onto something. I really like the Sigma, and the number of improvements that can be found in this newest edition seems to indicate they are on the right path. I have a feeling we will be talking about this company for years to come.

MACHINE RATING **32**



bcn3dtechnologies.com

- **MANUFACTURER** BCN3D
- **PRICE AS TESTED** $2,695
- **BUILD VOLUME** 210×297×210mm
- **BED STYLE** Heated glass
- **FILAMENT SIZE** 3mm
- **OPEN FILAMENT?** Yes
- **TEMPERATURE CONTROL?** Yes, extruder (290°C max); bed (100°C max)
- **PRINT UNTETHERED?** Yes (from SD card)
- **ONBOARD CONTROLS?** Yes (full color touchscreen)
- **HOST/SLICER SOFTWARE** Cura
- **OS** Windows, Mac, Linux
- **FIRMWARE** BCN Sigma Marlin variant
- **OPEN SOFTWARE?** Yes (GPL)
- **OPEN HARDWARE?** Yes (CERN Open Hardware License v1.2)
- **MAX DECIBELS** 50.4

PRO TIPS

Two colors are great in a dual extruder, but the real fun comes from two materials. Consider picking up some water-soluble PVA support material and some NinjaTek Cheetah (better for Bowden extruders) for some flexible fun.

WHY TO BUY

The IDEX technology has some serious advantages for dual extrusion. If you are in need of multi-material or two-color printing, the Sigma stands out.

MATT STULTZ is the 3D printing and digital fabrication lead for *Make:*. He is also the founder and organizer of 3DPPVD and Ocean State Maker Mill, where he spends his time tinkering in Rhode Island.

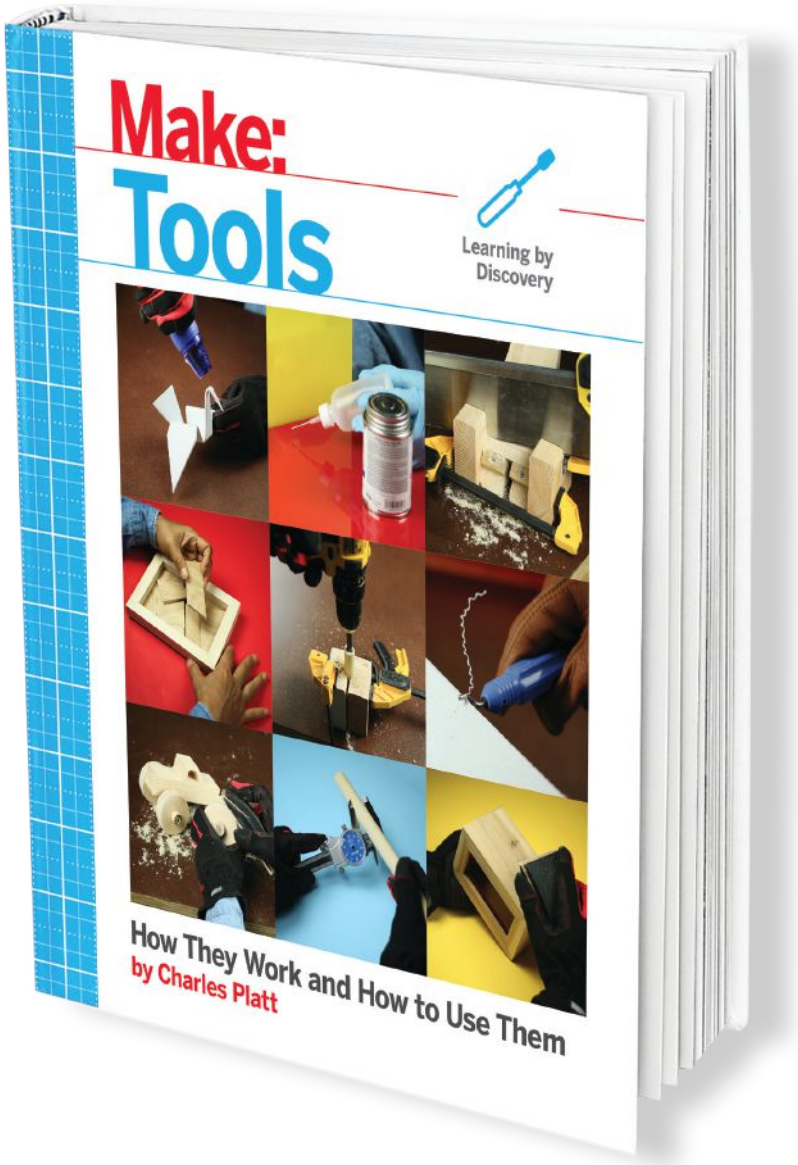
TEST PRINT

Matt Stultz

Make: the DIT Way

BOOKS

Do-It-Together with **Make:** Books



MAKE: TOOLS

By Charles Platt

Everything you need to know — and plenty you didn't know you needed to know — about everyday workshop tools. An essential maker text!

"By the end, you'll have been introduced to dozens of tools, materials, and techniques and have gained a solid grounding in how to use them in the real world."
— Gareth Branwyn, Boing Boing

MAKE: BOOKS ARE AVAILABLE AT MAKERSHED.COM AND FINE RETAILERS EVERYWHERE

High-Tech Guides:

The Makerspace Workbench
By Adam Kemp
Design, plan, build, and outfit your own makerspace.

Making Makers
By AnnMarie Thomas
What makes a Maker? Childhood. Here's how.

Zero to Maker
By David Lang
Learning the skills necessary to go from an unemployed office worker to an underwater robotics entrepreneur — one maker's story.

Maker Pro
Various authors
Essays on making the switch from hobbyist to pro.

The Maker's Manual
Various authors
Transform your ideas into your business using electronic prototyping, 3D printing, programming, and more.

Tinkering
By Curt Gabrielson
Kids learn science while fooling around with real things.

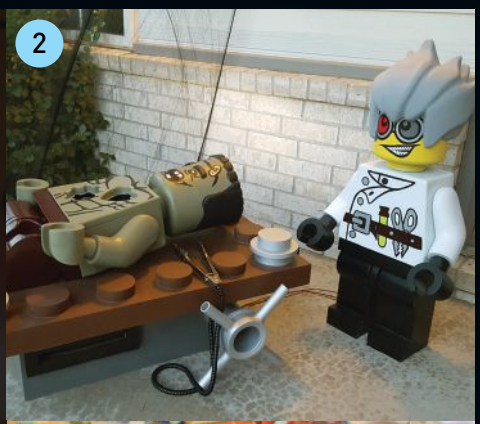
SHOW & TELL

Special Halloween Winners Edition

Sharing what you've made is half the joy of making! To be featured here, show us your photos by tagging #makemagazine.

Written by Sophia Smith

All good haunters know preparation is key — there are spooky scenes to set, enigmas to engineer, costumes to craft. Need some inspiration for your tricks and treats? Check out last year's winners of the *Make:* Halloween Contest to get your ghoulish gears going.



1 AMAZON ECHO GHOST

Bryant Schuck brought his ghost to life (or rather, Alexa to death) with an Amazon Echo and a Particle Photon.

2 ANIMATRONIC LEGO FRANKENSTEIN

Matthew Harrell supersized the Monster Fighters Lego kit using MDF, PVC, and Smooth-Cast, then installed speakers and servos to complete the scene.

3 MAGIC CAULDRON

Take a brass cauldron, add an Arduino, ultrasonic sensor, and NeoPixel ring, and you've got a magical fortune-telling device like this one crafted by **Ian McKay**.

4 REY AND HER FALCON

There were tons of Rey costumes last year, but 501st member **Dino Ignacio** also built a foamcore Millennium Falcon for his 5-year-old daughter to pilot.

5 WHERE THE WILD THINGS ARE

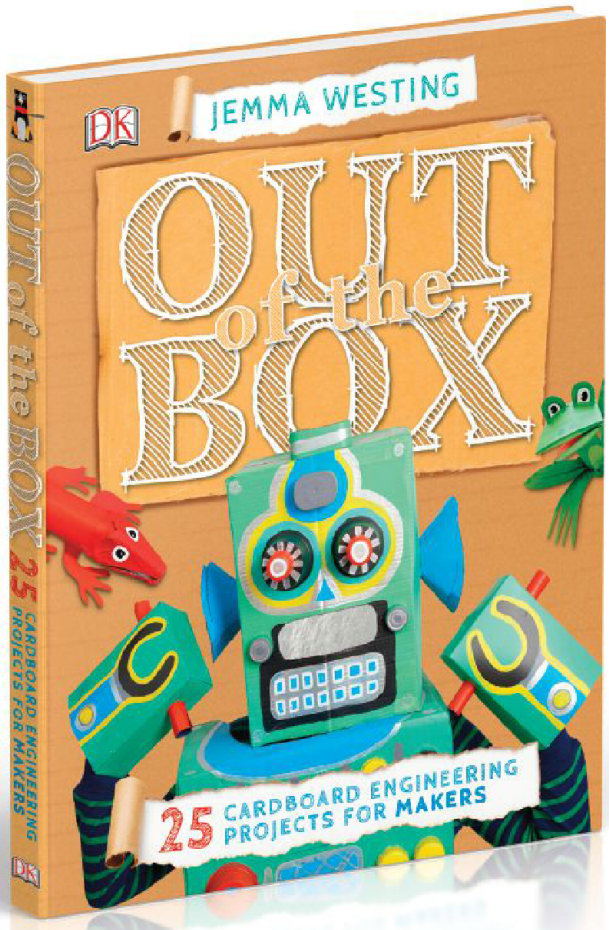
Kevin Harrington used BowlerStudio to create parametric, animatronic robot heads that he fashioned into characters from *Where the Wild Things Are*.

6 KRAKEN TENTACLES

This nautical nightmare started with just some air conditioning ducts and PVC. **Amy Velella** and her family have also done *Harry Potter*- and *Star Wars*-themed scenes for their 1,300+ trick-or-treaters.

Check out all the contest entries at makezine.com/go/2016-halloween-contest

POWERED BY STEAM



"When children make, even with their simplest materials, they get to realize with their hands what they can imagine in their minds. This book inspires young makers to discover creative, playful projects."

—DALE DOUGHERTY,
FOUNDER OF MAKER FAIRE

Maker Camp

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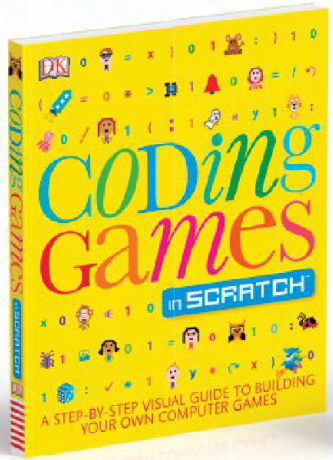

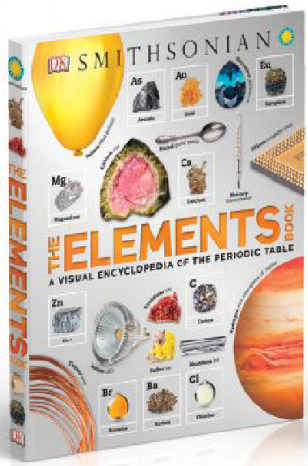

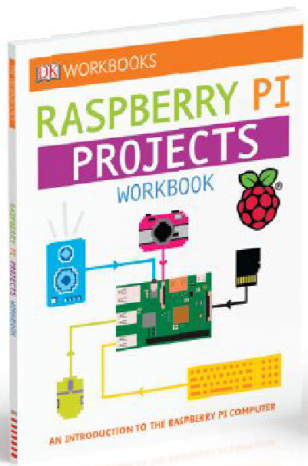

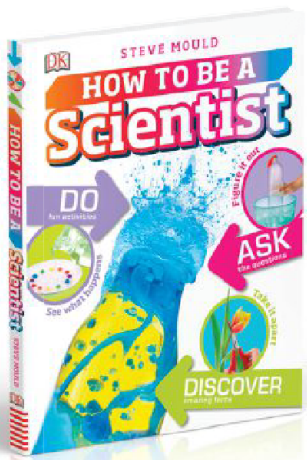

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