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The ShopBot Desktop has the right touch for prototyping **Keyboardio**

Who: Jesse Vincent and Kaia Dekker
Website: www.keyboard.io
Where: Oakland, CA
Tool: ShopBot Desktop CNC

Jesse, an open-source software designer, and Kaia, a former investment banker, are a couple who came up with an idea for a hackable, ergonomic keyboard. Keyboardio Model 01 features premium mechanical keyswitches that are easy to type on, and its custom-sculpted keycaps guide your fingers into the right place. What's most surprising, as well as pleasing to see and feel, is the keyboard's unique maple hardwood enclosure.

Keyboardio enjoyed a successful Kickstarter, and thousands of people are awaiting the product. To make prototypes, Jesse has been using a ShopBot Desktop. "That was after paying about $1000 each time we wanted bespoke milling of a prototype base from a vendor in Shenzen, and there was a turnaround of about two weeks. We needed a better solution." Kaia added, "Using our Shopbot, we can do a similar prototype project in a day. The tool quickly paid for itself."

"Going into this, we had the desire to make this product, but not all the skill sets," said Jesse. "Working with Shopbot CNC for rapid prototyping, we've been able to jump in and start making, going from CAD to CAM relatively easily." Keyboardio is about to go into full production.

Read more on the ShopBot Blog: shopbotblog.com

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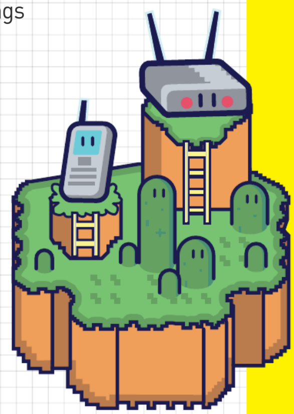
CONTENTS

Make: Volume 52 August/September 2016

Special Section
VIRTUAL REALITY 24



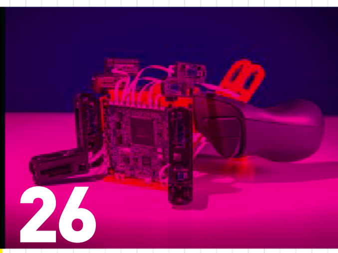
22

ON THE COVER:
NASA's JPL is using VR tech to create the next Mars rover. Illustration by Viktor Koen.

Google, James Burke

54

SKILL BUILDER



26

PROJECTS

TOOLBOX

OVER THE TOP

32

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"But [Case] also saw a certain sense in the notion that burgeoning technologies require outlaw zones, that Night City wasn't there for its inhabitants, but as a deliberately unsupervised playground for technology itself." ***— William Gibson, Neuromancer***

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What's something you would love to do in VR, but never do in real life?

Krista Peryer
Springfield, MO
(The Hollow Honda)

I'd love to be a doctor and perform surgery on a person. I wouldn't have the stomach for it in real life!

Tim Deagan
Austin, TX
(Getting Started with Propane and Fire Effects)

I'd love to do aggressive destructive testing in VR. Pushing flame designs past the fail point (without risk) would let me build far cooler stuff. Plus explosions!

Jenny Ching
San Francisco, CA
(Test Builder, Party Photo Booth)

I'd use VR to put myself in another person's shoes. We'd have more compassion for the homeless, refugees, and undocumented people if we were able to experience their lives firsthand.

Viktor Koen
New York, NY
(Cover Illustration)

Even though (very) deep sea wreck diving or being a medieval knight come to mind, I'd rather experience what my grandparents went through during WWII. Painful, but personally significant.

DC Denison
Cambridge, MA
(Data Plans)

I would get tiny and go into a beehive. I've entered hives from the top, as a cautious, human-sized beekeeper. With VR (and a tiny flashlight) I could stroll in at bee-scale for a leisurely look around.

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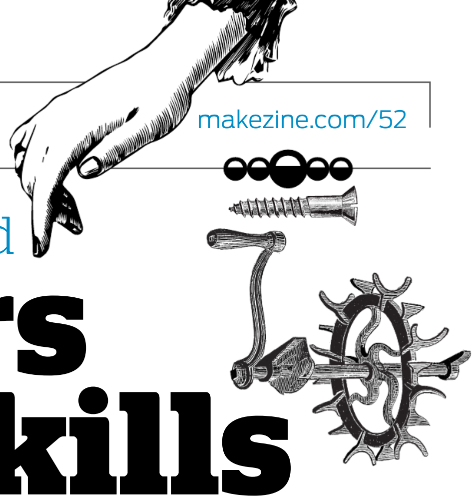

A New Perspective on Programming and Make: Readers Show Their Skills

IN RESPONSE TO *MAKE:* VOLUME 50

"Use a meter to measure the resistance ... which should be zero." ("Sound Squeezer," Volume 50, page 81.) No, it should read infinity, not zero. Zero resistance is a dead short, which you do not want in a capacitor.

—Gordon Martin, Mississauga, ON

Love your magazine, but on occasion its accuracy leaves something to be desired. Case in point: screw nomenclature ("Turning Heads," Volume 50, page 34). The head of the screw is the shape of the head, not the screwdriver shape (flat head, oval head, fillister head, button head, etc.). Flat blade, Phillips, hex head, square or Robertson, torx, hex-socket head, or Allen is the type of drive. And those are not wood screws in the illustration those are a high root, trumpet head screw for soft material. Wood screws have a larger unthreaded shank under the head that allows the materials to be pulled up tight as they are screwed together.

—Frank Wright, via the web

I'd like to point out that in the article "Metal Zone" (Volume 50, page 24), where the properties of metals are discussed, the term "temper" is used when describing the use of a torch to restore the ductile qualities after work-hardening copper. I believe that the correct term should be "annealing" when you need to make a piece of metal malleable after it's been hardened. This is an important distinction that makers should understand — so often one can hear people misuse these terms and get confused as a result. Understanding the qualities of metals as they are manipulated can have a very fundamental effect on the success of a project during the process of making something, and even while choosing the appropriate material based on the intended use. I often refer to *Machinery's Handbook*, and also Tim McCreight's book, *The Complete Metalsmith* for guidance regarding annealing, hardening, and tempering.

—Mark Simmons, Beaverton, OR

I'm writing about some concern over the advice given for a severe burn ("Accidents Happen," Volume 50, page 58). As a first-aider and community responder, the training given in the U.K. would be to irrigate the burn with running cold water for a minimum of 10 minutes as quickly as possible after the incident. Once irrigated, the injured limb should be wrapped in cling film and the casualty taken to hospital. A burn of the size shown in the picture, especially on the hand (or foot) needs to be seen by a doctor to ensure that there is no long-term loss of mobility.

—Paul Whitby, via the web

In *Make:* Volume 50, Digital Calipers ("Accuracy is Everything," page 54), the single most critical thing has been left out! Before zeroing, the outside jaws must be absolutely clean. The slightest bit of shop dust can throw you off by 0.0005" to 0.002". I use only my thumb (reasonably clean, of course), as I have found errors from fibers when using a cloth.

Also, as I have learned the hard way, stay away from dollar store versions of the button batteries; they are alkaline, and have about 1/10th the life of the proper silver oxide cells.

I love *Make:* magazine; I'm 72 and have been a maker/hacker since about 3 years old.

—Gordon Martin, Mississauga, ON

Ryan Huddle

INSPIRATION TO THINK COMPUTATIONALLY

» This is an incredible write up ("Programming Is Expression," Volume 50, page 42). Really opened my eyes to the philosophy of computational thought. I'm a photographer who has been flirting with the idea of learning how to code. This just convinced me to act on it, so thank you.

— Spencer Bentley, via the web

This is such an interesting and uplifting article; I came away with a different perspective on the "art form" that programming really is. I find it so fascinating that I have used many of [author Tom Igoe's] basic code samples as the building blocks for working projects that I use every day. Thank you for being a part of what I have grown to enjoy so very much.

— Bob Durk, via the web

James Burke

Fairely Innovative Future

BY MIKE SENESE, executive editor of *Make:* magazine

BACK IN 2006, I EXPLORED THE SITE OF THE VERY FIRST MAKER FAIRE, marveling at the incredible assortment of homebrew technology projects on display. Alternative energy vehicles. Telepresence robots. An electronic fashion show. A flame-bellowing fire truck. Those wonderful, unusual, and exciting builds — versions of which can now commonly be found in the mainstream world (except for that fire truck, but I'm not giving up hope) — each acted as a portal into a unique, dedicated, and open community.

It's this discovery of new projects and groups, and watching them progress over time, that is one of the best parts of hosting the great party that is Maker Faire. Sometimes this progress moves with exceptional velocity. Case in point: At that same event, I spotted a table sporting a compact A-frame creation built from threaded rod and metal bars, with an apparatus holding something that looked like a caulking gun. Its maker intently adjusted the device and configured settings on a laptop as I asked what it was. He replied, "It's an additive fabricator" — a term I hadn't heard before. At the following year's Faire in 2007, I noticed a few extra tables with additional makers and their additive fabrication RepRap machines. In 2009, MakerBot formed and released its first desktop 3D printer kit; four years later, there was hardly a table at the Faire without a MakerBot on it and the company was a month away from a half-billion-dollar acquisition.

Similar progress has happened with drones and electronic prototyping boards, and is now ramping up quickly with biohacking and virtual reality, among others. We don't create these communities, nor do we take credit for their success — that's all you! But we are happy to have a venue where so many diverse groups can gather and celebrate what they all have in common: openness and the love of sharing.

In this issue of *Make:*, we check into one of those quickly moving fields, VR. The top two devices in this area, Oculus Rift and HTC Vive, both heavily leveraged maker tools and ethos in their inception. We see this firsthand in our visit to the offices of Valve, the team behind the Vive. We also look at the hobbyists building engaging VR accessories alongside these polished products, and the software options for designing your next project inside virtual reality itself. Like computer-assisted design software that enhanced the physical creation process, these new tools will expand our options for creative output in every way, and it's only just getting started.

We're also introducing a new section in this issue — "Show & Tell" (page 14) Our magazine, like our events, is a sounding board for the incredible maker community, and in Show & Tell we want to give you even more opportunities to share your projects in our pages. Go to makezine.com/contribute to submit photos of your masterpiece — completed or in progress — for us to run in upcoming issues of *Make:*. We can't wait to see what you've built.

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The Hollow Honda

For artist **Jonathan Brand**, the dream of one day owning a motorcycle turned into a reality — just not quite the way he'd probably expected.

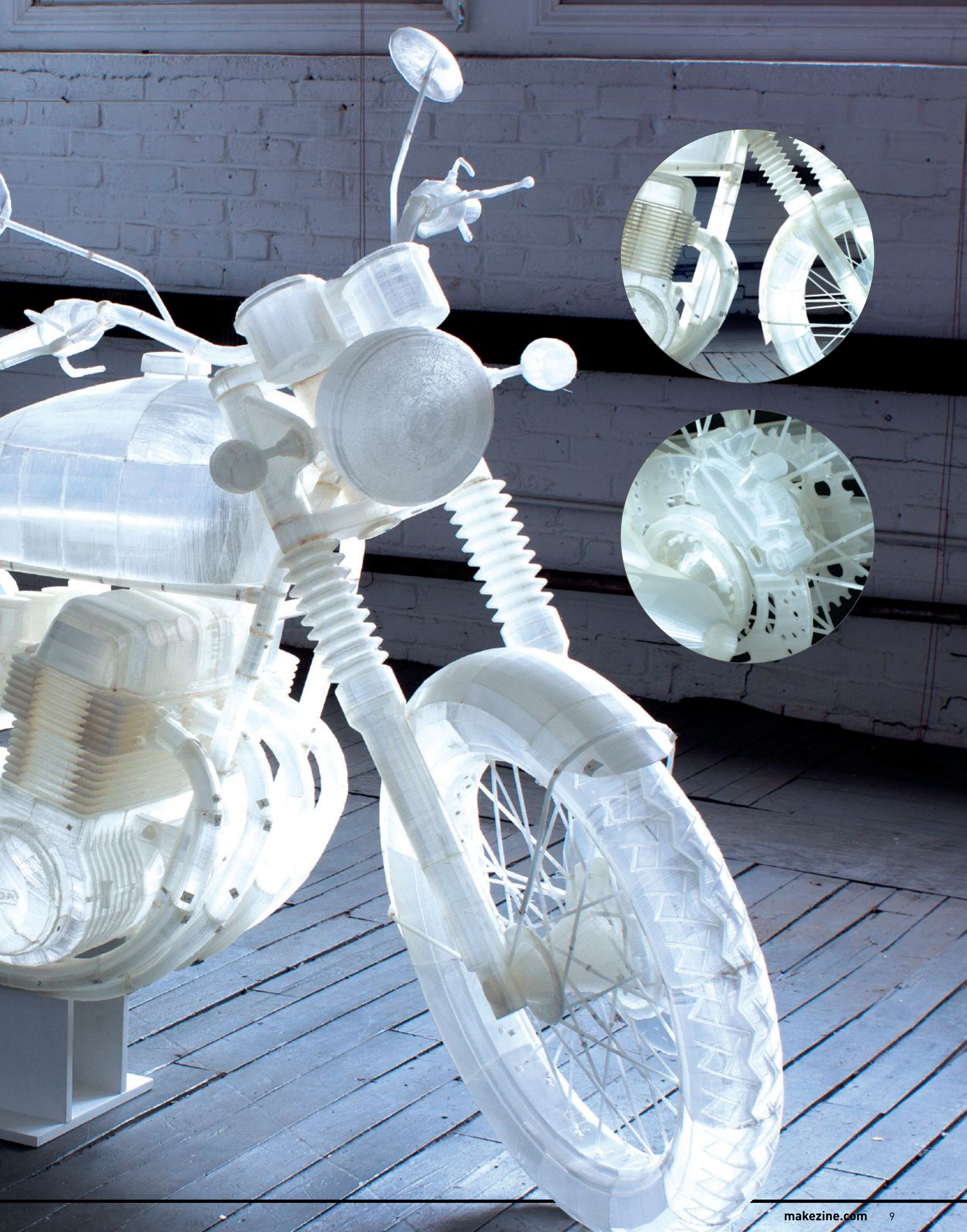
Using an original Ultimaker 3D printer and 18 rolls of clear 3mm PLA, Brand designed and 3D printed a life-size bike. "When I lived in Brooklyn, I was looking to buy a 1972 Honda CB500. It's something I wanted, but that was completely impractical and unlikely for me to ever own."

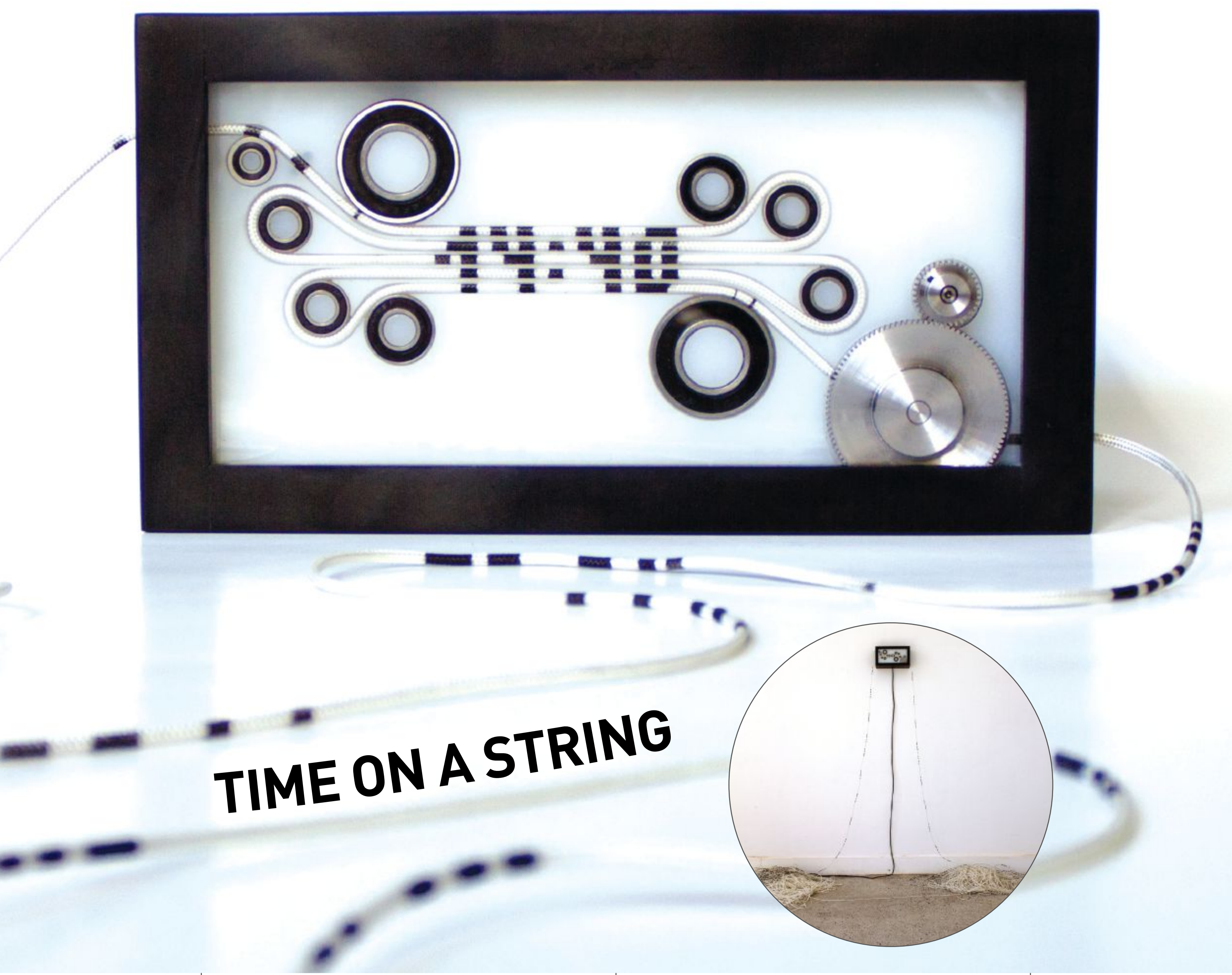
He based his design on a Honda bike he purchased online. Using Rhino3D, he traced parts or downloaded them from sites like TurboSquid. "In the end I redrew most of it to make sure all the parts fit and were water tight for 3D printing," he says.

At about 1mm thick, the parts are very fragile and consist of smaller pieces that Brand logged many careful hours welding together. Transporting the piece from one art exhibit to the next seems tricky, but with the help of some "museum quality foam and some seriously overbuilt shipping crates," Brand says the motorcycle may be stronger than he'd thought.

— Krista Peryer

Jonathan Brand





TIME ON A STRING

FEL-X.COM

After researching how time can be shown in uncommon ways, German artist **Felix Vorreiter** decided to make his own unique timepiece using string. His method, which some people said would be impossible to build, involves a long rope with a sequence of black rings painted on it. The "encoded" cord loops around bearings to form five lines, which come together once a minute to display the time.

To properly paint the string, Vorreiter wrote a script in Adobe Illustrator to generate a mask, which was then printed on self-adhesive foil and applied as a template. Even with help, it took over a day to paint. The rope is long enough to keep time for about 120 minutes. According to Vorreiter, it would take about .7 miles of rope to display all 1,440 minutes in a day.

To run the clock, a custom Arduino-based board controls a stepper motor that pulls the rope to the appropriate position. Contacts embedded inside of the string help align everything, and when it's running, the encoded cord advances once per second like a traditional clock.

— Jeremy Cook and Laura Cochrane

Felix Vorreiter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PLASMA PLAY

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Have you seen the century-old photo of Nikola Tesla wirelessly powering a light bulb? Two Colorado-based artists took this classic, mind-blowing experiment and made it Technicolor. **Joe Pawelski** built the Tesla coil. **Aaron Ristau** contributed the randomized rainbow of color, including his collection of vintage salesman sample tubes as well as his hand-built, curvaceous noble gas tubes. The beautiful sculptures at the core of this piece were a byproduct of Ristau's explorations in building custom bulbs for his fine art.

Ristau started working with glass lathe operators in 2011 to create sculptures that could hold the noble gases (specifically neon, argon, and xenon). He wanted bulbs that would last, just as classic 20th-century neon signs have survived for decades with their careful craftsmanship.

As in the original photo of Tesla, the only thing powering Ristau's dozens of gas-filled bulbs is Pawelski's Tesla coil. Ristau thinks of his collaboration with Pawelski as a performance piece, as each show they presented at NoCo (Northern Colorado) Mini Maker Faire only lasted 15–20 seconds every 5 minutes or so. They didn't want to flood fairegoers with too much ozone! — ***Michelle Hlubinka***

Alanna Break

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SHOW & TELL

The latest dazzling projects from inventive makers like you

From robots that swim to cars that glitter with electroluminescence, sharing and seeing what others have built is half the joy of making.

1 *Cosmic Dance* is a kinetic sculpture by **Nick Dong**, combining motors and magnets into a mesmerizing dance recital.

2 **Brian Roe**'s Roy the Robot is constructed entirely from laser-cut plywood and 48 hobby servos, controllable from a mobile device via Arduino.

3 When you load up the chassis of a 2004 Honda Civic with found objects, recycled steel, and literal garbage, you get **Detroitus**' *CarCroach*.

4 **Andrew "Captain Redbeard" Hostler** of the Cal Poly UROV team takes a swim with their bot Sebastian, which recently mastered complex swimming in vector configuration.

5 **Obscura Digital and the Ocean Preservation Society** collaborated to hack this Tesla Model S, complete with an electroluminescent paint job.

6 The folks of **MonkeyLectric** develop bike lights that spin custom 8-bit images across spokes for a safer, more awesome ride.

7 Huge mechanical pendulums rotate as their movement is recorded live and projected back onto them in **Joel Dream**'s *Portrait of Resonance and Chaos*.

8 **Tyrone Hazen**'s Fireside Audiobox syncs a cheery line of flames to your favorite tunes.

9 **Ryon Gesink** poses next to his fiery metallic behemoth, *Moloch*.

10 The *Mona Lisa* finds a new home with the help of **Joshua Schachter**'s Marky Mk2 dry erase bot, which draws an image with a single line.

11 **Brave Robotics** built this real-life walking Transformer, which stands about 4 feet tall and folds down into an R/C car.

12 **Lost&Found in Space** is a 3D printed suborbital spacecraft that deploys small sensor-laden sprites for collecting and relaying data back to Earth.

13 Hacked together from an Ikea lamp and Adafruit LED strip, **Cheng Xu**'s Knappa Tutu glows in response to movement.

14 **Priyanka Gupta Sarvaiya** bends and curls paper to her will to create beautiful paper quilling projects for Just Love Crafts.

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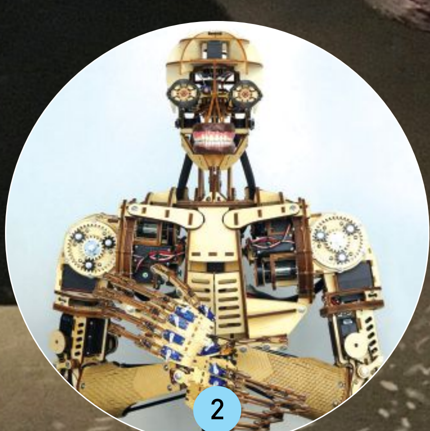

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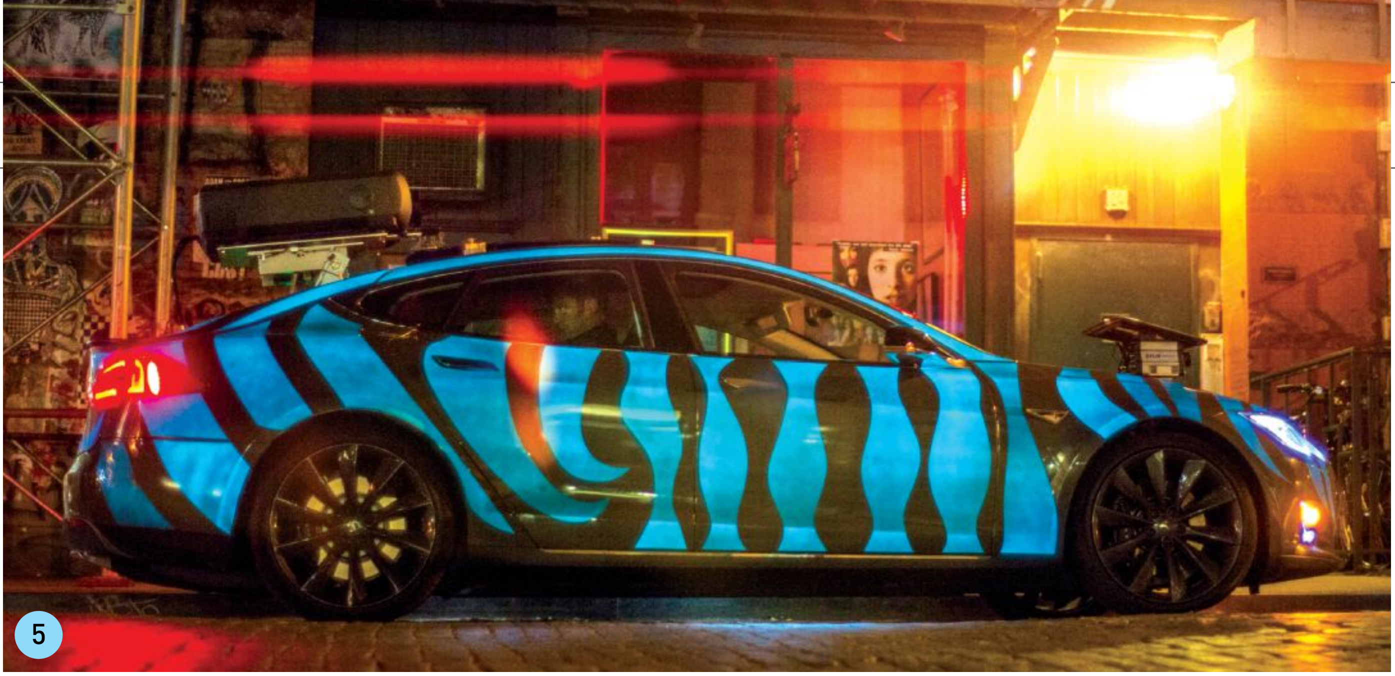
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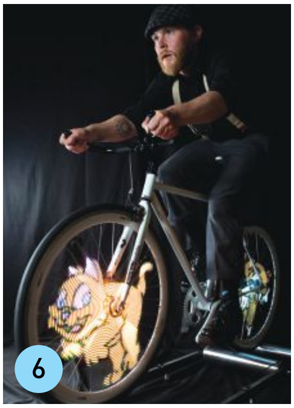
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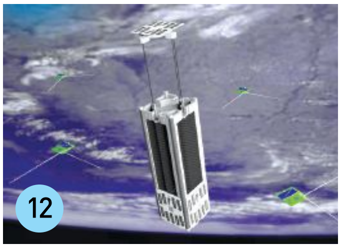
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13


14

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Nick Dong, David Goebel, Doyle Huge, Jonathan Lokos, Andrew Eckmann, Phillip Yip, Joel Dream, Charlie Thiel, Shannon Corr, Joshua Schachter, Hiroshi Kohno, Andrew Filo, Lulin Ding, Priyanka Gupta Sarvaiya

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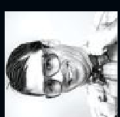
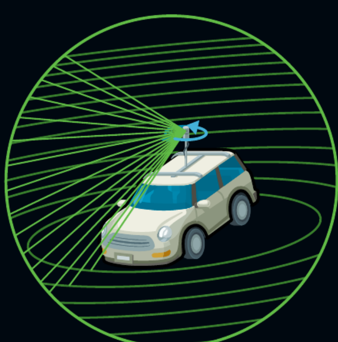
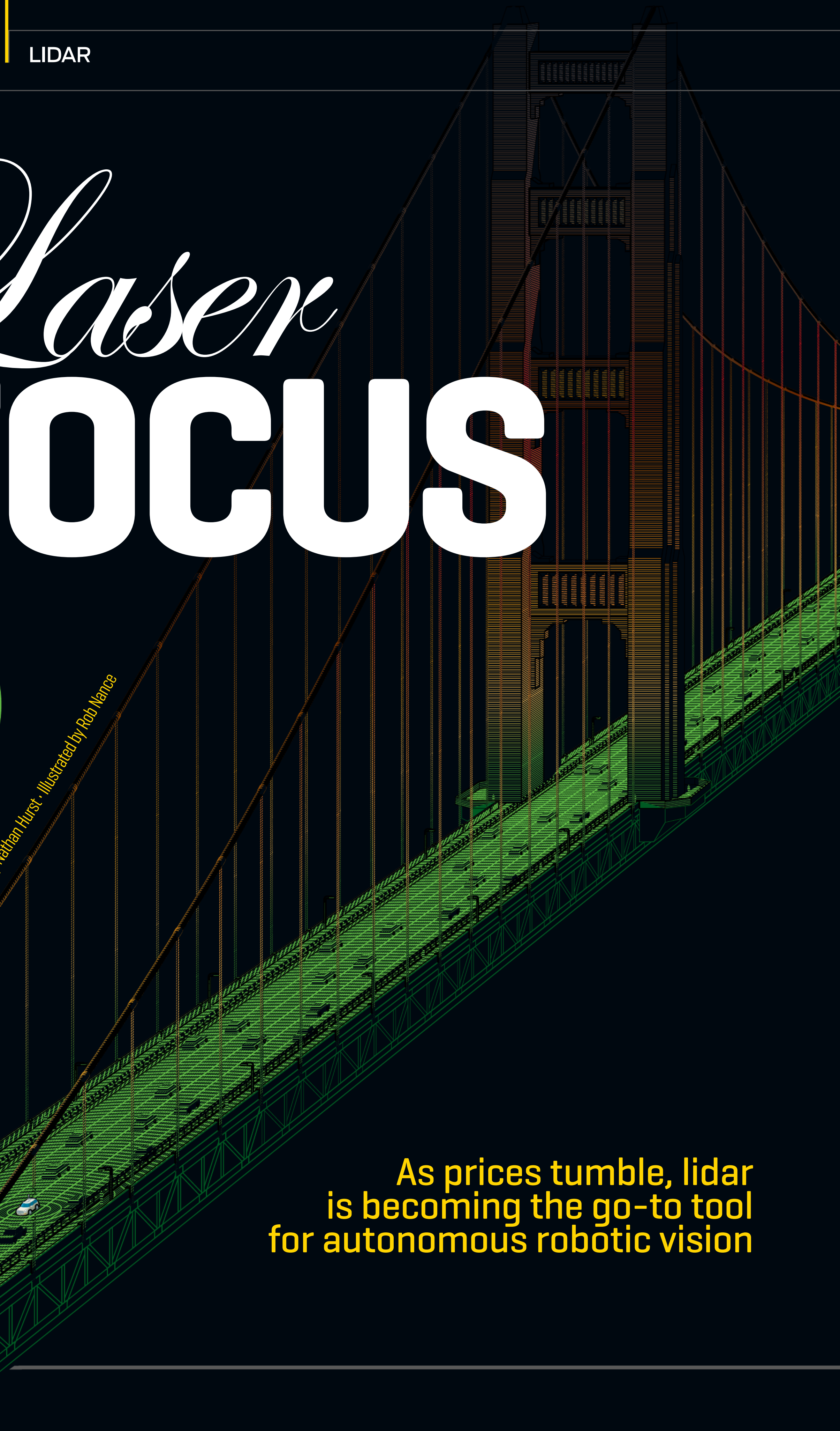


Laser FOCUS



Written by Nathan Hurst • Illustrated by Rob Nance



As prices tumble, lidar is becoming the go-to tool for autonomous robotic vision

If you've been living on Earth this year, you've probably heard someone mention self-driving cars. If you were tuned in, you might have heard the $70,000 price tag for just one of the early lidar units used in Google's driverless cars. The devices are a bit outside the typical price point for a family auto let alone a hobbyist's project.

Lidar is at once an acronym for Light Detection and Ranging and a portmanteau of "light radar." Its name is fairly descriptive: The unit bounces laser light off of objects, and senses the return of that light to measure the distance of said object. This is key to object detection in a self-driving car.

But forget cars for a moment. What about golf carts?

Alex Rodrigues, Michael Skupien, and Brandon Moak built a self-driving golf cart as part of a mechatronics engineering program at the University of Waterloo in Ontario, Canada. The sensor that made it possible was a new-ish, $8,000 lidar unit from Velodyne called the VLP-16, affectionately known as the Puck. After a $35,000 grant, Rodrigues, Skupien, and Moak dropped out of Waterloo to move to California and attend YCombinator. They founded Varden Labs, which just finished a round of fundraising, and has done pilot demos for automated shuttles, including bringing VIPs to a Sacramento Kings game.

That's not to say lidar makes automated driving simple, but if you can take some of the challenges out, reasoned Rodrigues, you could make it a lot easier to solve. "We intentionally chose to put constraints on the problem," he says. "We said building a fully self-driving car that can work in all conditions, in all places, at all times, is really hard. But making something that can be useful for transporting people doesn't have to be that hard. So we specifically are targeting shuttle service on private campuses." That means they could slow it down, place it in a controlled environment like a university or retirement community, and keep it on private property to cut down on the regulations they have to deal with.

A CHANGING LANDSCAPE

Varden Labs is just one of a number of groups tackling self-driving golf carts as people movers, and there's still more working in other segments of lidar computer vision and control. And not all are targeting big, expensive vehicles; the technology is rapidly becoming more accessible to makers — who are in turn making it cheaper and more accessible for the masses.

So forget self-driving golf carts. Reduce the problem even more. What about lawn mowers?

"We are trying to make it better than the average mower," says Alexander Grau, one of five members of the Ardumower project, an Arduino-powered DIY automated cutter.

"If you want average quality or average features, then you just can buy a normal mower, commercial mower. If you want something special, then you have to build yourself a mower."

Basically a Roomba for your lawn, right?

If only it were that simple. Roombas and other robotic vacuums (some of which use lidar) have a couple of advantages: They (mostly) don't operate in direct sunlight; they never have to go up- or downhill; and their environment doesn't change much. Take it outside, put a blade on it, and you have to contend with many other confounding factors.

"If you have flat ground, just a room for example, indoor it works nice," says Grau. "But outdoor it's too difficult, because the ground is not flat. So sometimes you get data, signal from the ground, and the processing software ... thinks it's an obstacle, but it's just the ground."

Grau would know. He's a computer scientist who is currently tackling all these issues, and more, in pursuit of the Ardumower. You can buy an automated lawn mower, points out Grau, but it relies on a cable strung around the perimeter to stay in bounds. Lidar seemed a better option.

In principle, lidar isn't very difficult. But its basic element only gives you one data point: You know that something is a certain distance away, but not how wide or tall it is, if it's moving, how it's oriented, or really anything else. A person appears the same as a wall appears the same as a chair, if the chair is even tall enough to be struck by the laser. To make lidar useful, you need to take many measurements over a period of time. And there's more than one way to do that.

Most simply, affix a unit on a spinning

CAPTURING ROUTES

A multi-laser lidar unit like those from Velodyne can quickly capture a three-dimensional model of a locale when set in a static position. The more advanced the unit, the more lasers it contains, which in turn collect a higher density of data, which allows for fairly detailed 3D images of their location.

Once you start moving a lidar unit, however, the data it is capturing begins to overlap, making recordings impossible to parse. Sophisticated systems overcome this by adding in positional awareness like GPS. Some of the mapping vehicles from big tech companies couple GPS with lidar units to track the exact point where each moment of lidar data is captured, "painting" their route with lasers. Combined with the location data, this can be used to create a nearly infinite 3D point cloud, valuable for various applications such as providing detailed street information to self-driving cars.

apparatus and let it go round, giving you a 360° picture every time it spins. Grau bought a $115 Lidar-Lite single-point sensor from PulsedLight, mounted it on a 3D-printed platform, and attached a DC motor. Using the Robotics Operating System (ROS)'s open-source hector_slam code (Simultaneous Location and Mapping), Grau was able to get visual maps of the lidar data, and have the mower interpret them.

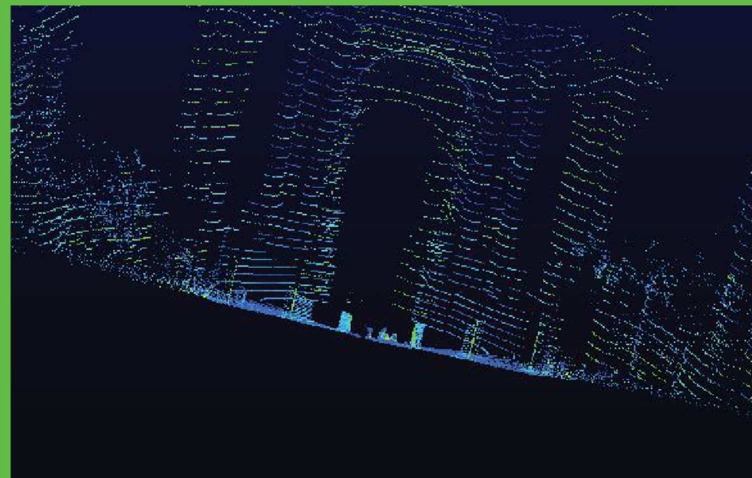
But ultimately, the rig was giving the Ardumower *too much* data, at least too much to process with an Arduino, especially when Grau experimented with 3D, in an attempt to address the signal interference due to topography. A more expensive unit, with still greater processing needs, could accomplish this. (For comparison, Rodrigues' Velodyne-powered golf cart requires the computing power of a desktop.)

MORE DETAILED DATA

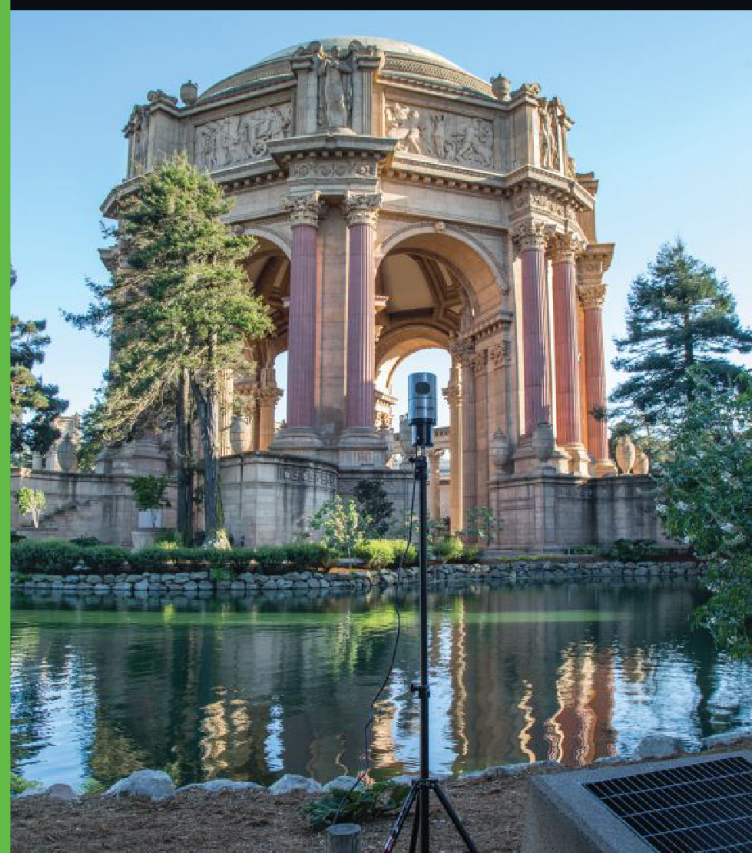
Grau's project is similar to an apparatus called Sweep, a small, rotating lidar scanning unit that also uses a Lidar-Lite. Sweep, developed by two-person company Scanse, just wrapped up a successful $273,000 Kickstarter.

Scanse co-founders Kent Williams and Tyson Messori were biding their time as robotics consultants when they decided they should start manufacturing a lidar unit. "What we found is that, you're basically not going to be able to accomplish any really capable autonomy outside unless you're using lidar," says Williams. "The existing cost of the sensors made that pretty much impossible." They spent two years designing Sweep before launching the Kickstarter, and have now begun production thanks to both the Kickstarter and $250,000 worth of venture funding from Rothenberg Ventures' River accelerator.

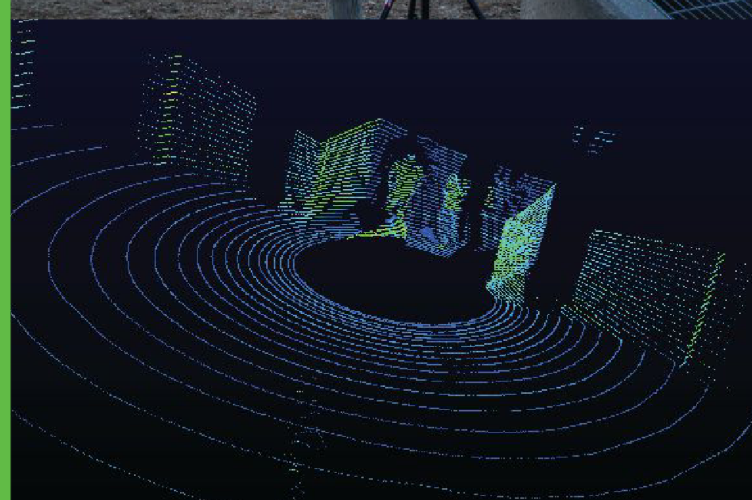
The tuna can-sized device, which looks like a little head with lopsided eyes, is on preorder for $255 (some 30 times cheaper than Velodyne's least expensive unit), also runs on ROS, can take data points up to 40 meters away, and fits nicely on a drone or robot. The Lidar-Lite unit employs a series of micropulses of laser light; the receiver recognizes these pulses, meaning it's easier to pull the signal out of ambient noise, requiring less processing power and giving a clearer picture. The sensor sits on a



A lidar's-eye-view of the Rotunda at the Palace of Fine Arts in San Francisco shows the shape of the venue and surrounding landscape.



The Velodyne HDL-32e lidar unit casts 32 lasers at a 40° spread to generate three-dimensional information about its environment. Introduced in 2010 for a list price of $29,900, it's an advanced piece of equipment found on many sophisticated robots and vehicles today.



Generating three-dimensional data lets you see a location from various vantages. Here: a birds-eye-view of the lidar unit (placed in center of black circle) and the traces each laser creates.

Velodyne, Hep Svadja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brushless motor, and Williams and Messori also developed a "spherical scanning kit" that mounts the unit on a servo, oriented at 90° to the brushless motor, so that it can record data in three dimensions.

Grau, too, was able to design a version of his sensor that offered a fuller, 3D view, by adding another motor. In both cases, the results are limited by the frame rate of the unit; if you're spinning it at 10Hz (the max speed for Scanse's device) and recording 500 samples per second (the max for PulsedLight's Lidar-Lite), you've just cut that by whatever your rotations per second are on the Y axis: You only get to see the full picture once every time it nods up and down, or goes round vertically. This means that, while the device is useful for real-time scanning of a plane of an environment in 2D, to get a 3D representation Sweep needs to sit still for around a minute.

Set on a table, Sweep rotates quietly, and a set of white dots appears on a black field on a ROS visualizer on Williams' laptop. It looks like an architectural drawing of the room, writ in pixel art, and you can see people, visualized as a line of dots, as they move. The 3D version is more like a pin art toy, showing a globe of dots with recognizable features — trees, tables, people.

Data like this, as recorded by a Velodyne unit, is naturally much more detailed. A "point cloud" appears in real time, colored lines rolling out in succession as the device progresses across space, with physical features appearing like waves in those lines.

Velodyne manages this, with both the Puck and its larger units, by adding more lasers. The Puck has 16, arranged to angle upward and downward by up to 15°, obviating the need for the unit to spin on two axes. Combine this with a spin rate of up to 20Hz and lasers that fire every 55.296 microseconds, and you get 300,000 points per second.

A MATURING TECHNOLOGY

There are other ways to measure environments with lidar. In the early '80s in Paris, France, Omar-Pierre Soubra founded a company called Mensi based on a laser triangulation. The goal was to offer a detailed 3D model of the inside of a nuclear power plant before it was decommissioned. To accomplish this, Mensi designed a one-meter-long metal tube with a rotating mirror on one end and a receiver on the other. A laser sent through the mirror would bounce off the interior of a space, and you can use trigonometry to locate the data point. As the tech advanced, incorporating a time of flight measurement based on sending identifiable packets of light rather than a constant stream, it was able to achieve extremely high resolution, capturing a million points per second and recording terabytes of information. Trimble, a multinational location services company, purchased Mensi in 2003.

The Sweep lidar unit from Scanse, a $250 single-laser device that rotates 360° to map a single plane of an area.

Roughly the size of a hockey puck, and just over a quarter pound in weight, Sweep is one of a few new lidar devices that hobbyists can access for experiments like aerial drone mapping.

Velodyne is a company with maker roots — founder David Hall is a BattleBots veteran, and developed their lidar, now used by Google and many other companies working on autonomous vehicles, for his entry in the DARPA Grand Challenge. But the units from Trimble and Velodyne aren't designed with Makers in mind: "We would not want to give the impression that our product is in any type of plug and play," a Velodyne representative told me. Trimble, points out Soubra, bought Mensi because the technology is useful for some of Trimble's core industrial businesses, like mining, construction, civil engineering, etc.

The uses for an inexpensive, single-laser unit are still myriad, though. Put it on a boat or wheelchair for assisted guidance. Place it in a stationary position in a room, and it can act as a security device, or as a smart light switch, or to tell how busy a room is, by recognizing movement. "All sorts of 3D detection stuff that you really would have a lot of trouble doing with a camera, is suddenly very, very simple with a lidar," says Rodrigues. Grau intends to combine his scanner with other sensors — perhaps a radio automatic direction finder — for a more robust mower.

Soubra says lidar is also useful as a scanner in conjunction with 3D printing: "It's one of those sectors that started to follow what I call the aftermath of 3D printing," he says. "One of the issues with 3D printing is that, you play with it, and quickly get tired of downloading objects that others have created ... sometimes you want to have a copy of something that you have. And you want to replicate it into a 3D printing model, maybe scale it down, or scale it bigger, or whatever it is. So that's when 3D scanning becomes part of the toolchain of doing stuff yourself."

Lidar is still progressing, despite challenges like speed, and resolution. "Compared to most other sensors in this price range, like sonar and infrared range finders, this provides way more data," says Messori. Along with these improvements will come additional uses, with lidar tailored to them. "This first device is really intended to be a developer product," says Messori. "We definitely intend on improving it for specific applications, or tuning it for specific applications." That could be adding accelerometers or gyroscopes to make it work better on drones, upping its durability, or adding connectivity to pair with phones, and Messori and Williams anticipate, eventually, building a robot around their device.

Lidar is just hitting the DIY market. The cost continues to drop, and better lasers and processors will make resolution go up, enabling ever more applications.

"The technology is starting to specialize into different fields," says Soubra. "Now it is well known enough that it can be tweaked for specific applications. That's how you know when a technology is mature."

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Data Plans

Particle CEO Zach Supalla's road map for navigating the IoT frontier

Dana Widman

Maker ProFile
Written by DC Denison

James Burke

Zach Supalla is the founder and CEO of Particle, a self-described "prototype-to-production platform for developing an Internet of Things product." Particle offers two wireless-enabled microcontroller boards, the Photon and Electron, as well as software development tools and an Internet of Things Cloud platform for both Wi-Fi and cellular connected products.

Q. WITH THE PHOTON AND ELECTRON RESPECTIVELY, PARTICLE OFFERS TWO KINDS OF CONNECTIVITY: WI-FI AND CELLULAR. HOW SHOULD MAKERS CHOOSE BETWEEN THEM?

You have to identify the problem you're trying to solve, and your business model, and then work backward. Is your customer willing to pay the monthly data fee for a cellular device?

If your product is out of range of Wi-Fi, you'll need a cellular connection. Another consideration is reliability. If your product is mission critical, like a security system, you might want cellular connectivity.

One unexpected thing we discovered: For a lot of commercial or industrial applications, they have a Wi-Fi network, but they don't want to deal with the hassle of getting their device on that network, so they use cellular. A lot of business decisions are made to go around the IT department.

If you make the right decision at the beginning, a lot of the rest of the technology flows from there. The way the devices react to each other, and the way they react to the web — all of it becomes kind of intuitive, if you figure out the business model and strategy up front.

Q. HOW CAN A MAKER CUT THROUGH THE NOISE, AND THE HYPE, SURROUNDING THE INTERNET OF THINGS?

We used to avoid the term "Internet of Things," because of the hype. We preferred "connected devices." But a lot of our customers are IoT people, they've bought in, so we want to respect that. For others, IoT is meaningless jargon. What they care about is what problem the product is solving.

For instance, we work with Opti, a stormwater management system. It's a great product, given the increase in extreme weather and flooding. They don't say, "We are an IoT product." They say, "We have a great stormwater management system."

I have an advisor who likens the term "IoT" to "robots." You use the term "robot" until a product has utility and deserves its own word; it's not a "robotic bread warmer," it's a "toaster." That's happening with IoT as well.

Q. WHAT ARE SOME FUTURE IOT TECHNOLOGIES THAT MAKER PROS SHOULD KEEP THEIR EYES ON?

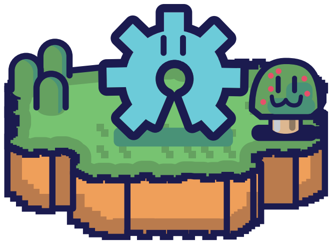
There are interesting and semi-related battles happening in three areas: new IoT aspects to the current LTE wireless standard (Cat-0, Cat-1, Cat-M), mesh networking (ZigBee, Thread, 802.15.4, 6LoWPAN), and low power wide area networking (LoRa, Sigfox). It's not clear who's going to win these battles, but it will probably play out over the next 5 years.

Q. THAT'S CHALLENGING IF YOU'RE TRYING TO LAUNCH A PRODUCT THIS YEAR.

It's frustrating, because if you have an application that you're trying to build today, you're probably thinking, "Just tell me which one to use! I don't want to wait for 5 years!" But if you're sitting on the sidelines, it will be fun to watch this play out.

Q. PARTICLE HAS A "HYBRID OPEN SOURCE" BUSINESS MODEL: A LOT OF OPEN SOURCE, BUT SOME PROPRIETARY CODE AS WELL. IS THAT A MODEL YOU RECOMMEND?

The hybrid open source model can be effective if you do it right. We believe in peer review, and we believe that code that has more eyes on it will become better code. A big part of our philosophy is that we wanted developers and engineers to be comfortable using our hardware and software, and not to perceive too much risk in working with us. Open sourcing a lot of what we do has been helpful in reducing that risk.



Q. YET IF EVERYTHING IS OPEN SOURCE, HOW WILL YOU MAKE MONEY?

We don't need to make money from every single customer; we need a ratio that works. A maker can use 100% of our stuff and it will all be open and free. That's fine. For an enterprise, maybe 40% of what they need is free, so that's a business that's available to us: providing that 60%.

Q. SO DO YOU THINK IT'S A MODEL MAKER PROS SHOULD CONSIDER?

You have to be thoughtful. Don't just do open source because you love open source. It builds a community, and it gets developers, engineers, and makers involved in a way they wouldn't engage with proprietary products. But you also have to build a business.

Q. HAVE YOU DISCOVERED THAT CREATING A COMMUNITY AROUND YOUR PRODUCTS HAS TURNED OUT TO BE MORE IMPORTANT THAN YOU ORIGINALLY THOUGHT?

Community is huge, and really hard to get right. I didn't understand that before we built the community. It's incredibly valuable when you're a startup, because it gives you something to build off of, it makes you robust and self-sustaining.

Imagine you have a product with no fan base, no community, no one talks about you except you. Then it's really expensive to get people to buy your product, because you have to put up ads. Most of what we do is community generated. By working with the community, our voices and their voices are amplified.

Q. WHEN SHOULD A MAKER PRO BOOK A TRIP TO CHINA?

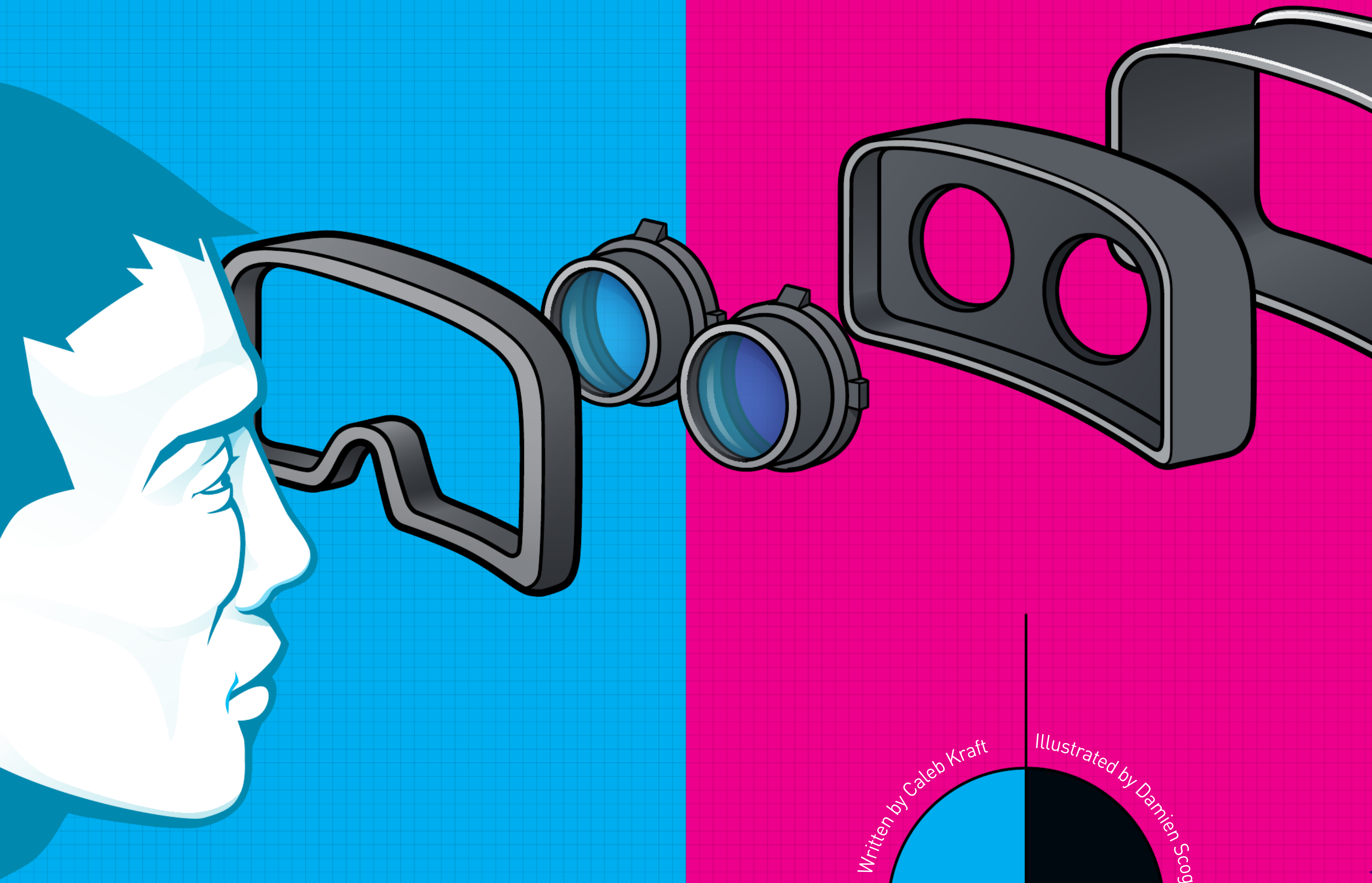
Everyone should book a trip to China. Like tomorrow. There's a lot of value in understanding what China is, and isn't, and how to navigate that ecosystem. The earlier you learn those lessons, the better, because if you're manufacturing electronics overseas, you're going to be designing for China. Going on factory tours and talking with various people who do different kinds of services — contract manufacturers, engineering firms, logistics firms — makes developing your product a lot more intuitive from that point on.

Q. PARTICLE HAS A LOT OF INDUSTRIAL CUSTOMERS. DO YOU THINK MORE MAKERS SHOULD AIM THEIR PRODUCTS TOWARD INDUSTRIAL MARKETS, RATHER THAN CONSUMER ONES?

Consumer stuff is more obvious out of the gate, but it's the less sexy, dirtier, more industrial products and applications that make better businesses. If you target the consumer, you'll likely be facing five or 10 or 20 companies that will be trying to do the same thing. But if you go down the industrial path, you'll find big areas, big opportunities, with no competitors. You'll find lots of customers with big problems they need to solve and high willingness to pay.

DC DENISON is the editor of the *Maker Pro Newsletter*, which covers the intersection of makers and business. He is the former technology editor of *The Boston Globe*.

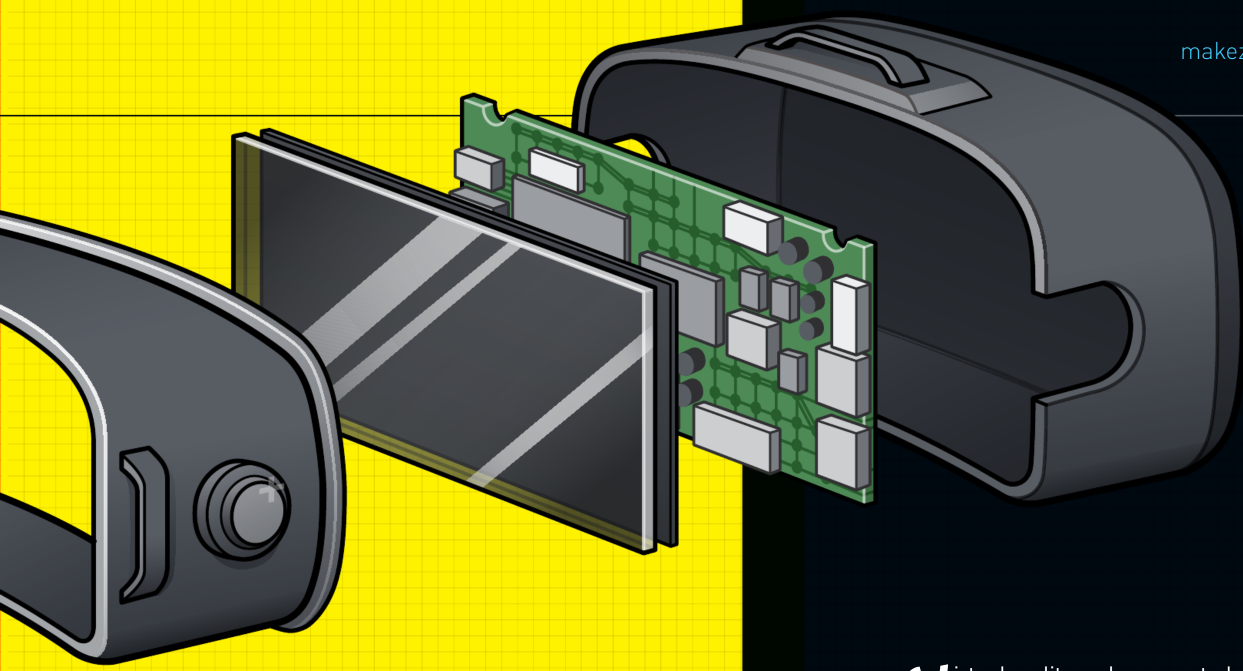
For more Maker Pro news and interviews, visit makezine.com/go/maker-pro.



Written by Caleb Kraft
Illustrated by Damien Scogin

VIRTUALLY Real

IN THE VR FUTURE, MAKERS WILL LEAD THE FOOLING OF OUR SENSES

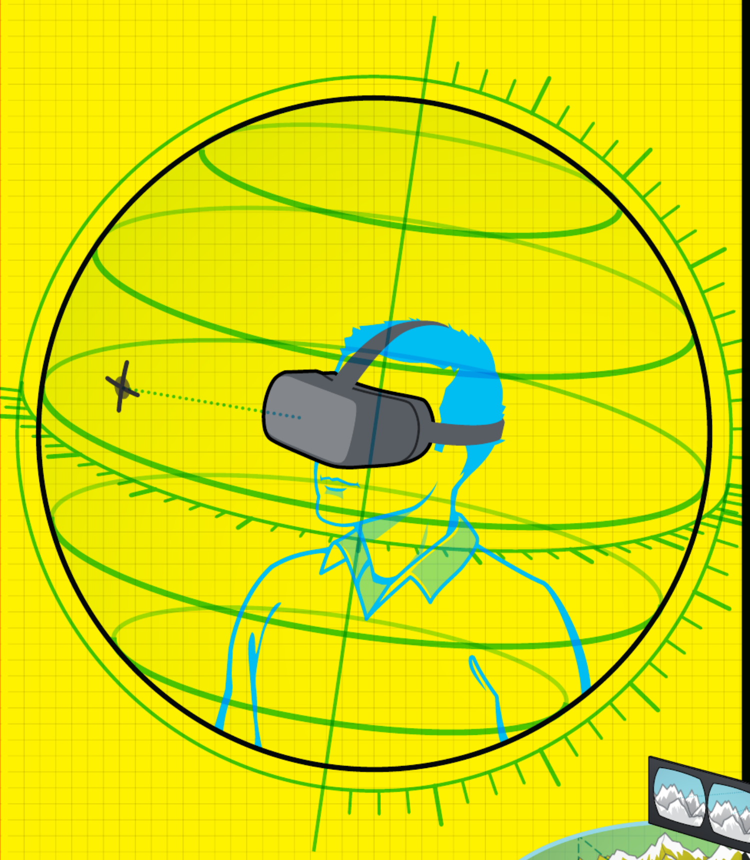


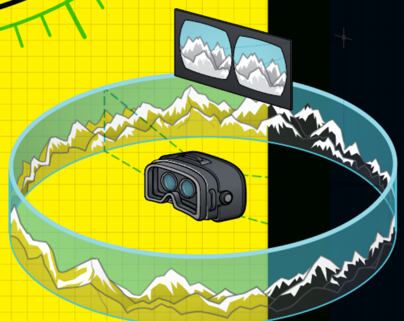
Virtual reality and augmented reality are words you'll hear a lot this year. They'll be on the radio, on nightly news, and even on late-night talk shows. But what do these terms mean to us as makers?

Both refer to devices that feed information to our senses to convince us, to some degree, that something false is real. The only real difference between the two lies in our current technology. Virtual reality replaces our senses of sight and sound; augmented reality adds data to them.

As amazing as virtual reality is right now, current devices are merely the beginning, like a single cell organism that will eventually evolve into a race of beings. During the next few years, all our other senses will be addressed in many ways, from technological research to wild and ridiculous attempts to capture the essence of "presence."

It is in this new frontier of simulation that makers will thrive. Exploring the complexities and surprises that come along with attempting to tackle the incredibly difficult task of imitating a walk on a cobblestone road or the smell of an incoming storm will fall on the shoulders of our community. Arduino-driven prototypes and Raspberry Pi-powered sensor systems will be coming from all directions. This will be a very exciting time. And we can start making it now.





ALL MAJOR VR HEADSETS SHARE THE FOLLOWING COMPONENTS:

- **OPTICS** — Most systems use a single custom lens per eye to allow you to focus on the screen.
- **DISPLAY** — Either LCD or OLED. They're tiny, but high-resolution.
- **CONTROL BOARD** — The electronics for motion tracking and display.
- **TRACKING NODES** — These live on the device housing and can use various components — LEDs on the Rift, optical sensors on the Vive.
- **EXTERNAL TRACKING DEVICE** — The Rift uses a camera; the Vive, a laser array.

AN OPEN Valve

Written by Caleb Kraft

HOW A MODDING COMMUNITY SHAPED THE FUTURE OF VIRTUAL REALITY

CALEB KRAFT

is a senior editor for *Make:* He has been a VR enthusiast since he shot a pterodactyl in a digital nightmare in the '90s. VR makes him sick, as does riding in cars, but he does it anyway because it is the future.

In a private room, deep within the walls of one of the most respected game studios in the world, I stand before a veritable smorgasbord of electronics prototypes. These are the primordial building blocks that have evolved into what we call modern-day virtual reality. I scan the assortment, letting my eyes find their own path through the wires, LEDs, motors, displays, and 3D-printed shapes. One catches my attention; I can't seem to identify its purpose.

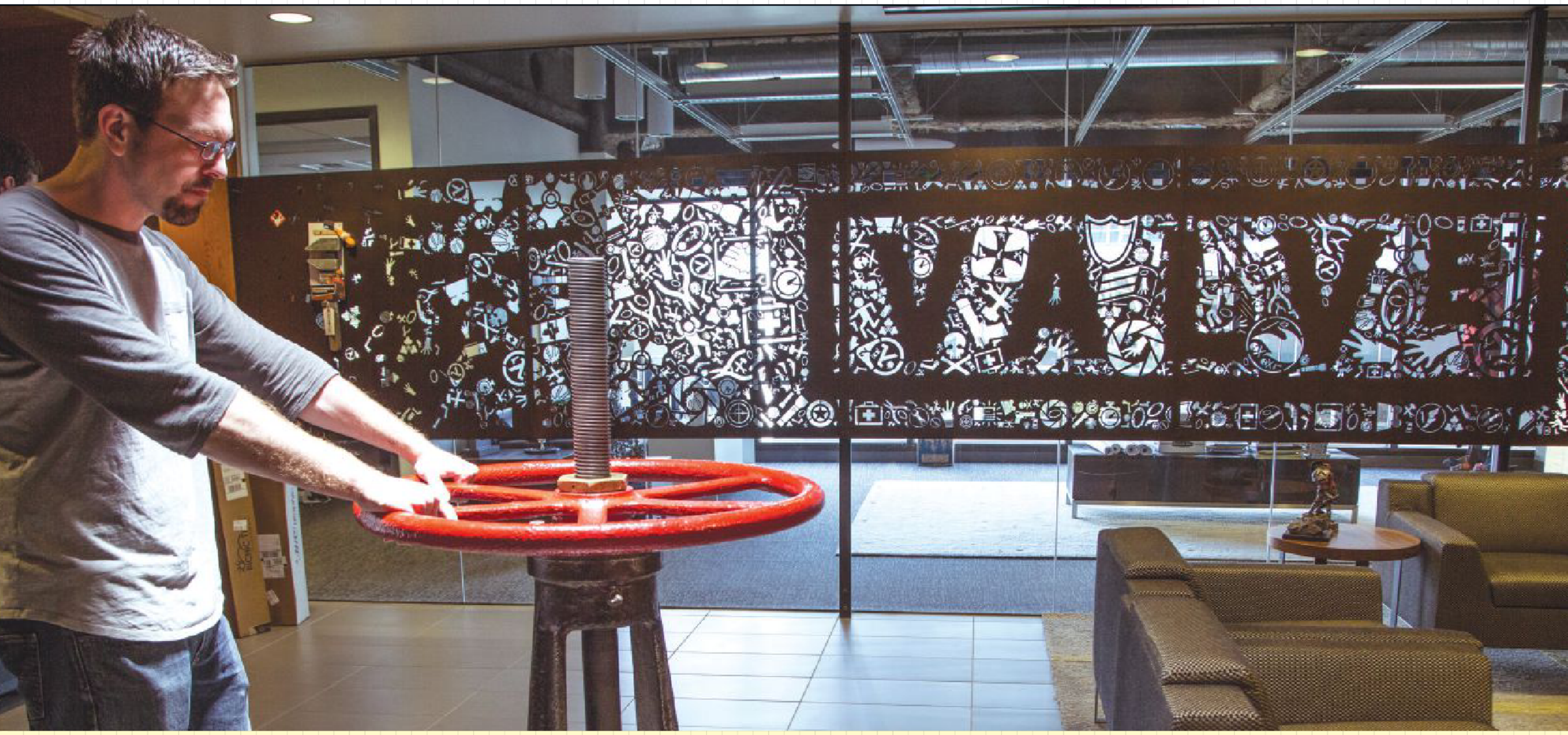
"This is the zombie machine, we put it on people's heads to turn them into zombies we can remotely control."

I'm tempted to laugh. I look at the device, a head strap with several 9-volt batteries attached, a circuit cobbled together on protoboard, and a couple stick-on electrodes. Then I realize Alan Yates, virtual reality engineer for Valve Software, is not joking.

Valve, a game company famous for titles like *Half Life*, *Portal*, *Team Fortress*, and *Dota* (and possibly more famous for the sequels of each of those) has a very tight relationship with makers. Valve owes its incredible success to those who, in the early days of computer gaming would modify and contort games to their liking, affectionately called "modding." Instead of gasping and running scared from these adjustments, revisions, and bizarre twists of their product, the company embraced the community and it has served them very well. They're valued at several billion dollars and their employees are the envy of anyone in the field. The games are so popular that there are entire ecosystems within them where players can develop custom, virtual items and sell them for real money, sometimes earning enough to supplant their day jobs.

I was visiting the Bellevue, Washington

Hep Svadja



headquarters to see how this traditional gaming software company ended up as the creator of arguably the most cutting-edge VR hardware on the market, the HTC Vive. Yates, my tour guide, didn't disappoint.

I pick up a device that looks like some kind of optician's torture tool, a set of lenses lined up to the bright and shiny end of a dismantled pico laser projector. Yates explains that initially, the company was thinking that augmented reality deserved some research as a possible direction to go in hardware design. This prototype was an exploration in that path, but not one that was pursued any further.

"Ultimately," he tells me, "what we found was that virtual reality was an easier problem to tackle right now."

The distinction between augmented reality and virtual reality is a blurry one; both are immersive, virtual, and augmenting our surroundings. The main difference is that with virtual reality, the headset completely obscures your vision as opposed to showing an overlay on your actual viewpoint.

It was this direction that led to what we now know as the HTC Vive, a display that sits on your head like a pair of ski goggles, simultaneously tracking your head movement in 3D space and placing you into the virtual world it displays before your eyes. This unit stands apart from the others in that it also includes two controllers that allow the system to track your hand position similarly with incredible accuracy.

IN THE BEGINNING, THERE WAS NAUSEA

In 2012 the team began collecting old headsets and dug up old research. What they found was not inspiring. Anyone who had a chance to try the VR of the '90s will be quick to admit that it wasn't ideal. The poor performance of the machines meant that your experience was laggy, poorly rendered, and more often than not, nausea-inducing.

"We actually experimented for about two years acclimating people to virtual reality, attempting to get around nausea," Yates says.

There were tons of tests and different angles approached to tackle the problem of the queasiness that occurs when your inner ears and your eyes aren't detecting the same motion. The "zombie machine," a galvanic vestibular stimulation prototype, is one example of this. The device uses electrical pulses to stimulate your inner ear to make you actually feel motion. By stimulating one side while someone is walking, they'll naturally turn that direction. By triggering this stimulation remotely, you can crudely control a person like a radio-

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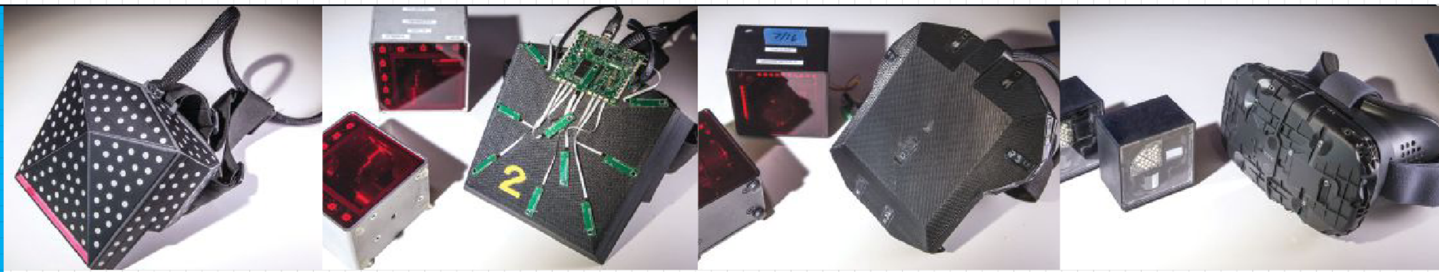


controlled car, or make them into a zombie as Yates puts it. Luckily, the zombie machine didn't make it into the final product.

The magic formula to stop nausea ended up being a mixture of several things all working fluidly together. The physical display needed to be able to update at incredible speeds to keep your eyes from noticing any delay, and the tracking of your movements needed to be extremely accurate. Any little movement had to be translated through the system and to your eyes before you could perceive a change.

"Finally … the conversation could move on from motion sickness," says Yates' teammate Christen Coomer.

FABRICATING PROTOTYPES

Once Valve settled on a tracking technology and a display system, things began to go incredibly fast. Modern desktop fabrication tools allowed the team to try new ideas very quickly. Many of the early prototypes looked like things that someone could make at home, and Yates agreed, this tech isn't out of the reach of an enthusiast.

"3D printing is core to our ability to do this," says Yates. "I don't know how we could have done all of this without it. We have 3D printers, laser cutters, and a PCB mill. Those are really the three fundamental tools you'd find in a makerspace and that's really all you would need to do most of this."

Valve's background was in software, where you can make an update or "patch" and distribute it within hours. Rapid prototyping allowed them to carry this methodology over into hardware. The engineers could create a prototype and get feedback from their peers in the morning, and have a revised physical item fresh out of the 3D printer in the afternoon. Previously, something like this would involve weeks of waiting while a prototype was constructed elsewhere, then delivered.

During this type of process, there are happy accidents that take on a life of their own. You can be developing one experience and every tester steps inside and does the same unplanned action, but they all love it. That unplanned feedback ends up being the direction you should go. This is true in both hardware and software experiences. If everyone picks up a controller the same "wrong" way, it is your design that is wrong and should be adjusted.

Sharing is integral, Coomer explains. "If you're doing something privately, you're not learning," he says. And what the team learned is that in virtual reality there were no hard rules. "Everything we thought we knew was out the window."

Valve continued refining the design drastically even a few weeks before the commercial release of the VR headset. The team didn't have an established road map, so trying new ideas was their primary method of determining what worked and what didn't. They'd push out prototypes to coworkers to get feedback as early and often as possible, and cancel those that didn't pan out — they realized there was no point refining and polishing a prototype that they were not going to pursue.

Since Valve was built on the makers who modded games, the team is eager to see how people mod the HTC Vive hardware. The device had only been out on the market for a few weeks and yet people were already customizing and altering them. One person replaced the elastic straps with the head harness from a welding mask, allowing for easier transition from wearing to not wearing the goggles. One team of developers used a tracked controller mounted to a camera to overlay the game environment onto footage of a person playing it, allowing someone to watch a video and see the player immersed into the game world. These were unexpected modifications, and welcomed completely by the company.

RECRUITING AT MAKER FAIRE

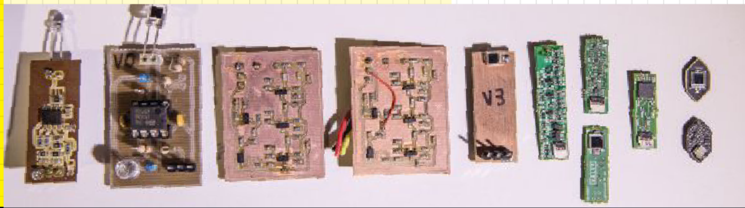
How does a person end up as a virtual reality engineer at Valve? The short answer is to get out there and make stuff. Valve has been very open with their hiring practices. Their employee handbook, riddled with humor and great illustrations, is open to the public. The most striking illustration in that handbook is the description of the ideal employee. They call it the "T-shaped" employee — someone who has a single area of specialty, but a very broad range of general knowledge. This is necessary, as you really need to be flexible and able to react to feedback, constantly pivoting toward a better product.

Maker Faire, as it turns out, is a perfect place to find these people. Of the handful of virtual reality engineers I spoke with during

PHOTOS

1. Vive prototypes, from oldest to newest.
2. The "zombie machine," a galvanic vestibular stimulation prototype.
3. Evolution of the laser detecting sensors that allow the Vive tracking system (called Lighthouse) to work.
4. Lighthouse base station evolution. Note the early prototype that used two hard drives hacked in half.
5. Designing various geometries to find the best results in tracking controllers.
6. Alan Yates models an early unit featuring a hacked LCD monitor moved by gripping a handle with your teeth.
7. The robotic arm used for testing accuracy of positional tracking.

3



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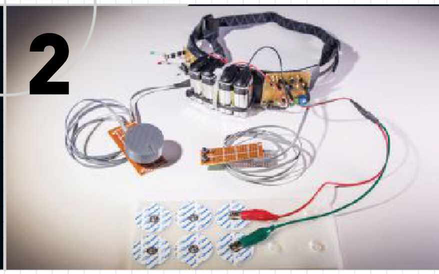


my office tour, at least three told stories of being approached by Valve while running a booth at Maker Faire.

When asked about the engineering degrees and education often required by positions in R&D, Yates explained that having someone with a self-taught and diverse background is actually an asset. He and the teammates contend that when someone has spent years approaching problems the "typical" way, they tend to become locked into a way of thinking, and to use standard methods to solve problems. When someone has a more diverse background, they may be missing some specific knowledge, but they often approach each problem with a unique perspective that can result in some unexpected outcomes. They may solve problems in ways that a traditionally trained professional never would have considered, or worse, discarded as "not the way it is done."

THE BIG LAUNCH

For shipping a hardware product of this scale, Valve partnered with Taiwan-based HTC. They talked with several manufacturers but liked the good reputation HTC had with their hardware construction, bringing years of experience to the table to help ensure a smooth launch.

One crazy aspect about the launch is that most developers didn't have final hardware, not because of some secretive plan to keep it under wraps, but because the hardware was being refined all the way up to the very last possible seconds.

The official launch date for the HTC Vive was April 5 of this year. My visit was on May 2. Every person I spoke to within the company was still giddy with the excitement of units being shipped to the public.

The Vive and the competing Oculus Rift VR headset that launched on March 28 are the two major players in the high-end virtual reality device arena. Both are just getting started and will soon have to contend with Sony's PlayStation VR, slated to arrive this October.

THE FUTURE OF VR AT VALVE

What accessories Valve is working on next are a mystery. I asked, prodded, and begged for a hint no matter how subtle, about the next toys I could hope to see. Images of body suits ripped from the sets of science fiction TV shows flashed in my mind. The only answer they would divulge is that their R&D has not stopped or slowed. The giant grins seen across every member of the team told me that whatever they're working on, it's cool.

"WE EXPERIMENTED FOR ABOUT 2 YEARS TO GET AROUND NAUSEA"

"The eyes and hands were kind of the minimum level of tracking we had to achieve for a product," Yates says. "Supplying feedback for the rest of the body is much more complex, and probably the next 10 years of research."

Virtual reality is in its infancy right now. The devices that were laid out in front of me ranged from cobbled together to completely refined, and yet this is the absolute beginning. These are the Atari days of virtual reality, a time when the technology is fresh in people's homes. A time we'll look back on, and joke about how arcane our methods seemed. I can't wait to find out what kind of cool things we'll be playing with when we make those jokes.

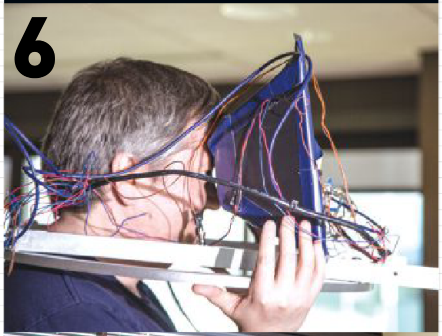
Hopefully, they won't be zombie machines.

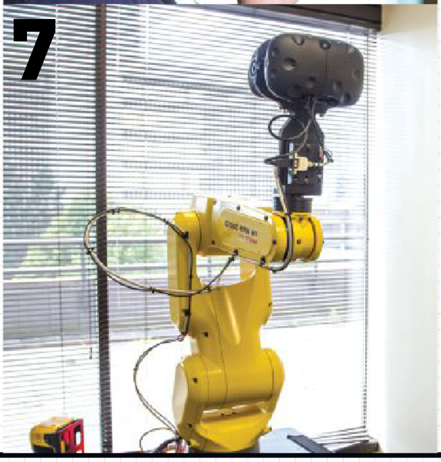
For video and more prototypes, visit makezine.com/go/valve-virtual-reality.

MAKING CUSTOM TOOLS FOR CUSTOM PROTOTYPES

When you're working with technology that simply didn't exist before, testing can be a real problem. There aren't tools that you can buy to gauge how your cutting-edge virtual reality tracking system is functioning.

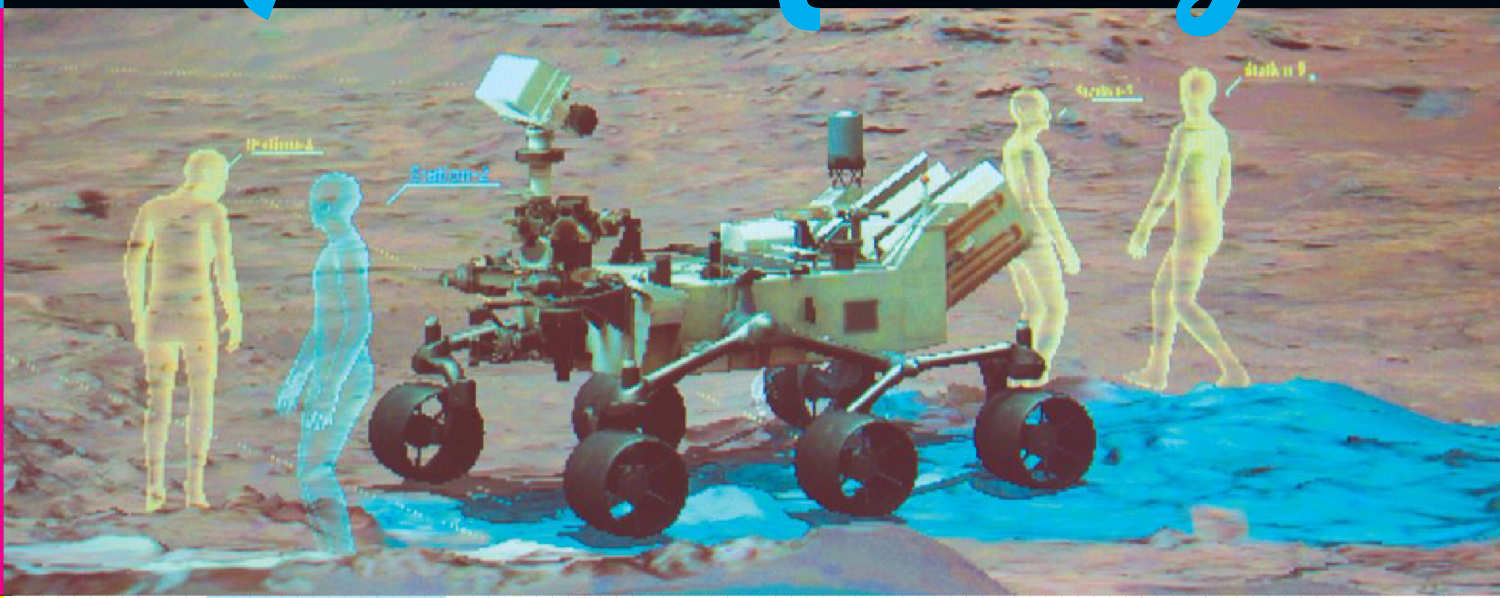
The engineers at Valve had to develop tools in parallel with the things they needed to test. This pocket-sized oscilloscope was hacked to add a sensor capable of detecting the tracking signal, and custom firmware was added so that it could display data about that signal.





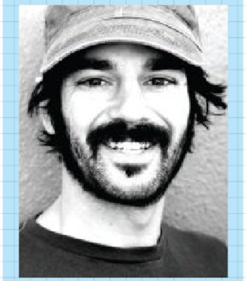
ROCKETS AND ROVERS WITH Mixed Reality

Written by Mike Senese



With JPL's OnSight program, users explore the terrain of Mars made from actual photos collected by the Curiosity rover.

JPL GIVES US A PEEK INTO THE FUTURE OF MAKING



MIKE SENESE is the executive editor of *Make:* magazine. He spends his spare time tinkering with remote control aircraft and attempting to cook the perfect pizza. Find him on Twitter as @msenese

NASA's Jet Propulsion Laboratory in Pasadena is a small city of sleek, modern towers propped tight between the San Gabriel Mountains and the dry arroyo landscape of Southern California. Inside, the smartest minds on the planet gather daily to design, build, and launch rockets, satellites, and rovers to explore space and faraway worlds.

My visit here in mid-May is to get a sneak peek at one of the newest rovers, launching for Mars in 2020. It's a flagship mission, announced in December 2012, a few months after the landing of Curiosity, and will feature a similar but slightly larger six-wheeled craft. JPL, however, doesn't have a high-tech prototype. Instead, they lead me into a demonstration room, have me put on a Microsoft HoloLens headset, and boot up a CAD projection of the rover. It appears in full scale and fully explorable right in front of me, while they explain that this virtual approach to engineering is not a future part of their organization — it's happening now.

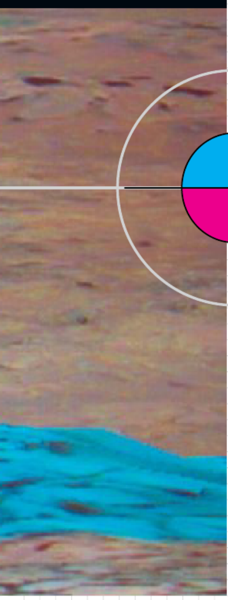
BUILDING VIRTUAL ROVERS

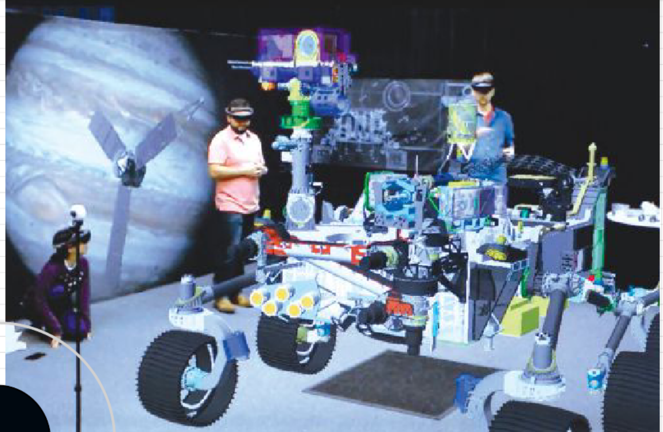
JPL terms this mixed reality, a relative to virtual reality and augmented reality. "The manifestations that we're creating feel like real objects that interact with the world in the same way that real objects do," explains Jeff Norris, the head of JPL's Mission Operations Innovation Lab, differentiating his output from the full immersion of VR and the heads-up-display overlay he associates with AR. And even though it's clearly just a multicolored CAD rendering visible through a postcard-sized viewing area in my headset, the mixed-reality projection of the Mars 2020 rover is quickly convincing.

The program, called ProtoSpace, perfectly tracks my movement around the rover, letting me peek up top or kneel down to inspect the underside, while seeing my actual surroundings as well. My brain buys in so much that at multiple times I reach for my camera before remembering nothing is actually there. After a point, I'm directed to put my head through the rover itself. It is momentarily challenging to get my body to agree, but as I do, I watch the components peel away layer by layer, until I am in the hollow center of the vehicle.

"I think a tool like ProtoSpace allows

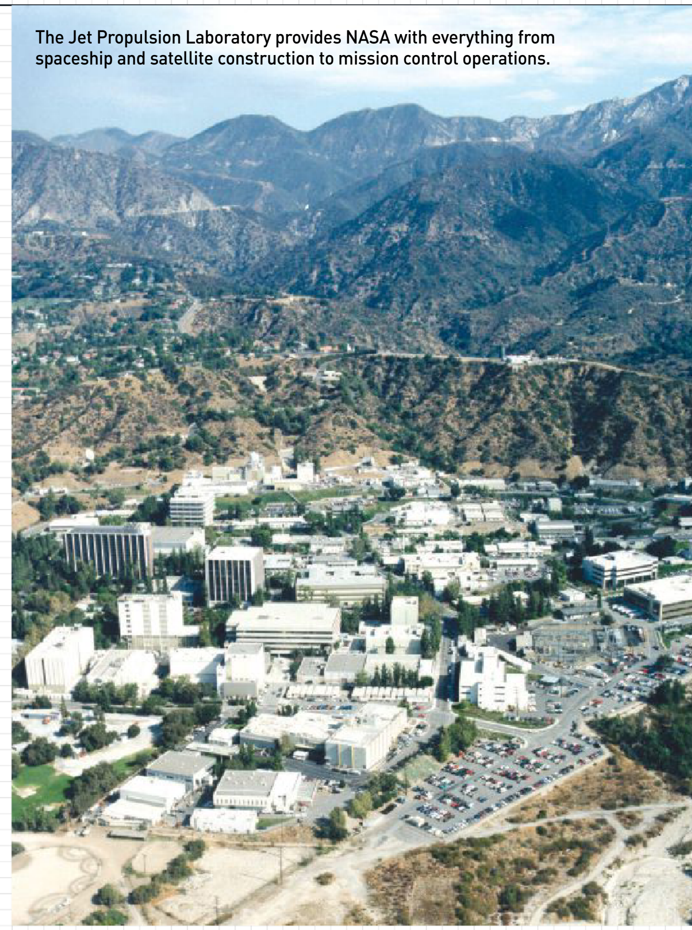
Mike Senese





ProtoSpace projects a life-size rendering of whatever craft JPL wants to examine. Here, the upcoming Mars 2020 rover.

Mission Ops Lab director Jeff Norris has visitors inspect the rover from all angles.



The Jet Propulsion Laboratory provides NASA with everything from spaceship and satellite construction to mission control operations.

Mike Senese, NASA

us to access the same intuition that we have when we're stacking up a bunch of blocks, but we're working with far more sophisticated blocks and much more challenging goals," Norris says. It's already shown its worth on at least one project, an Earth-science satellite that was designed with tight clearance for assembly. Upon examination in ProtoSpace, one of the technicians realized it would be too narrow for the tooling to fit inside. So they redesigned it long before a single physical part was built, saving time and resources.

"The field is moving so quickly right now that I feel like it's totally different from where it was a year and a half ago," Norris says about the technology used. And they're still expanding ProtoSpace, planning new features such as the ability to pull individual pieces off of a model for inspection, add animation and movement, and eventually even create designs in the mixed-reality environment itself.

WALKING ON MARS

In the next room, Norris and his team show off their other mixed-reality project: OnSight, a virtual visit to the surface of Mars using images collected by Curiosity. It's similarly believable, with a photo-realistic Curiosity in the center of the room, but this time the planet's terrain extends outward to the horizon as you look up and turn around.

Mars data scientist Fred Calef shows me the details of the rocky outcroppings as I step around. He's physically in a different part of the building, but I see him as a glowing blue avatar next to me on the planet. This is a big advantage of these two projects, the ability to interact with colleagues who aren't actually with you. JPL engineers can easily beam together with scientists on the other side of the world to examine and discuss a spaceship design, or determine the next destination a rover on another planet should head to.

A few minutes later Calef comes into the room. I ask if, when Curiosity successfully touched down on Mars in 2012 he had any idea that four years later, he'd be standing next to the rover on Mars itself. He shakes his head no. "It really snuck up on us."

And he's glad it did, because it makes his job easier. "It's really about saving time as much as we can," he says. "Because time is science."

PUBLIC CONSUMPTION?

NASA is opening a Destination: Mars experience at the Kennedy Space Center in Florida to let visitors have the same HoloLens Martian visit, guided by a holographic Buzz Aldrin. After that, Norris is excited about more community access, eventually seeing ProtoSpace and OnSight coming into your home. "If you can imagine a future mission on Mars where we have millions, even a billion people, exploring right alongside with the vehicle — and maybe someday with humans — from their living rooms with headsets on their heads, I think that's a great way to share this," he says.

And it's not just for sightseeing, but also for new ways of designing and building, for everyone. Norris continues, "My hope is that tools like ProtoSpace and mixed reality in general can unlock a whole new sophistication ... not just for professionals, but for amateurs ... people who are just enthusiastic about making things."

Hep Svadja, Pinball FX2 VR by Zen Studios

SHAKE, RATTLE, AND *Tilt*

Written by Jeremy Williams

BUILD THE "PINSIM" CABINET CONTROLLER AND PLAY VR PINBALL WITH REAL FLIPPER BUTTONS AND AN ACCELEROMETER-BASED NUDGE SYSTEM!

JEREMY WILLIAMS is a team member at Tested. He grew up on an Atari 2600 and IBM PCjr. Since graduating from Kenyon College, he has managed a LAN gaming center, started a video company, been an editor at *PC Gamer* magazine, and helped engineer Qore on the PlayStation Network. Now living in San Francisco, he's interested in Arduino and "making" stuff. He also loves pinball. And his kids.

I attended the Oculus event at GDC this year, where I first heard Pinball FX2 VR was in the works. I tried the game and after 5 minutes I knew I wanted to build a VR interface for it!

VR solves my biggest gripe with traditional "virtual" pinball games — you can't move your head around to get a better read on shots or the ball. Well, now you can. And with my PinSim cabinet you can actually feel the game in your hands too. I'm sharing the SketchUp files, dimension renders, wiring diagram, and Arduino code so that anyone can make one. You can order my custom PCB or just use an ordinary breadboard.

The VR pinball cabinet is essentially the first 8 inches of a real pinball table. My original cabinet was made from foamcore but wood will provide a more lasting frame. Just make sure to consider the width of your material in cutting the sides of the cabinet. My drawings show the exterior dimensions and button hole placements, but the diameter of the drill holes will depend on the buttons you choose to use.

The joystick is used to conveniently navigate the game menus. And an accelerometer is used to simulate nudging the table, which can help you guide the ball or can backfire ("Tilt!") just like the real game, if you overdo it.

MY FIRST BUILD

One week before the Oculus release date I made a trip to Walgreens and picked up two sheets of

MATERIALS

- **Teensy LC microcontroller board, with pins** $15 from pjrc.com. Mount it on a breadboard or on my custom PCB.
- **Micro USB cable**

FOR PCB BUILD:

- **PinSim printed circuit board (PCB)** oshpark.com/shared_projects/ngC13rwO
- **Female headers, 1×14 (2)** such as Amazon #B00899WQ6U
- **PCB screw terminals, 2 pole, 3.5mm pitch (12)** such as Uxcell #a14122500ux0169, Amazon #B00W93KCDQ

FOR BREADBOARD BUILD:

- **Solderless breadboard** Adafruit #239
- **Jumper wires** Adafruit #1957
- **10 screw terminal block, breadboard plug-in type** such as eBay #400546234141

- **Foamcore board or plywood** I used two 22"×28" sheets of foamcore. Anthony in the *Make:* Labs used ½" plywood, about 2'×4' total.
- **Arcade buttons, 30mm (2)** Adafruit Industries part #473, adafruit.com, for flippers
- **Arcade joystick, small** Adafruit #480
- **Accelerometer, triple axis, ADXL345** Adafruit #1231
- **Hookup wire, black and red** Adafruit #290 and 3068. Any 2-conductor speaker wire also works fine.
- **"Start" button** Williams-Bally #20-9663-1, Pinball Life #956, pinballlife.com
- **"Launch Ball" button** Williams-Bally #20-9663-B-4, Pinball Life #919
- **Pinball legs (4)** Pinball Life #140. Browse the site for more color options!
- **Leg bolts (8)** Pinball Life #1792
- **Leg brackets (4)** Pinball Life #144
- **Leg levelers (4)** Pinball Life #921
- **Cabinet leg protectors (4)** (optional) Pinball Life #1403
- **Wood screws and/or hot glue**

FOR OPTIONAL UPGRADES:

- **Xbox rumble motors (2)** about $10/pair on eBay
- **Transistors, 2N222 (2)** for rumble motors
- **LEDs, white (2)** to replace lamps in Start and Launch buttons
- **Resistors, 22Ω (2)** for LEDs
- **Pinball shooter assembly** Pinball Life #pbl_B-12445-6
- **Shooter mounting plate** Pinball Life #535-5027-00
- **Shooter spring, brown (low tension)** Marco Specialties #10-148-6, marcospec.com
- **Machine screws, #10-32 × ⅝", pan head with lock washer (3)** Marco Specialties #4010-01006-10
- **Analog distance sensor** Sharp GP2Y0A51SK0F, Pololu #2450, pololu.com
- **JST ZH-style cable, 3-pin female** Pololu #2411

TOOLS

- **Saw or hobby knife** depending if you're using plywood or foamcore
- **Drill**
- **Soldering iron**
- **Screwdrivers and wrenches**
- **Sandpaper or sander**
- **Computer with free software: Teensy Loader application** (pjrc.com/teensy/loader.html) **and PinSim project code** (github.com/jerware/pinsim). The GitHub page also links to the Arduino libraries you need. You won't even need the Arduino IDE (or Teensyduino extension) unless you intend to edit the project code.
- **3D printer** (optional)

A

B

PINSIM CABINET BUILD NOTES

FROM ANTHONY LAM, *MAKE:* LABS

» To cut the plywood, a table saw is ideal. You can also use a band saw or handsaw; it's safest to measure exact dimensions and cut at a ⅛" offset, then sand the excess down to the marked dimensions so everything fits precisely.

» Test-fit the corners together using the cabinet leg protector. This not only helps you plan a butt joint for the boards, it also lets you trace the drill points for the leg bolts.

» The front panel's top edge is cut at a 14° angle to match the rake of the top. And the top panel's front and rear edges are cut similarly to fit flush with the other panels.

» We left our top panel free floating for now, resting on short wood screws as stops, in case we want to make upgrades. You can also screw it directly to the other panels and then touch up the paint.

foamcore. I already had everything else (I've collected real pinball games for years, and I'm a compulsive Adafruit buyer).

I started by measuring the front body dimensions of a real pinball game and then cut a 1:1 replica from the foamcore. Then I measured for button placement, cut those, and glued the whole thing together overnight. Then I measured accurate body height and attached legs using off-the-shelf leg bolts and brackets. The buttons and joystick are pretty generic (Figure A). It was important that the flipper buttons don't "click," so it would feel realistic. I thought I'd have to install real pinball leaf switches, but these silent 30mm translucent buttons from Adafruit work great.

Everything ties into a Teensy LC microcontroller connected via USB to the computer. The Teensy has a mode that conveniently fools a computer into thinking it's a generic gamepad, so the code simply turns grounded pins into emulated gamepad button presses. There's also an accelerometer that converts X/Y movement into an analog gamepad stick for nudging the table. The Start and Launch Ball buttons have lights pre-installed, so I just connected these to the USB 5V line.

The biggest hurdle was getting the game to recognize the gamepad. Unfortunately the Teensy doesn't support Xinput, and the *Pinball FX2* VR game only supports Xbox gamepads. I found a wonderful open source program called x360ce (github.com/x360ce/x360ce) that converts gamepad signals to Xinput, and later I upgraded to the incredible MSF-XINPUT library by Zachery Littell (github.com/zlittell/MSF-XINPUT). It fools the computer into thinking the Teensy LC is an Xbox 360 gamepad, thus minimizing latency and maximizing compatibility. It even supports force feedback rumble! Zack spent time improving his library to assist with this project, so major thanks to him.

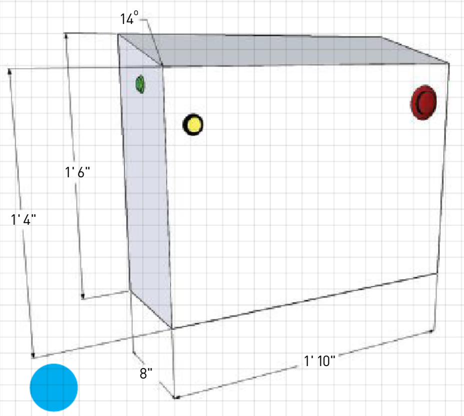
BUILDING YOUR PINSIM

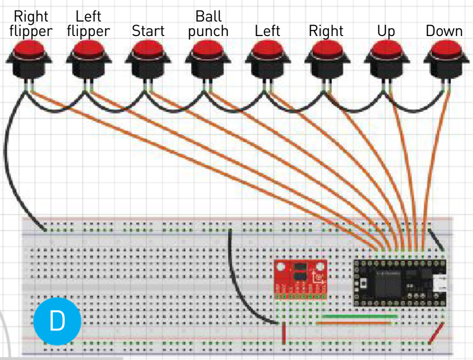
Here's how to make the upgraded version of the PinSim controller (Figure B). (Portions of this guide appeared previously on Tested.)

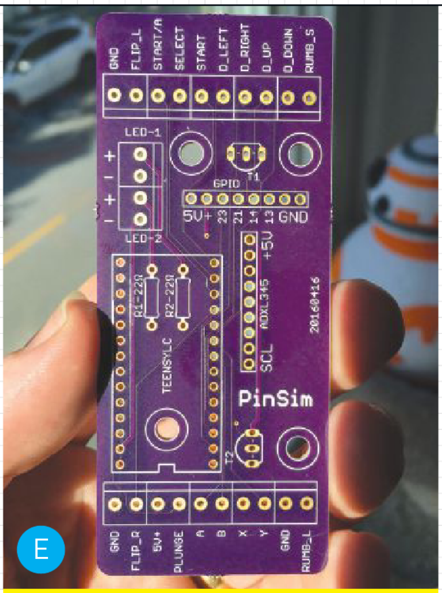
1. CONSTRUCT YOUR CABINET

Cut the panels and drill holes for your buttons, joystick, and legs, following the SketchUp drawings on the project page at makezine.com/go/pinsim-vr-pinball-cabinet (Figure C). The holes for the leg bolts can be tricky, because they enter at the

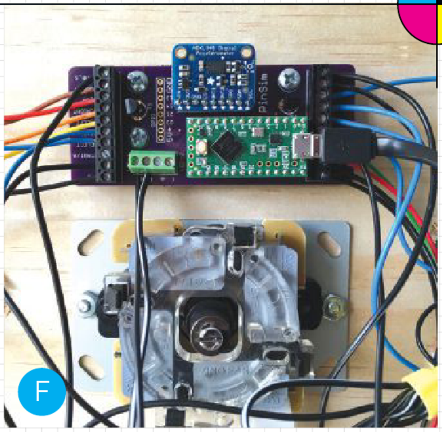
Jeremy Williams, Hep Svadja, Anthony Lam

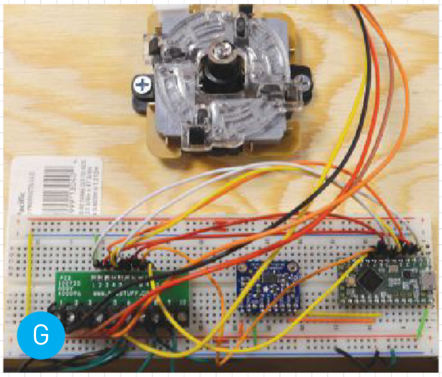






IMPORTANT:
If you're not installing a plunger, connect the PLUNGE terminal on the PCB (Teensy pin 15) to GND. This will disable the plunger. Failure to do so will leave the pin "floating," causing the virtual analog stick to move unintentionally.





corners at 45° angles. I recommend drilling these from the inside out. Paint your cabinet (optional) before bolting the legs on.

2. WIRE THE ELECTRONICS

Follow the wiring diagram (Figure D)and Teensy pinout (Figure E). After I showed off my first PinSim cabinet on Tested (youtu.be/18EclxywXHg), I created a custom PCB at OshPark to replace the breadboard; just solder the female headers and screw terminals to the board where indicated. Or you can stick with the breadboard build.

3. MOUNT THE ELECTRONICS

Mount the joystick on the top panel according to its mounting plate, wherever you think it fits best. (You could use a gamepad for this instead.)

Install your breadboard or PCB on the underside of the top of the cabinet so that the accelerometer is positioned horizontally at center, toward the front (Figures F and G). This will give the most accurate readings.

4. PROGRAM THE TEENSY

Download the compiled firmware from github.com/jerware/pinsim (and install all the associated libraries). Then flash your board using the Teensy Loader application. You can find instructions on the GitHub page.

You're done! Plug in the Teensy LC using a USB micro cable and it will power up (Figure H). You can test the PinSim by launching the Windows USB Game Controllers app from the Control Panel.

THE UPGRADES

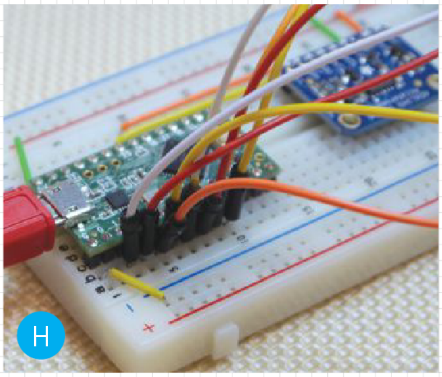
LED LIGHTS

If you replace the light bulb inside the Start button with a white LED and wire it up (through a 22Ω resistor) to pin 16 on the Teensy (terminal LED-1 on my PCB), it will blink 1–4 times when powered up, mirroring the 4 LEDs on an Xbox gamepad. This is a useful indicator since game software often requires controller #1.

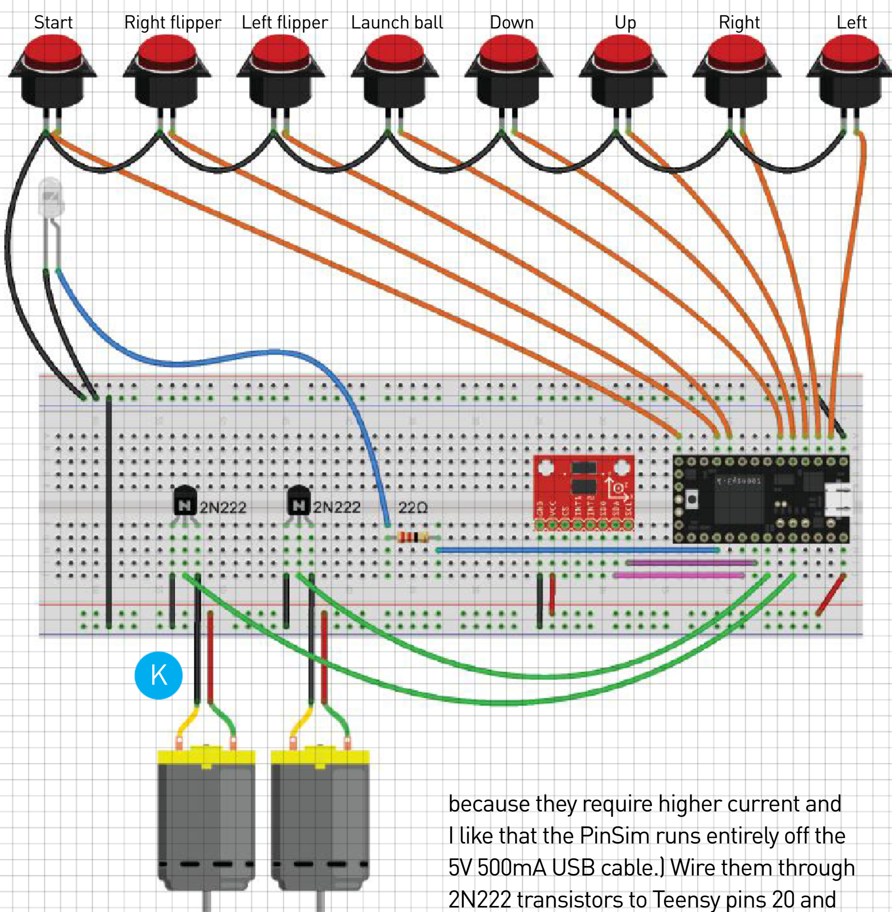
Do the same with the Launch Ball button and connect that LED to Teensy pin 17 (or PCB terminal LED-2). It will remain steady on (Figure I). If you have a 3D printer, you can print my 555 bulb LED holders (Figure J) from thingiverse.com/thing:1537176.

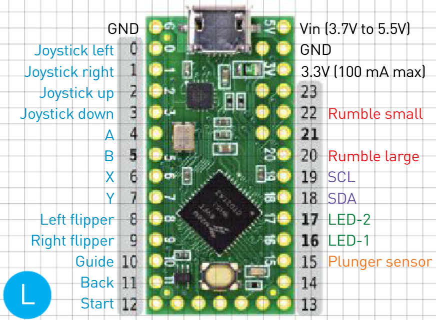
RUMBLE MOTORS

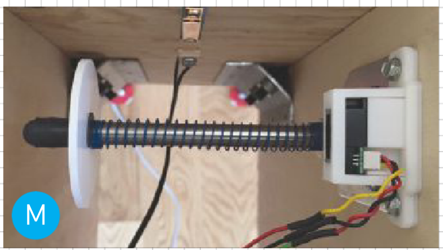
For haptic feedback, I added 2 Xbox rumble motors. (I didn't want to use solenoids,



Jeremy Williams, Hep Svadja







Jeremy Williams, Hep Svadja

because they require higher current and I like that the PinSim runs entirely off the 5V 500mA USB cable.) Wire them through 2N222 transistors to Teensy pins 20 and 22, as shown in Figure K. If you have a 3D printer, you can also print a couple of my handy rumble motor mounts (thingiverse.com/thing:1537210).

MORE ARCADE BUTTONS

Why not add more buttons and use PinSim as an upright arcade controller too? Just drill more holes beside the joystick and connect them to the labeled terminals on the PinSim PCB. For the breadboard crowd, the Teensy LC pinout is shown in Figure L.

LAUNCH PLUNGER

I also decided to replace the Launch button with a real pinball shooter. I had all the parts, I just needed to decide how to convert the shaft movement to a consistent analog signal. I played with bendable resistors and sonar but ultimately I mounted a 3D-printed disc to the end of the shooter, directly in the path of a Sharp IR distance sensor (Figure M). Get the details at Tested (makezine.com/go/tested-pinsim). It works brilliantly, but I have to warn you it's a lot of extra work for minimal payoff. The plunger is important for hitting skill shots, but not much else!

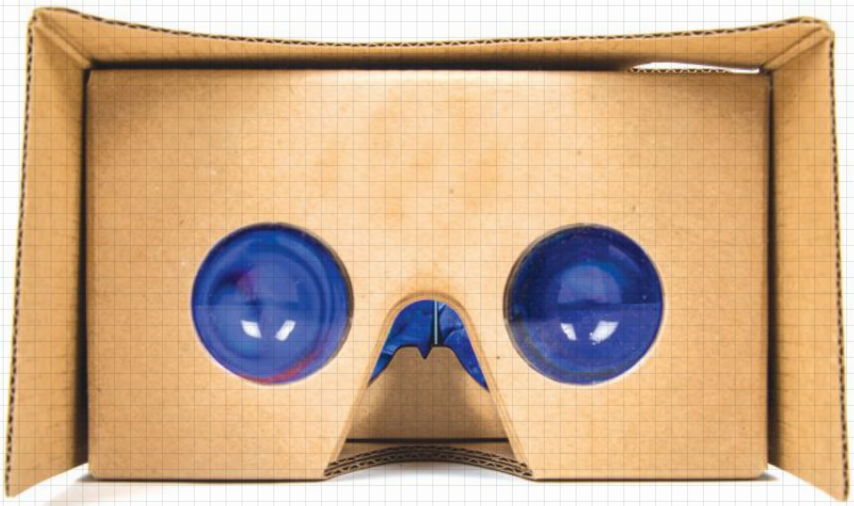
A WORTHY CABINET

After the electronic upgrades, I convinced my carpenter friend Christopher Mann to cut the cabinet from something more beautiful than foamcore. Here's my new wooden PinSim cabinet (Figure N).

Then James Burke and Anthony Lam at *Make:* created a plywood cabinet with the most beautiful paint job I could imagine. Absolutely outstanding. I'm still stunned!

Eventually I did swap my flipper buttons for real pinball leaf switches. These buttons have slightly more travel, for that extra 10% of authenticity — but they don't really affect game play. Build the PinSim as described here, and I think you'll be overjoyed. I'd love to hear how yours turns out.

Download complete drawings and diagrams and share your build on the project page at makezine.com/go/pinsim-vr-pinball-cabinet.



CARDBOARD Creativity

Written by Caleb Kraft

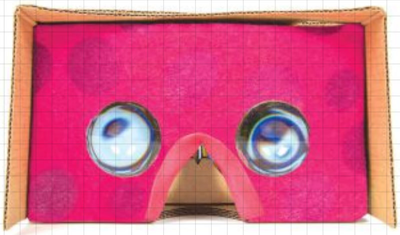
IMPROVE YOUR SIMPLE GOOGLE VR VIEWER WITH THESE EASY TIPS

For dabbling in VR and 360 video, the cheapest and most accessible option by far is Google Cardboard, a fold-together headset that houses your smartphone to display VR content. Google started producing these in June of 2014 and has sold over five million since. Not only are they reasonably priced at $15 directly from Google, you can find a plethora of variations ranging from a dirt-cheap $4 kits (less than buying the parts!) up to full, fancy injection-molded versions that look fantastic. No matter what model, they all offer similar VR experiences, changing only the ergonomics of the device.

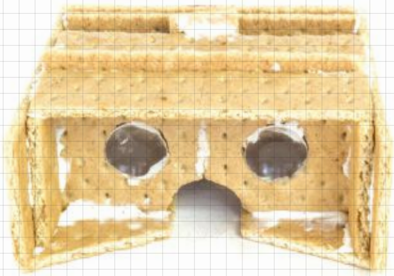
As great as Cardboard is, it is lacking in some areas. Here are a few modifications that can really improve the experience.

CALEB KRAFT
has a tendency to customize and modify things far beyond any necessity to do so. Extra straps, fabric, and aesthetic changes are not uncommon in his personal collection of VR tools.

HANDS FREE Google Cardboard is designed to be handheld, but holding the device to your face can be annoying. Add an elastic strap to keep yours on your head like a pair of ski goggles. A second strap over the top of your head will help secure it and make it feel much lighter. You can use any elastic strapping from a hobby store and staple it into place (isn't cardboard great?). Using two straps and a section of velcro will allow for more adjustments for multiple head sizes.



STAIN FREE As soon as you try a Google Cardboard, the oils from your face will discolor the material. Decorate the faceplate of your device to help hide this unfortunate aspect. A piece of cloth glued to the surface can not only look better, but feel better as well. Choose a dark and soft cloth and secure it in place using a glue stick — liquid glues will soak into the fabric, making it hard and abrasive on your face. You can also use self-adhesive, or regular craft foam with a glue stick to pad sharp edges.



HUNGER FREE All variations of Cardboard work off of the same basic design: a pair of 45mm focal-length Biconvex lenses is set 40mm from a cellphone screen. The rest is simply something to hold it all together. You can download Google's plans or go completely nuts and design yours from whatever you want. We even made an edible version from graham crackers and icing, piecing it together just like a simple gingerbread house — you can watch your VR, then eat everything but the lenses!

Hep Svadja

BUILDING VR SOFTWARE MEANS CREATING NEW SOLUTIONS TO PROBLEMS WE HAVEN'T EVEN IMAGINED YET

The digital and actual sets for *The FOO Show* pilot; Will Smith (left) discusses the hit game *Firewatch* with creators Sean Vanaman (center) and Jake Rodkin (right).

WELCOME TO MY *World*

Written by Will Smith

Norman Chan

WILL SMITH is the founder and CEO of FOO VR and the host of *The FOO Show*, an interactive, 3D-rendered VR talk show. In addition to *The FOO Show*, FOO is building software to make production of interactive, television-like VR content faster and easier than ever before. You may also know Will from his work on Tested.com, the Tested YouTube channel, or as the editor of Maximum PC. You can find him on Twitter @willsmith.

I was in a small room at a game convention last year the moment I first understood the power of virtual reality. It was my first time trying a social VR experience, my first time in a virtual space that I shared with another person. Despite my cohabitant being represented as just a wireframe rendering of a head and hands, the experience was transformative. Within moments, I was interacting with the other person's avatar as if it was an actual person, noting and interpreting the small body language cues that are lost in other forms of communication, like video or phone calls.

That's the moment that I realized that VR would be able to do everything we use video for and much, much more.

If I could read body language from an avatar with no limbs, no eyes, and no mouth, a more realized avatar could convey real human emotion. TV, film, web video, and more were all about to change. It took a while for me to realize it, but that was the moment that lead to me quitting

Eric Florenzano

my amazing job at Tested, and starting a company to build VR software. That was the moment I realized that you'd be able to tell incredible stories in virtual worlds.

I wanted to build those worlds. That's what we do at FOO VR, with our first being a virtual talk show called *The FOO Show*.

I'm getting a bit ahead of myself though. At the lowest level, VR is transformative because it represents a more natural way for humans to interact with computers. The human brain innately understands three-dimensional worlds because 3D is our native environment — every conscious moment of our lives is spent in a three dimensional world, the real world.

"But," you say, "I've used 3D applications on my computers for 20 years." That's absolutely true … from a certain point of view. When you use a 3D application, whether it's a game or a CAD program, on a traditional computer monitor you're actually looking at a 2D projection of a 3D scene. We've built 2D interfaces that work around this limitation, and we use some tricks to add the illusion of depth to those 2D projections, but when you look at a 3D object on a 2D monitor, it's still akin to looking at a shadow and trying to determine the 3D shape that cast it.

I've always had trouble working in the traditional CAD interface, or using the XY/YZ/XZ window convention of most 3D modeling programs to create the object I'm visualizing. The first time I used a sculpting or drawing program in VR, I didn't have to make that mental leap anymore. I was interacting with a virtual object in exactly the same way I could interact with actual objects in the real world, but with the benefit of multiple save files, copy and paste, and an undo/redo chain.

The upshot: It is much easier for me to manipulate objects in VR, using my hands, than it is to do the same in a CAD-like window in a more traditional 2D application.

One of the unexpected, but interesting side effects of the 3D-native nature of your brain is that things that aren't particularly fun in traditional games are much more entertaining in VR. People love exploring VR environments, picking up and inspecting props and set dressing, and performing even the simplest of physics-based actions, like throwing a paper airplane.

At this point, I've demoed our software to hundreds of people. Because of that, I've given many people their first taste of real VR, and boy is that fun. However, the big lesson from those demos is that …

HAVING HANDS IN VR IS IMPORTANT

Using a gamepad or mouse and keyboard to control a VR experience is kind of like trying to write your signature using a mouse. It's clumsy, doesn't work the way you'd expect, and can leave you frustrated at the whole process. On the other hand, people immediately grok how to use hand controllers to interact with virtual environments. If you have them squeeze and hold a trigger to pick something up, then you've taught them more than just how to grab something; you've also shown

Eric Florenzano

For *The FOO Show*'s pilot, recording three participants together meant squeezing everyone, along with three gaming PCs and three Vives, into a tight 20'×20' space.

them how to hand it to someone else or throw it across the room, and you've set up the opportunity to layer on more advanced tasks, like sorting many objects, hiding them, or even shrinking or enlarging them.

For VR developers, the downside of giving your users hands is that the users expect VR environments to be more interactive than a traditional game. When we populated our test world with some small props, the first thing people tried to do was pick them up. When we let people pick those objects up, they tried to throw them. When we let them throw them, they expected them to bounce and interact with other objects. We wouldn't have figured out that people expected all this, but luckily, we ...

TEST EARLY AND TEST OFTEN

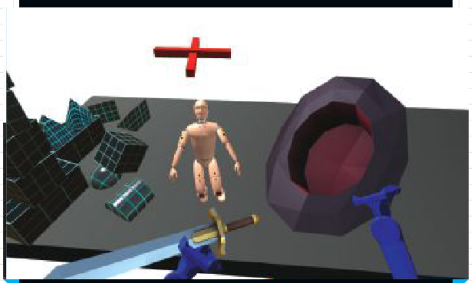
Remember when I said I've run a few hundred people through our VR demos? That wasn't just for fun. Every time we showed someone new what we'd built, we used that as an opportunity to get feedback on our software. It's good to set up so you can see both the user and the monitor with what they're seeing on it.

Sessions in VR can be long, and I don't like to interrupt anyone to ask questions when they're in the goggles, so it's really important that you take good notes as you watch the tester. This lets you prompt your testers with specifics about their experience once they've taken the goggles off.

The big takeaway here is that everyone reacts differently to different experiences in VR, so get as many people to try your software as you can. And above all ...

DON'T MAKE PEOPLE SICK

Our number one rule is: Avoid making people sick, at all costs. Yes, the alcohol and theme park industries have made bank by



Watching a hundred people figure out how to grab things gave much-needed insight into designing a way to pick up objects that makes sense to most users. Even simple tasks are complex in VR.

Using VR, Smith was able to interview the people behind the game *Firewatch* inside their creation, something never before done. More importantly, viewers at home could step inside too.

Many people had trouble understanding the talk show concept, so Smith and team mocked up an episode where he interviewed himself about his new company. "It turns out interviewing yourself is tough," he says.

making their customers hurl, but I don't ever want to be responsible for ruining someone's day. Because VR software has such an intimate connection to your user's brain — it takes over two senses entirely — developers have a greater responsibility than with most traditional software or games. I'm not suggesting that there's any Lawnmower Man-style reprogramming possible with VR, but bad or malicious software definitely can make users feel extremely uncomfortable.

When most people sense a disconnect between the movement they see and the movement (or lack thereof) they detect with their inner ear, they start feeling motion sickness. That discomfort builds the longer you stay in the headset — the only way to get a reprieve is to take a break.

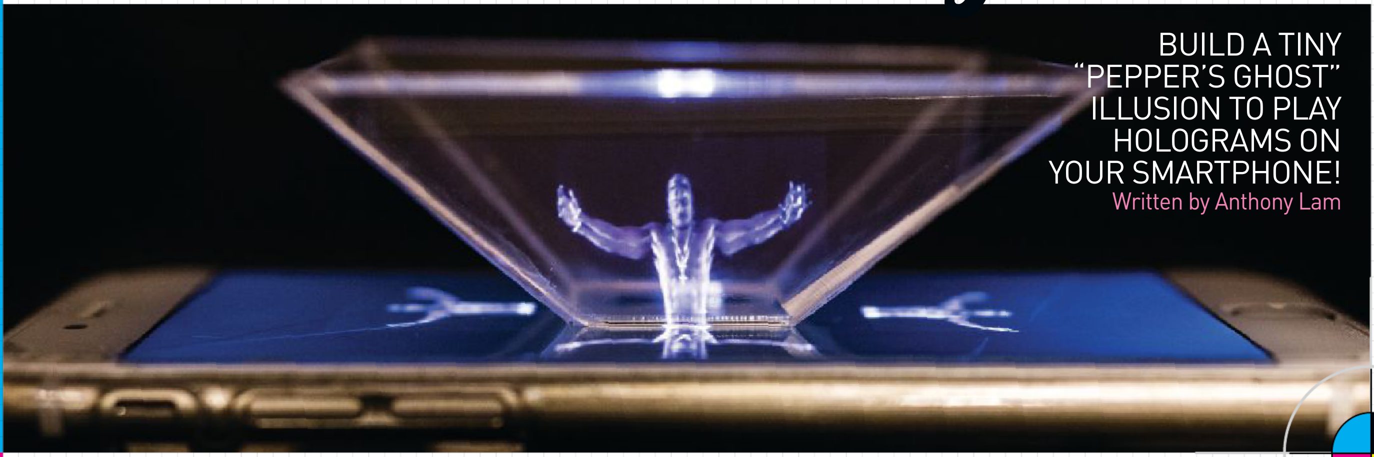
The good news is that VR-related motion sickness is avoidable for almost everyone. As a developer, it's your responsibility to ensure your application never sags below the target frame rate for your platform and to avoid moving the player's camera in ways that will make them feel ill. To be safe, we never take control of the camera from the user.

Every question about VR we answer just begs another dozen questions. Many of the lessons we've learned from decades of traditional software development don't apply to VR, so we need people who are excited about the possibility and ready to create new solutions to problems we haven't even imagined yet. If you'd like to know more, we regularly share our findings at foovr.com/blog.

If you'd like to check out what we've built, search for *The FOO Show* on your VR headset's storefront, we're on Oculus and Vive right now, and may be on Gear VR and PlayStation VR by the time you read this.

FOO VR

1+2+3 CD Case Hologram



BUILD A TINY "PEPPER'S GHOST" ILLUSION TO PLAY HOLOGRAMS ON YOUR SMARTPHONE!

Written by Anthony Lam

Hep Svadja

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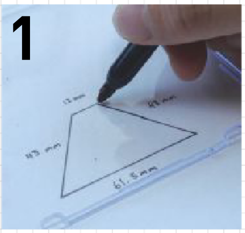

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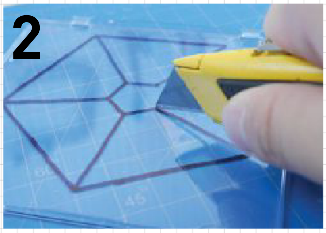

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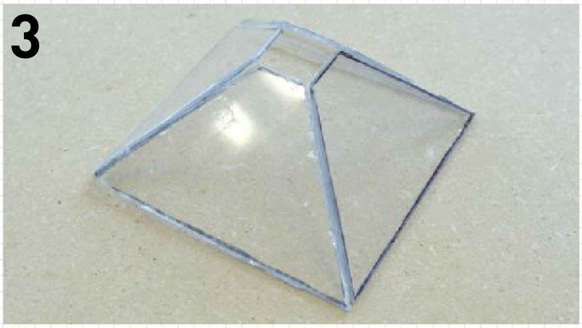


The holographic appearance of the late Tupac Shakur onstage at Coachella in 2012 blew minds because of how lifelike and detailed he appeared. The dancing illusion used a technique first described by 16th-century Neapolitan scientist Giambattista della Porta, and later developed by Henry Dircks and John Henry Pepper, from whom it got its name: Pepper's Ghost.

This illusion originally required almost a whole dedicated room to perform. Nowadays you can make a tiny hologram using just a small acrylic pyramid and your smartphone. Here's how.

1. MEASURE AND MARK

Draw a trapezoid on a piece of paper with a bottom length of 61.5mm, top length of 12mm, and side lengths of 43mm. Trace the shape on the acrylic CD case with your pen, repeating it 4 times.

2. SCORE AND CUT

Slowly score the lines drawn on your CD case with a box cutter, and repeat carefully until it cuts through. Take care when removing the cut pieces, as the acrylic has relatively sharp edges.

3. ASSEMBLE THE PYRAMID

Place the 4 pieces next to each other along their 43mm sides, and attach them using a thin strip of cellophane tape at each shared edge. When 3 of the edges have been taped, fold them into the shape of a pyramid and tape the remaining edge.

USE IT. Simply lay your phone on a flat surface, place the pyramid upside-down on the center of the screen, and conjure up any of the content that's widely available on YouTube — search for "pyramid hologram" to find videos specially made for this trick. Like magic, you'll have dancing holograms floating in midair.

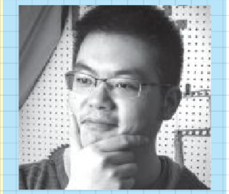
Anthony Lam

Time Required:
20–30 Minutes

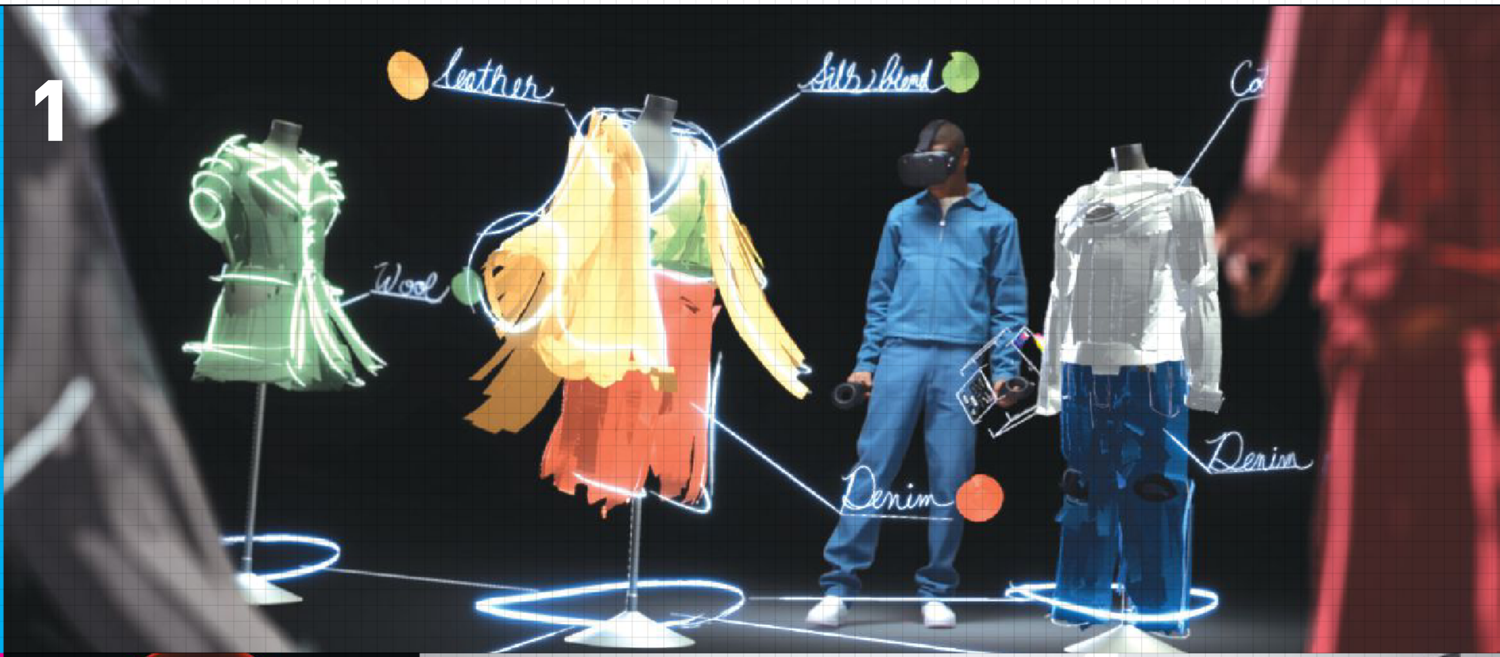
Cost:
$10–$20

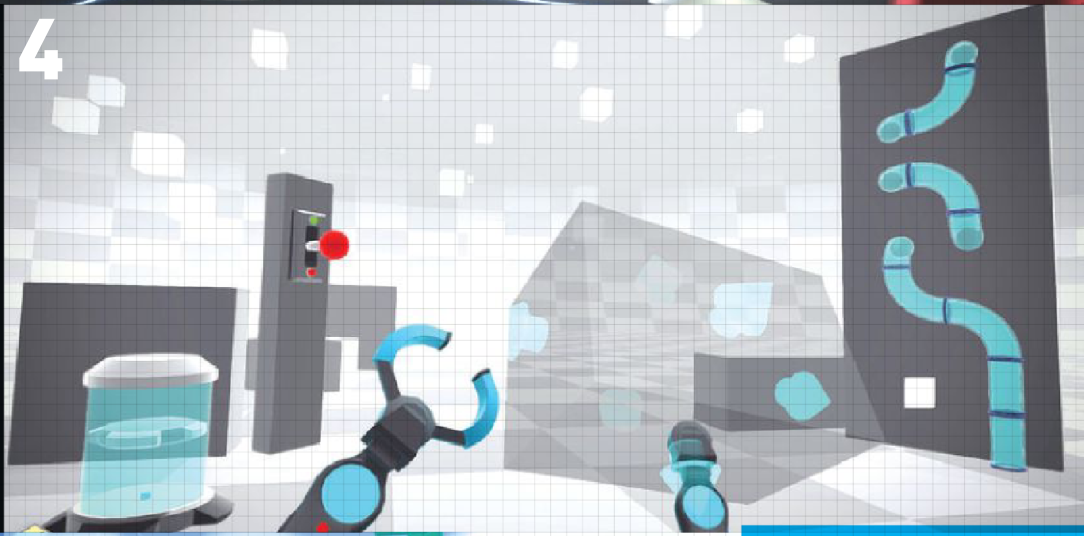
You will need:

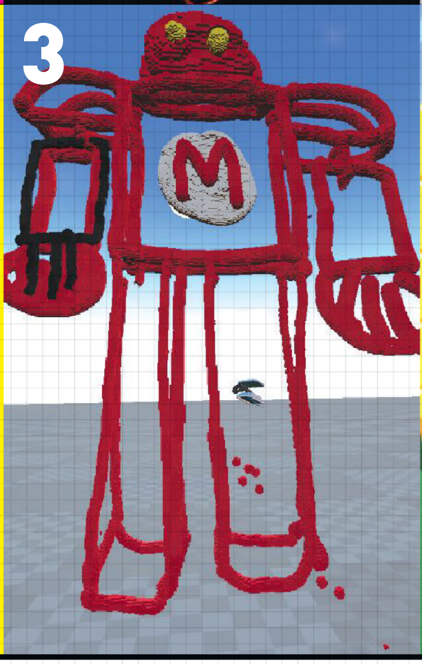
- **CD case** Fun fact: The proper name for these is *CD jewel case* or *jewel box*, because designer Peter Doodson, who created the case for the Philips company, "specified polished ribs because they pick up the light and shine."
- **Paper, plain white**
- **Tape, transparent**
- **Smartphone**
- **Utility knife**
- **Pen**

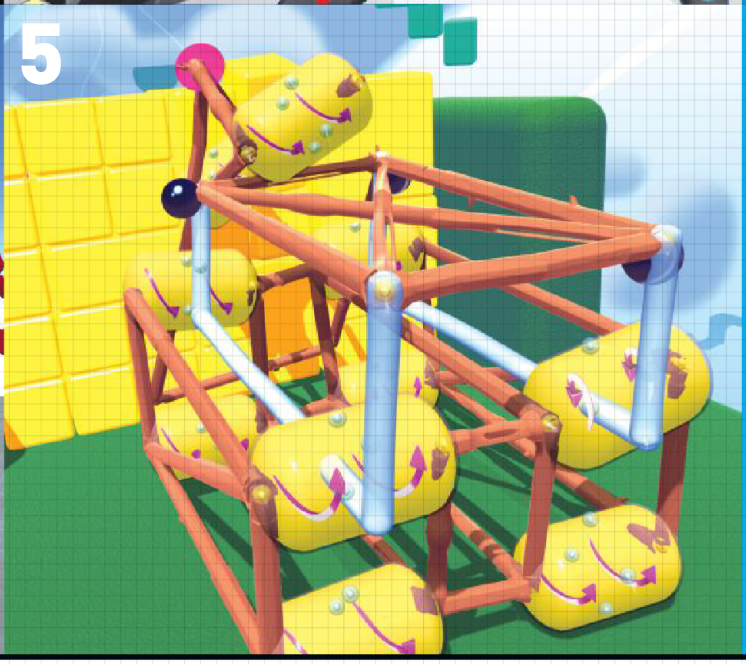


ANTHONY LAM is a lab assistant and engineering intern for *Make:*. An industrial designer by trade, he is easily excited by anything regarding technology, DIY projects, or video games.









JON OAKES is part of the Silicon Valley Virtual Reality (SVVR.com) team. He was an early backer of the Oculus Rift and a VR developer. He now heads up business development helping VR startups get up and running.

1: Google, 2 & 3: Jon Oakes, 4: SculptrVR, 5: Fantastic Contraption

DESIGN, ASSEMBLE, AND BUILD WITH THESE VR SOFTWARE TOOLS

VIRTUAL Creation

Written by Jon Oakes

Virtual reality is more than just games and interesting experiences. Every piece of creative software we use today is likely to have a VR equivalent that puts you in the same space as your design, and some are already allowing you to bring those digital works out into the real world via 3D printing. Here are some of my current favorites, and a couple of the new titles coming soon.

Painting and Sculpting

These take you off of a flat canvas or screen, letting you create digital masterpieces in immersive 3D.

1. TILT BRUSH

tiltbrush.com

Tilt Brush was the first VR art application to have an avid following. The program puts a drawing implement in one hand and a palette of tools, brushes, and colors in the other. It allows the artist to sweep their artwork not only along a plane in front of them but in all directions — up, down, left, right, and behind them too. It's quite an experience to create a drawing and then take a step into it to continue working on it from a totally different angle.

Art shows have already featured live exhibitions of artists creating wild 3D landscapes, and YouTube is a good place to find "replays" of these sessions. Even untrained artists seem to have a great time with it. The tools also serve as a rapid 3D sketchpad for other ideas such as roughing out a design for a new chair or table, or any scale object, so you can see how it might look in 3D before you get more detailed.

2. PAINTLAB

paintlabvr.com

A relative newcomer to the VR art scene, PaintLab currently has a distinct appeal: it's free. While it boasts a wide range of features for 3D painting, it may take a more determined user to get all they can out of it. The developers are very active in adding new features and smoothing things out for users. One nice option is the ability to "spray paint" on your sculptures, making PaintLab useful for trying out different color schemes on 3D models.

3. SCULPTRVR

sculptrvr.com

SculptrVR bills itself as a world-building game and uses "voxels," scalable 3D blocks that look like something out of Minecraft, to paint the space you inhabit. It has a unique ability to let the users scale themselves — up to the size of a giant or down to that of an ant — to add as much detail as they want.

Some simple physics and object interactivity is supported, and they've also added fun elements such as a rocket gun that you can shoot at your worlds to blow them up. Last but not least, you can export your creations to print them on your 3D printer.

Physics Sandboxes

If you want to hack around in virtual space or are new to VR, there are a couple of apps you should check out to learn what you can do.

4. MODBOX

alientrap.org/games/modbox

Modbox is like the ultimate physics building block set for VR. While still very early in development, a community of users has already shown some amazing concepts for games built within it. There's no game in the product itself, it's strictly a set of tools you can use to do things like build a bowling alley or archery range, or re-create a haunted mansion in 3D and walk around in it. The developers promise support for mods and different tile sets in the coming months. While not completely accurate physics, I could see this being used by makers to quickly sketch out simple machine concepts or a room-size experiment to see how it functions. But perhaps the greatest value is the workout it gives your imagination.

5. FANTASTIC CONTRAPTION

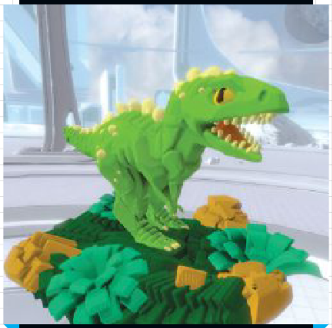
fantasticcontraption.com

In this puzzle game, the wearer builds 3D machines to deliver a pink glowing ball to a goal. It sounds easy but the challenges get hard fast. The great thing about this game from a maker perspective is that it rewards experimentation. Many sessions abandon the stated goal and instead players make musical xylophones, imaginary helicopters, or any Rube Goldberg-inspired assemblage they can dream up.

Razmig Mavlian

COMING SOON

There are a few titles in the pipeline that you can't get your hands on yet, but should be available later this year.



OCULUS MEDIUM

youtu.be/IreEK-abHio

Oculus is working on an input system called Oculus Touch, which will let Oculus Rift owners get their hands into the virtual world. Medium is a sculpting application designed by artists to behave like real material might under the hands of a sculptor. No release date has been set, but Oculus has shown it at events and it looks promising.

MAKEVR

sixense.com/makevr

MakeVR has been in development for some time and will provide the ability to create highly detailed VR CAD designs. It's easy enough for a novice to use but powerful enough to do real 3D CAD work. MakeVR promises to allow the user to create any 3D shape using all the tools of a CAD engine, but in VR. From there, because it's built on a professional grade CAD software engine, the user can export those designs for printing or use in other applications.

Written by Craig Couden

GATEWAY

Virtual reality is still in its early stages of adoption and, like many new technologies, the hardware you choose will greatly affect your experience. Here are a few of the VR setups that we're excited to get our hands on.

HEADSETS

OCULUS RIFT

One of the two top-tier VR systems hitting the market, Rift uses a small sensor placed in front of the user to track the position and rotation of a series of infrared LEDs embedded in the headset. Currently, Rift includes an Xbox One controller, and while it's familiar to the gaming crowd, it won't track body movements. Trackable controllers, called Touch, will be sold separately by the end of 2016.

- **PRICE:** $599
- **INCLUDES:** headset, sensor, remote, cables, Xbox One controller
- **CONTROLLER:** Xbox One controller, optional Touch controllers (available late 2016)
- **TETHERED?** HDMI cable runs from headset to computer
- **HURDLES:** Rift requires some beefy (and particular) computer specs. Download Oculus' Compatibility Tool to see if your machine is up to the task.

HTC VIVE

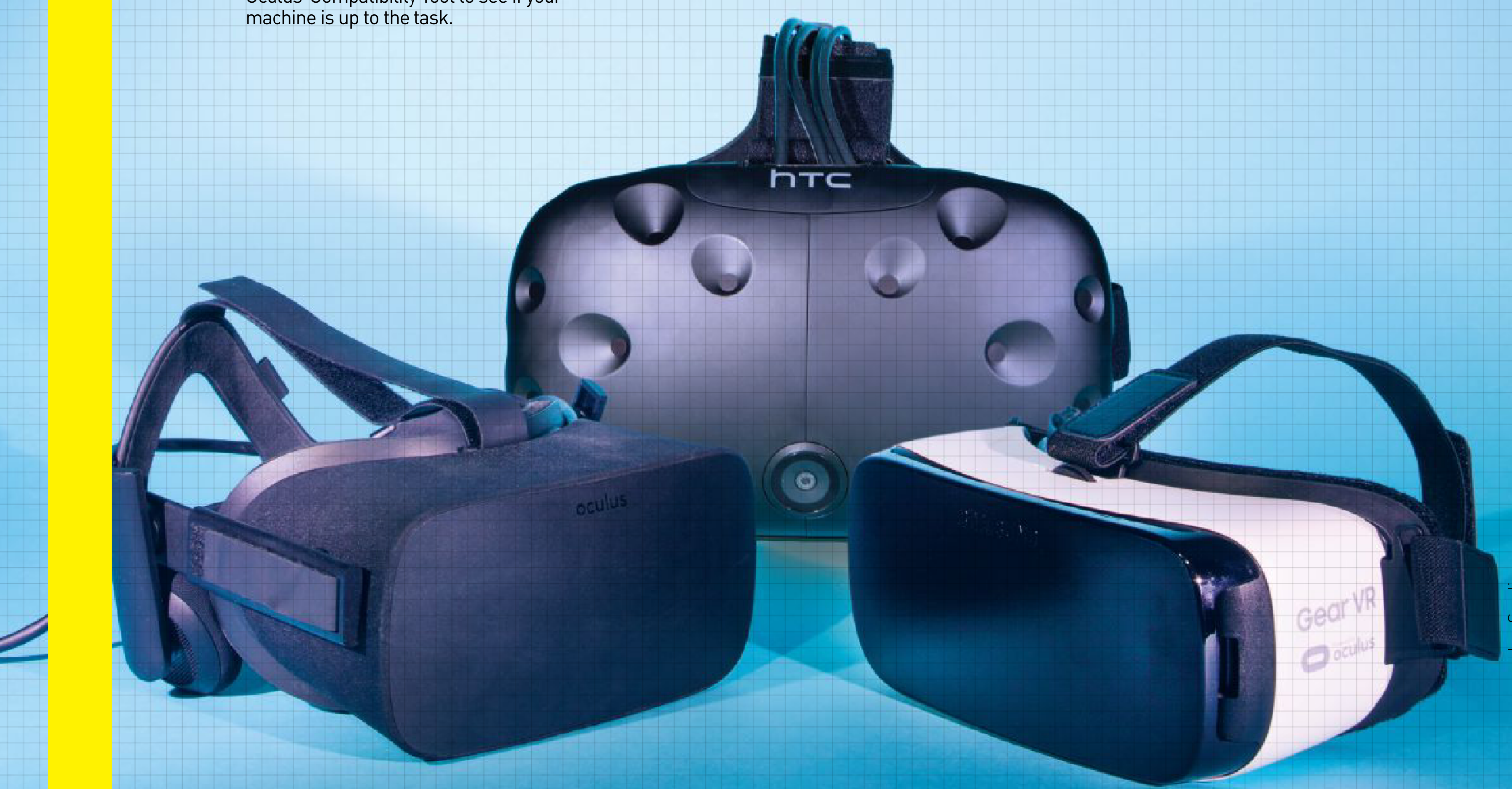
The other premier VR system, Vive, is a joint venture from HTC and Valve and uses two sensor stations to establish a 3D space and help the headset's 32 sensors track its position and rotation. Vive comes with two handheld controllers to track your hand movements in real time. Blue lines overlaid onto the virtual space by the OS keep you from roaming outside your designated area.

- **PRICE:** $799
- **INCLUDES:** headset, two wireless controllers, two base stations, accessories
- **CONTROLLER:** wireless Vive controllers, set of 2
- **TETHERED?** 3-cord bundle from headset to computer
- **HURDLES:** Like Rift, Vive too requires some hefty computer specs. Download the SteamVR Performance Test to check your computer's compatibility.

SAMSUNG GEAR VR

The Gear VR is a smartphone-based setup from Oculus and Samsung. Instead of a high-end computer, Gear VR runs on recent Samsung Galaxy phones, which snap right into the headset. It's similar to Google Cardboard in that software and a set of lenses fool your eyes into seeing a virtual world, but Gear VR includes additional sensors that augment the phone's motion tracking and onboard touch controls in addition to gamepad support.

- **PRICE:** $99
- **INCLUDES:** headset (compatible Samsung phones sold separately)
- **CONTROLLER:** touchpad on the side of the headset, optional game pad (sold separately)
- **TETHERED?** no
- **HURDLES:** only works with a selection of new Samsung Galaxy phones



Hep Svadja

Gear

PHYSICAL HARDWARE YOU NEED TO ENTER THE VIRTUAL WORLD

INTERFACE

Hep Svadja

ZSPACE

ZSpace is targeting education with their blend of AR/VR for the classroom. Four onboard cameras track head movement using a special pair of glasses and create a parallax effect as you move around. Meanwhile, a stylus can be used to manipulate objects and interact with a 3D space that jumps off the screen. Focusing on education, the early killer app is Newton's Park, where students can design Rube Goldberg-esque experiments to learn basic physics principles.

- **PRICE:** contact zSpace for pricing
- **DIMENSIONS:** 25.4"×16.5"×2.8" (footprint)
- **CONTROLLER:** stylus

LEAP MOTION

The Leap Motion controller debuted in 2012 to much fanfare, but little mainstream adoption. However, with the expanded Orion software update and the resurgence of interest in VR, the company is poised to make our dreams of cyberpunk virtual worlds a reality. The small USB-connected sensor can interface with a variety of VR systems and tracks hand and finger positions to give you a virtual set of hands to interact with what you see inside the headset.

- **PRICE:** $80 (or less online)
- **DIMENSIONS:** 5"×5"×2"
- **CONTROLLER:** hands!

CORSAIR BULLDOG

While many systems can drive your VR experience, the Corsair Bulldog elegantly blends in with your current A/V setup and is well ventilated and spacious enough to house high-end, HG10 bracket-equipped graphics cards. A DIY kit is currently available and includes an Intel-based motherboard with DDR4 support, but Corsair also plans to release fully built Bulldog units for sale this summer, plus an upgraded DIY kit for self-builds.

- **PRICE:** $399 (DIY kit; GPU not included. See corsair.com for recommendations
- **DIMENSIONS:** 15"×18"×5½"
- **MOBO:** Mini-ITX with Intel Z170 Chipset
- **COOLING:** Hydro Series H5 SF Liquid CPU Cooler

Written by Caleb Kraft

FULL Immersion

CAPTURE THE WORLD IN 360º WITH THESE NEW CAMERAS, THEN EXPLORE THEM WITH YOUR VR GEAR

One of the fun, new experiences that VR equipment has brought us is immersive 360° video and images. These can be enjoyed by simply holding up and moving around your mobile device, using Google Cardboard, or even the latest and most advanced virtual reality headsets.

Creating these, like any video or photography piece, can span from exceedingly easy to complex high-quality systems.

Currently there are two main types of cameras for this kind of imagery. Point-and-shoot units function like normal cameras; more complicated rigs synchronize multiple cameras for richer detail or even stereoscopic recording.

POINT AND CLICK

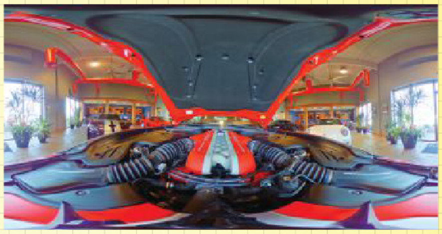
In the point-and-shoot-style arena, you'll find that most options cost less than $500. Most popular are the **360 Fly**, **Kodak SP360**, and the **Ricoh Theta S**. These allow you to simply record and upload to the 360-capable platform of your choice. The ease of use is fantastic since you don't need to mess with multiple pieces of hardware, multiple batteries, or complex software. Unfortunately that ease is offset by the lack of resolution.

MULTI-CAMERA RIGS

Professionals tend to use rigs that include multiple cameras, commonly GoPros, facing different directions. You can buy these, or assemble your own with a 3D-printable frame found on Thingiverse or elsewhere. There is a lot of variation in the number and arrangement of cameras used, usually depending on the quality desired. Each additional camera adds to the overall resolution captured, which translates into clarity for the viewer. You can find some with as few as 6, and others with more than 16.

When recording with a multi-camera array, it is necessary to synchronize the cameras so that they all share exposure and shutter speed settings. The resultant video is then all brought into a software package and "stitched," giving a final high-definition video of the entire scene.

An added benefit to the multi-camera setups is the ability to double your cameras up for recording stereoscopic or 3D videos.



360º image of a 2012 Ferrari FF engine. Peek around 12 cylinders and 600HP of beauty at carsupclose.com.

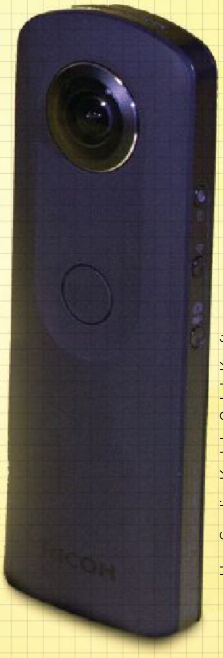
360 VIDEO TIPS

Keep these notes in mind when filming 360 video or images.

- Get out of the way! We can see you standing there; remember that your audience can see everything.
- If you're doing a scripted video, don't go crazy with trying to divert people's attention in 360°. Turning your head back and forth gets annoying very quickly. Try to keep the action in a 120° section and slowly transition from one area to the next.

360 Fly

Kodak SP360



Ricoh Theta S

Hep Svadja, Kodak, Caleb Kraft

LET'S GET Real

THESE BUILDS MAKE VIRTUAL REALITY AN EXPERIENCE

Written by Lisa Martin

Your VR experience doesn't have to be limited to twisting your head to look at things and moving around joysticks on a game controller. Makers and VR companies alike are already pushing the boundaries of where the virtual world ends and the real world begins. We're talking temperature changes, creative controllers, ambient wind, motion. Here are some ideas you can try to recreate in your VR setup.

TAKE THE LEAP

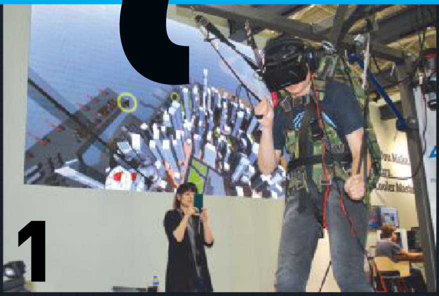
revresh.com/paraparachute

Eward Hage and Kevin Derksen have you strap on a real parachute harness to enhance their parachute simulator (Figure 1). The finished rig, dubbed Para Parachute, uses a winch to lift the user off the ground, and then drops them from a horizontal position to vertical dangling position when the parachute is released in the game. With the Oculus Rift on your head and your feet off the ground, it feels like the real deal. This is just one example of how an item can be hacked into a controller with the right sensors in order to completely transport the user.

FLY LIKE A BIRD

somniacs.co

A team of interactive artists from the Zurich University of the Arts wanted to capture the firsthand experience of a bird flying through a city, so they built Birdly (Figure 2). What really makes this special is the motion platform that acts as both controller and feedback. Lying on top of it, the user controls the direction and speed of their flight through a simulated metropolis by flapping and twisting a pair of outstretched wings. As a fan blows in your face and the platform dips and leans along with your flight path, the game uses movement to create a full-body experience. Of being a bird, that is.


1


2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4


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FEEL THE HEAT

whirlwindvr.com/pages/vortx

Haunted houses have used pressurized air to create fast scares for ages. The same effect can add an exhilarating element to VR gameplay — short bursts of air for near-miss gunfire, larger for explosions. At this year's Game Developer Conference we spotted the Vortx (Figure 3), created by Whirlwind VR. It goes further by adding a heating feature, which lets you feel a campfire's glow — or that dragon's breath.

A KICK IN THE BUTT

If you just want an extra kick in the pants, try mounting a "tactile transducer" (aka bass shaker) directly to your couch. These work by transmitting low frequency vibrations through whatever it's attached to. You can buy bass shakers (Figure 4), but it's easy to make them from scratch by hacking a subwoofer (there are some good tutorials for this on YouTube). To get the most boom for your buck, mount your bass shaker to the biggest, most central piece of wood in your couch or chair. Or for a standing experience, you can build a simple wooden platform and attach the shaker to that.

GET UP AND GO!

Systems like Infinadeck, Virtusphere (Figure 5), and CyberWalk are taking steps to create platforms that will allow you to actually walk around your virtual environment. The basic principle is simple: You move in one direction and the platform beneath you moves in the opposite direction, like a treadmill. Once you factor in more than one direction you'll need to get creative. So far we're seeing conveyor belt systems that have an X- and Y-axis movement, and oversized hamster balls on wheels. No one has a perfect system (yet), so falling down should be something you take into consideration.

Revresh, SOMNIACS, WhirlwindVR, Parts Express - parts-express.com, Virtusphere, Inc

Skill Builder

TIPS AND TRICKS TO HELP EXPERTS AND AMATEURS ALIKE

Getting Started with Propane and FIRE EFFECTS

Learn the basics and build a low-pressure source for all kinds of flame projects!

WRITTEN BY TIM DEAGAN

PROPANE IS A WONDERFULLY COMMON FUEL SOURCE. Blacksmiths and metal casters use propane to power torches; artists and makers use it to create flame effects like flambeau torches, flame cannons, Rubens' tubes, and other visual displays. It's available almost everywhere, is nontoxic and, given simple precautions, very safe to handle.

But when I'm inspecting people's propane projects as a licensed flame effect operator (FEO) at events, I frequently end up explaining to people why their project, device, or effect is unsafe. Most of the time, it's because they have no basic understanding of what propane is or how it interacts with the world.

You don't need extensive chemistry or engineering knowledge. My book *Make: Fire* will provide you with everything you need to know to safely make use of this amazingly useful fuel.

Here's how to build a simple low-pressure propane source for all kinds of fun fire projects — along with an overview of the key equipment and some critical mistakes to avoid.

Hep Svadja

TIM DEAGAN likes to make things. He casts, prints, screens, welds, brazes, bends, screws, glues, nails, and dreams in his Austin, Texas, shop. A career troubleshooter, he designs, writes, and debugs code to pay the bills. He has written for *Make:* magazine and *Nuts & Volts*, *Lotus Notes Advisor*, and *Database Advisor*.

This article is adapted from *Make: Fire*, available at the Maker Shed (makershed.com) and fine bookstores.

PROPERTIES OF PROPANE

Chemically, propane is extremely safe — nontoxic and noncarcinogenic. It's colorless and odorless. If you think you smell propane, you're really smelling an additive like ethyl mercaptan, put there so you can detect leaks.

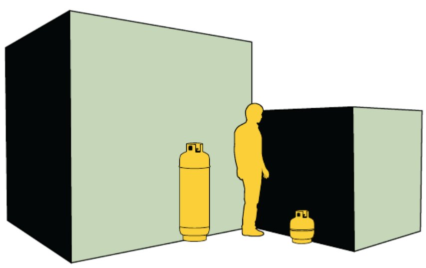
Mechanically, propane is extremely dangerous because of the pressures and temperatures involved. Propane accidents can cause explosions, burns, frostbite, and asphyxiation. But compared to other fuels, these accidents are relatively easy to avoid with safe practices.

LIQUID AND VAPOR

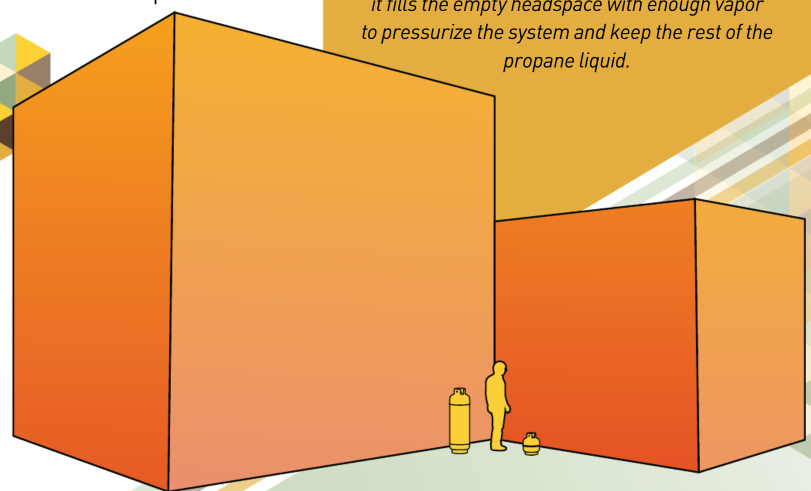
At normal pressures, propane boils at −44°F (−42.2°C). So ordinarily you'll only encounter unpressurized propane as vapor. Inside the cylinder at room temperature, the propane boils just until it fills the empty headspace with enough vapor to pressurize the system and keep the rest of the propane liquid.

FUEL-AIR MIXTURE

At normal temperatures and pressure, propane liquid will expand 270 times to become vapor (Figure A). However, that vapor will mix with air (a combustible mix is around 5% propane and 95% air) so that the amount of combustible vapor is much larger than the propane vapor alone (Figure B).



A Comparing unpressurized vapor to cylinder sizes. A 20 gal. of liquid expands to 721ft^3 of pure vapor. A 5 gal. of liquid expands to 180ft^3 of pure vapor.

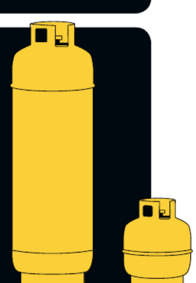


B Mixed with air, the combustible mixture is 20 times larger than propane vapor alone. A 20 gal. of liquid propane mixed with 5% air creates 14,556ft^3 of combustible vapor. A 5 gal. of liquid propane mixed with 5% air creates 3,639ft^3 of combustible vapor.

HEAVIER THAN AIR

Propane vapor is 1.5 times heavier than air. This causes it to sink rather than rise. This is important. If an indoor propane system leaks, the propane will pool in the bottom of the room, potentially asphyxiating people or causing an explosive hazard.

STRONG SOLVENT



Liquid propane is an excellent solvent of petroleum fractions, vegetable oils and fats, natural rubber, and organic compounds of sulfur, oxygen, and nitrogen. Acetylene red welding hose and other natural rubber hose is not appropriate for propane use due to its composition, nor is any equipment with rubber O-rings or seals.

Propane does not corrode or dissolve metals, polyvinyl chloride (PVC), or polyethylene (PE) — but its pressure and temperature may cause these materials to fail (perhaps catastrophically).

James Burke

COMBUSTION

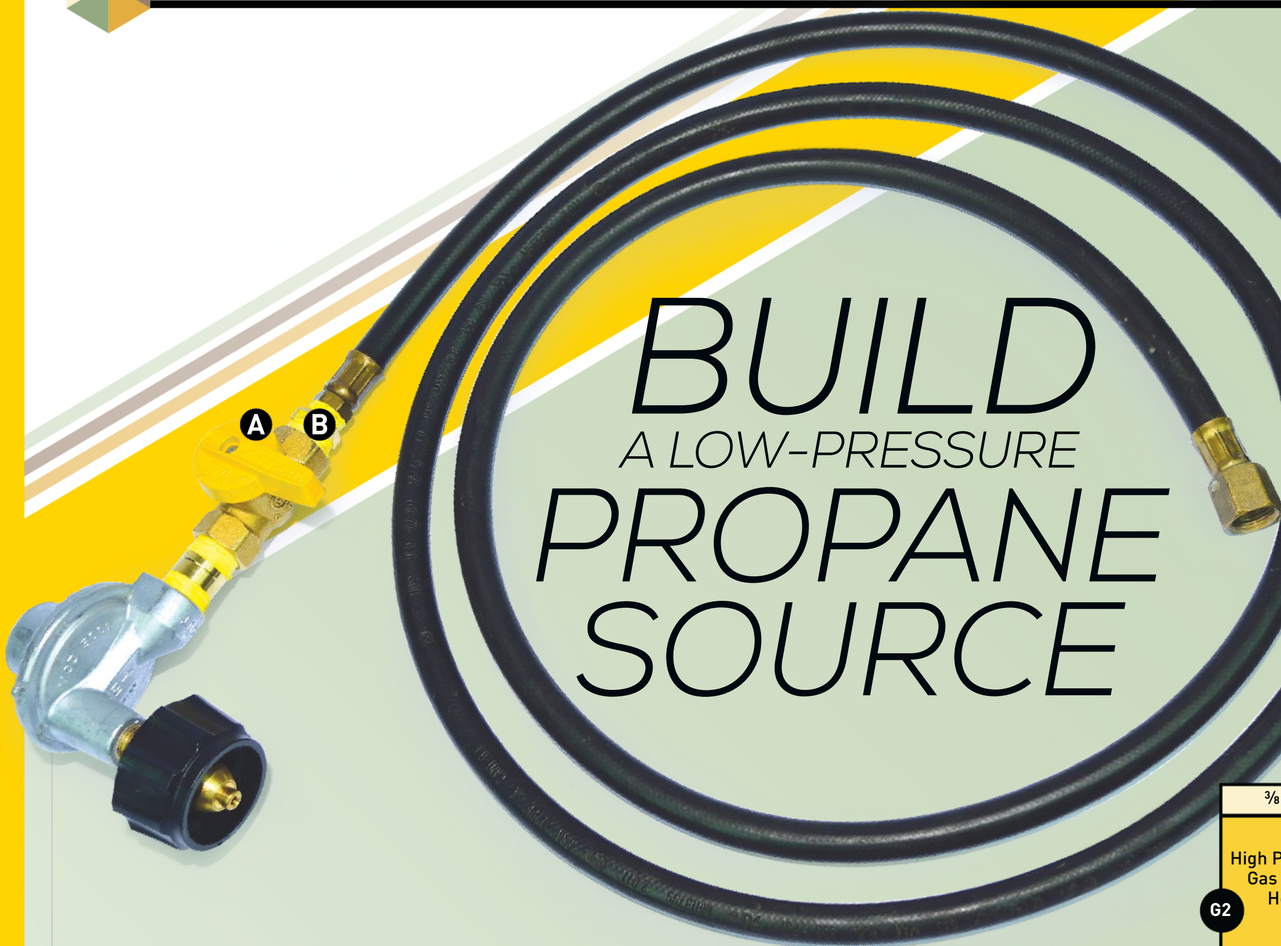
For most readers, the point of working with propane is to burn it!

- » Propane **requires a spark to ignite** in air, unless the temperature is above 920°F (493°C).
- » Propane **will only burn in a specific propane-air percentage**, generally between 2.1% and 10.1%.
- » For propane **to burn cleanly it must be 4.2% in proportion to air**. This is complete combustion, producing only carbon dioxide and water as byproducts (or stoichiometric combustion for you chemists and word lovers).

Less propane results in a *lean* burn, where the flames lift from the burner and try to go out. This is an oxidizing flame that introduces extra O2 into the atmosphere.

More propane gives a *rich* burn that creates large, yellow flames. This is a reducing flame that will pull oxygen from the air, creating carbon monoxide (CO) and possibly soot (carbon).

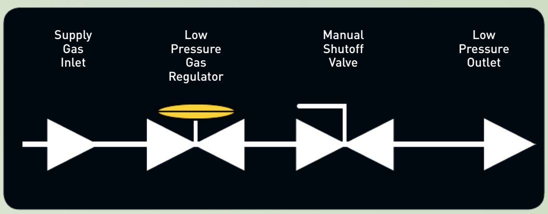
BUILD A LOW-PRESSURE PROPANE SOURCE



MOST PROPANE PROJECTS BUILT BY MAKERS (AND THE ONES IN MY BOOK) REQUIRE ONLY A BASIC LOW-PRESSURE SOURCE. This can be made from standard parts found in big-box hardware stores, local plumbing supply companies, or on the internet. This source will provide propane vapor at approximately ½ (0.5) psi and allow you to safely build low-pressure fire projects that will introduce you to skills like correctly assembling gas-rated fittings and brazing.

I'm specifying high-pressure hose even though this is a low-pressure source, because I believe it's dangerous to have a mix of high- and low-pressure hoses in your propane gear. The high-pressure hose works fine for low pressure but the reverse is most definitely not true. So it's better to invest a little more and know that your hoses work for all situations.

Throughout my book, I present a schematic and block diagram for every project. The schematic (Figure A) conveys the essential function; the block diagram the specific parts (Figure B). You can also use the block diagram as an assembly guide.



A Low-pressure source schematic diagram.

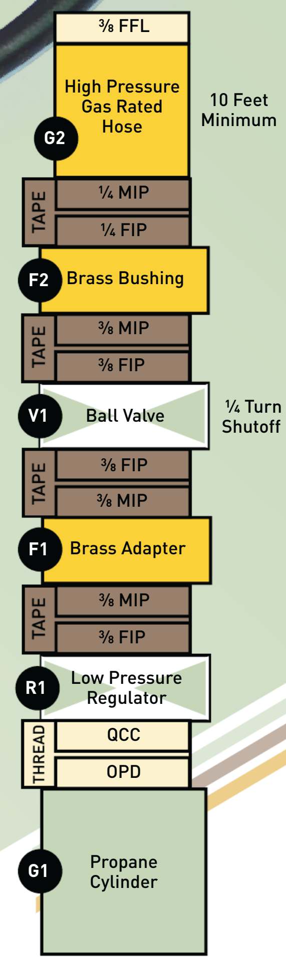
CONSTRUCTION

You'll assemble the low-pressure source before attaching it to the cylinder.

1. Start by taping and threading both ends of the ⅜" male-male brass adapter (F1). Tighten one end into the outlet of the low pressure regulator (R1) and the other end into the ball valve (V1).

2. Tape the male-female brass bushing (F2) with yellow Teflon tape and thread it into the ball valve.

3. Tape the male threaded end of the hose (G2) and thread it into the bushing on the end of the ball valve.



B Low-pressure source block diagram.

Tim Deagan, James Burke

LEAK TESTING

1. Put your safety glasses on. Verify that the ball valve is turned off.

2. Attach the regulator's QCC fitting to the propane cylinder without Teflon tape. If your regulator has a large plastic grip around the fitting, it is threaded by hand. If there's no hand grip, tighten with a wrench, but do not overtighten; some regulators won't supply propane at all if overtightened.

3. Open the cylinder valve all the way and then back off about a half turn.

4. Using a little soapy water in your spray bottle, spray the fittings from the cylinder to the ball valve (Figure C). Check for bubbles. If you see any, depressurize and tighten the joint until they stop. A valuable addition is a ⅜" flare plug to cap the end of the hose; this will allow you to test the ball valve-to-hose connections as well.

5. Close the cylinder valve all the way and then open the ball valve to vent the line.

That's all there is to constructing a low-pressure source for all kinds of fun flame projects.

C Leak-test the low-pressure source.

Materials

- **Propane cylinder, standard 20lb (5gal)**
- **Propane regulator, low pressure** such as a gas BBQ regulator
- **Ball valve, gas rated, ⅜" FIP × ⅜" FIP**
- **Propane hose, high pressure, ¼" MIP × ⅜" FFL**
- **Brass bushing, ⅜" MIP × ⅜" FIP**
- **Brass bushing, ⅜" MIP × ¼" FIP**
- **Teflon tape, yellow (gas-rated)**
- **⅜" flare plug fitting (optional)** to fit hose end, for leak testing

Tools

- **Adjustable wrenches (2)**
- **Safety glasses**
- **Spray bottle**
- **Dish soap**
- **Towel**

CAUTION
DON'T USE

WHITE TEFLON TAPE. It's too thin, so it shreds and clogs your valves and fittings. Use yellow gas-rated Teflon tape.

CAST IRON BUSHINGS. They're too brittle; they'll crack under torque, then leak gas. Use brass bushings.

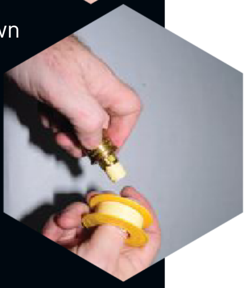
HOSE CLAMPS. They're not rated for gas pressures. Use pre-fitted propane rated hose instead.

PLASTIC VALVES. Typically designed for water or other liquids at pressures far below gas ratings. Plastics may also be corroded by propane. Use brass valves.

COMPRESSED AIR FITTINGS. They're unrated for gas pressures, and they frequently have rubber seals that will corrode under contact with propane. Use gas-rated fittings with appropriate seals.

Tim Deagan

TAPING AND TIGHTENING THREADED FITTINGS



TAPING JOINTS

I'm a taper, not a doper. Therefore, most of the joints in my book, other than the flare fittings, rely on **yellow Teflon tape** to become gas-tight. Taping a joint correctly is easy to do. **Four wraps of tape clockwise around the fittings** will do the job. Use your thumb to hold down the first wrap so it doesn't slip. Wrap with enough tension to allow the threads to make a sharp crease (but don't overdo it), and don't let any tape hang over the inner passageway of the fitting. When the wrapping is completed, pull the tape until it breaks itself off at the back of the threads.

If you take apart a taped joint, use a wire brush to get all of the old tape out of the threads (on both the male and female sides of the joint). **Never retape over old tape.** Tape is relatively cheap. Pull a joint apart and retape if you need to; it's better to use a little extra tape than to have an unsafe joint.

TIGHTENING

How tight should you tighten threaded fittings? Unfortunately, the answer is, **"Tight enough to stop the gas from leaking."** This isn't typically described in terms of torque — it's something you develop a feel for. I typically tighten a taped NPT fitting until it starts to feel like it won't turn much more, and then I give it a turn or two more. That's vague, because the difficulty varies tremendously between fittings (and people's ideas of difficult). So tighten it and then leak-test under pressure to get a feel for it.

The important tip here is to always use a wrench to brace a part you don't want to have move. Use the second wrench to tighten the next part into it.

SAMUEL BERNIER is the creative director of le FabShop, a French design and innovation firm. He's also the designer behind the popular elephant and articulated Makey printables. His first book, *Design for 3D Printing*, is published by *Make:*.

Makey in red MDF, milled on Inventables' Carvey CNC machine.

CNC MILLING with Fusion 360

Turn a vector drawing into a wooden bas-relief in this simple exercise

WRITTEN BY SAMUEL BERNIER

SOFTWARE IS A KEY PIECE OF DIGITAL FABRICATION. Numerous programs exist that let you design digital models, and others convert those models into commands for your specific machine, allowing it to produce physical builds. Autodesk's Fusion 360 has become one of the go-to software options for makers that offers both of these elements. It is light and intuitive while integrating computer-assisted design (CAD) modules such as free-form modeling, rendering, assembly, and physical simulation. And you can even use it to aid in fabrication processes like CNC milling with its computer-aided manufacturing (CAM) module.

If you want to learn Fusion 360 and are coming from a 3D-modeling environment such as Inventor, Pro-Engineer, Catia, or Solid Edge, the switch shouldn't be too painful. The biggest difference is using A360, Autodesk's cloud platform which houses and shares your designs. I like this feature, and even wonder now how I lived without it, especially when I work with a team.

Let's review the CAM module, which can export toolpaths in a variety of formats, to prepare complex designs for CNC milling.

First create a Setup, where you select the type of milling you wish to do (Fusion 360 also supports turning), specify the stock's dimensions, and place the bit's starting point.

Next, apply a different type of successive milling operation (pocket clearing, parallel, 2D contour, etc.) to clear the excess material. For each of these operations, the proper tool (bull nose mill, ball end mill, chamfer mill, etc. — learn more at makezine.com/go/endmills) needs to be selected. If your tool isn't on the list, you can create a profile in the tool library to add it. From there, you'll need to make some choices, from the height and tolerance of each pass, to the use of tabs — which keep your model in place until you manually saw it out, rather than it being carved loose and compromising its position while underway.

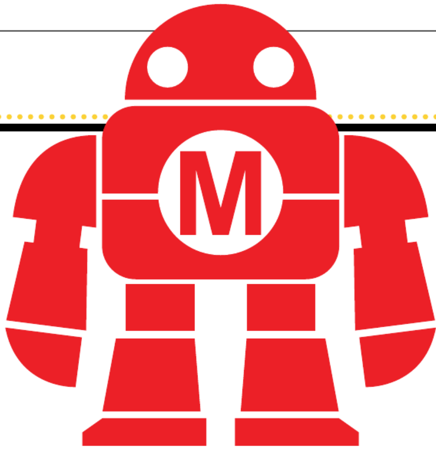
Satisfied with the simulation of the generated toolpaths? Then just send it to post-processing in a format your CNC machine will recognize.

THINGS YOU SHOULD KNOW

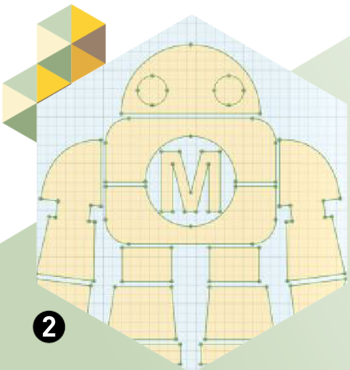
Overall, Fusion 360 gives a great "design to manufacturing" experience. Here is a simple exercise showing how I turned a vector drawing into a wooden bas-relief.

While you can easily import a large selection of 3D files directly into the Fusion 360 workspace, it is currently very difficult to use embedded mesh volumes, such as STL or OBJ with the CAM module. While tools to convert mesh into solids do exist in the software, they won't work with large or complex files. Don't despair! Mesh modeling is on the 2016 improvement schedule, but until then, it might be tricky to mill your favorite Thingiverse designs.

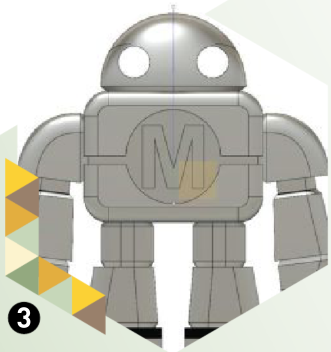
Inventables



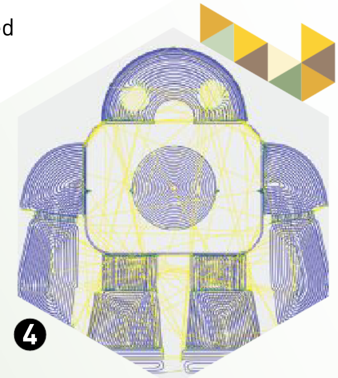
1 Fusion 360 can insert an SVG drawing as a sketch from a selected plane. Here, I used a vector drawing of our beloved Makey.



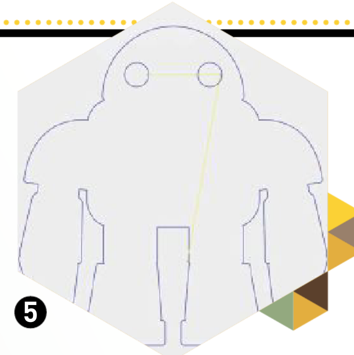
2 Before importing your vector file, create a sketch and draw a line measuring the length you would like your drawing to be. This will facilitate more accurate scaling. All closed areas will appear in clear orange, which means they can be used for 3D functions.



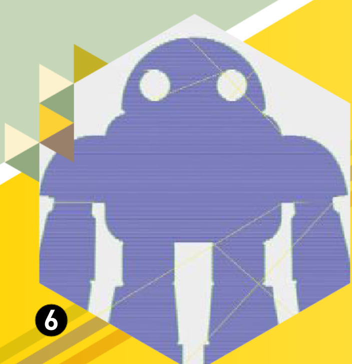
3 The modeling tools are fairly straightforward: You'll use Extrude, Revolve, Fillet, and Mirror to create this 3D Makey.



4 The first 3D toolpath generated is an Adaptive Clearing with a ⅛" flat end mill. The robot measures 6½".



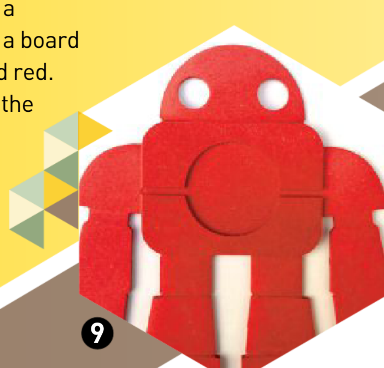
5 In this case, the second toolpath is a 2D Contour following the part's bottom outline, using the same mill as the previous action. To keep the model locked in place until the end of the milling, you can enable the Tabs and choose their shape, thickness, and position. I set mine to triangular, 3mm wide, and with a thickness of 0.75mm.



6 The last toolpath applied to finish this model is a Parallel pass using a ⅛" ball end mill. The closer the passes, the better the result, but also the longer it will take. An SBP file was exported directly from Fusion 360's Post Processing tool.

7 For this milling, I used a ShopBot Desktop with a board of Valcromat MDF dyed red. Here's the result after the Adaptive clearing.

8 After the 2D Contour and the Parallel pass, following the X axis.



9 The Makey was easily removed from the board, using the tip of a flat screwdriver to cut the Tabs.

10 A little bit of sandpaper, clear varnish to bring out the color, and a laser-cut "M" is all you need to finish this awesome MDF Makey!

Samuel Bernier

FORM WITH FOAM

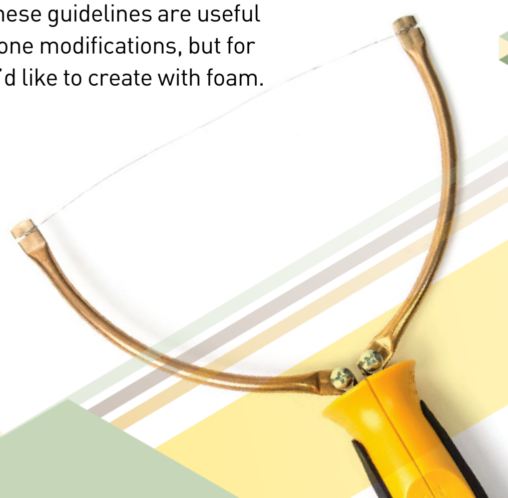
How to cut, glue, and finish styrofoam for custom creations

WRITTEN BY CALEB KRAFT

Olivier C

IN THE CUSTOM DRONE COMMUNITY, THERE ARE FUN BODY MODIFICATIONS MADE OF FOAM CALLED "FOAMIES." These are shaped, lightweight bodies that slips over your drone to give it a stylized appearance. We've seen everything from imaginative one-off aircraft to crazy recreations of ships from *Star Wars*.

To build your own foamie for your drone, you'll need to know how to cut, glue, and finish foam. These guidelines are useful not only for drone modifications, but for any forms you'd like to create with foam.



CUTTING AND SHAPING

For any custom body type, you're going to have to cut some foam. For extruded polystyrene such as the blue foam board insulation, you can cut it well with any sharp blade. Often it isn't even necessary to cut all the way through, you can simply score it and then snap along the scored line.

If you're going to cut a lot of foam, or desire to work with expanded polystyrene, you'll want to get a hot wire cutter. (Build your own at makezine.com/go/5-minute-foam-factory.) These use a bit of electricity passed through a wire to produce enough heat to cut smoothly through the foam. Cutting expanded polystyrene without one is a nightmare — the knife will rip the tiny balls loose, resulting in a jagged and messy cut.

CHOOSING A FOAM

Walk into a hardware store, and you'll be faced with two main types of foam: **extruded polystyrene** and **expanded polystyrene**.

EXPANDED POLYSTYRENE

is easy to identify because it looks like tons of tiny balls pressed together. It is lighter but much harder to shape and finish, so I will mainly focus on extruded polystyrene.

Hep Svadja

EXTRUDED POLYSTYRENE

is typically pink or blue, and comes in large sheets. It cuts easily and can be sanded and painted very well. It can be slightly heavier, but much easier to work with at home.

CALEB KRAFT has created an assortment of foam bodies for R/C cars and drones. None are pretty enough to share, but he's learned many lessons along the way.

FINISHING

After you've cut the foam to your desired shape, you can further refine things with simple sandpaper. You can get very nice results sanding extruded polystyrene with medium grit sandpaper. Start with a low grit, like a P100 to shape the body, then work your way upward to a higher grit to get the surface smoothness you want.

After your surface is reasonably smooth, you can apply a material to it for proper aesthetics and protection from bumps and bangs. While a prop builder might go at this job with Bondo or other automotive body putty, a drone customizer needs to consider weight above all else.

PEN/MARKER

Sometimes you're perfectly fine with it looking like a piece of foam. Sometimes the shapes themselves are enough to convey the custom form you want.

PAINT

A layer of paint can give the visual appeal you're after without much addition to weight. This option offers the least protection, so rough landings may leave your custom drone with some battle scars that aren't easily repairable.

A LAYER OF GLUE OR RESIN

Painting on a layer of PVA glue and letting it harden will create a shell. This won't be unbreakable armor, but will be slightly more robust than a simple layer of paint, at the expense of a tiny bit of weight. You can then paint on top of this.

GLUING

In many cases, you'll need to glue several bits to get a large enough block to start with. Sticking two pieces of foam together can be more difficult than it sounds. Do not use any glue that contains a solvent. Solvents will eat through your foam, leaving visible dents and craters. Some glues also struggle to dry when not exposed to air, which is exactly what happens when you're sticking two sheets of foam together.

Gorilla glue dries quickly and adheres foam together quite well. It expands as it dries, so expect to clean up some edges. Don't be surprised if you have big bulging yellow globs around the perimeter after a few hours.

A neat trick that has surfaced in online forums is to use a paint primer called "**Gripper**" by Glidden. It dries quickly and bonds sheets of foam together as well as any glue. The resultant bond can be sanded and cut just like normal.

No matter the method, you should apply pressure to the two pieces of foam being joined to avoid any gaps that will become visible as you cut shapes from your block.

Hep Svadja, James Burke

Time Required: A Weekend

Cost: $150–$200

Raspberry Pi Wi-Fi Party Photo Booth

Use the new Pi 3 to make a touchscreen photo booth that instantly uploads to Google Photos!

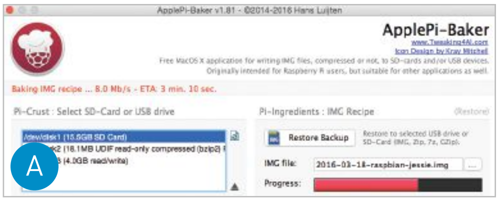
Written by Kevin Osborn and Justin Shaw (WyoLum) and Jenny Ching (*Make:* Labs)

EVERYBODY LOVES CLOWNING IN A DIGITAL PHOTO BOOTH AT PARTIES AND WEDDINGS, THEN SHARING THE PHOTOS ONLINE. But who wants to risk a laptop getting doused with margaritas or champagne?

These days, cheap single-board computers make it easy to roll your own standalone photo booth that can connect to the internet with no help from your precious PC. Here's a simple build that's based on the Raspberry Pi mini computer and Pi Camera Module. It's touchscreen-controlled by partygoers, and it automatically emails your photos (if you wish) and uploads them to Google Photos where anyone with the password can see and share. All the software is open source.

Our gang at WyoLum originally made a Raspberry Pi photo booth to write custom images for E Ink badges at the Open Hardware Summit in 2013, pairing the Pi with our popular AlaMode Arduino-compatible development board. The touchscreen display we used (also used in the "PiPad" tablet in *Make:* Volume 38, makezine.com/go/pipad) was nice, but expensive. Since then, the official Raspberry Pi Touchscreen has been released, and the new Raspberry Pi Model 3 has integrated Wi-Fi. Perfect for this project!

So we redesigned our OpenSelfie photo booth as the TouchSelfie, and tied it all together with a minimal set of mounting brackets you can 3D print (or laser-cut) to mount the whole thing on a tripod. You can also design and build your own amusing enclosure if you prefer.



BUILD YOUR TOUCHSCREEN WI-FI PHOTO BOOTH

First you'll set up the Pi with the right software, then connect all the hardware. I like to use a wireless keyboard for setup, but you can use a wired keyboard, or after initial configuration, you can use SSH.

1. CONFIGURE THE PI'S OPERATING SYSTEM

If this is your first Pi project, follow the Quick Start Guide at raspberrypi.org/help/quick-start-guide. Download the latest version of Raspbian, the official Linux operating system for Raspberry Pi, from raspberrypi.org/downloads/raspbian.

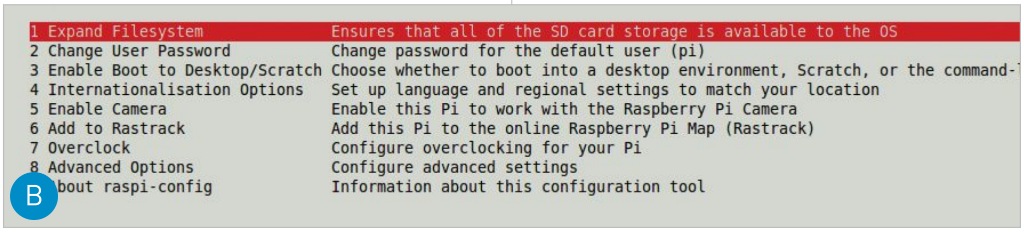
Then copy the *Raspbian-Jessie.img* file onto your SD card (Figure A), using Apple Pi Baker (Mac) or Win32DiskImager (PC).

Place the SD card in your Pi, and plug the Pi into a monitor and keyboard. Plug in your camera module too (you'll connect the touchscreen later).

Now power up the Pi, open Terminal, and run the command:

```
sudo raspi-config
```

Follow the Setup Options (Figure B) to:
a) Expand Filesystem, b) Enable Camera, c) Change User Password, and d) set your Internationalization Options (locale/time zone). Now reboot the Pi.



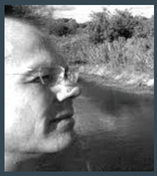
Materials

- **Raspberry Pi 3 single-board computer** with microSD Card. If you use an older model you'll need to add a Wi-Fi dongle.
- **Raspberry Pi Camera Module** v2 (8MP) or v1 (5MP)
- **Raspberry Pi Touch Display, 7"** with included standoffs, screws, and jumper wires
- **Micro-USB power supply** like a wall phone charger or battery pack — providing at least 2A at 5V for the Pi 3, or 700mA at 5V for earlier, lower-powered Pi models.
- **Machine screws, M2.5: 10mm (2), 6mm (2)** for the tripod mount. Substitute two 14mm and two 16mm if you make the tabletop mount.
- **Machine screws, M2×6mm (4)** for mounting the camera. You could also use double-sided foam tape, or M1.5×8mm screws with nuts.
- **Mounting brackets and/or enclosure (optional)** You can 3D print our desktop stand or tripod stand, and print or laser-cut our camera mount; get the files at github.com/wyolum/TouchSelfie/tree/master/fabricate. Or mount the project your own way in an enclosure of your choice.
- **Hex nut, ¼-20 (optional)** for the 3D-printed tripod stand. For bigger enclosures, try a speaker tripod mounting bracket like Yamaha #ADP138.

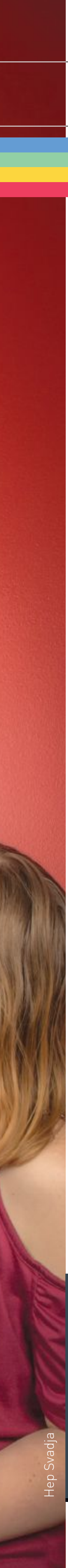
Tools

- **Computer with internet connection** for initial setup of the Raspberry Pi. You'll also need free software to flash the SD card: ApplePiBaker for Macs (tweaking4all.com/software/macosx-software/macosx-apple-pi-baker) or Win32DiskImager for PCs (sourceforge.net/projects/win32diskimager).
- **Monitor, keyboard, and mouse** for setup only. Once the project's done, you can operate it using just the touchscreen.
- **3D printer or laser cutter (optional)** if you're making our custom brackets


KEVIN OSBORN lives in Boston, Massachusetts. He started messing around with computers when they were still in big buildings and soon after college was making office appliances, video games, and enterprise software. He builds prototypes by day, and spends his nights creating open source electronics.


JUSTIN SHAW co-founded WyoLum and now lives in Washington, DC. His training is in mathematics but lately he's been enamored with interacting with the "real world." After experimenting with BASIC Stamp and PIC microcontrollers, he came across the Arduino platform and has never looked back.


JENNY CHING studied at Loyola Marymount University where she got her bachelor's in mechanical engineering and minor in Chinese (Mandarin). She is passionate about designing and building, and loves spending time working in the wood shop with her dad. jenniferching.weebly.com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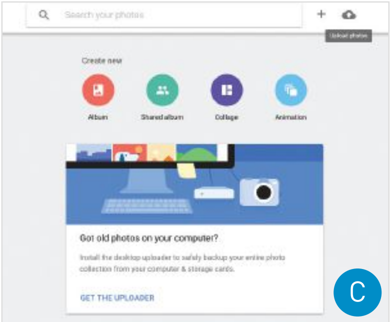
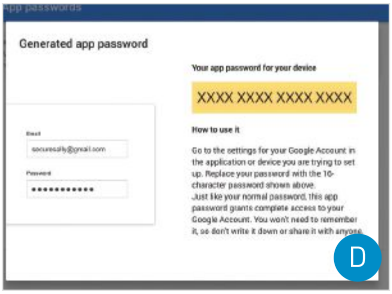
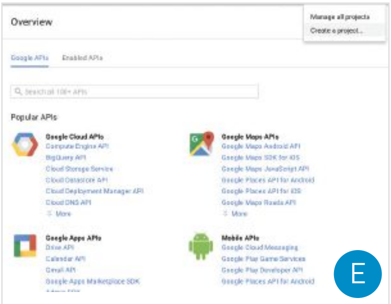
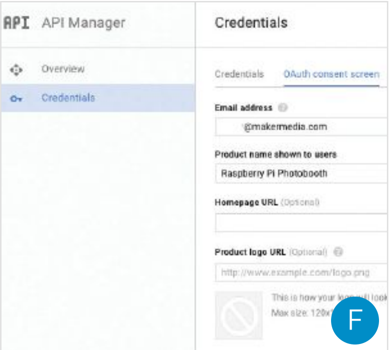
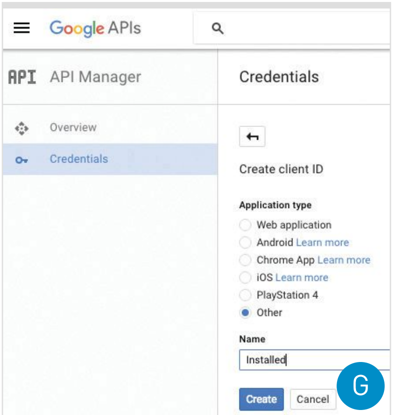










2. INSTALL THE REQUIRED PLATFORMS ON THE PI

Connect the Pi to your network (Wi-Fi or Ethernet) and type the following commands:

```
sudo apt-get update
sudo apt-get install python-imaging
sudo apt-get install python-gdata
sudo apt-get install python-imaging-
tk
sudo pip install --upgrade google-
api-python-client
sudo apt-get install luakit
sudo update-alternatives --config
x-www-browser
```

This will provide you with a menu of browsers to pick as the default; set it to `luakit`.

NOTE: We're using luakit because Raspbian's default browser doesn't work with Google 2-part authentication.

3. DOWNLOAD THE TOUCHSELFIE SCRIPTS

Still in Terminal, run:

```
mkdir git
cd git
git clone https://github.com/wyolum/
TouchSelfie
```

NOTE: Be sure that for the following steps you're continuing to use the web browser on your Raspberry Pi / monitor setup.

4. SET UP YOUR GOOGLE PHOTOS ALBUM

Go to google.com and create a Google account (or use your own account if you have one already). Then go to photos.google.com and create a new Album. You'll have to upload at least one photo to create it (Figure C).

5. GET AN APP-SPECIFIC PASSWORD

Visit myaccount.google.com/security and enable 2-Step Verification. Then return to the same page and click on "App passwords" to generate a 16-character application password (Figure D). Write it down in a safe place. You'll use it later to connect your photo booth to Google Photos.

NOTE: If you lose the app password or forget it, don't worry; you'll just have to generate a new one.

6. CREATE API KEYS WITH GOOGLE DEVELOPER

While logged in to your account, visit console.developers.google.com. Click on Select a project → Create a project, and name it whatever you'd like (Figure E).

While your new project is selected, click on Credentials on the left menu, and then select the "OAuth consent screen" tab. You'll need to create a "Product name shown to users," which can be anything you'd like (Figure F).

Now select the Credentials tab, select "OAuth client ID," and click the "Create credentials" pulldown. Select "Other" for Application type, name it "Installed," and click Create (Figure G).

NOTE: You don't have to explicitly enable any additional APIs; here you're dealing with basic authentication and authorization which is used by every API, and the photo APIs haven't been explicitly added to the console.

Now you'll be able to see it in your list of credentials for this app. Select the "Installed" credential. Click the Download JSON button, and a file named something like *client_secret_903284092384092 38xxxxx.json* should download to your computer (Figure H).

Once it's completed downloading, rename the file *OpenSelfie.json* (Figure I), then drag and drop it into the */home/pi/git/TouchSelfie/scripts* directory.

7. CONNECT TOUCHSELFIE TO GOOGLE PHOTOS

If you haven't already, connect the camera board to the Pi. Power up the Pi, open Terminal, and run:

```
cd /home/pi/git/TouchSelfie/scripts
python ./photobooth_gui.py
```

Since this is your first time running the photo booth interface (GUI), it doesn't yet have the proper credentials to connect to your Google account. Your web browser will pop up; sign in to Google (with the same email address and password you used to configure everything in the previous steps), and then it will ask you whether your Pi photo booth can manipulate your photos (Figure J).

Click on Allow, and then it will display a long string of numbers and letters. Copy this string and paste it into the Terminal window after the prompt that says "Enter the Authentication Code" (Figure K). Hit Enter, and if all is well your photo booth will snap a photo and upload it to the album you have previously configured! (Or fail if you haven't set it yet.)

An Album ID error will pop up, indicating that you have not yet selected an album in your Google photos account to send your photos to. Open another terminal window on the Pi and run:

```
cd /home/pi/git/TouchSelfie/scripts
python ./listalbums.py
```

Copy (or write down) the ID number of the album that you want to use.

In the */home/pi/git/TouchSelfie/scripts* folder, open up the *openselfie.conf* file. Here you will be able to enter the album ID number: `albumid = XXXXXXXXXX` (Figure L). You can also use the configuration dialog from the main screen of the photo booth GUI.

Fortunately, you only have to do this once! After this it will remember the credentials and periodically refresh them. The cached credentials are stored in a file called *credentials.dat*, so if you delete it, you'll have to do the web dance again, as long as your JSON file is still there.

TROUBLESHOOTING TIPS

If you get an error that says "cannot connect to Google Account," it's probably because Google periodically invalidates the credentials. To refresh them, try the following:

- Double-check that you're connected to the internet
- Remove the file *credentials.dat* from the *scripts* file folder
- Run: `cd /home/pi/git/TouchSelfie/scripts`
- Run: `python ./photobooth_gui.py`
- Allow access to Google Photos
- Re-enter credentials in Terminal window

8. CUSTOMIZE MESSAGES AND LOGOS

While you're still in *openselfie.conf* (or the GUI configuration screen) you can also create a customized message for your event. Just edit the text shown in italics here:

```
emailsubject = Subject line of your email
emailmsg = Message that accompanies email
photo caption = Photo caption on Google Photos account
logopng = logo.png
albumid = XXXXXXXXXX
```

To customize the logo that's stamped on each photo, just save a new PNG file (1366×235 pixels, with transparency if you wish) in the folder */pi/git/TouchSelfie/scripts*. Then run the photo booth again (*photobooth_gui.py*) and click the Customize button. In the pop-up window, next to "Logo File" click the Browse button. Select your file, and click Open. You should see a preview of your new logo. When you're done, click Done (Figure M).

9. ENABLE FULLSCREEN AND TOUCHSCREEN KEYBOARD

Reopen the *photobooth_gui.py* file and remove the # symbol from the beginning of the line `#root.attributes("-fullscreen",True)`. Now the photo booth interface can run fullscreen on the Touch Display.

Once you connect your Pi 3 to the touchscreen, you won't want to be lugging around your USB keyboard to type commands. To install a touchscreen keyboard on your Pi, follow the step-by-step instructions by ModMyPi at makezine.com/go/matchbox-keyboard.

10. MAKE THE MOUNTING BRACKETS (OPTIONAL)

We created simple brackets you can 3D print for standing your photo booth on a tabletop or mounting it on a standard tripod (Figure N, following page). You can also laser-cut the camera mount from 1⁄16" acrylic if you prefer that look, but the 3D-printed version seems to hold up longer. Download the files from github.com/wyolum/TouchSelfie/tree/master/fabricate.

- **Tabletop mount** Print the files *camera_mount.stl* and *PiTouchScreenStand.stl*. This requires using two M2.5×14mm and two M2.5×16mm screws.
- **Tripod mount** Jenny Ching at *Make:* created an updated version of our tripod mount that's a great improvement. Print the files *PiTouchScreenMount.stl* and *PiCameraMount.stl*. and use 10mm and 6mm M2.5 screws instead.

11. ASSEMBLE YOUR PHOTO BOOTH

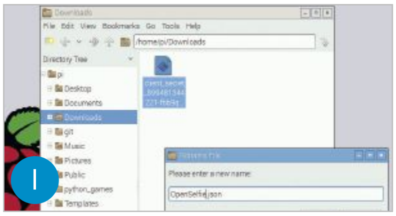
Fasten the Pi 3 and the Touch Display together using the included screws and standoffs. Connect the touchscreen's ribbon cable to the Pi headers marked "Display." Use a red jumper wire to connect the touchscreen's 5V pin to the Pi's GPIO pin 2. Use a black wire to connect touchscreen GND to Pi GPIO pin 6 (Figures O and P).

Thread the camera's ribbon cable through the slot in the camera mount. Plug it into the camera, and affix the camera to the mount with the M2 screws (Figures Q and R) or double-stick tape. Plug the camera cable into the Pi (Figure S).

Fasten the tripod stand to the touchscreen with M2.5×6mm screws (Figure T) through the 2 bottom holes. Then fasten the camera mount

TIP: If you use tape, be sure to connect the cable first; at the *Make:* Labs our tape sometimes interfered with detecting the camera.

H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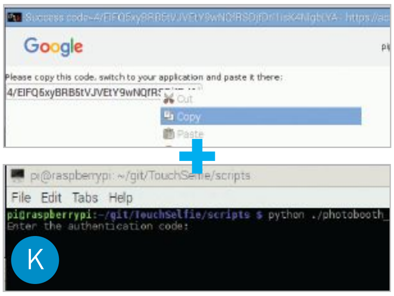

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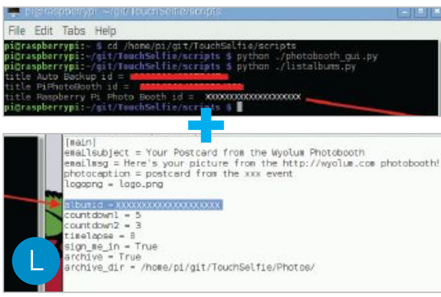
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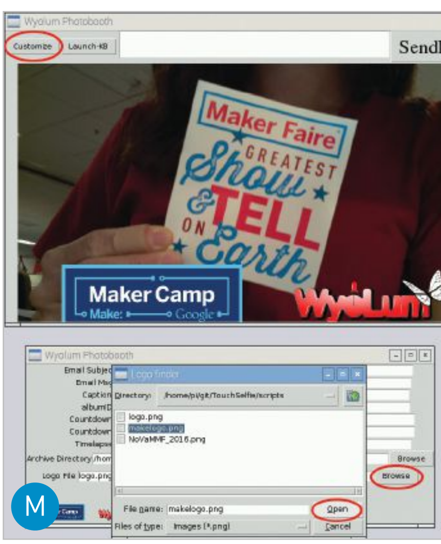

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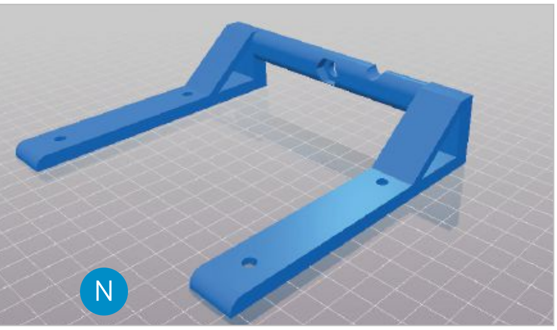
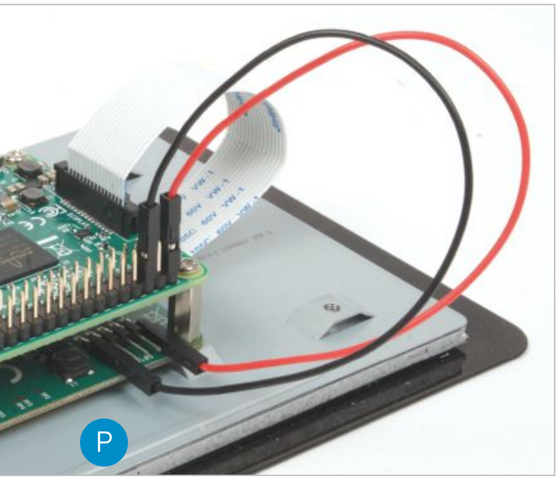
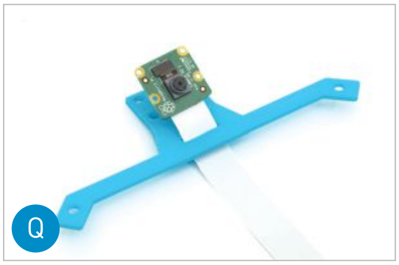
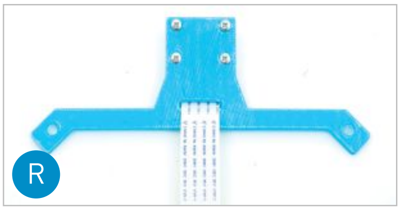
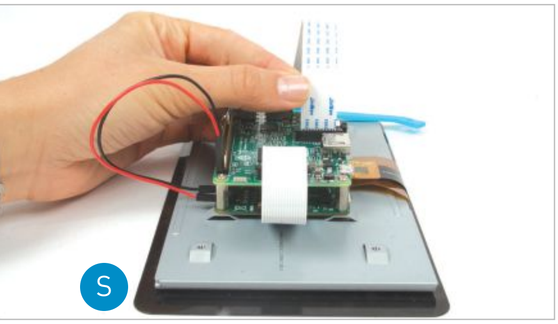
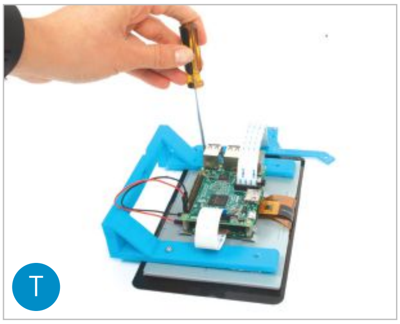


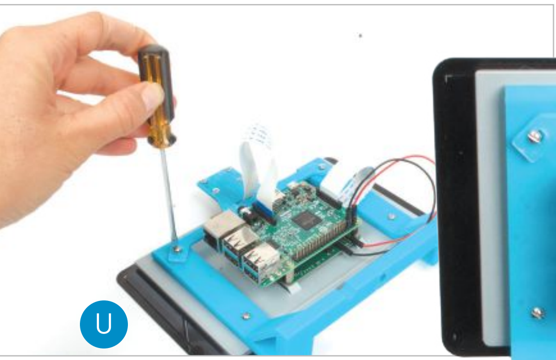


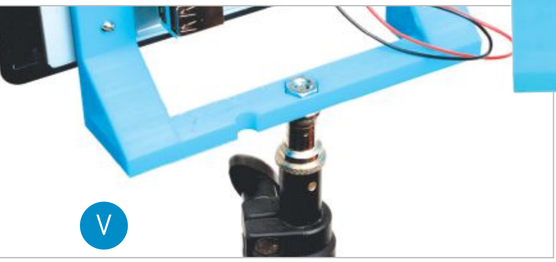


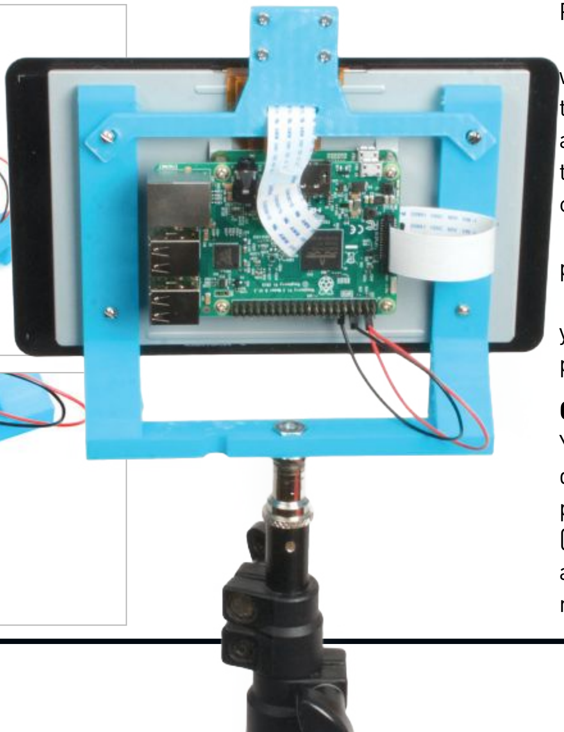












using M2.5×10mm screws through the top holes in the stand (Figure U).

Next, press-fit the ¼-20 hex nut tightly into the stand's base and mount it to any standard camera tripod (Figure V).

Finally, connect the Pi 3 to the wall charger or a portable battery pack using the Micro-USB cable. Your photo booth is complete!

NOTE: The portable battery must be able to output 2A at 5V to power both the touchscreen and Pi. It should also be rated at least 10,000mAh to last through a long party or event.

STRIKE A POSE

Your Raspberry Pi Photo Booth is ready for all manner of festivities. Here's how to use it.

START UP

Open Terminal and run:

```
cd /home/pi/git/TouchSelfie/scripts
python ./photobooth_gui.py
```

When the photo booth launches, it will automatically take a photo and upload to Google Photos, to check that everything's working. (If not, you probably just need to refresh the credentials — see "Troubleshooting Tips" page 59.)

TAKE AND SEND PHOTOS

To take a photo, tap the touchscreen anywhere on the image. The photo booth will count down from 5 and then snap the picture (Figure W). Then it will automatically upload the photo to Google Photos on your Google account (Figure X).

If you want to email the photo too, touch the white box next to the Send Email button. The touchscreen keyboard will pop up. Enter an email address, press the Close KB button to close out of the keyboard, then press Send Email to send the current photo to that address (Figure Y).

Touch the screen again to initiate the next photo. And so on.

When your party is all said and done, log into your Google account and view all your party photos in Google Photos!

CUSTOMIZE MESSAGES

You can also edit the *photobooth_gui.py* script to display different on-screen messages during your party. For example, we uncommented line 165 (remove the # symbol from `#can.create_text`) and edited it to prompt users "Tap here when ready" — but this could say anything you like!

Jenny Ching

Hep Svadja

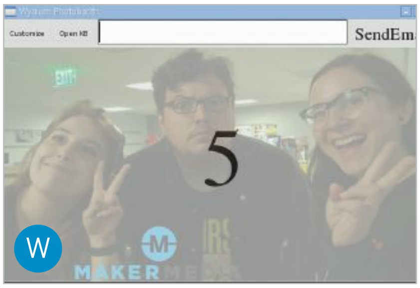
BUILD YOUR OWN ENCLOSURE

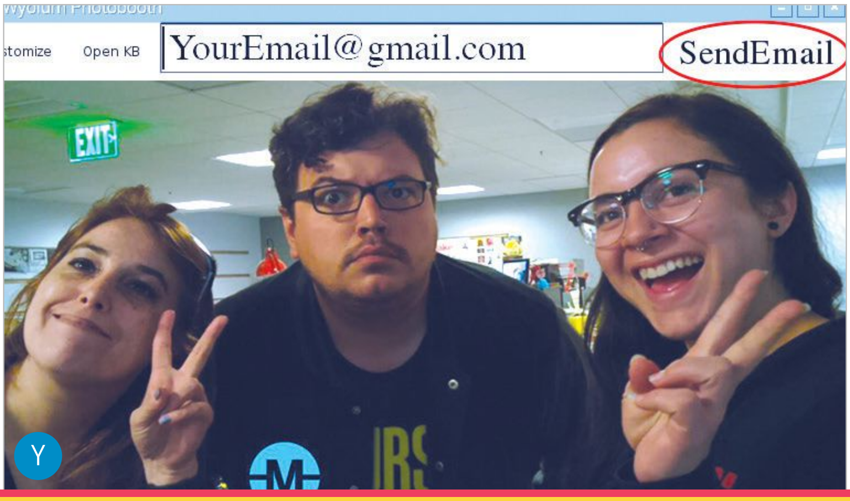
Our 3D-printed mounts are very handy, but you might prefer to build a fun enclosure to house your new Raspberry Pi photo booth! To help you design it, you can grab dimension drawings of the Touch Display and the Camera Module on the project page at makezine.com/go/raspberry-pi-3-photo-booth. Jenny Ching at the *Make:* Labs built an awesome jumbo SLR-style enclosure for our photo booth, using ¼" plywood and round gift boxes from The Container Store.

MORE FUN ENHANCEMENTS

Of course you'll want to have props and masks handy, but why not take it further? You could add your own lighting effects, modify the code to take multiple pictures in a row, or even add face detection. We're excited to see where you'll take this project.

See more photos, screenshots, and diagrams, and share your build at makezine.com/go/raspberry-pi-3-photo-booth.





Monster Detector

Build a (pretend) bedtime scanner to repel creepy critters — so easy a kid can operate it

Written by James Floyd Kelly and Chris Jones

JAMES FLOYD KELLY is a technology writer and maker living in Atlanta with his wife and two sons. In summer he teaches tech camps for kids.

CHRIS JONES is a software engineer in San Francisco, who likes chess, cats, and code.

Time Required:
2–4 Hours
Cost:
$30–$40

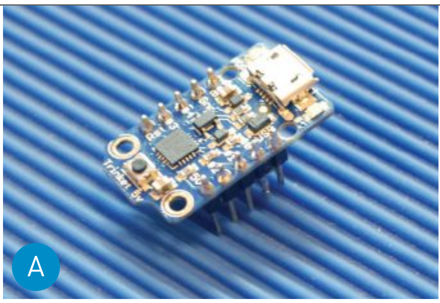
Materials

- **Trinket microcontroller board, 5V version** Adafruit Industries #1501, adafruit.com
- **NeoPixel Ring, 16 LED** Adafruit #1463
- **Plastic project box, approx. 3"W ×6"L × 2"H** or make your own enclosure
- **Switch, momentary pushbutton (normally open)** A big red one for little hands.
- **Battery box, 3xAAA** Adafruit #727
- **Batteries, AAA (3)**
- **Hookup wire, or female jumper wires (6) with male headers (11)** such as Schmartboard #920-0007-01, schmartboard.com
- **Velcro tape or double-sided tape**
- **Heat-shrink tubing or electrical tape (optional)**
- **3D-printed shell for NeoPixel ring (optional)** Download the free STL file for printing at makezine.com/go/monster-detector.

Tools

- **Computer with internet connection and Arduino IDE software** free from arduino.cc/downloads
- **Soldering iron**
- **Wire cutter/stripper**
- **Drill or drill press**
- **Drill bits: ¼" and ½"**
- **Solderless breadboard (optional)**
- **3D printer (optional)**

Hep Svadja, Brandon Steen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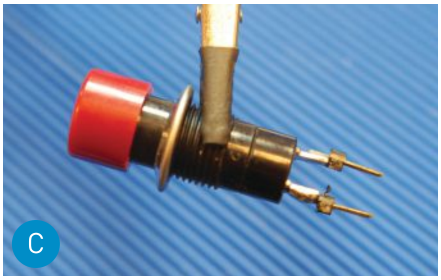
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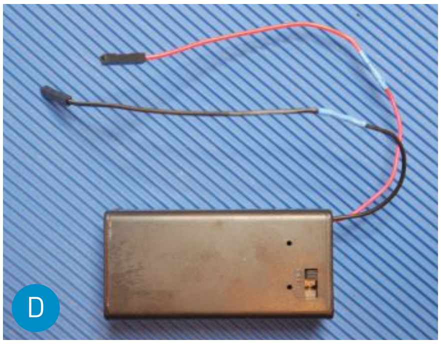
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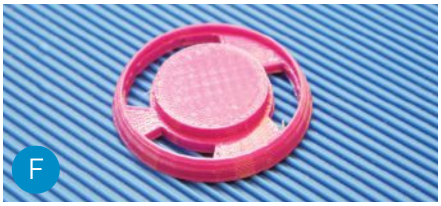
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NOTE: If you don't have access to a 3D printer, services such as ponoko.com, i.materialize.com, and shapeways.com will print the shell for you and ship it to you for a fee.

Anthony Lam

DO YOU HAVE A CHILD WHO WORRIES ABOUT LURKING BEASTS IN HIS OR HER BEDROOM? Are you weary of inspecting closets for fanged creatures? Are your knees sore from examining beneath the bed for clawed critters?

If so, then the Monster-B-Gone is just the solution you need to confirm a fiend-free room for your youngster. Even better, it's easy for kids to operate, requiring no adult supervision.

Just push the button — the swirling blue lights let your child know a scan of the surroundings is taking place. Of course, the blue light combines with a beyond-human-hearing ultrasonic wave (um, yeah, that's it), unpleasant to any monster's eyes, ears, or antennae. So any monsters within, say, half a mile (800 meters) will immediately disperse and return to their places of origin. When the light turns green, the room is clean.

If you so choose, the Monster Detector will occasionally detect a monster — red alert! — but a subsequent scan will green-light the room again. Whew. Children, sleep tight.

BUILD YOUR MONSTER-B-GONE

The Monster-B-Gone is easy to assemble in a couple of hours, and costs less than $40. Basic soldering skills are required; an understanding of simple circuits and basic electronics is useful, but not necessary if the steps are carefully followed. A drill press or handheld electric drill is needed for part of the assembly.

The NeoPixel LED ring used in this project can be mounted directly on the top of the project box, or you can 3D-print an optional shell for the LED ring. Holes will still need to be drilled through the top, but the shell gives the project a more finished look.

Most of the project's parts can be purchased from any local electronics supply store, but a few will need to be ordered online. You'll also need an internet connection to download the free software used for the Monster-B-Gone's microcontroller (an Adafruit Trinket), and the Monster-B-Gone logo if an adhesive sticker is desired.

1. PREPARE ELECTRONIC COMPONENTS

For easier assembly and disassembly, I typically use a combination of headers and female jumper wires to connect all electronics components. The flexible jumper wires can easily be inserted onto the headers and pulled off during programming and testing. For this reason, the first task I recommend is adding headers to the Trinket, the NeoPixel Ring, and the pushbutton.

The 3xAAA battery box also needs its V+ and GND wires cut and trimmed. You can just solder these trimmed wires directly to their desired locations, but I prefer to add female jumper wire ends onto these exposed wires to make them plug-able too.

The Trinket comes with its own set of headers. Figure A shows the Trinket sitting on top of 10 non-soldered headers. To solder them, I used a small breadboard to hold the headers so the Trinket could be aligned on top.

Next, add 3 headers to the NeoPixel Ring (Figure B) at the following locations (they're labeled on the backside): Power 5V DC, Power Signal Ground, and Data Input.

Soldering headers to the pushbutton and the battery box wires isn't required, but I really find them easier to work with during the wiring stage; Figure C shows 2 male headers soldered onto the 2 legs of the pushbutton. Figure D shows the battery wires with female jumpers soldered on. I used some shrink tubing to cover up the solder joint, but electrical tape will work just as well.

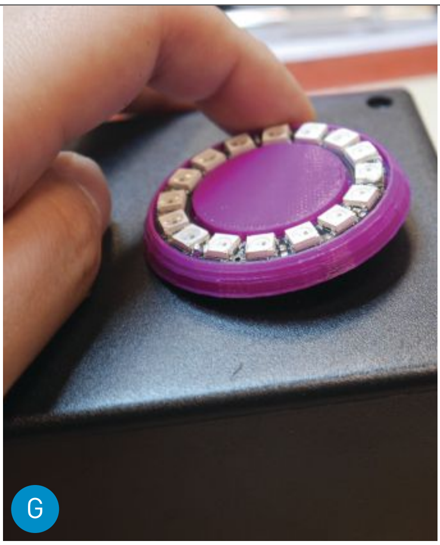
Finally, add a glob of solder to two 3-pin headers to short them (Figure E). These are used to create shared connections for 5V and GND that are needed for both the NeoPixel Ring and the Trinket, as well as a method for plugging the pushbutton into the circuit. You can wrap the solder glob in electrical tape, but leave the longer pins exposed for connecting the jumper wires.

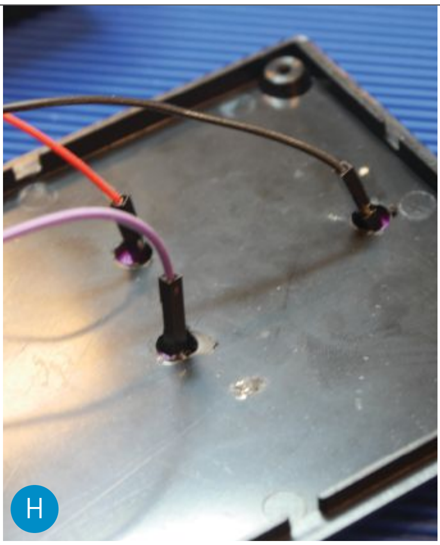
2. 3D-PRINT THE NEOPIXEL SHELL (OPTIONAL)

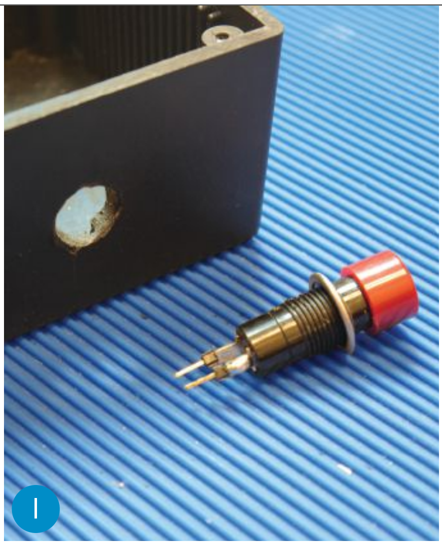
If you have access to a 3D printer, you can print out the mounting shell for the NeoPixel Ring. Download the STL file for the shell from the project page at makezine.com/go/monster-detector. Figure F shows the shell printed in purple.

3. PREPARE THE PROJECT BOX

You'll need to drill a few holes in the project box. Carefully place the NeoPixel Ring (with







headers) on the project box lid and make 3 small marks where the headers touch the lid. Drill a ¼" hole at each mark, then test-fit the NeoPixel Ring (and shell, if you're using it) and ensure the headers fit into the drilled holes (Figures G and H).

If the headers can be reached from beneath the lid, glue the shell to the project box lid and set the NeoPixel Ring aside until final assembly. (If the headers can't be reached, you may need to drill the holes a little larger.)

Next, decide where to place your pushbutton. I drilled a ½" hole in the left side of the project box (Figure I), but it could easily be mounted on the box lid beneath the location of the NeoPixel Ring.

4. PROGRAM THE TRINKET

To program your Trinket, first you must install the latest Arduino development environment (IDE), version 1.6.9 at the time of this writing, and update it to recognize the Trinket. Adafruit has detailed instructions for this task at learn.adafruit.com/introducing-trinket/introduction. Be sure to follow those steps related to your specific operating system (Mac or Windows); Windows users will also need to download special Trinket drivers.

Once you've got your Trinket blinking using the Flash test program, you're in good shape. All you need to do now is replace the Flash sketch (program) with the modified Monster-B-Gone sketch. Download the file *MonsterBGone.ino* from the project page at makezine.com/go/monster-detector, open it in the Arduino IDE, then hit the Upload button to load it onto the Trinket.

5. ASSEMBLY

Before you assemble the Monster-B-Gone in the project box, I highly recommend wiring everything up outside the box and testing first. Pay careful attention to the wiring; one misplaced wire could result in a damaged Trinket or NeoPixel LED, so double-check all your connections against the wiring diagram (Figure J).

Once everything is wired up, flip the battery box switch to the On position (after inserting the batteries, of course) and press and hold the pushbutton (it takes a few seconds for the Trinket to boot up). You should see a short animation of spinning blue lights, followed by the all-green "coast is clear" lights.

If you're not seeing any animation, you'll want to check all your wiring again. If the Trinket is powering up (a solid green-yellow LED stays lit when it's powered) but the NeoPixel animation isn't playing, you've likely got a wire connected to the Trinket incorrectly. Verify the Data Input header on the NeoPixel Ring is connected to pin 0 on the Trinket. If you're still not seeing any animation, verify you've uploaded the MonsterBGone sketch to the Trinket.

Once you've got the animation playing on the NeoPixel Ring, it's time to pull everything apart and reassemble inside the project box (Figure K). Wire everything up as before and use velcro or double-sided tape to secure the battery box inside the project box. You might also want to use a dab of hot glue (in place of tape) to secure the Trinket to one of the inner walls as well. Use the project box's screws to secure the lid in place.

6. FINISHING TOUCHES

I created my own graphics for the top and sides and had a local print shop print them for me on a vinyl sticker sheet. Then *Make:* illustrator Brandon Steen came up with the awesome purple monster design you see here. You can download the monster graphic from the project page at makezine.com/go/monster-detector.

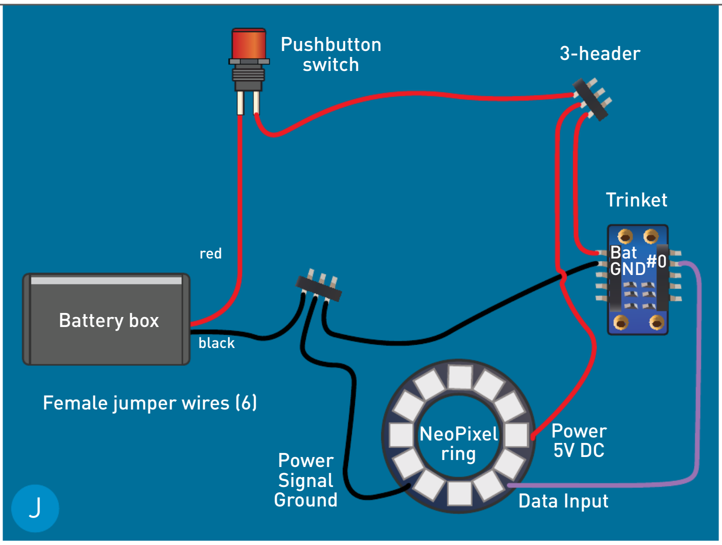
UPGRADES

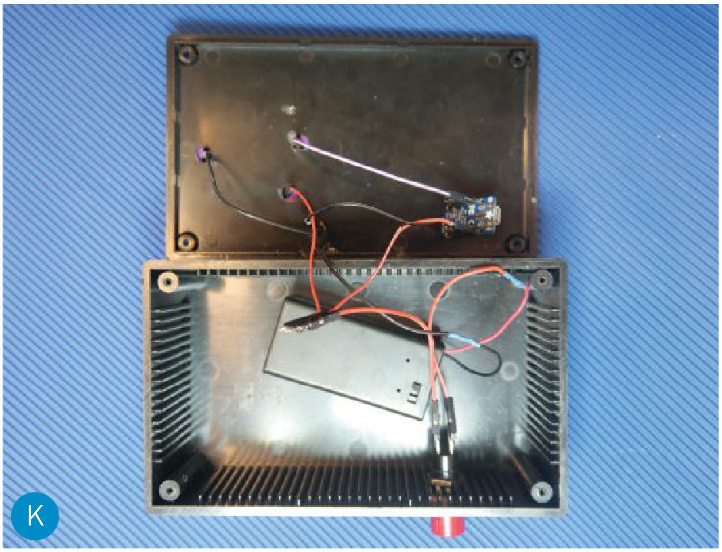
Where to go from here? An obvious choice would be to add a **sound effect**. One easy way would be to use an inexpensive sound recording module (such as RadioShack #2761323). Drill some tiny holes in the project box, hot-glue the speaker in place, and wire the module's Play button directly to the Monster-B-Gone pushbutton so it triggers your sound effect.

And I've always liked the **moving arms** on the "P.K.E. Meter" in the movie *Ghostbusters* — a couple small servos could be easily added, one per side, with holes drilled into the project box for the shafts. Create an eye-catching "antenna" for each motor and you've got sound, lights, and motion.

I hope you like the Monster-B-Gone. Even better, I hope some children will find peace at night when their parents introduce them to this useful device. Imagination is a powerful thing, and giving a child a tool (and letting them help you make it!) to help combat an imaginary monster can turn a parent into an instant hero. Have fun!

Download the project code, optional 3D file, and graphics, and share your build at makezine.com/go/monster-detector.





Brandon Steen

CUSTOMIZE YOUR MONSTER SCAN ANIMATION!

The Monster-B-Gone sketch is a modified version of the Kaleidoscope Goggles sketch created by Adafruit. You can easily open the sketch in the Arduino IDE and experiment with different colors, patterns, and timing! To adjust the behavior of the LEDs, just change the following values, found near the top of the source code, then upload your new version to the Trinket.

Scan Time

By default, the "searching" spinner will be blue for a random duration between 5 and 8 seconds, then will always change to solid green. Lines 11 and 12 can be adjusted to make this duration longer or shorter. Setting these to the same value will effectively fix the duration.

```
11: #define MIN_SEARCH    5   // min possible
search animation (secs)
12: #define MAX_SEARCH    8   // max possible
search animation (secs)
```

Finding Monsters!

Line 13 sets the probability of "finding monsters," which will cause a bright, solid red instead of green when the animation finishes. To avoid terrifying children, this is set to a default of `0`. Setting it to `50` would cause monsters to be found half the time.

```
13: #define MONSTER_PCT  0   // chance of finding
monsters (percent [0-100])
```

Customize Colors

Lines 15 through 17 define the colors for each state. These are RGB hex values similar to HTML/web colors, but do note that the order is GRB (green-red-blue), so `0xff0000` is green rather than red. You can find HTML color tables online and experiment with customizing all 3 colors.

```
15: #define COLOR_SEARCH 0x0000ff   // color of
search spinner (GGRRBB hex)
16: #define COLOR_OKAY   0xff0000   // color
indicating NO MONSTERS (GGRRBB hex)
17: #define COLOR_NOTOK  0x00ff00   // color
indicating MONSTER FOUND (GGRRBB hex)
```

Spinner Animation

Lines 19 through 21 adjust various aspects of the spinner such as its rotational speed and how long the "taper" of the spinner extends across the ring. Note that the speed values here are in milliseconds, so 1000 would be one second. Fool around with these for your own custom animation style.

```
19: #define SPIN_SPEED   128   // search
animation speed (ms)
20: #define SPIN_DELAY   20    // timing delay
(ms)
21: #define TAIL_LENGTH  33    // length of tail
of total ring (percent [0-100])
```

—Chris Jones

NOAH FEEHAN (aka AKA) makes stuff with hardware, software, and spaces. He lives and works in Brooklyn, New York, with his lovely wife and pet dog.

CNC an Inductive Phone Charger

Written by Noah Feehan

Design and mill an elegant charging block for your Qi-compatible device

Time Required: 4-6 Hours
Cost: $25-$45

Materials

- **Hardwood, approximately 7"×4"×1"** such as walnut or mahogany
- **Wireless charging transmitter, Qi Standard, PCBA** such as Adafruit #2162 or Deal Extreme #298892. *PCBA* just means it's a bare circuit board ready to be built into your project.
- **Wood finish** I like mineral oil because it's nonconductive and easy to renew.

Tools

- **Ruler**
- **Calipers** inexpensive, with depth measurement
- **CNC mill, with hold-down bolts or clamps** If you use bolts, you'll also need a drill to make bolt-holes in your workpiece.
- **End mill, ⅛", flat nose** I use a 4-flute end mill, which gives a slightly better finish.
- **Handsaw**
- **Soldering iron**
- **Sandpaper, fine** I used 320 grit.
- **Hot glue gun**
- **Computer, with CAM and G-code software** This project is very basic, so you can use most any CAM you like. I find CamBam to be a great balance of ease-of-use and depth-of-control. And I use the excellent, open-source, free Universal G-code Sender.

Hep Svadja

I MADE THIS LITTLE INDUCTIVE CHARGER FOR MY QI-COMPATIBLE PHONE in a few hours using basic tools and a mini CNC mill. Not having to plug and unplug my phone every time I get to work, or go to bed, is delightfully convenient!

This project is ideal for honing your skills if you're just starting out with your CNC mill. It gets even easier the second and third times you try it, and these chargers make great gifts — beautiful, unusual, and useful. Here's an overview; you'll find complete instructions online at makezine.com/go/cnc-qi-phone-charger.

1. DESIGN YOUR CHARGER

Carefully measure your wood (at its thickest point), phone, Qi coil, and PCB to make sure they'll all fit. Input the dimensions into your CAM program.

2. FACE THE WOOD

First is a *facing* operation: mill 0.25mm off the top and bottom surfaces of your workpiece. Repeat if necessary to get level, smooth faces.

3. MILL THE POCKETS

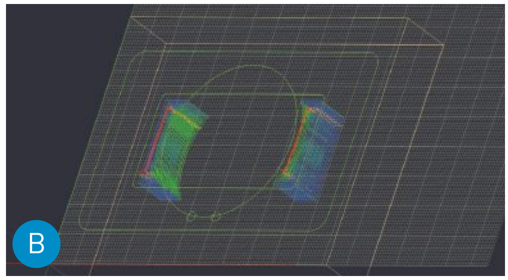
Next come the *pocket* cuts — removing material inside an outline (Figure A). For the coil pocket, calculate the center of your workpiece in the CAM program and place a circle slightly larger than the coil, plus 2 tiny circles overlapping it, to accommodate the wires.

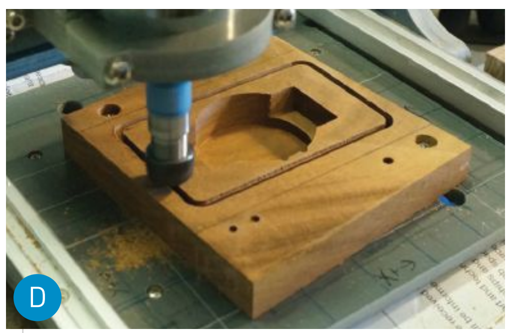
The board pocket overlaps the coil pocket, but I didn't want to waste time cutting air. So I used the Break at Intersections function to select only the polylines that comprised the actual material I'd need to remove on either side of the coil pocket (Figure B). Finally, mill the pocket for the USB port.

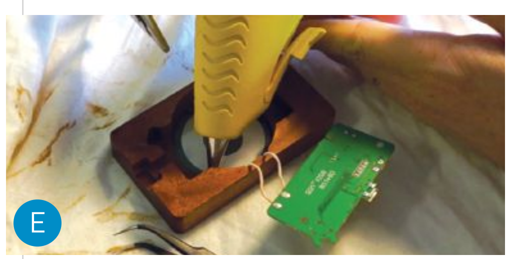
4. PROFILE FOR FIT

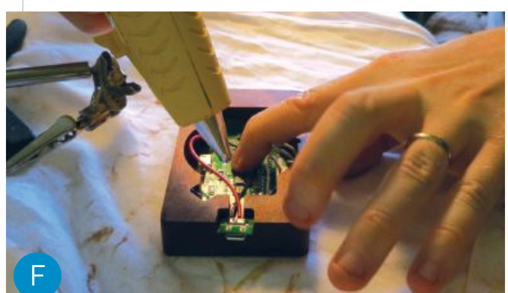
Test-fit the components. If they're a bit snug, create a new outline by joining the perimeters of all your pockets. Then use the *profile* operation — cutting on an outline — and set a "roughing clearance" or "offset" (I used –0.1mm) to mill all around the inside of the cavity and smooth rough edges (Figure C).

Noah Feehan









5. PART AND REMOVE PIECE

Finally, select the polyline that defines the boundary of your charger and "part off" the entire piece with another profile cut (Figure D). I use the feature that creates perimeter tabs to keep the piece in place during this operation, then I finish up by cutting the tabs manually.

6. SAND AND OIL

Sand the edges, wipe clean, then soak a clean rag in mineral oil and gently wipe it into all visible surfaces and leave it to soak in. Mineral oil is nonconductive, so you can oil the board side too.

7. INSTALL THE COIL AND BOARD

Place the coil into the cavity, with the gray ferromagnetic side facing you, and route the wires up through the channels you milled. Gently press the coil flat and run a bead of hot glue around the edge (Figure E).

Next, re-solder the coil wires to the charging board, and then glue the board in place.

Finally, plug a cable into the USB connector (to keep glue out), then glue the connector in place. Press the wires flat into the channel, glue them in place (Figure F), and re-solder these wires to the board too.

8. CHARGE UP

Plug the USB cable into power, and place a phone on top. If you see the "charging" animation on your phone, congratulations — you're done!

GOING FURTHER

Once you've modeled this project in your CAM of choice, it's easy to experiment with different woods, different shapes, making the charging LEDs visible, and so on.

And if you make a really cool one, I'd love to see a picture of it — please let me know in the comments on the project page online!

Get the complete how-to instructions, including detailed CAM tips, and share your build on the project page at makezine.com/go/cnc-qi-phone-charger.

Shiny Globes of Mud

Written by Jason Arnold

JASON ARNOLD lives in California with his wife and four daughters, and he's set to graduate nursing school this year. When not studying, Jason can be found modifying or building something for his gaming or home theater setup.

Make the mysterious *hikaru dorodango* that has Japanese schoolchildren crazy for dirt

Bruce Gardner is the artist who created the dorodango in this photograph. This project is based on a process he developed and documented on his website: dorodango.com

EVERYONE ENJOYED PLAYING IN THE MUD AS KIDS, RIGHT? Well, that's what you get to do with *hikaru dorodango* ("shining mud ball" in Japanese). Except that instead of washing the mud away, you create something beautiful and unique with it — an earthen sphere that can be polished to an amazingly high shine. You may also form a surprisingly strong affection for your artwork despite its mundane origins.

Professor Fumio Kayo of the Kyoto University of Education has published an easy method that anyone can follow. He used dorodango to study children's developmental psychology, and found that they would become attached to their mud and put tremendous effort into shaping and polishing their dorodango.

1. MAKE YOUR MUD

Choose dirt that's free of rocks and twigs. Different textures or colors can create a very different final product. Mix your dirt with a little water in a clean bucket until you create mud about the consistency of dough.

Amelia Milazzo

2. FORM YOUR CORE

Take a handful of mud and jostle, roll, and gently shake it to bring water to the surface as you shape it into a smooth, round core with a diameter of roughly 4" (Figure A). Fix any protrusions or depressions, or they will affect the final shape. Add more dirt as needed to help absorb some of the moisture. Your sphere should become sticky to the touch, like paste.

3. ADD A LAYER

Take a handful of fine dirt and sprinkle it over the sphere's surface. Continue to shape it as you rub the dirt onto it, which helps to pull moisture out. While rubbing the dirt in, I use the curvature at the base of my thumb to brush off excess dust, rolling the ball with the left hand, shaping it with the right (Figure B). Don't rub so much that you remove the added dirt or top layer already there. Continue this process to dry out the surface.

Now it becomes harder to fix depressions and protrusions, so take care not to drop or smack your sphere. If the surface cracks, add a bit of water to smooth it over. Once it is dry and firm enough to retain its shape, it's ready for the sauna.

4. CREATE A DORODANGO SAUNA

Put your dorodango in a plastic bag (Figure C) and lay it on a soft surface such as a folded towel. Leave it in the bag for about half an hour — enough time for moisture to condense on the surface of the sphere and the bag.

Remove the ball from the bag and repeat Step 3, drying out the surface again. Then replace it in the bag for another "sweat." Do this about 10 times, until it feels right. Each time you repeat Steps 3 and 4, it takes longer for moisture to condense on the sphere's surface.

5. DUST YOUR DORODANGO

Now you need a finer particulate of dirt. To see if your dirt is fine enough, pat it gently. If your hand has a fine layer of dust on it, you're good to go. If not, keep sifting. With the layer of dust on your hand, apply it all over your sphere's surface. Use the thumb-and-index-finger technique used in Step 3 to remove excess dirt. Gently rub dust into the surface until it becomes dry.

The sphere should now feel dry and dusty. Place it in a new, dry plastic bag and leave it for a longer sweat; try putting it in the fridge overnight.

Continue dusting until you've removed all moisture from the sphere's surface. You can tell you've achieved this once dust no longer sticks. Afterward, place your sphere in a new bag for one final sweat.

6. MAKE IT SHINE

Remove the sphere, add another layer of dust, and gently rub it in. Now grab a nice soft cloth and proceed to very gently polish it. If this creates scratches or marks, your sphere is still too wet. Repeat Step 5. If it looks fine after polishing for 10–20 minutes, you can apply more force.

I had to polish my sphere for over an hour before it shone. But the next day, it lost some of its luster because it still had moisture that had surfaced overnight. I repeated this step and ended up with a beautiful hikaru dorodango (Figure D). And it has retained its luster. I am now addicted to making dorodango. Every chance I get, I love teaching my friends and family how to make them.

TIP:
A refrigerator can speed the "sweat" process, but be careful not to over-chill — it could turn the bottom of your dorodango back into mud. For the first few sweats in the fridge, 20–30 minutes is enough. After the third or fourth sweat you can up the time to 1–2 hours. If you need an extended break, bag your sphere and store it in a cool, dry area on a soft surface.

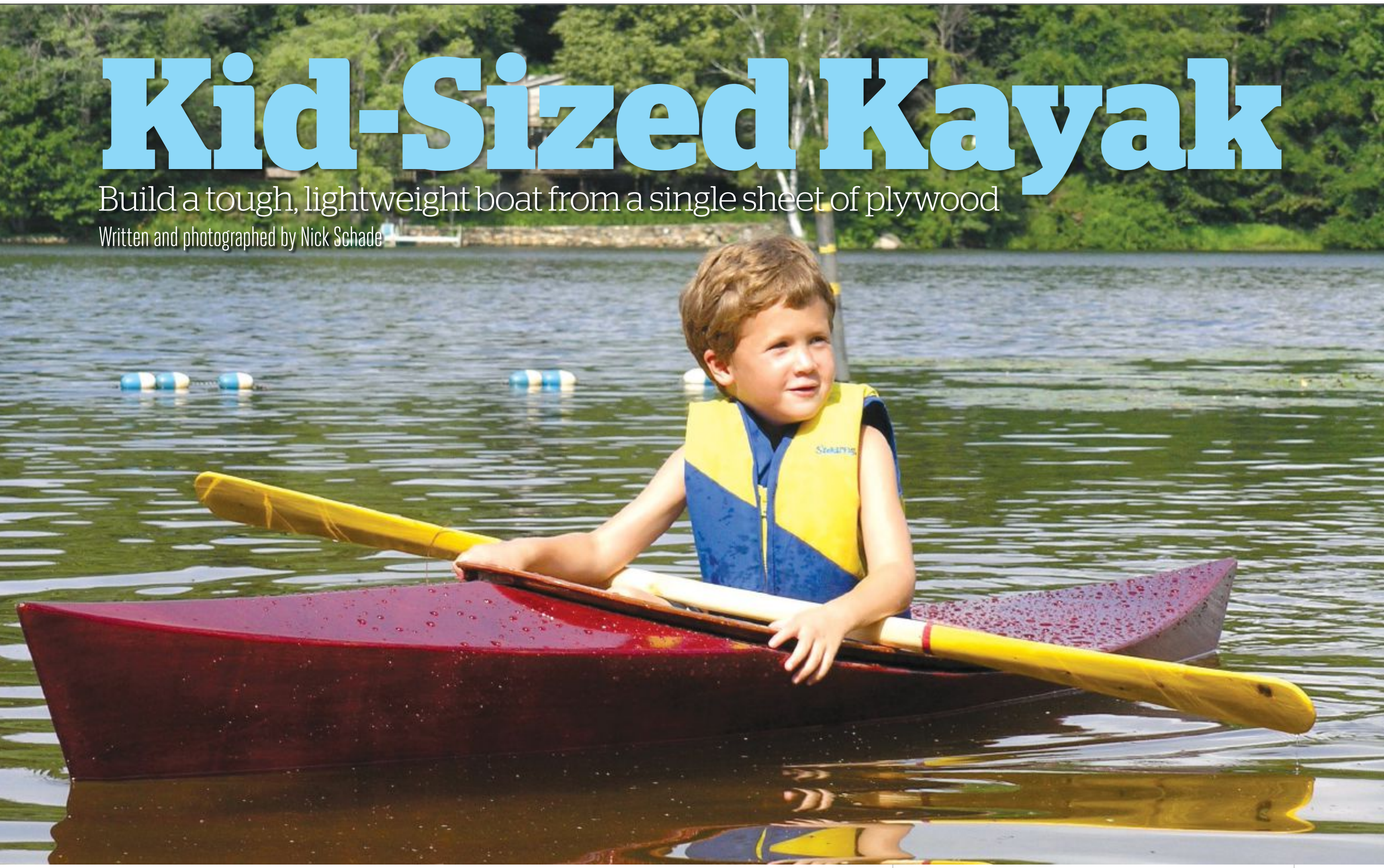
To see more step-by-step photos and share your own *hikaru dorodango*, visit the project page at makezine.com/go/hikaru-dorodango.

Time Required:
A Weekend
Cost:
$0

Materials
» **Dirt**
» **Water**
» **A display stand (optional)**

Tools
» **Buckets or containers** for your dirt and mud
» **Screen or sifter** if you don't have dirt of a fine particulate
» **Plastic bags**
» **Soft cloth**

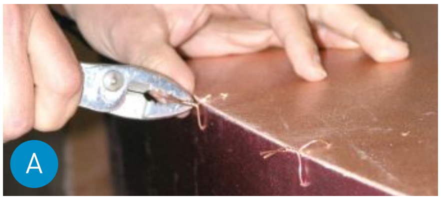
Sam Murphy



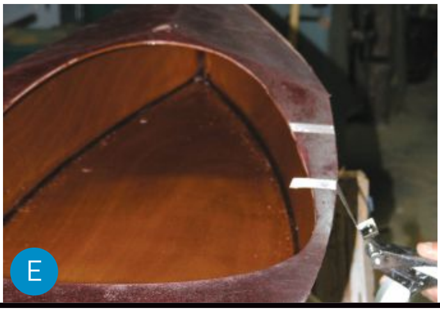
Kid-Sized Kayak

Build a tough, lightweight boat from a single sheet of plywood

Written and photographed by Nick Schade



TIP: Carefully lay the fiberglass in while the "dookie schmutz" is still wet, to avoid needing to sand after the fillet cures.



I'M A BOATBUILDER, SO WHEN MY OLDEST NEPHEW WAS ABOUT 5 YEARS OLD I DECIDED HE REALLY NEEDED A KID-SIZED KAYAK. I wanted it to be fun to paddle, easy to handle, lightweight, inexpensive, and straightforward to build, using "real" boatbuilding methods and only a single sheet of marine plywood.

I used a "stitch and glue" building method, where plywood panels are wired together then glued with epoxy and reinforced with fiberglass. The result is lightweight, strong, and durable, and shows off the wood nicely.

Of course, kids this young should never be on the water without close adult supervision, so think of this project more as a pool toy than a mode of transportation.

THE DESIGN

I design in Maxsurf naval architecture software, which can "unroll" 3D surfaces into flat 2D panels. I transferred the panels into a CAD package, arranged them on a single 4'×8' sheet, and laid out the holes for the wire stitches. The resulting DXF file was sent to a CNC shop to cut out of plywood.

The cockpit is relatively big so there's no risk of getting trapped. I made the front deck high for legroom, and gave it a bit of "V" to shed water. I left the back deck simple and flat, extending it up in front of the cockpit a little to make it easy to add a coaming, which serves as reinforcement and gives the kayak a more finished look. With a little upward sweep at the ends of the sheer to cut through waves, I had a cute, classy little kayak that's made from only 6 panels: the bottom, 2 identical sides, 2 identical front deck pieces, and the back deck.

THE BUILD

You'll find detailed instructions and a PDF of the plans at the project page online, makezine.com/go/kid-sized-kayak. Here's an overview of the key steps:

STITCHING

The kayak is assembled with copper wire serving as temporary clamps. Push lengths of wire through the pre-drilled stitch holes, then twist them to tighten the pieces into place (Figure A). Before stitching, I chose to stain my kayak, followed by a quick protective coat of epoxy, but this is optional.

GLUING

To "spot-weld" the panels together, apply several small dots of cyanoacrylate (CA) glue between each wire stitch (Figure B), followed by a light mist of glue accelerant. Then remove all the stitches by clipping them with wire cutters on the inside and pulling them from the outside. You now have the 2 basic pieces: the hull and the deck.

JOINT FILLETS

To strengthen the hull's sharp-angled joints, you'll use liquid joinery to create a structural fillet that transitions stresses smoothly between the panels. To do this, make the mixture of epoxy resin and wood "flour" — very fine sawdust — known to boat makers as "dookie schmutz." Squeeze a ¼" bead of schmutz (I use a gallon zip-lock bag with a corner cut off) into each seam and shape it with the back of a plastic spoon (Figure C).

FIBERGLASSING

Apply the fiberglass cloth and epoxy resin in sections, starting with the hull interior and the deck, and let it cure overnight.

You'll want to get the fabric as smooth as possible — I use a dry chip brush to remove wrinkles — before adding the resin. Once mixed, the resin starts to cure, so it's best to mix small batches and use them quickly. Spread the resin evenly with a plastic squeegee (Figure D), and scrape off any excess into a "grunge cup" receptacle. Use a brush to smooth any bridges in the cloth.

Properly saturated fiberglass should have a distinct weave texture with only enough resin to completely wet the fabric, not leave it shiny. Too little resin and the layup will lose strength, too much and it will gain weight.

Next, align the deck on the hull using strapping tape (Figure E), then attach it using fiberglass tape and epoxy along the inside seam. Finally, round over all the sharp exterior edges using a block plane, then lay the exterior fiberglass — hull first, then deck — and let cure (Figure F).

FILL COATS

After installing the raised cockpit coaming (I describe two methods on the project page online), I gave the whole kayak a "fill coat" of epoxy resin. Creating a smooth finish is all in the prep work: sanding. Start with coarse 60 grit sandpaper to quickly level the epoxy, without actually sanding into the fiberglass itself. Then move on to 120 grit, then 220. With a couple of fill coats I quickly got a nice surface using a random orbital sander.

PAINT OR VARNISH

Ultraviolet light will eventually break down epoxy resin, exposing the fiberglass and ultimately delaminating from the wood. Prevent this with paint or varnish. I built up 3 coats of varnish with light sandings between.

FINISHING TOUCHES

Chunks of foam were glued in place with contact cement to make a seat, and more foam shoved into the ends for flotation. I also made a quick little Greenland Inuit-style kayak paddle out of a piece of 2×3.

UPGRADES

I found that the kids were sliding sideways in the seat, which threw off their balance, so I created a horseshoe-shaped seatback to keep them centered. I also updated the coaming design to make the boat easier to build. Let me know how yours goes!

NICK SCHADE likes to go out on the big ocean in small boats, so he started Guillemot Kayaks, where he designs small, car-toppable, wooden boats for DIY boat builders and makes custom boats for those who don't want to do it themselves.

Time Required: 2 Weeks (of Evenings)

Cost: $150–$300

Materials

- **Okoume marine plywood, 4mm, 4'×8' sheet** This is standard thickness, but 3mm would be lighter and probably strong enough for a kid's boat.
- **Wood board, 2"×3"×60"** to make a paddle
- **Epoxy resin**
- **Copper wire**
- **Scrap wood**
- **Cyanoacrylate (CA) glue and accelerant**
- **Wood flour** for the "dookie schmutz" mixture
- **Fiberglass cloth, 4oz, 50" wide, about 6 yards**
- **Fiberglass cloth tape, 3" wide**
- **Varnish or paint**
- **Upholstery foam**
- **Stain, alcohol based (optional)**

Tools

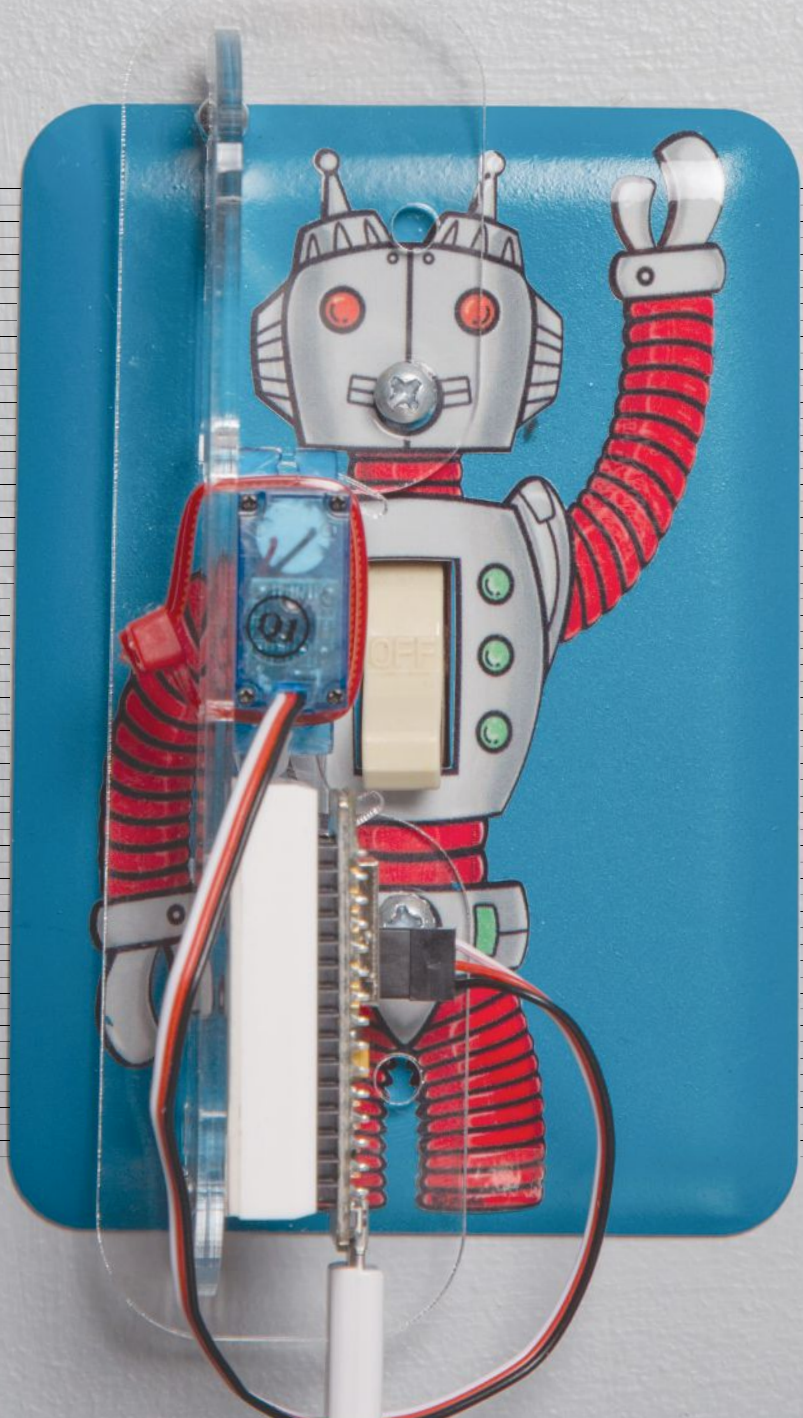
- **Jigsaw or CNC router (optional)** or send the plans to a CNC shop to cut them for you
- **Pliers**
- **Wire cutters**
- **Zip-lock bag, 1gal**
- **Plastic spoon**
- **Plastic squeegee**
- **Chip brush**
- **Utility knife or scissors**
- **Disposable cups**
- **Stirring sticks**
- **Packing tape, filament style**
- **Masking tape**
- **Permanent marker**
- **Waxed paper**
- **Block plane**
- **Sandpaper: 60, 120, and 220 grit**
- **Random orbital sander**
- **Dust mask or respirator**
- **Disposable gloves**
- **Drill (optional)**
- **Cotton swabs (optional)** for touching up stain

Get the PDF plans and step-by-step instructions, and share your build, at makezine.com/go/kid-sized-kayak.

Flippin' Sweet

Written by Dirk Swart and Vel Pendell

Use a servo to flick a light switch mechanically — without ever touching 110V power — with this Wi-Fi "Turner Onner"



HERE'S THE PROBLEM: You have a light switch on your wall that you want to control over the internet. But you don't want to mess with the house wiring — scary! — or damage the switch. What do you do?

Answer: Use a mechanical, motor-driven "finger" to flick the switch for you. As a bonus, you can still flip the switch normally, and can easily remove it when you're done, — essential if you rent your home. As with many engineering problems, it's a tradeoff — you have an "internet thing" externally attached to your light switch. But if you don't want to mess with house current or open up the light switch to conceal the apparatus, this is the way to go. It's fun to have a tiny robot dedicated to flipping a switch whenever you say!

You control the Turner Onner over your smartphone or computer, using the provided code. And it's self contained — it doesn't use a base station, and you don't need to sign up to any services (or hope that any third party remains in business) for your switch to continue working!

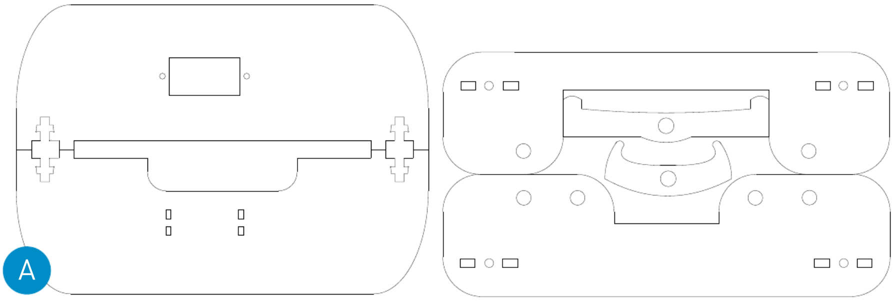
The Turner Onner simply publishes a web page to your local network. You flip the switch by accessing this web page and pushing On and Off buttons there. If you want to control it outside your local network (over the internet from anywhere) you need to set up port forwarding on your router. (For security reasons this may or may not be a good idea; we leave that to you.)

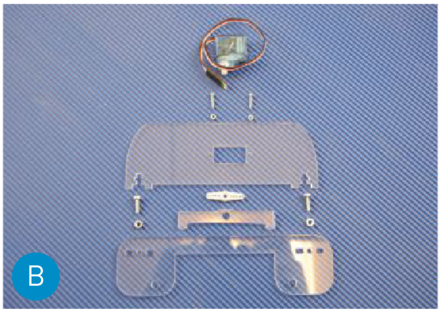
Here's how to make it.

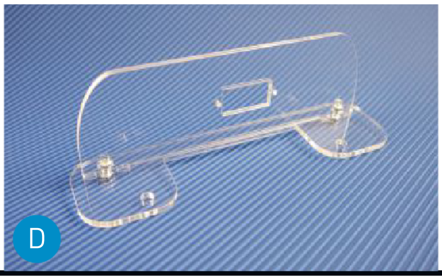
1. RIG THE PLEXIGLASS SLED FOR YOUR SWITCH

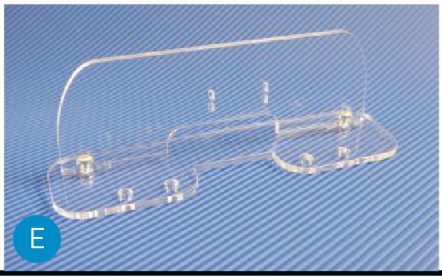
You can buy our kit, or cut your own parts from ⅛"-thick acrylic; just download the templates (Figure A) from the project page at makezine.com/go/light-switch-turner-onner. There are 2 common types of light switch, the flat rocker and the vertical lever or toggle, and we provide templates for each type. The principle is the same in both cases (Figures B and C).

Assemble either the rocker sled (Figure D) or the lever sled (Figure E), using the two M3 screws and captive nuts. For the lever sled, also check which pair of mounting holes is the correct distance









Hep Svadja, Anthony Lam

DIRK SWART is a co-founder of Wicked Device LLC, a maker of fun electronic kits.

VEL PENDELL has a bachelor's degree in engineering physics from Cornell University and enjoys tinkering with electromechanical toys.

Time Required: 2–3 Hours
Cost: $25–$40

Materials

» **Turner Onner kit** $30 from wickeddevice.com/turneronner. Includes all the following parts.

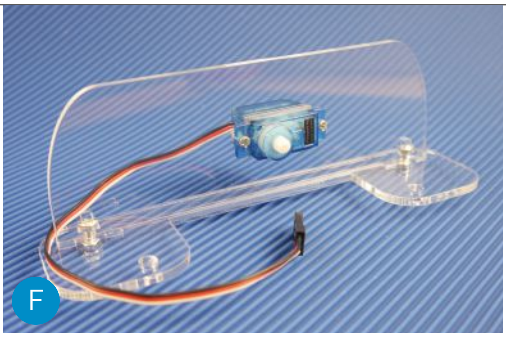
— OR —

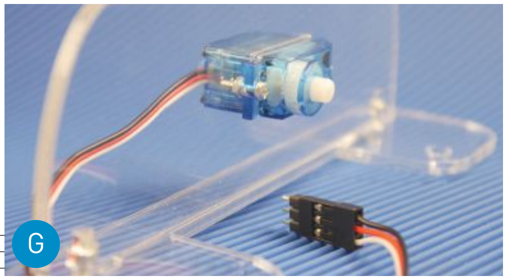
You can easily source the parts separately:

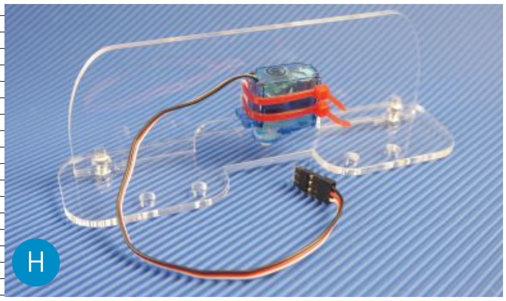
» **Mini servomotor, Turnigy 9g** Don't use knock-offs — they're not powerful enough.
» **NodeMCU ESP8266 Wi-Fi microcontroller board**
» **Mini breadboard, adhesive backed**
» **USB power supply with Micro-USB cable**
» **Plexiglass cutouts, ⅛" (3mm)** for lever style switches and/or flat rocker style switches. The kit includes both. Or you can cut your own; we're sharing the cut files on the project page at makezine.com/go/light-switch-turner-onner.
» **Machine screws, M3×10mm, with nuts (2)** for assembling plexi cutout
» **Small cable ties (2) or machine screws, M2×10mm, with nuts (2)** for mounting servo; kit includes both
» **Switch faceplate mounting screws (2)** a little longer than your original screws

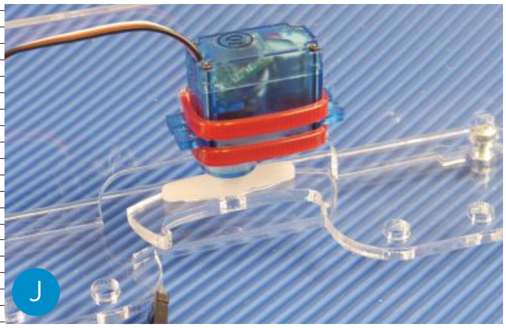
Tools

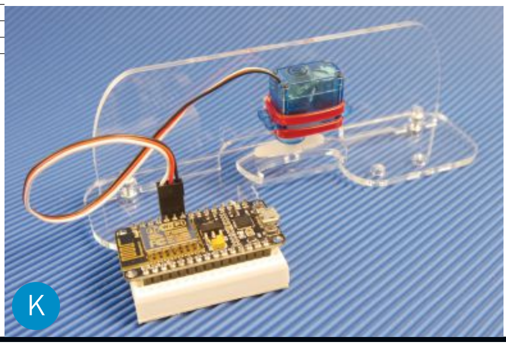
» **Phillips screwdriver, small**
» **Super glue** aka or cyanoacrylate (CA) glue
» **Computer with internet connection and free software:**
- **Arduino IDE** Get the latest version from arduino.cc/downloads.
- **ESP8266 support for Arduino IDE** from github.com/esp8266/Arduino
- **Turner Onner project code** from github.com/WickedDevice/TurnerOnnerFirmware











apart for your switch plate; these come in a "home" size, where the holes are closer together, and a larger "office" spacing.

2. ADD A SERVO AND "FINGER"

For the flat rocker switch, the servomotor lies flat, parallel to the wall; mount it to the sled using the two M2 screws (Figures F and G). For the lever type, you'll mount the servo vertically using 2 small cable ties (Figure H). This means the flat switch ends up looking nicer than the lever kind, but you probably can't choose your switches.

Super-glue the acrylic servo "finger" to the servo horn (Figures I and J). Again, there are 2 different kinds of finger, depending on your switch.

3. INSERT MICROCONTROLLER

You could use a service that proxies to the internet for you, but we prefer using a super simple web server on your own local network. So we chose the ESP8266 NodeMCU, a nifty little $4 microcontroller with built-in Wi-Fi. Plug it into the mini breadboard, peel the adhesive, and stick the breadboard to the sled next to the servo.

The only thing you need to wire up is the servomotor. You can cut the end off the servo cable, split the wires apart, and just poke them into the breadboard. Or add a 3-pin male header to the connector (Figures G and K) — lucky for us, all 3 pins are next to each other. It's really simple:

MCU	SERVO
Ground	Ground
3v3	Power
D4	Signal

4. ADD ESP8266 SUPPORT TO YOUR ARDUINO IDE

The final step before testing is to add your network credentials to the code and upload it to the NodeMCU. That requires the Arduino development environment (make sure yours is up to date) with the ESP8266 board package.

To install the Arduino ESP8266 support files from github.com/esp8266/Arduino, just open the Arduino IDE, go to File → Preferences and look for "Additional Boards Manager URLs." Enter the URL `http://arduino.esp8266.com/stable/package_esp8266com_index.json` (Figure L) and then click OK.

Now go to Go to Tools → Board → Boards Manager. Scroll down to the ESP8266 listing, click anywhere in that block, and then click Install (Figure M). That takes a few minutes. When it's done, click Close and restart the Arduino IDE so the settings can be refreshed.

5. PROGRAM THE MICROCONTROLLER

Download the Turner Onner project code from github.com/WickedDevice/TurnerOnnerFirmware. It's based on a simple ESP8266 Web Server program. To modify the sketch to add your own Wi-Fi network, just open it in the Arduino IDE and find these 2 lines:

```
const char *ssid = "";
const char *password = "";
```

and add your network name (SSID) and password inside the quotation marks.

Change the board type to NodeMCU 1.0 wth Tools → Board → Node MCU 1.0 (ESP 12E Module). Hit the Verify button and it should compile with no problems. Be aware that doing this erases the NodeMCU, and if you want to use Lua to program this board, you'll need to reflash it. The board is now Arduino-ized (cue maniacal laughter!).

Finally, connect your board to your computer using the Micro-USB connector. If you have a Mac or Windows 10, it should register within a few seconds. (Windows 7 can take several minutes.) Eventually you'll see the relevant port under Tools → Port. Select it.

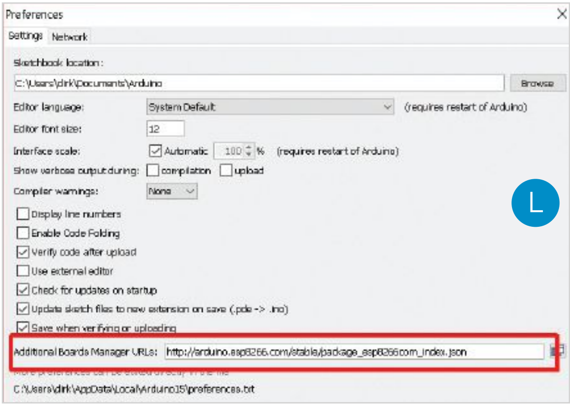
Hit the Upload button and wait for it to say "Upload complete."

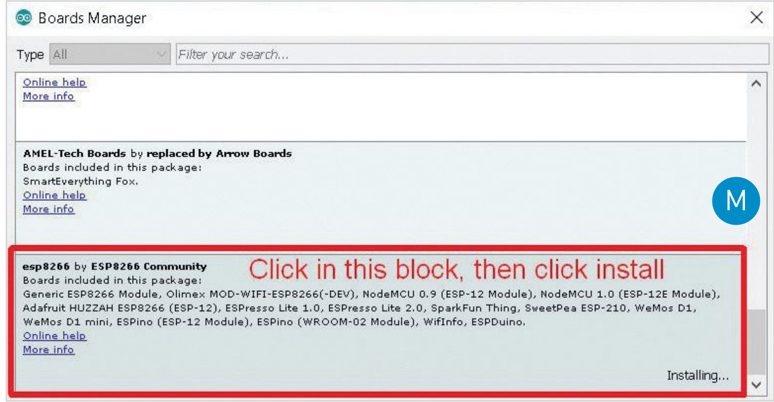
6. CONNECT TO THE INTERNET

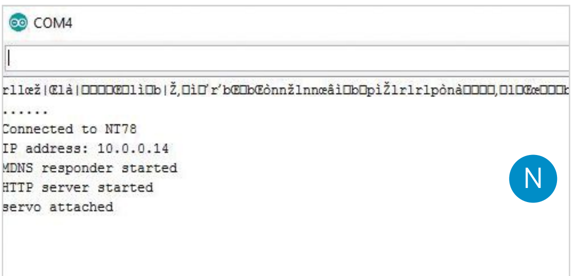
You're all set. The only problem left is finding out the IP address that your router has given to your tiny new web server. In the Arduino IDE, click the Serial Monitor button at top right, and make sure the speed is 115200, or you'll just get garbage. Connecting the serial port automatically resets the NodeMCU.

Stuff will be printed to the serial port, including the IP address (Figure N) — probably something like `192.168.1.3` (the last two digits are probably different).

Point your web browser to that IP address by cutting and pasting it into the address bar just like a normal URL. Voilà — the Turner Onner web page (Figure O)! You should be



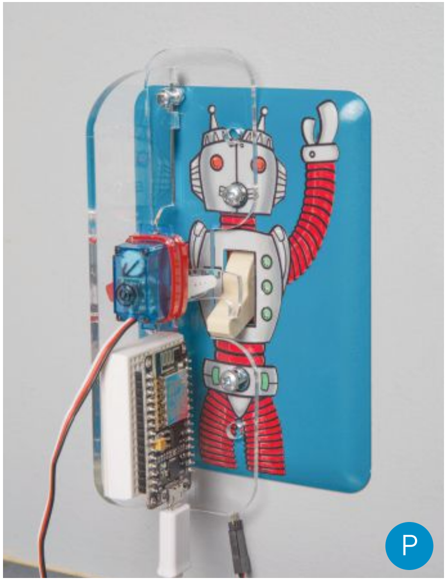


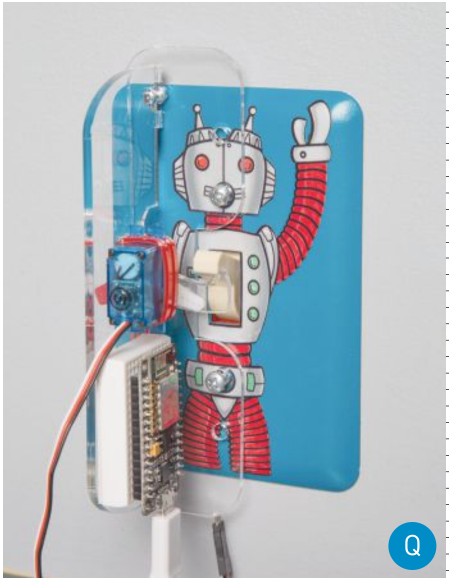


all set. Go ahead and try out your new On and Off buttons.

7. ADD POWER AND START FLIPPING

We have to get power from somewhere. Since we don't want to get it from the 110V supply, there are two choices: battery or a wall-wart power adapter. The wall-wart is a little unsightly, but it will operate indefinitely. Plug it into the NodeMCU (Figures P and Q). Whoo! You're off to the races.





KID FRIENDLY

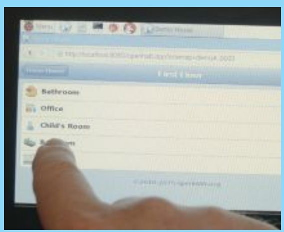
Because the Turner Onner draws only minimal power from USB, it's safe for kids' rooms. Try decorating the servo finger with a robot hand, dragon claw, superhero, or other favorite character that will move when the Turner Onner flips. Or just get a fun robot switch plate, like this one that we found at Maker Faire Bay Area, made by Natalie McKean, etsy.com/shop/natalierobots.

Questions? Ask us at support@wicked-device.com. And have a great time flipping your Turner Onner.

Get the templates for cutting and share your build at makezine.com/go/light-switch-turner-onner.

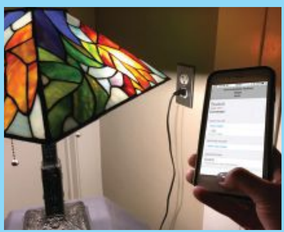
Hep Svadja, Anthony Lam

HOME AUTOMATION TRICKS



OPENHAB HOME AUTOMATION SYSTEM
Build a Raspberry Pi touchscreen command center to control "smart home" products and your own Wi-Fi projects (like the Turner Onner).

VOICE CONTROL WITH RASPBERRY PI
Bark orders and behold, as your computer, your Roomba, even your light bulbs obey your spoken commands.



BLUETOOTH SMART LIGHT SWITCH
Don't wanna Wi-Fi? Control lamps and other AC devices directly via Bluetooth, using your phone and a PowerSwitch Tail.

Find these and other home automation projects at makezine.com/projects

Written by Mark Wrigley

PiKon: A 3D-Printed Telescope with Raspberry Pi

Build your own 120X astro-cam using printed components and the Pi Camera Module

THE PIKON TELESCOPE IS A DIY ASTRO-CAMERA YOU CAN EASILY BUILD AT home, based on two disruptive technologies: 3D printing and Raspberry Pi cameras. Andy Kirby and I started it as a project for Sheffield University's "Festival of the Mind" in September 2014 (with much duct tape and over-engineering!). We wanted to show how these technologies could put a homemade reflector telescope within the reach of anyone. The response was fantastic, with national press coverage in the U.K., and a successful Indiegogo campaign partnering with Darren Barker and WeDo3DPrinting in Sheffield.

We're now offering everything from 3D files to a complete kit with 3D-printed components and optics. We even offer fully built PiKons for those who just want to create Raspberry Pi programs for astronomy. But we're sharing our design and 3D files freely because we hope to establish a community where makers, astronomers, Pi programmers, and educators can share information, experiences, and of course, images.

HOW IT WORKS

The PiKon telescope is based on the Newtonian reflecting telescope. This 350-year-old design uses a concave mirror (objective) to form an image, which is examined using an eyepiece. The objective mirror is mounted in a tube and a secondary mirror is placed in the optical path at a 45° angle to allow the image to be viewed from the side of the tube.

The PiKon telescope is similar, but the image formed by the objective is focused onto a digital camera sensor instead (Figure A). Because of the small size of the Pi camera board (25mm × 25mm), we can mount it directly in the optical path at prime focus. The amount of light lost by doing this is similar to the losses caused by mounting the 45° mirror in a conventional Newtonian design.

BUILDING YOUR OWN PIKON

The PiKon telescope consists of two main assemblies based on 3D-printed parts. At the bottom of the scope, the mirror assembly (Figure B) holds a standard 4½" diameter spherical mirror.

At the top of the scope, the spider assembly (Figure C) supports the Pi camera and lets you move it back and forth along the telescope axis to focus the image, using a rack and pinion setup. The camera sensor is exposed by unscrewing the lens on the Pi camera.

Brett Porter, Mark Wrigley

The two assemblies are mounted into a simple telescope tube made of 6" plastic pipe. In the U.K. we use ventilation duct; in the U.S., Scott Miller of San Francisco Amateur Astronomers worked with *Make:* to modify the 3D parts to fit standard PVC pipe.

Finally, we 3D printed an astronomical dovetail wedge mount that's also fitted with a standard ¼-20 (¼" Whitworth) thread, so you can mount the telescope on either astro or photo tripods.

Images captured by the Pi camera (Figures D and E) can be viewed on a monitor plugged into the Raspberry Pi, then transferred to PC or Mac from the Pi's microSD card or uploaded from the Pi straight to Dropbox (or similar) using an internet connection. (We're excited to try it with the new Raspberry Pi 3's built-in Wi-Fi!)

MIRRORS AND MAGNIFICATION

The PiKon telescope has a magnification factor of about 120X (based on the 600mm focal length and 3.6mm×2.4mm camera sensor) and a field of view of about ¼ degree. The moon subtends ½ degree at your eyeball, so the PiKon can see about half the moon at a time.

Spherical or parabolic mirrors can be used. Different focal lengths may also be used; just cut the telescope tube to length accordingly. To determine the focal length of a third-party mirror, simply image a distant object onto a piece of paper and measure the distance between mirror and paper. The PiKon is designed with a long travel on the focusing rack so it's forgiving of small inaccuracies in measurement.

TOUCHSCREEN CONTROL

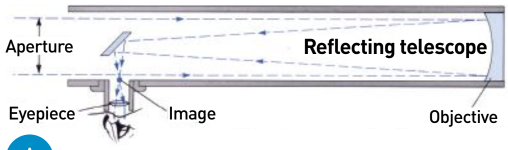
Brett Porter built the PiKon kit and wanted to make his telescope portable for field trips, so he baked his own touchscreen controller with a 2.8" TFT display, 4 programmable buttons, and a 5200mAh lithium-ion battery that also powers the Pi and camera (Figure F). You're looking at his moon photos on these pages. Learn more at makezine.com/go/pikon-touchscreen.

One member of Newcastle Maker Space even mounted an accelerometer on the telescope to synchronize with a star map — we're excited to hear more about that idea.

Build one and share with the community!

Get the complete PiKon build instructions and step-by-step photos at makezine.com/go/pikon-raspberry-pi-telescope.

Mark Wrigley, Brett Porter



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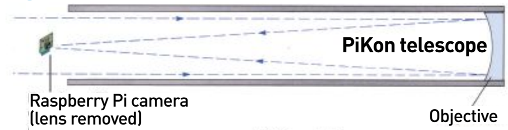
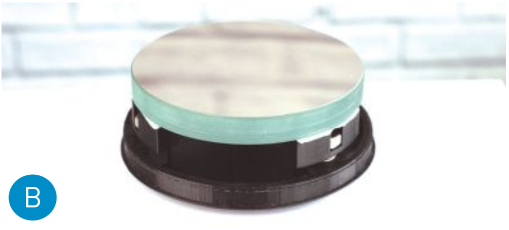




B

C

D

E

F

MARK WRIGLEY is a commercial physicist who stepped out of the world of high-tech mobile phone technology to set up his own company evangelizing the value of physics, science, and technology.

Time Required: 1–2 Hours

Cost: $150–$300

Materials

- **Raspberry Pi single-board computer** with microSD card and power supply
- **Pi Camera Module, v1 or v2** with ribbon cable
- **3D-printed parts: spider, camera mount, Raspberry Pi mount, focus knob, mirror mount, mirror base, and tripod mount** You can buy a complete kit at the PiKon shop, pikon.online. Or download the free 3D files at makezine.com/go/pikon-raspberry-pi-telescope and print them out.
- **Plastic duct or pipe, 6" (150mm) diameter, 610mm long** for the telescope tube
- **Spherical mirror, 4½" (114mm) diameter, f5, focal length 600mm** Get them from the PiKon shop or try eBay.
- **Raspberry Pi case (optional)**
- **Self tapping screws, 3.5mm×10mm (8)**
- **Bolts, 8mm×25mm, with nuts (3)**
- **Compression springs (3)**
- **Double-sided tape**
- **Nylon bolts, M2×12mm (4)** with nylon nuts
- **Timing belt, T2.5 (2.5mm pitch), 6mm wide, 110mm length**
- **Cog, 20 teeth, 2.5mm pitch, 5mm shaft**
- **Threaded rod, 5mm, 100mm length**
- **Square nuts, 5mm (2)**
- **Dome nut, 5mm**
- **Camera bushing, ¼-20 thread** for tripod mount
- **Bolts, M4×16mm, with nuts (2)**
- **Paint, matte black (optional)**

Tools

- **USB keyboard, mouse, and monitor**
- **Drill and bits: 2.5mm and 4mm**
- **Allen wrench, 1.5mm**
- **3D printer (optional)**

This project is excerpted from *Make: Action* by Simon Monk, available at the Maker Shed (makershed.com) and fine bookstores.

Written by Simon Monk

Crushin' It

Use an Arduino and an H-bridge motor circuit to build an automatic can crusher

LINEAR ACTUATORS CONVERT THE FAST ROTATION OF A DC MOTOR into slow linear movement, and they can provide quite a strong pushing or pulling force. You can easily control these actuators using a simple H-bridge circuit — put it together with an Arduino and a bit of woodwork, and you can make yourself an automatic beverage-can crusher — no soldering required!

1. WIRE THE CIRCUIT

Figure A illustrates the wiring diagram for the project, and Figure B shows a close-up of the Arduino and H-bridge module.

The L293 module has jumper pins that by default keep its H-bridge circuits enabled, and so only the two Arduino outputs connected to IN1 and IN2 are needed.

Conveniently, the H-bridge module includes a voltage regulator that provides a 5V output that you can connect directly to the 5V pin of the Arduino to supply it with power.

2. BUILD THE CRUSHER

The basic structure of the crusher is a length of 2×4 wood. At one end, the actuator is anchored using the fixtures supplied with it. The actuator's shaft is then fixed to a block of wood that crushes the can against an end stop. Two plywood sides help prevent the can escaping while it's being crushed.

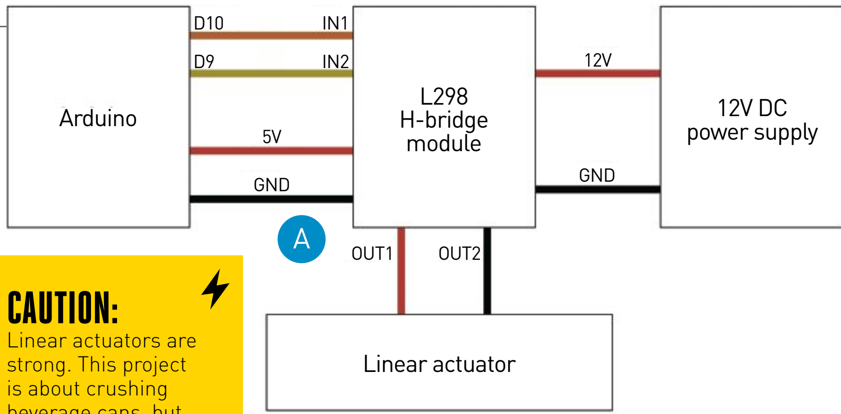
I haven't used exact dimensions, because your actuator is likely to be a little different in size than mine. The best way to get it right is to place the actuator on the 2×4 and then calculate the spacings. Remember to leave a bit of a gap between the fully extended crushing surface and the end stop; otherwise, the machine might push itself apart.

3. PROGRAM THE ARDUINO

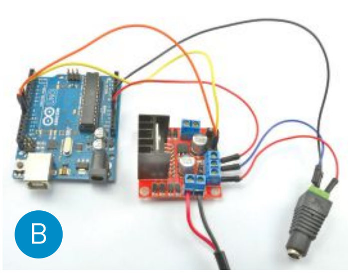
Download the project code file *can_crusher.ino* from makezine.com/go/arduino-can-crusher and upload it to your Arduino. Here's how it looks:

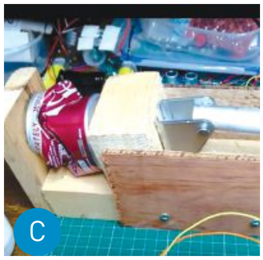
```
const int in1Pin = 10;
const int in2Pin = 9;
const long crushTime = 30000; // 1
void setup() { // 2
  pinMode(in1Pin, OUTPUT);
  pinMode(in2Pin, OUTPUT);
  crush();
  stop();
  delay(1000);
  reverse();
  stop();
}
void loop() {
}
void crush() {
  digitalWrite(in1Pin, LOW);
  digitalWrite(in2Pin, HIGH);
  delay(crushTime);
}
void reverse() {
  digitalWrite(in1Pin, HIGH);
  digitalWrite(in2Pin, LOW);
  delay(crushTime);
}
void stop() {
  digitalWrite(in1Pin, LOW);
  digitalWrite(in2Pin, LOW);
}
```

Hep Svadja



CAUTION: Linear actuators are strong. This project is about crushing beverage cans, but the actuator will quite happily crush a hand or anything else that you put into the crushing area. So be careful, especially while you're getting it to work, when there is a temptation to adjust and intervene.





Be Nice to Your Motors

Imagine a car driving along and then suddenly being thrown into reverse gear — that's pretty much what you're doing if you suddenly reverse the direction of a motor. For small motors without a great deal of mass attached to them, this isn't normally much of a problem. But you may find that if you're using a Raspberry Pi or Arduino board that's powered from the same power source as the motors, then the Pi may crash or the Arduino may reset. This happens as a result of the large current that flows when you suddenly switch directions, causing the board's power supply voltage to dip.

For larger motors that are driving something with a lot of inertia, sudden changes in speed or direction can cause big problems. The resultant large currents may damage the H-bridge, and there's also the mechanical shock to the bearings of the motor.

This is something to bear in mind when designing control software for larger motors. One way to be nicer to your motors is to precede any change in direction by setting the control lines to let the motor stop, pausing for enough time for it to actually stop before setting it running again in the opposite direction.

In Arduino, setting up this kind of delay function might look something like this:

```
forward(255);
delay(200);
reverse(255);
```

In our can crusher code, you can see we've set full **stops** and also a **delay** of 1 second (1000 milliseconds) between crushing and reversing.

1. Although the actuator will automatically stop when it gets to the end of its travel, this **crushTime** period (30 seconds for my motor) sets how long the motor should be on, before reversing.
2. The **setup** function controls the whole operation of the project. After setting both control pins to be outputs, it immediately starts the crushing action using the **crush** function.

4. SMASH CANS!

Push the Reset button on the Arduino to trigger the crushing action (Figure C). Whenever the Arduino resets, it automatically starts to move the linear actuator. Smoosh!

GOING FURTHER

H-bridges can be used to control other types of motors, including stepper motors. They can also be used to switch power to other devices, such as Peltier heating and cooling elements. You'll learn all this and a lot more in my book, *Make: Action.*

Watch the prototype crusher in action at makezine.com/go/arduino-can-crusher and learn more about making movement, light, and sound with Arduino and Raspberry Pi in the book *Make: Action*, available at makershed.com.

Simon Monk

SIMON MONK (simonmonk.org) writes books about electronics for makers, including *Programming Arduino* (Maker Media) and *The Raspberry Pi Cookbook*. He and his wife, Linda, make and sell kits to accompany his books at monkmakes.com.

Time Required:
2–4 Hours
Cost:
$40–$60

Materials

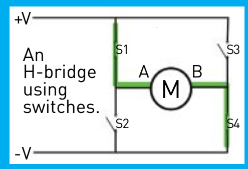
- **Arduino Uno microcontroller board**
- **Linear actuator, 6" stroke, 12V 3A** Find them on eBay.
- **H-bridge module with L298 chip** from eBay. If your actuator's maximum current is not 3A, choose a different H-bridge module (and power supply) that will cope.
- **Jumper wires, female to male (2)** Adafruit #826
- **Jumper wires, male to male (4)** Adafruit #758
- **Adapter, female barrel jack to screw terminal** Adafruit #368
- **Power supply, 12V 3A** Adafruit #352
- **Wood, 2×4**
- **Plywood, scraps**
- **Wood screws**

Tools

- **Woodworking tools**

H-Bridges

An *H-bridge* is a simple circuit that uses 4 switches to change the direction of a DC motor (forward or reverse) by simply reversing the polarity of the motor's connections.



An H-bridge using switches.

With all 4 switches open, no current can flow through the motor. However, if switches S1 and S4 are closed, but S2 and S3 are open (as shown here), current will flow from the positive supply to terminal A of the motor, through the motor and S4 to the negative supply, and the motor will turn in one direction.

If S1 and S4 are now opened and S3 and S2 closed, the positive supply will be applied to terminal B instead and flow out through the motor and S2 to reverse the direction of the motor. Interestingly, you can brake the motor by closing S1 and S3 simultaneously (or S2 and S4). Just don't close S1 and S2 at the same time (or S3 and S4) or you'll cause a short circuit!

The L298 chip in your H-bridge module contains 2 miniature H-bridge circuits that work in exactly this way.

Get a Grip

Build a carnival-midway strength tester game using strain gauges and a comparator chip

Written and photographed by Charles Platt

Time Required: A Weekend
Cost: $40-$50

THE GRIP CHALLENGE USED TO BE A POPULAR GAME IN CARNIVAL MIDWAYS, encouraging guys (mostly) to flaunt their strength by squeezing a pair of handles together. Figure A shows a version you can still find in some amusement arcades. It sells for almost $2,000 new — so I decided to build my own.

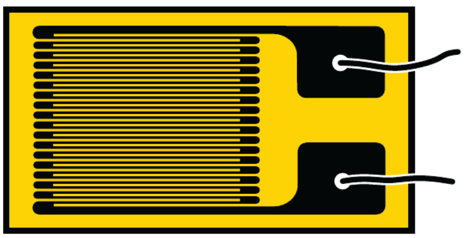
To measure the gripping force, I used *strain gauges*, which work on the principle that the resistance of a conductor increases fractionally when you stretch it. A typical strain gauge uses the configuration shown in Figure B, in which parallel conductors multiply the effect.

When 4 strain gauges are glued to the topside and the underside of a bar of aluminum, you have a *load cell* of the type shown in Figure C. The pairs of gauges are wired in a configuration known as a *Wheatstone bridge*, in Figure D.

An actual load cell is shown in Figure E. Almost always, the power input wires are red and black, while the output wires are green and white. Load must only be applied in the direction of the arrow printed on the bar, and causes the voltage on the green wire to increase while voltage on the white wire decreases. The voltage difference is the output from the cell, expressed in millivolts per volt at maximum load. For example, if a 50kg cell

Figure A: This arcade machine sells for $1,995 at joystixamusements.com.

Joystix Classic Games and Pinballs



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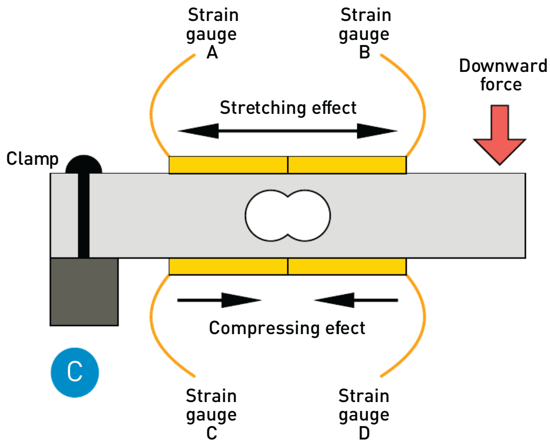

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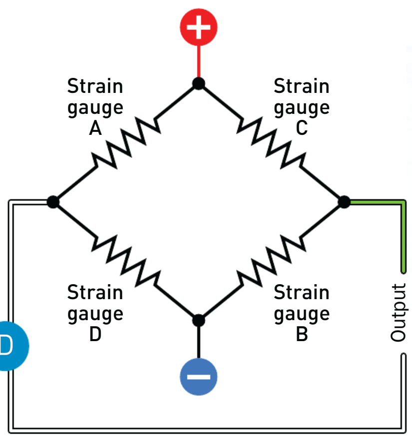

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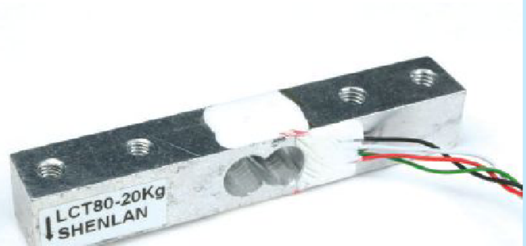


E

Figure E: A typical load cell. For this project, use one with a maximum rating of 20kg to 50kg, with a pair of holes at each end, as shown here.

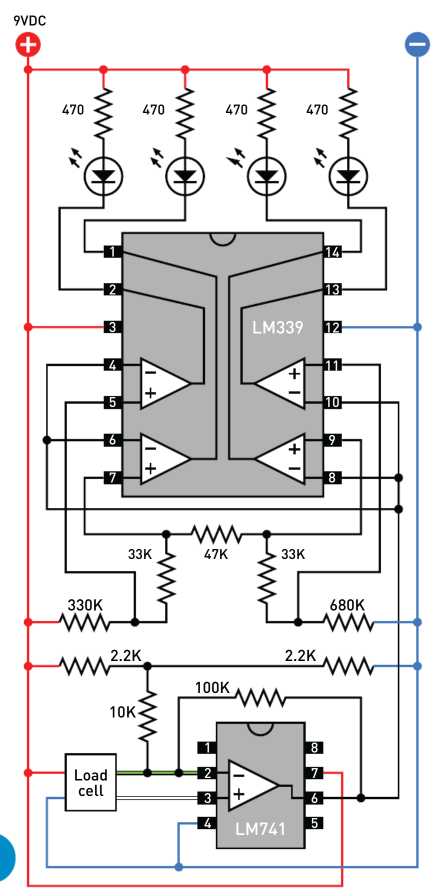
is rated at 1.1mV/V, and you energize it with a 9V battery, the output will reach 9.9mV when the load increases to 50kg.

Breakout boards are available to interface a load cell with a microcontroller, but it's cheaper and easier to use a couple of analog chips. A basic LM741 op-amp can amplify the voltage from the cell, while a quad-comparator LM339 will light 4 LEDs in succession as the load increases.

Figure F shows the schematic laid out for easy breadboarding. The pinouts of the LM339 make it convenient to place at the top of the circuit. I also added a toggle switch and 3mm "power on" LED with 1.5K current-limiting resistor (not shown).

I chose a 20kg load cell for this project, but higher values up to 50kg can be used by adjusting the mechanical leverage in your Grip Challenge design. Test the cell by screwing one end into a hefty piece of scrap wood, including washers to allow room for the cell to flex. Most load cells have metric threads, but you can drill them out to provide room for your choice of screws or bolts.

Apply 9VDC to the red and black wires, set your meter to measure millivolts, and use a screw clamp to increase the force on the free end of the load cell (Figure G, following page). If it is rated around 1mV/V (which is typical), tighten the clamp



F

Charles Platt

CHARLES PLATT is the author of *Make: Electronics*, an introductory guide for all ages, and its sequel *Make: More Electronics*. makershed.com/platt

Materials

- **Load cell using strain gauges, rated 20kg or higher** e.g., eBay #281926816093 or RobotShop #RB-See-414 or RB-Phi-119
- **Op-amp IC chip, LM741 type**
- **Quad comparator IC chip, LM339 type**
- **Resistors: 470Ω (4), 1.5kΩ (1), 2.2kΩ (2), 10kΩ (1), 33kΩ (2), 47kΩ (1), 100kΩ (1), 330kΩ (1), 680kΩ (1)**
- **LEDs: generic (4), 3mm (1)**
- **Switch, mini toggle**
- **Battery, 9V alkaline**
- **Solderless breadboard**
- **Hookup wire**
- **Oak or maple board, ¾"×3½", 6' total length**
- **Wood screws, pan head #6×1¼" (4)**
- **Washers, #8 (4)**
- **Wood glue or epoxy glue**
- **Plywood or ABS plastic, ¼" or ⅛" thick, 6"×6"**

Tools

- **Wire strippers**
- **Pliers**
- **Soldering iron**
- **Multimeter**
- **Woodworking tools**

Figure B: Resistance between the connections to this strain gauge increases when it is stretched horizontally. Vertical flexing makes very little difference.

Figure C: Pressing down on one end of a load cell stretches the strain gauges attached to the top while reducing tension on the strain gauges attached to the bottom.

Figure D: The strain gauges are wired as 2 voltage dividers that respond oppositely, creating a voltage between the green and white output wires.

Figure F: Grip Challenge schematic. Input from the load cell is amplified by the LM741 at the bottom. The LEDs light up in sequence from right to left.

till you measure 9mV. This tells you that the cell is now experiencing its maximum load.

Leave the clamp in place while you disconnect your meter and connect the green and white wires to the op-amp. Using the component values in my circuit, the output from pin 6 of the LM741 should be around 6.3V. If you measure less than that, substitute a larger value for the 100K feedback resistor. If it's more than 6.5V, use a lower-value feedback resistor, because the comparators in the LM339 cannot compare voltages that rise too close to the power supply.

To provide reference voltages for the comparators, I put 5 resistors in series as a voltage divider. The values 680K, 33K, 47K, 33K, and 330K provide reference voltages of approximately 5.0V, 5.3V, 5.7V, and 6.0V. As the output from the op-amp increases from 4.5V with no load to 6.3V with maximum load, it passes each of the reference voltages and triggers the next comparator, which lights another LED. You can experiment with different resistor values if you wish.

Because the LM741 is sensitive to stray electromagnetic fields, twist the wires from the load cell together to prevent unwanted flickering of the LEDs.

To mount your circuit permanently, you'll need hardwood to withstand the forces involved. I made a heavy-duty oak box, shown under construction in Figure H. One handle is fixed while the other pivots around the round dowel. I moved the dowel up and down to adjust the leverage of the handles until I needed all my strength to trigger the fourth LED. After that, I made a permanent pivot for the handle and glued the box together using a biscuit joiner (Figure I).

GOING FURTHER

If you build your own version, you can challenge people to a strength contest — which can be serious or not-so-serious. To fool your friends, add a hidden switch connecting a second 100K feedback resistor in parallel with the first. This will reduce the power of the op-amp, making it physically impossible for anyone to light the fourth LED (except you, of course). I think people should expect a bit of trickery when they play carnival midway games.

In addition to load cells, many other types of force sensors exist. You can learn more about them in my *Encyclopedia of Electronic Components, Volume 3*, published by Maker Media.

See more photos and share your Grip Challenge build at makezine.com/go/get-a-grip!

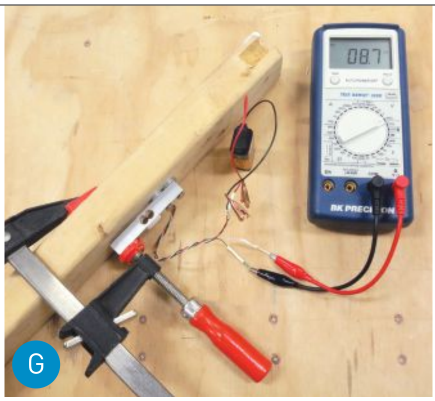
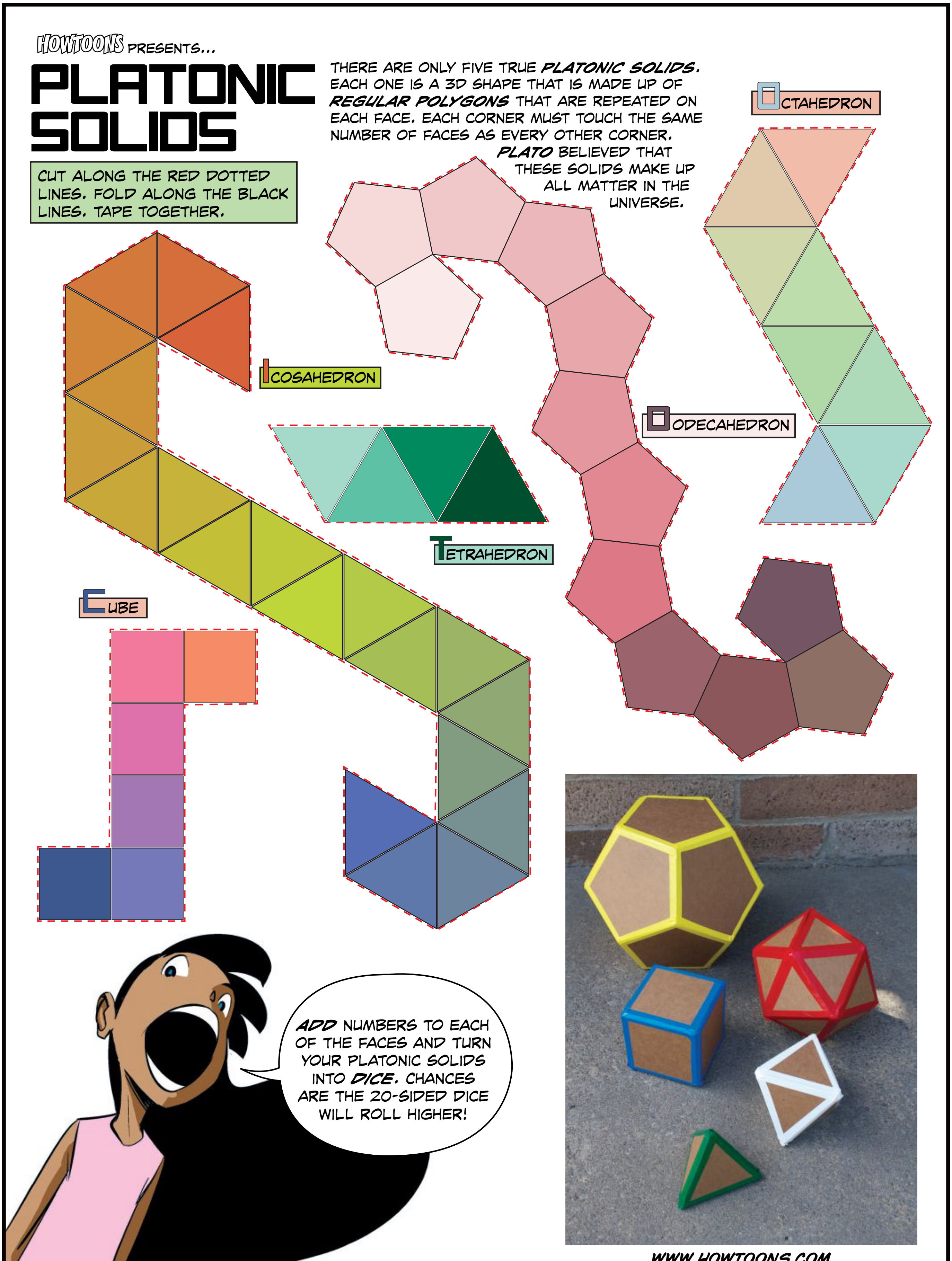


Figure G: Use a screw clamp to calibrate the Grip Challenge.

Figure H: You can adjust the leverage by moving the round dowel that works as a temporary pivot point.

Figure I: The completed Grip Challenge, ready for the crush.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ADD NUMBERS TO EACH OF THE FACES AND TURN YOUR PLATONIC SOLIDS INTO DICE. CHANCES ARE THE 20-SIDED DICE WILL ROLL HIGHER!
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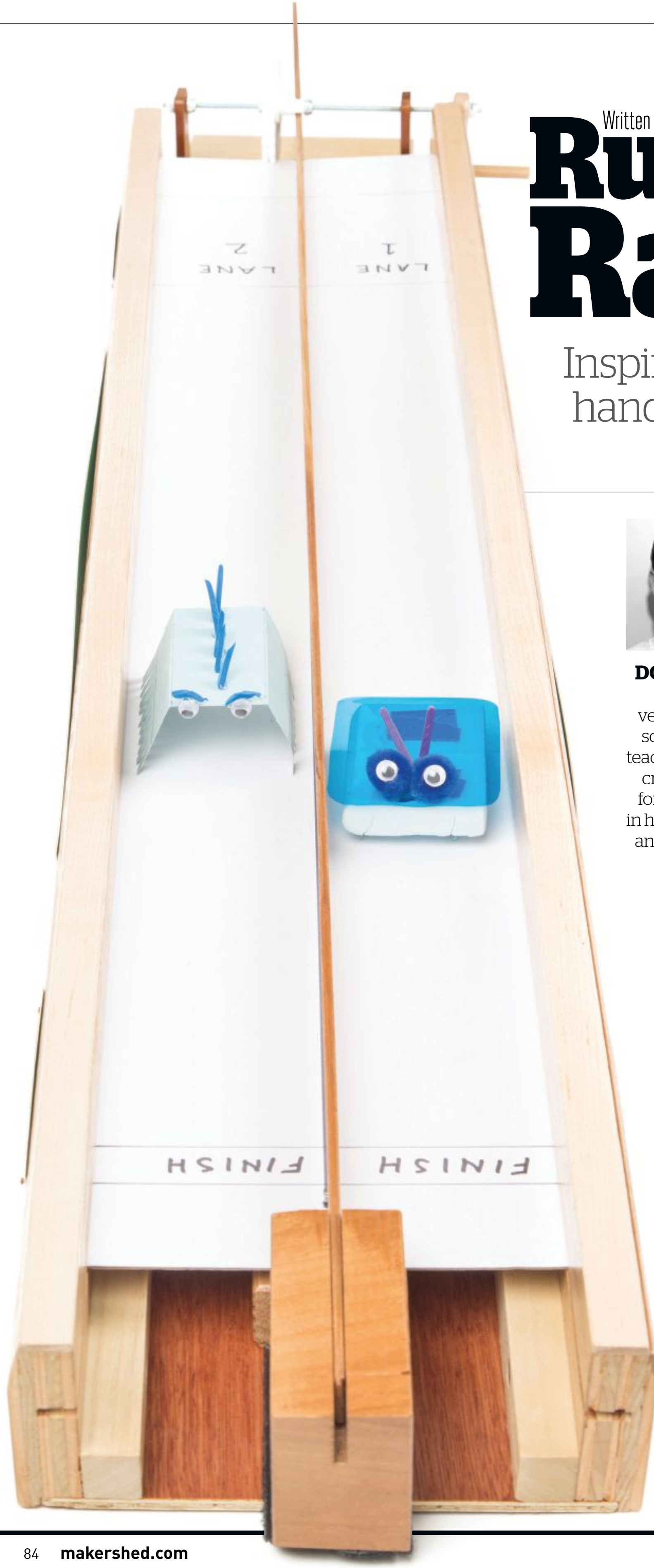


Written by Douglas Stith

Rumblebots Raceway

Inspired by a *Make:* article, here's a hand-cranked classroom science project that's also a lot of fun

DOUG STITH is a 29-year veteran middle school science teacher. He loves creating things for his students in his woodshop, and is currently setting up a home metal shop.

Time Required: 4–5 Hours
Cost: $30–$50

Materials

- **Poster board, about 1/16" thick and 30" long** I used Staples illustration board, 20"×30".
- **Plywood, ¾": 32"×6" (2)** for sides
- **Plywood or MDF, 32"×7",** any thickness for the base
- **Square dowel, 1"×1", 30" lengths (2)**
- **Wood strip, about 32" long** straight and smooth, for lane divider
- **Gear with medium-sized teeth** Try 20- or 40-tooth gears from Ajax Scientific (e.g. Amazon #B00EPQMI2S) or cut your own out of thin plywood. A laser cutter (or 3D printer) makes it even easier.
- **Axle** I used a bolt with 4 lock nuts.
- **Various bits of wood** for hand crank, cantilever block, etc.
- **Wood screws**

Tools

- **Table saw**
- **Drill**
- **Screwdriver**
- **Clamps**
- **Sandpaper or sander**

"COOL! BUT WHAT THE HECK MAKES THEM MOVE *FORWARD*?!"

When I first read about Bob Knetzger's "Hog Holler" toy in *Make:* Volume 41 (makezine.com/2014/11/04/how-to-get-your-toy-made), I was captivated. I knew I had to make something similar for my 6th-grade science students to investigate. The concept seemed simple: vibrations from the player's voice jiggled a platform, causing little plastic "hogs" to move down a path (Figure A). But wouldn't their movements be random, not directional? Perhaps the path angled slightly downhill? Hmmm.

Hep Svadja

I contacted Bob and he explained that angled "legs" are the key to directional movement. Folk toys often used broom bristles or thin wooden strips, he explained. Aha! Progress.

The next problem was devising a new source of vibrations. Initially, I banged drumsticks on a large plastic pan, which *did* move my critters forward. Still, I sought a more consistent vibration. I considered speakers playing set tones, or motors with off-center weights attached to their shafts. After making little progress, I again reached out to Bob. He sent me a video in which the teeth of a gear turned by hand engaged the edge of the track. How simple! Here's my classroom version of Bob's invention.

MY RUMBLEBOT RACEWAY

The vibrating track is a 6"×30" piece of poster board, about 1⁄16" thick (Figure B).

This track rests in table saw blade grooves cut into 2 wooden sides made from ¾" plywood, 32" long and 6" tall. The grooves begin about 1½" up from the bottom and are about ⅜" deep. (None of these exact dimensions are crucial.)

A wooden strip, cantilevered over the track, creates 2 lanes for the racers.

A single gear about 2½" in diameter, mounted on an axle, grates against one end of the track to drive my Rumblebots. A freestanding base allows adjustment of the gear's position on the track (Figure C).

THE RUMBLEBOTS

For the bots themselves, I settled on two basic designs. In the first, I cut a block of styrofoam to fit in a given lane. On its bottom, I cut angled grooves with a razor saw, perpendicular to its length. Into these grooves I placed paper, cardboard, pine needles, pins — most anything imaginable — to serve as legs (Figure D).

In the second design, I took index cards and angled the front and back in similar directions. I then cut wedge-shaped legs on the front and back (Figure E).

RUMBLEBOT RACERS — A FAMILY SCIENCE PROJECT

I offered Rumblebot Racers as a Family Science project to my 6th graders. This means it was not required, nor were any rewards (candy, extra credit) given. Rather, the joy of learning was the motivator for students. I encouraged them to work with friends or family members. I made them a video to explain the project, at makezine.com/go/rumblebots-explainer.

Nineteen students built rumblebots. Two of our custodians even participated. (Their first design featured porcupine quill legs!) Many of my students, taking my suggestion of researching "bristlebots," used toothbrushes. To my dismay, I finished *second* to one of my students! Here is Alex with her winning rumblebot (Figure F).

HOW DO STUDENTS BENEFIT?

Here's what Alex had to say about the project: "I watched the video and made a list of materials I needed. I followed your suggestion on the video and researched Bristlebots. I saw they were made from toothbrushes and motors. I tried using some old, used toothbrushes, and also hairbrushes. Toothbrushes worked best. The toothbrush tipped over easily, so I attached a cardboard top to keep it upright. To test my rumblebots, I placed a piece of cardboard over two pencils and tapped on the cardboard. Once I knew they worked, my mom bought some new toothbrushes. I tried connecting two and three together, but one by itself worked best for me. I liked beating Mr. Stith!"

Another student, Felicia, built a bot that did not move forward, only bounced up and down (Figure G). Her design problem? Vertical legs. Did this mean Felicia's effort was a waste of time? "I still had fun thinking up my own design, and I'm glad I did the project. I saw that when we put the Q-tips into the block at an angle, it did move forward!" (Learning achievement unlocked!)

The world our students inhabit grows more and more virtual every year. Much of what they experience is through a screen. I love seeing students manipulate materials according to their own designs (as opposed to fitting one Lego into another). You can see all the student rumblebot designs and watch actual races at makezine.com/go/rumblebot-races.

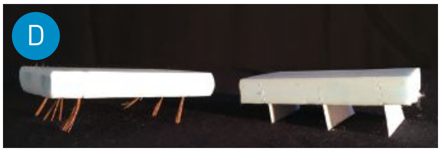
Next, I'll challenge my students to create Rumblebot Sumos (push opponents out of a central zone) and a Rumblebot U-Turn (execute a half-circle turn, and exit the surface on the same edge as they started). Who knows what projects my students may soon be designing for others?

A

B

C

D



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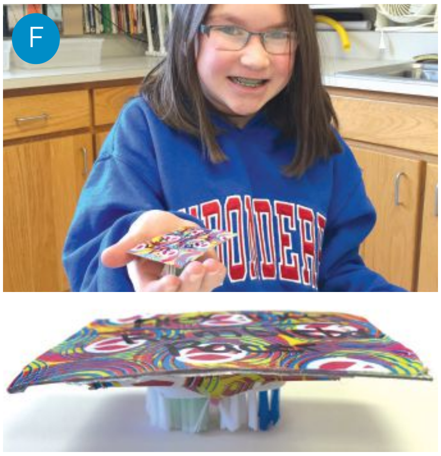


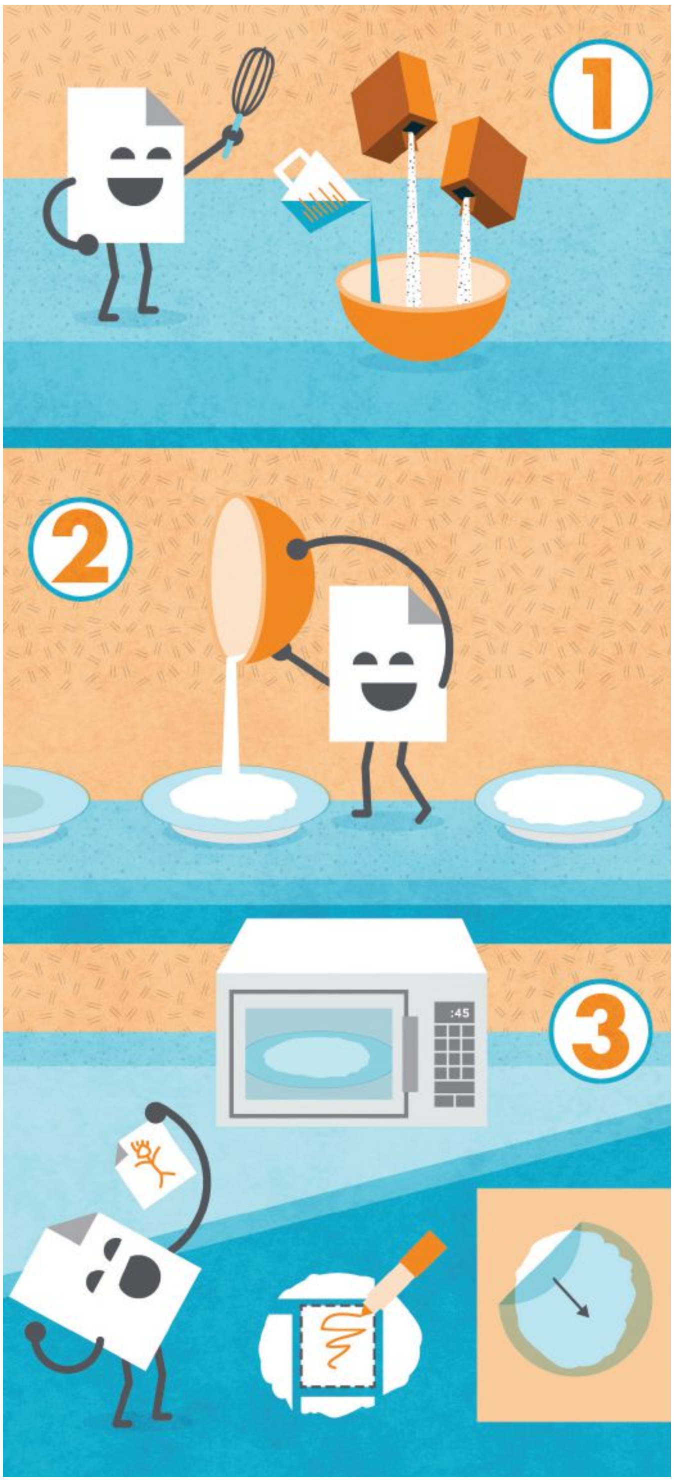
G

See race videos, more photos, and share your rumblebots at makezine.com/go/rumblebots-raceway.

A: Bob Knetzger, [B, C, E]: Hep Svadja, [D, F, G]: Doug Stith

1+2+3 Edible Paper

Written by Kathy Ceceri
Illustrated by Andrew J. Nilsen



PAPER IS COMMONLY MADE FROM PLANT MATERIAL — SO WHY NOT FOOD PLANTS? Every plant's cells are surrounded by a tough, fibrous material called *cellulose*. When chopped up and soaked, the tiny fibers connect with each other, bonded by an intermolecular pull called the *van der Waals' forces*.

Those photos you see on birthday cakes are printed on wafer paper made from vegetable starch. In China rice paper is used for edible candy wrappers, and in Vietnam a different rice paper is used to wrap spring rolls.

You can use edible paper to create place cards for fancy dinners, takeout boxes to hold sweets — or for secret messages. (Devour after reading!) Here's a quick and easy recipe for Vietnamese-style rice paper.

1. MIX

Whisk rice flour, potato starch, salt, and cold water together. It should be about the same thickness as white glue.

2. POUR

Stretch plastic wrap across the plate, tight like a drum. Pour the mixture onto the plastic wrap. Tilt the plate to spread the mixture into a circle at least 7" across.

3. COOK

Microwave on high for 45 seconds. The paper puffs up as the water steams. Use oven mitts to turn the plate upside down on the wax paper. Remove the plate, then carefully peel the plastic wrap away. Your edible paper will curl as it cools. Cut it into a square to help it stay flat. Store 1–2 days in a zip-lock bag.

To add color and flavor: Try a little vanilla, cinnamon, orange juice, maple syrup, coconut milk, mashed banana, or berries. Adjust ingredients to get the right thickness.

To write notes on your edible paper: Buy edible-ink markers or make your own ink by boiling grape or cranberry juice until thick. Or try edible paint made of melted chocolate!

KATHY CECERI (craftsforlearning.com) is the author of kid-friendly books like *Making Simple Robots* and the upcoming *Make: Edible Inventions*. This project is excerpted from *Make: Paper Inventions*, available now from Maker Media.

Time Required: **10–15 Minutes**

Cost: **$1–$2**

You will need:

- 1 tablespoon rice flour
- 1 tablespoon potato starch
- 1½ tablespoons cold water
- Pinch of salt (optional)
- Small mixing bowl
- Whisk or fork
- Spoon or spatula
- Microwavable plate
- Plastic wrap
- Microwave oven
- Oven mitts
- Wax paper
- Cooling rack (optional)
- Knife or shears

Toy Inventor's Notebook

FRIENDLY FAKE-OUTS

Invented and drawn by Bob Knetzger

USE MOLDABLE PLASTIC TO CREATE GREAT NEW PRACTICAL JOKES!

Time Required: 1–2 Hours

Cost: $5–$10

Materials

- **Moldable plastic pellets** such as Friendly Plastic, ShapeLock, InstaMorph, ThermoMorph, or U Mold, aka polycaprolactone
- **Dye pellets for moldable plastic** from U Mold, InstaMorph, Polly Plastics, etc.
- **Hot water**

I'VE WRITTEN ABOUT MAKING PROJECTS USING SUGRU BUT HERE'S ANOTHER versatile and easy-to-use plastic you should know about: Friendly Plastic. Its unfriendly chemical name is *polycaprolactone*. It's sold under other names, too, like InstaMorph, ShapeLock, and U Mold. It's a biodegradable polyester with a low melting point.

Just soften the material in hot water, then shape and form it by hand. When it cools, it solidifies into a tough, nylon-like material that you can cut or drill. And you can add dye pellets to blend any color you'd like. Strong plastic parts instantly molded in custom colors: very practical!

Here are some new versions of classic practical jokes you can quickly make with polycaprolactone. Sure, there's the iconic doggie doo, but check out these other updated fun fakes:

A FAKE KETCHUP AND MUSTARD BLOBS
Add a real empty pouch and put one on mom's iPad!

B CHEWING GUM SMARTPHONE EASEL
Looks gross, works great!

C OOPS SPILLED CREAMER
Surprise someone on their issue of *Make:*!

D CRAZY CRAYON
Won't color no matter how hard they draw. Pack some softened, colored Friendly Plastic into a tube. When cooled, use a pencil sharpener to make a point and wrap it with the paper label from a real crayon.

Share your prank ideas for Friendly Plastic at makezine.com/go/friendly-fake-outs.

Bob Knetzger

Craftsman 10" Benchtop Band Saw

$220 craftsman.com

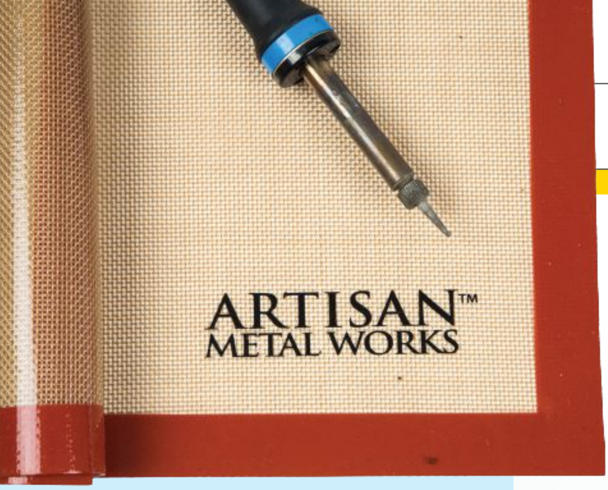
The *Make:* office's Craftsman 10" band saw definitely met the high expectations I've come to have for Craftsman tools. Even after repeated use, I'm pleasantly surprised with its smooth cut and relatively low noise level.

Like many band saws, its 13 ¾"×12 ⅝" build platform has an adjustable angle for cutting at different degrees. You can attach a shop vac to keep dust to a minimum, then remove it for better portability.

The only issue is the work fence; its locking mechanism is similar to a bike cam lock, which isn't the most secure design. It has a tendency to skew slightly, so I use a 90° straightedge to ensure true cuts.

This band saw is great for anyone working in small spaces. It's a decent investment if you're looking for an efficient, cost-effective shop tool.

— Anthony Lam



ARTISAN METAL WORKS SILICONE MAT

$10–$35 for set of 3
artisanmetalworks.biz

Silicone work mats are useful for holding projects steady while protecting your bench top. Unfortunately, they tend to be pretty pricey. We spotted these silicone baking sheets that are similarly made and realized they'd be a useful alternative for a much lower price. Great for electronics projects, the silicone surface helps keep parts from sliding away, and is rated for temperatures up to 480ºF, so those blobs of solder won't pit your desk. The three-pack includes small, medium, and large mats and lists for $35, but can be found online for less than $10. Just be sure to mark "not for food" on it before yours accidentally gets used for a batch of cookies.

— *Mike Senese*

JACKCLAMP SYSTEM

$125 (pair) jackclamp.com

These versatile, beefy bar clamps resemble super-sized quick-grips with 13½" clamping capacity. Thanks to patented parallel, removable bars, you can reassemble the clamp around tricky work pieces or reconfigure it entirely. You can reverse the upper bar to make a spreader for gaps from 32" to ¼" (wish I'd had these when I rebuilt my kitchen deck) or a vertical jack using the foot attachment. Use two together and you can easily jack a cabinet, microwave, or sheet of plywood siding into precise position on the wall — ordinarily two-person jobs. This configuration will even hoist up to 300lbs, as holes in the ends of each rail let you attach hooks. V-jaw attachments let you clamp round pipes, and you can also invert the lower bar to create an offset clamp or offset spreader.

JackClamps are strong enough to align warped 2×4s or lift a quad ATV off the garage floor, and guaranteed not to slip or fade, thanks to four internal braking jaws (where most bar clamps have only two). Integrated bubble levels seem useful mostly for keeping the jacks in vertical plumb, but who knows what uses you'll find for them? They're heavy and spendy — $55 bare, or $125 for the pair with all the accessories — but they're USA-made guaranteed for life, and frankly they look and feel like they'll outlive us all. Now if you'll excuse me I have a deck to go level.

—*Keith Hammond*

BOUTON TRADITIONAL SAFETY GLASSES

$10 safetyglassesusa.com

Reminiscent of the retro specs of Buddy Holly and Woody Allen, these frames put the fashion back in safety. Aside from making you the coolest person in the shop, they block 99.9% of the sun's ultraviolet rays, with lens transmission of UV-5, VL-20 and IR-7. The polycarbonate lenses are anti-scratch/anti-fog, and the frames are extremely comfortable, with a molded nose bridge design that fits most wearers. They also have foldable side-screen protection aiding in anti-fogging, while making them safety compliant. I've worn these for years, using them at home, in the shop, and in large manufacturing facilities. Simply put, they look good, are comfortable, and last a very long time.

— *Emily Coker*

FLIR ONE THERMAL IMAGER

$250 flir.com

One of the troubles with thermal cameras is that details in heat emission visuals aren't always simple to distinguish. The Flir One imager overcomes that by merging the video output from your iPhone or Android's camera with the heat imaging from the clip-on Flir sensor. The result is a unique and fascinating display of the scene you're investigating, with clean, clear lines between objects. It's useful for everything from finding spots in your house where insulation might be lacking, to detecting moisture leaks, or just making and sharing awesome dance videos with your friends.

— MS

KERSHAW KNIFE SHARPENER

$25 kershaw.kaiusaltd.com

I decided to sharpen my beloved Kershaw blade myself, and found that the company sells a handy on-the-go sharpener. I was immediately impressed with its quality. The case is made of 6060-T6 anodized aircraft aluminum — it's ultra-lightweight, and doubles as a screw-on handle. The sharpener unfolds to 9" and offers a 600-grit, diamond-coated oval shaft. This grit is perfect for a knife that is in good shape, not a severely damaged blade. It requires no oil or water to use. To get a wicked sharp edge, simply pull the blade at a 20° angle from bottom to tip.

— EC

IDEVICES OUTDOOR SWITCH

$80 idevicesinc.com

After adding some string lights to the backyard recently, I wanted a way to turn them on and off without having to go outside to unplug the cord from the wall socket. I considered having an electrician run an inside switch to the socket, but then saw iDevice's Wi-Fi-enabled Outdoor Switch. The weatherproof box with two sockets connects to your home network, letting you instantaneously click the power on and off with the tap of an app. But I also discovered that this works with Apple's HomeKit service, meaning I can voice-control my lights with Siri. I'm now certainly driving my neighbors crazy by constantly commanding the lights on and off, and I'm also discovering a world of DIY HomeKit projects I can add to my network.

— MS

Z1 SMOOTH-C SMARTPHONE GIMBAL

$230 zhiyun-tech.com

When documenting your latest and greatest build, sometimes the movement of the camera can make more of a difference in quality than the camera itself. Smoothing out the footage can make even an iPhone shot look incredibly professional.

Three-axis electronic gimbals, like those seen on quadcopters, are now showing up for handheld use. I've been using the Zhiyun Smooth-C, which takes most of the shake and wobble out of my footage. Solid construction, compact size, and a price tag under $250 make this a smart tool for the videographer on the go. And you're not locked into using your cellphone either. This device can work just as well with a small point-and-shoot camera, a GoPro, or even a 360° camera!

— Caleb Kraft

RASPBERRY PI 3

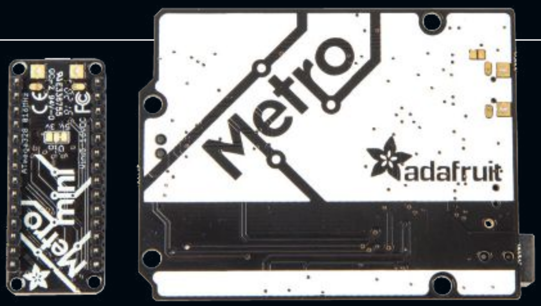
$35 raspberrypi.org

While it keeps the same $35 price tag, a lot has changed under the surface of the latest Raspberry Pi. Dropping the ARM v7 architecture of the previous Pi, the RPi3 has a quad-core 64-bit ARM Cortex A53 clocked at 1.2GHz, which is fast enough to replace a standard desktop PC for most people. It's the first 64-bit Raspberry Pi, but perhaps the biggest change is that it comes with built-in Wi-Fi and Bluetooth 4.1, making it perfect for an Internet of Things project. Interestingly the BCM43438 that provides Wi-Fi and Bluetooth also has an FM receiver, so building an FM radio with an RPi may have just gotten a lot easier.

Running in headless mode the board is well suited as the hub of a sensor network, however watch for unresponsiveness in this mode if the board is only connected via Wi-Fi. You can enable `keep-alive` in your SSH client to avoid this problem with the power-saving mode.

With more than 8 million Raspberry Pi boards sold, the size of the community behind the board is really reassuring, as is the backwards compatibility that the Foundation believes to be vital to the platform.

— Alasdair Allan



ADAFRUIT METRO AND METRO MINI

$19.50/$14.95 adafruit.com

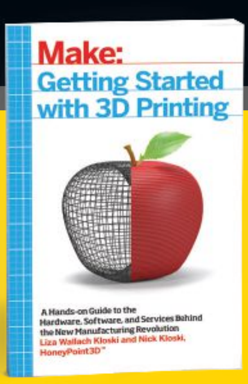
If you said the Adafruit Metro fills the same space as the Arduino Uno, you'd be right and wrong. More accurately, it duplicates the Uno, but adds so much more. At first glance it's an Arduino-sized PCB with an ATmega328P in the center and rows of GPIO pinouts on the top and bottom. Adafruit says all of their shields work with the Metro just like any Uno.

However, the company has added some appealing hardware tidbits, such as a much-needed power switch. You can also solder closed a jumper to change the logic level to 3.3V from the usual 5V. They've swapped in a micro USB socket for powering and programming the board. Finally, they offer the Metro with or without female headers. I used the Metro recently for a client project, leaving off the headers and soldering wires directly into the board. When the project changed and I needed to add a shield, I simply desoldered the wires, added female headers, and mounted the shield as slick as any Uno.

Adafruit levels up the Metro by adding a Mini version offering the same capabilities as the full-sized board, lacking only the power switch. If you're not expecting to use a shield, the cheaper Mini offers the full ATmega328P experience as well as the same FTDI USB-to-serial converter. Contrast this with SparkFun's Pro Mini 328, which requires that you buy a separate FTDI board to program the board.

— John Baichtal

BOOKS



MAKE: GETTING STARTED WITH 3D PRINTING

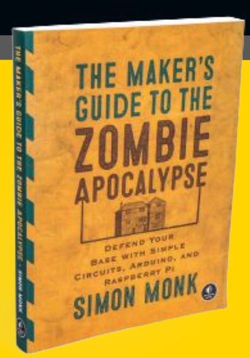
by Liza Wallach Kloski and Nick Kloski

$20 makershed.com

When I started reading *Make: Getting Started with 3D Printing*, by Liza Wallach Kloski and Nick Kloski of HoneyPoint3D, I felt fairly knowledgeable about how to use, maintain, and repair a 3D printer. But even as an experienced user, I found a surprisingly useful breadth of tips and information on topics including how to optimize your prints and how to handle and store filament.

One of the most useful sections is the guide that covers open source 3D modeling software — namely Tinkercad, Autodesk Meshmixer, and Fusion 360. With the authors' guidance, Fusion 360 was a lot less scary and difficult to use for the first time. I highly recommend *GSW 3D Printing* as exceptional reference material to everyone who tinkers with 3D printing, regardless of skill level. I only wish it had been available when I was in college!

— AL



THE MAKER'S GUIDE TO THE ZOMBIE APOCALYPSE

by Simon Monk

$25 nostarch.com

If you're a tech nerd with a penchant for zombie survival tactics, this book is super fun. Even if you're not into zombies, you'll find some great projects for Arduino and Raspberry Pi — although the awesome illustrations keep the theme running even through the technical sections. The various chapters cover everything from home defense and monitoring to how to obtain power for survival (and for building projects). I especially enjoyed learning how to link car batteries together to create a power bank, and the book covers a great range of problematic scenarios and survival skills that the whole family can learn from and enjoy.

— EC

MANNEQUIN

A LITTLE COMMUNITY SUPPORT COULD GO A LONG WAY FOR THIS QUIRKY 3D PRINTER KIT

WRITTEN BY MATT STULTZ

WHILE WALKING AROUND THE TIGHTLY PACKED BOOTHS OF WORLD MAKER FAIRE last fall, I ran into the OpenCreators team and found something just quirky enough to catch my interest: a cardboard 3D printer.

SOME ASSEMBLY REQUIRED

The OpenCreators Mannequin comes as a mostly flat-pack kit and hails from South Korea. The X/Y gantry is a pre-built H-bot system, which drastically reduces the amount of work it takes to assemble. The rest of the parts are fairly intuitive to put together with keyed rods and only a couple of plates. OpenCreators only provides instructions in Korean, but I was still able to assemble the printer in about 3 hours (a record for a kit machine), thanks to the excellent diagrams included in the manual.

The base structure of the Mannequin is all steel and aluminum, making for a rigid machine. The outer shell, which is mostly for aesthetics and to minimize drafts, is made from cardboard. There's even a door with a clear plastic film for a window that's magnetically attached to the front of the machine. The cardboard skins come in multiple colors and make for a lightweight shell that helps reduce the shipping expense and most definitely the production costs of the printer. If you have access to a decently sized laser cutter you could have some fun cutting your own custom exteriors.

BUMPS IN THE ROAD

The onboard LCD is full color and diverges from the standard menus often found on most printers, but is still very easy to navigate and use. I encountered one error when the bed-leveling probe failed to retract after the measuring script completed — although I had selected English as the operating language, the alert still showed in Korean.

My test prints showed lots of problems with the Mannequin, but many of them felt like they could be adjusted in a better Cura profile or by possibly using their optional Simplify3D profile (or a custom one). Many of the issues came from too much ooze from the hot end, something that could be fixed by adjusting the retraction settings.

Some problems are harder for the user to change. The two fans attached to the hot end blow across the heat break, helping to prevent the machine from jamming, but there are no fans pointing at the print to help cool it. The extruder temperature fluctuates wildly and seems to need a PID tuning to bring it into line. The bed-leveling script stalls on the second print after a power cycle, requiring a new power cycle to continue.

CONCLUSION

A little community support could go a long way for this machine. The Mannequin's simple build, decent print space, and fun cardboard shell make it appealing, but until some of the issues with this machine are worked out, OpenCreators will have a hard time finding a market here in the U.S.

For more reviews and testing procedures, go to makezine.com/go/3dp-comparison.

MANUFACTURER OpenCreators
PRICE AS TESTED $670 USD
BUILD VOLUME 200×200×200mm
BED STYLE Non-heated textured plastic
FILAMENT SIZE 1.75mm
OPEN FILAMENT? Yes
TEMPERATURE CONTROL? Yes, tool head
PRINT UNTETHERED? Yes (SD card)
ONBOARD CONTROLS? Yes (LCD with control wheel)
HOST/SLICER SOFTWARE Custom Cura
OS Windows only (but Cura profile can be imported into versions on other OS's)
FIRMWARE Marlin
OPEN SOFTWARE? Yes
OPEN HARDWARE? No
MAXIMUM DECIBELS 48.9

opencreators.net

PRO TIPS

Wrap the X-carriage ribbon cable around the Bowden tube to keep the printer from crunching it when homing.

I needed to power cycle my machine between each print to keep the bed probe operation from jamming.

WHY TO BUY

While this quick-to-assemble machine is rough around the edges, it has a lot of potential for hacking.

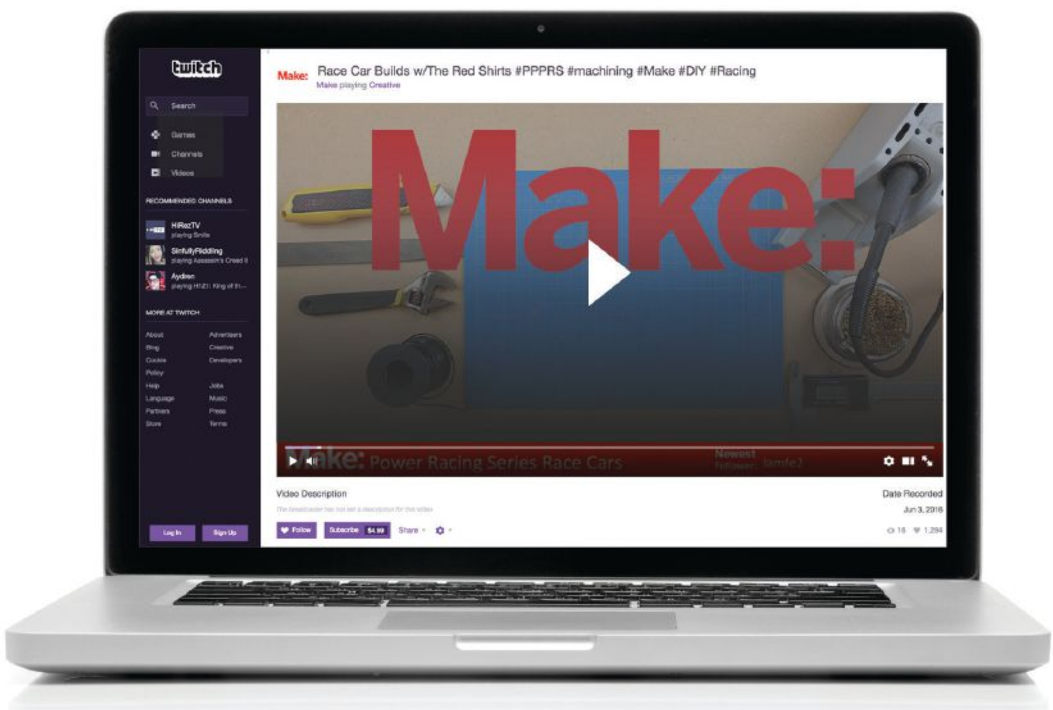
RESULTS

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.

Make:

What are you watching?

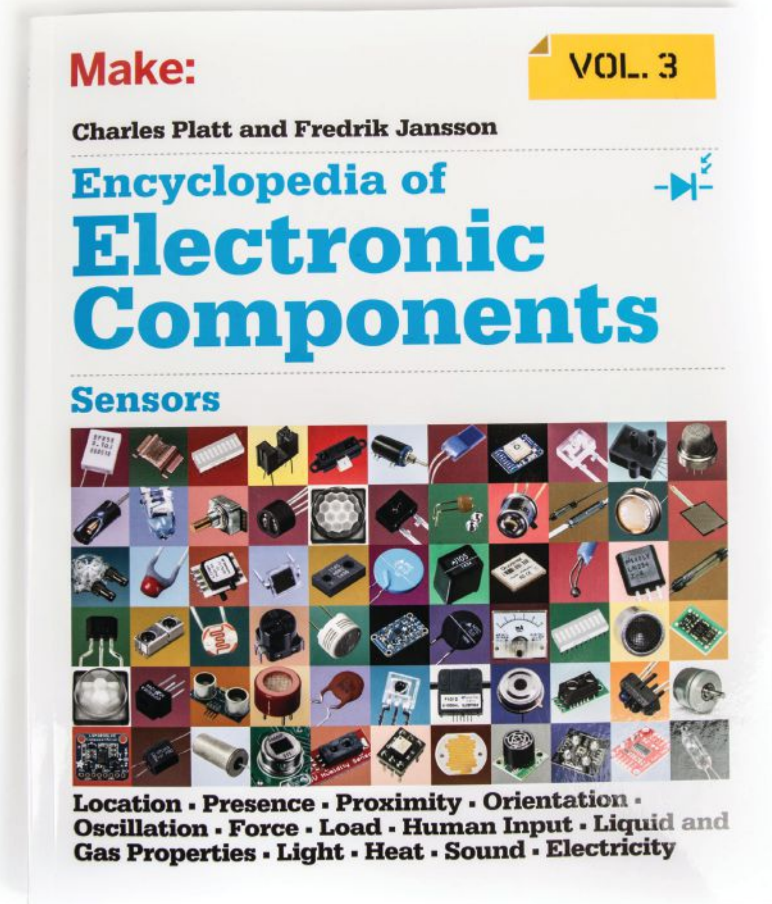


WE'RE LIVE ON TWITCH

Tune in to catch even more making!

Watch the action at
twitch.tv/make

Maker Shed NEW BOOKS



Make: ENCYCLOPEDIA OF ELECTRONIC COMPONENTS, VOLUME 3

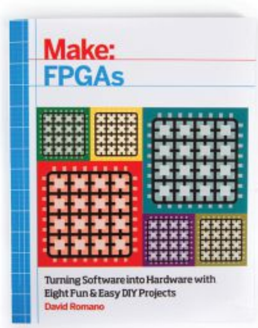
by Charles Platt
$29.99
The final volume in Platt's *Encyclopedia* series focuses on sensors and ways to experience the physical world through light, sound, heat, motion, ambiance, and electricity. Perfect for teachers, hobbyists, engineers, and students.

Make: FIRE

by Tim Deagan $29.99
Learn how to safely build projects that burn, poof, "boosh," and flare! *Make: Fire* explains the history, chemistry, and combustion of propane. With simple tools, you'll learn to build a gorgeous flambeau, a torch capable of melting aluminum, or flame effects that ignite fireballs in the sky. This guide helps readers develop the skills they need to safely create their own flame devices and artworks.

GETTING STARTED WITH PROCESSING.PY

by Casey Reas, Ben Fry & Allison Parrish $29.99
The Processing language opened up the world of programming to artists, designers, educators, and beginners. Written by the co-founders of the Processing project, this book introduces the core concepts of computer programming and working with Processing.



Make: FPGAS

by David Romano $29.99
Learn to design chips that go beyond programming and work faster than code can describe — without going through the manufacturing process. FPGAs let you do that and more. With *Make: FPGAs*, you'll learn to break problems down, design the logic, and run electronics on your finished projects.

UPCOMING BOOKS FROM MAKER MEDIA

Make: KIDS CRAFTS

by Ji Sun Lee & Jaymes Dec
(August; $19.99)
Easy electronics projects for the littlest makers.

ReMaking History, Volume 1: EARLY MAKERS

by William Gurstelle
(August; $19.99)
Create your own artifacts using ancient ideas and new technology.

Make: PROPS AND COSTUME ARMOR

by Shawn Thorsson
(August; $29.99)
Gain the secrets of making professional-looking sci-fi and fantasy wearables.

Make: DESIGN FOR CNC

by Gary Rohrbacher and Anne Filson
(September; $34.99)
Learn to design, fabricate, and assemble your own furniture.

FORREST MIMS' SCIENCE EXPERIMENTS

by Forrest Mims
(September; $19.99)
The best of Forrest Mims' *Make:* magazine columns in one spot!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From Her Majesty's Secret Service

Written by James Burke

Mr. Furze,

Thank you for your application to the Secret Intelligence Service for the position of Lead Inventor. Whilst we admire the fortitude of your designs and curious nature of your civilian imagination, the agency does not foresee a tactical advantage in the field for your type of creations.

Granted, your work is a fine demonstration of classic English ingenuity, and possibly without peer. We just simply do not have a use for a rocket bike, not even for domestic office transportation. Our agents were also slightly concerned for the sanctity of their knees while piloting your hoverbike, even though the long queue for a ride suggests otherwise.

As such, we have to decline your request for a position with the agency. We will, however, keep your information on file, in the event that a particular mission may require your uniquely eclectic skill set.

On a personal note: Whilst your service might not find a home in our global offices, my youngest son has suggested you pursue a career in online video production. It would also serve as an excellent cover, in the event we pursue a professional relationship sometime in the future.

Thank you for you time, Mr. Furze. We shall continue watching your career with merriment.

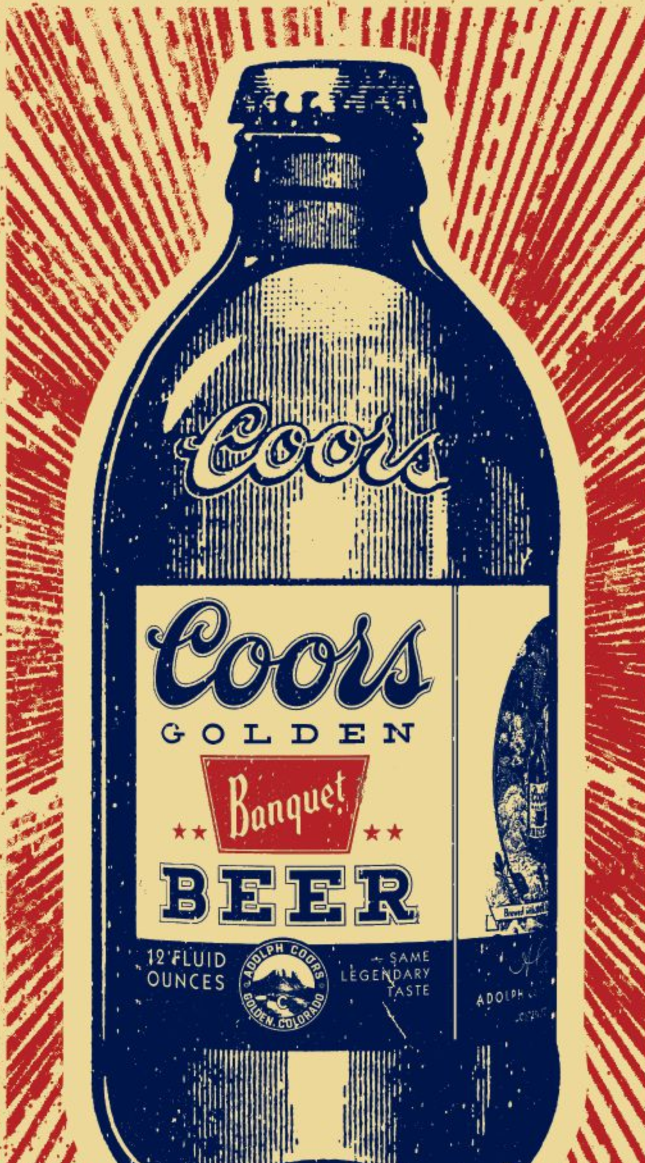
— Agent C
9 April 2009

Paul Burton

See all of Colin Furze's crazy builds and videos at youtube.com/user/colinfurze

Banquet

STANDING



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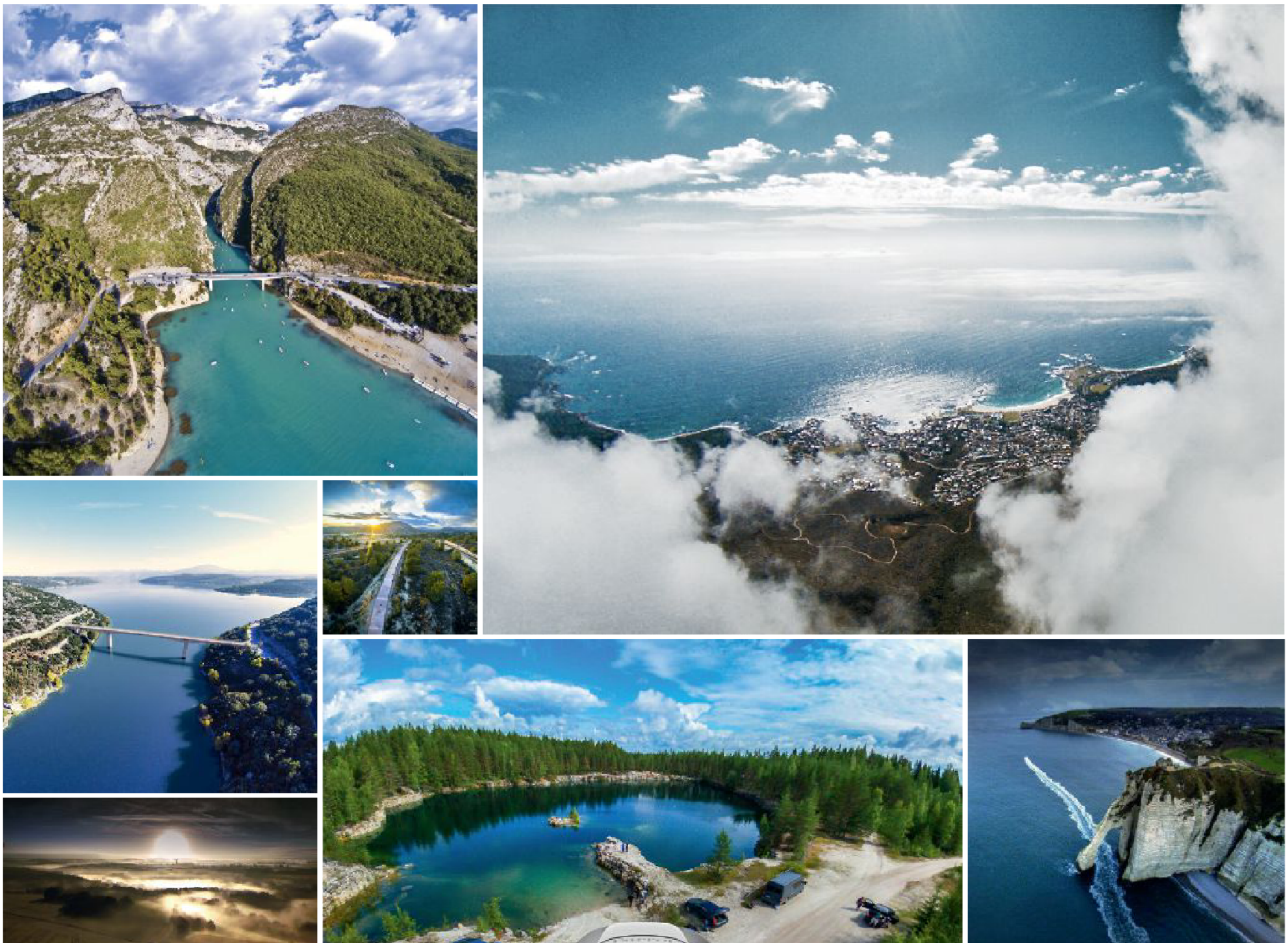

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