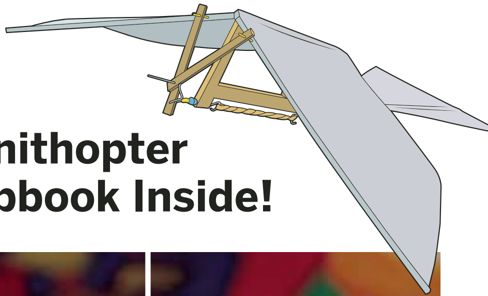
Make:

technology on your time



Ornithopter Flipbook Inside!

PLAY!

8 TOYS & GAMES PROJECTS

» Bring a Vintage Pinball Machine Back to Life

+ MythBuster Adam Savage's Moldmaking How-To

» Shoot Your Alarm Clock

» MIDI Control Sock Monkey

» Small-Batch Coffee Roaster

90 100 110

vol. 08

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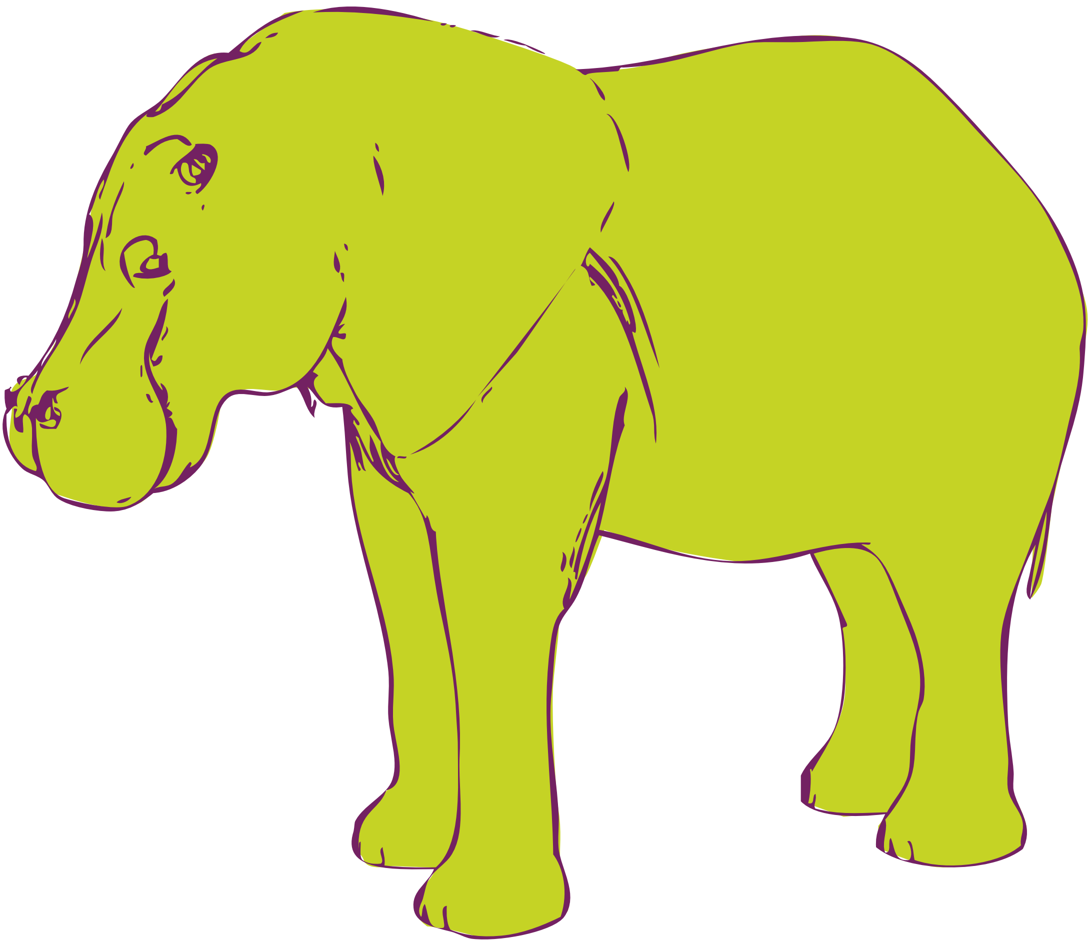
hippophant

= cool hack



spiffysearch

= really cool hack

You've Found SpiffySearch.

SpiffySearch, which stands for "Semi-Permeable Inline Free-Form Yahoo! Search," uses Yahoo!'s Web Search APIs and related Suggestion APIs to field search queries and return them in JSON format, wrapped in JavaScript callbacks.

In layman's terms, SpiffySearch is a Web app that turns any normal search into a live, dynamic search. Which is, of course, way more fun than your everyday search.

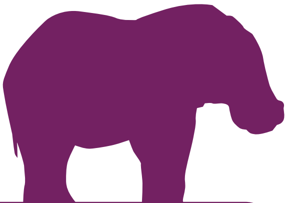
Spiffy DIYer Kent Brewster.

SpiffySearch was created by Kent Brewster. Kent is an engineer at Yahoo! and a devoted hacker. Kent keeps himself pretty busy. When he's not creating cool instant-search boxes so simple that even his mom can use them, he's writing mind-blowing sci-fi. Or updating Brewster's Field Guide to Web 2.666 at www.kentbrewster.com. And when he's not doing that, he's hanging out with his growing family.

Kids, Try This One at Home.

Cut 'n paste the SpiffySearch code from Kent's website and watch your searches go! Get it at www.kentbrewster.com now. And no worries, the code is free.

Check out and download Kent's hack at www.kentbrewster.com/spiffysearch



We're all about DIY. Our engineers are hackers in name and heart. We have a huge number of open APIs. We love seeing the fun, innovative and powerful ideas people come up with, both inside and outside the company. It could be Flickr combined with Yahoo! Maps, or a bright new take on the Yahoo! Search API. Whatever—just make it cool, and make it yours.

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Volume 08

Make:

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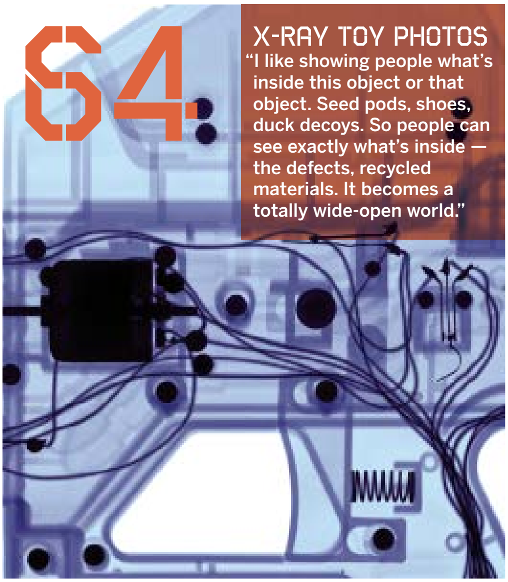
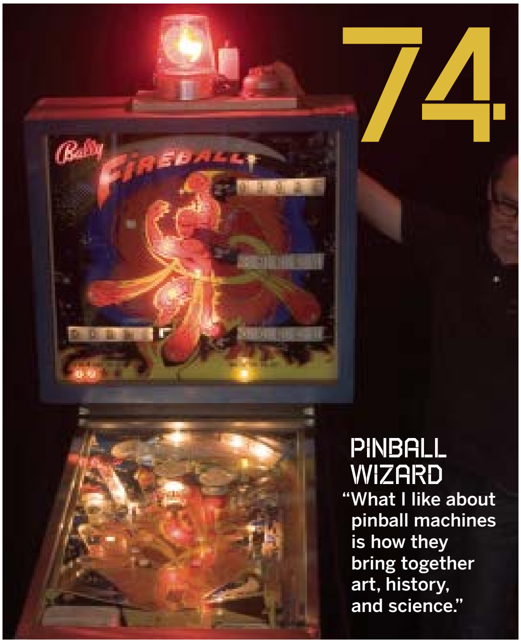
Special Toys & Games Section





ON THE COVER

When MAKE Creative Director Daniel Carter (shown at right) went to the Lucky Ju Ju pinball arcade photo shoot, he was given the task of muffling the bell on the *Fireball* pinball game so it wouldn't bother the beauty salon next door. *Photography by Steve Double*

Columns

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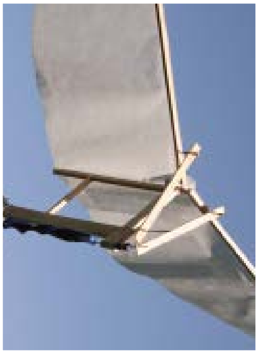
Volkswagen owners love their cars more than other drivers. Whether it's changing the oil or sharing a trip to see a fun part of the world. That's why we call them Pre-Loved Volkswagens. Of course, every one of them has to pass our 112-point inspection to be certified. And we back it with a 2-year/24,000 mi. limited warranty. So head down to your local VW dealer, we think you'll fall in love with one yourself.

Certified Pre-Loved Volkswagens

Make: Projects

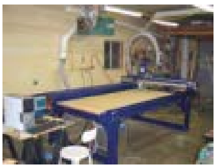


"There's something about seeing children playing with toys that I've made and the smiles on their faces that makes all the hard work worthwhile."

Ed Lang, Mountain View Wood Works
www.mvww.org

Ed Lang, founder of **Mountain View Wood Works**

in Troy, Virginia, has been making toys for an expanding group of enthusiastic customers for more than 20 years. He learned early from his father the importance of doing a project right, with pride and integrity. Ed's friends and customers recognized that passion for quality, and as demand for his toys grew, so did Ed's shop needs. An affordable ShopBot CNC machine allows Ed to quickly make precise, repetitive cuts so he can focus on the assembly and finishing of his one-of-a-kind creations.



Ed brought his ShopBot home to the workshop in late 2005.

"My ShopBot allows me to increase production of the toys I make without compromising quality and pride of workmanship. The toymaker is alive and well in my shop; he has just embraced technology."

ShopBot CNC Routers — What have you created today?

ShopBot

ShopBot Tools, Durham, NC 919-680-4800

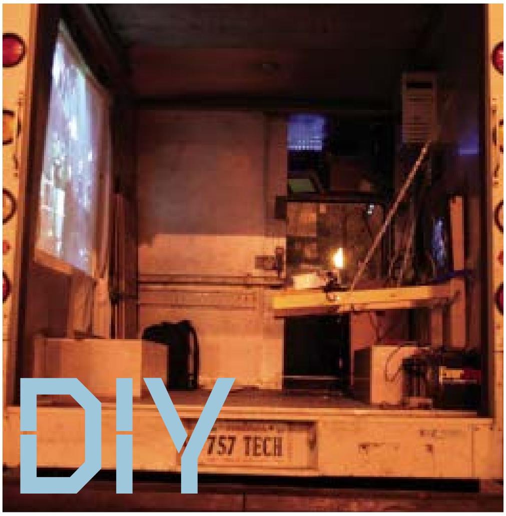
www.shopbottools.com

Volume 08

Columns

Maker

READ ME: Always check the URL associated with each project before you get started. There may be important updates or corrections.



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MAKER PROFILE
Can a machine have a soul? Can it laugh and cry, bug you for a snack, tease you, and dream robotic dreams? Can you sell it for $250?

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Your safety is your own responsibility, including proper use of equipment and safety gear, and determining whether you have adequate skill and experience. Power tools, electricity, and other resources used for these projects are dangerous, unless used properly and with adequate precautions, including safety gear. Some illustrative photos do not depict safety precautions or equipment, in order to show the project steps more clearly. These projects are not intended for use by children.

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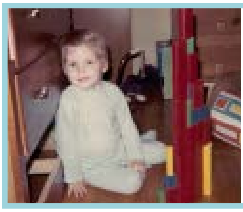
Contributors

Steve Double (*Pinball Restoration* photos) has been working as a professional photographer for 21 years. Some highlights are having 90 seconds to photograph Bill Gates, waiting six hours for the Spice Girls, being chided for lateness by Public Enemy, drinking caipirinhas with Nick Cave, blagging an upgrade off Richard Branson, spending five days in a van with Nirvana, and never having to wear a tie. He recently acquired a digital back for his Hasselblad and now embraces techniques from Polaroid image transfer and emulsion lift to completely filmless shooting. He is old enough to know better.

Mikey Sklar (*Making It*) likes to blow things up. It started innocently enough just placing Black Cat firecrackers in dog poop and running. This technique basically covers you in crap. Twenty years later he has created an open source fire-shooting trampoline. When he is not thinking about fire, his time is well-spent programming microcontrollers, cooking up vegan meals, and watching how-to documentaries. He is presently building a self-balancing electric vehicle and a bed-and-breakfast out of garbage.

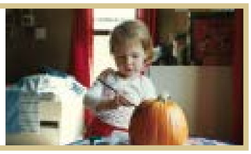
Roger Ibars (*Toy Gun Alarm Clock*) remembers: "Once when I was a kid, my dad could not open a door. The key somehow got jammed into the lock and he tried everything ... twisted it, banged it, pushed it. Nothing. I was 3 years old and I remember I had a strange feeling. I felt I could open that door! ... So I waited until my dad left, I put my hands on the key and ... magic! I opened it! This picture shows the outfit I was wearing that day."

Larry Cotton (*Small-Batch Coffee Roaster*) is a "musical, energetic, creative, happily married, semi-retired power tools engineer-turned-math teacher" (try saying that in one breath), lives in New Bern, N.C., with his wife, Sylvia, and "one irrationally exuberant dog." He is a compulsive tinkerer who is currently playing with "weird clocks based on an el-cheapo time-base device" and who loves lasagna, bright colors, and his 1950s vintage Shopsmith. His dream project is the "Pixbox," a hardware USB digital photo editor loaded with switches and knobs, a randomize button for creative types, unlimited undo, and in Google's honor, an "I Feel Lucky" button. It doesn't exist yet, but Larry is open to collaboration.



Brian Biggs (*Flipbook* illustrations) was born in Little Rock, Ark., in 1968, the son of a Portuguese train bandit and a mystical one-armed sailor with secret powers. He grew up mostly in Pasadena, Texas, where he learned to talk to cows. He went to Parsons School of Design with the mistaken notion that he would be a magazine art director. Later, he realized that he was not cut out for regular jobs. Brian now lives in Philadelphia, where he rides bikes, draws robots, plays the accordion, teaches illustration, and hangs out with his two kids (who are magical raccoons and know how to fly). Visit him at MrBiggs.com.

Adrienne Foreman (MAKE web intern) is a Jill of some trades, and master of none. She assists with web production, helps keep the MAKE website up and running smoothly, and adds the entire Table of Contents online for each issue. A college student without a major, she generally has a hard time making up her mind. She is currently in the middle of a love affair with the color green and chocolate-covered PayDay bars.



Simply put, **Adam Savage** (*Moldmaking*) makes stuff. He's constructed everything from spaceships to Buddhas, puppets to rifles, sculptures to toys. His fascination with creating things started when he began building his own toys at age 5. In addition to co-hosting Discovery Channel's *MythBusters*, Adam also teaches advanced model making in Industrial Design departments and somehow finds time to devote to his own art. His sculptures have been showcased in more than 40 shows in San Francisco, New York and Charleston, W.V.

FOLLOW THE BOUNCING BALL

By Dale Dougherty

PULL BACK THE LAUNCHER AND LET GO. The silver ball rides up the side, follows the curve at the top, and then begins to descend. This is the much-anticipated moment that makes playing pinball so great. You just don't know what the ball is going to do.

Michael Schiess of Lucky Ju Ju Pinball Gallery (ujuju.com), profiled in our pinball feature (*see page 74*), gave me a brief history of the game. Pinball started as a French game known as bagatelle, something the aristocracy enjoyed playing.

The playfield was a raked wooden board with fixed pins. The ball was launched with a cue; it would bounce off the pins and eventually drop into holes, which had number values for scoring. During the American Revolution, the French brought bagatelle to the United States, where it became popular. Then, during the Depression, this pin game became a machine, fully mechanized; then electrified; and finally digitized. Manufacturers competed by offering compelling art themes and new features; for instance, flippers were added in 1947.

The first pinball machines were placed in the corner grocery store but were soon clustered in arcades, where teenagers could hang out and act depraved like French nobles. Schiess and others emphasize this social side of pinball, which was lost when kids stayed home to play video games.

In his book *The Pinball Effect*, techno-raconteur James Burke uses the unpredictable path of the pinball as a metaphor for technological innovation. His book is not about how things work, but "the crazy way the pinball of change works its magic, bouncing here and there across time and space." This book, like his well-known TV show *Connections*, attempts to follow the nonlinear path of discoveries and new ideas and how they jump across borders, industries, and disciplines.

From Burke's book, let's take the real-life example of Gideon Sundback, a Swedish-born Canadian engineer who works for the Universal Fastener Company in the early 1900s. Sundback works for an engineer named Judson, who's been trying to solve what I'll call a "boot sequence" problem. Burke sets up the linkages: Goodyear's synthetic rubber is used to make better bicycle tires, and bicycles become so popular that even women want to ride them, which causes women's fashion to change and hemlines to rise. Women's boots follow suit, rising to cover more of the leg. The number of hook-and-eye fasteners on a boot was at 20 and growing, a time-consuming number to fasten.

Judson had patented the "C-curity Fastner" but it didn't take off. Sundback improved it. His version had 10-11 teeth per inch to Judson's four. He called it the "Separable Fastener" in his first patent, which was awarded in 1913. He also created machines to make these fasteners. But his invention was also slow to take off, perhaps because his fasteners weren't yet fashionable.

In 1923, the BF Goodrich Company created rubber boots for the military that used Sundback's fastener, which they named the Zipper. Only later, in the 1930s, did zippers begin to be used widely in clothing as a convenience.

Now I'll take Burke's example one step further, jumping beyond technology. In 1971, Andy Warhol designed an album cover for the Rolling Stones that used a real zipper. The zipper had to be left open partway so that the back of it would line up with the record label, and not the record itself, which it might scratch. *Sticky Fingers* transformed zippers from a functional item into a pop-art icon of desire.

But wait, there's more. The same year, a new pinball game called *Fireball* introduced a new feature: "Zipper Flippers." The flippers actually slide together to catch the ball and prevent it from dropping down the hole.

Even pinball machines are subject to the Pinball Effect. That's just crazy.

Dale Dougherty (dale@oreilly.com) is editor and publisher of MAKE and CRAFT.

GAMES WITH A PURPOSE

By Tim O'Reilly

IN JULY OF 2006, CARNEGIE MELLON professor Luis von Ahn gave a tech talk at Google entitled, "Games with a Purpose." In it, he described his ESP Game, which matches up two people selected at random over the internet and asks them to guess the same label for photos that are shown simultaneously to each of them.

Participants have a good time — players report a great feeling of satisfaction as they get "in sync" and make similar guesses. People have played for 15 hours at a stretch, and many regularly play as much as 20 hours a week.

The outcome: 75,000 players have provided 15 million labels for images. And labels generated by agreement between two independent players are remarkably accurate and useful. Von Ahn estimates that if the game were played by 5,000 simultaneous players — a number common on popular gaming sites — it would take about two months to label all the images in Google Images. In September, Google launched the Google Image Labeler, putting customers to work in much the way von Ahn has proposed.

This story is interesting, not only as an illustration of one of the themes I've written about previously — that our software is becoming bionic, fusing human and machine intelligence rather than achieving artificial intelligence — but also because it highlights the importance of play as an outlet for human energy.

In his talk, von Ahn pointed out that in 2003, about 9 billion human-hours were spent playing solitaire. By contrast, only 7 million human-hours (6.8 hours of solitaire) were spent building the Empire State Building, and only 20 million human-hours on the Panama Canal. That's a staggering amount of play, and that's on only one small game. Von Ahn waggishly pointed out that harnessing humans to play games, especially games that solve computer problems that AI cannot yet solve, would have been a far more plausible pretext for the AI of the Matrix to keep humans around. In fact, he's committed to just that goal, saying: "We're going to consider all humanity as an extremely advanced and large-scale distributed processing unit that can solve large-scale problems that computers cannot yet solve."

I liked von Ahn's phrase, "games with a purpose," but of course, all games have a purpose, not merely those that put us to work helping out our computers. Play is so central to human experience that historian Johan Huizinga suggested that our species be called *Homo ludens*, man the player. (Notably, in the same paragraph, he also mentioned *Homo faber*, man the maker, as another alternative to the familiar *Homo sapiens*, man the thinker.)

What makers understand is that play is as important as work. It's not just how we pass the time, it's how we learn and explore.

As I mentioned in my last column, back in August, in Wired News John Seely Brown told the story of how status as a *World of Warcraft* guild master helped Stephen Gillet win a senior engineering management position at Yahoo.

"The process of becoming an effective *World of Warcraft* guild master amounts to a total-immersion course in leadership. ... To run a large one, a guild master must be adept at many skills: attracting, evaluating, and recruiting new members; creating apprenticeship programs; orchestrating group strategy; and adjudicating disputes. ... Never mind the virtual surroundings; these conditions provide real-world training a manager can apply directly in the workplace."

Perhaps even more importantly, he writes: "Unlike education acquired through textbooks, lectures, and classroom instruction, what takes place in massively multiplayer online games is what we call accidental learning. ... Accidental learning relies on failure. Virtual environments are safe platforms for trial and error. The chance of failure is high, but the cost is low and the lessons learned are immediate."

We play to learn. What we make when we play is ourselves.

Check makezine.com/08/nff for related stories.

Tim O'Reilly (tim.oreilly.com) is founder and CEO of O'Reilly Media, Inc. See what's on the O'Reilly Radar at radar.oreilly.com.

WHY THOSE KIDS FROM PODUNK ARE KEEPING YOU DOWN

By Merlin Mann and Danny O'Brien

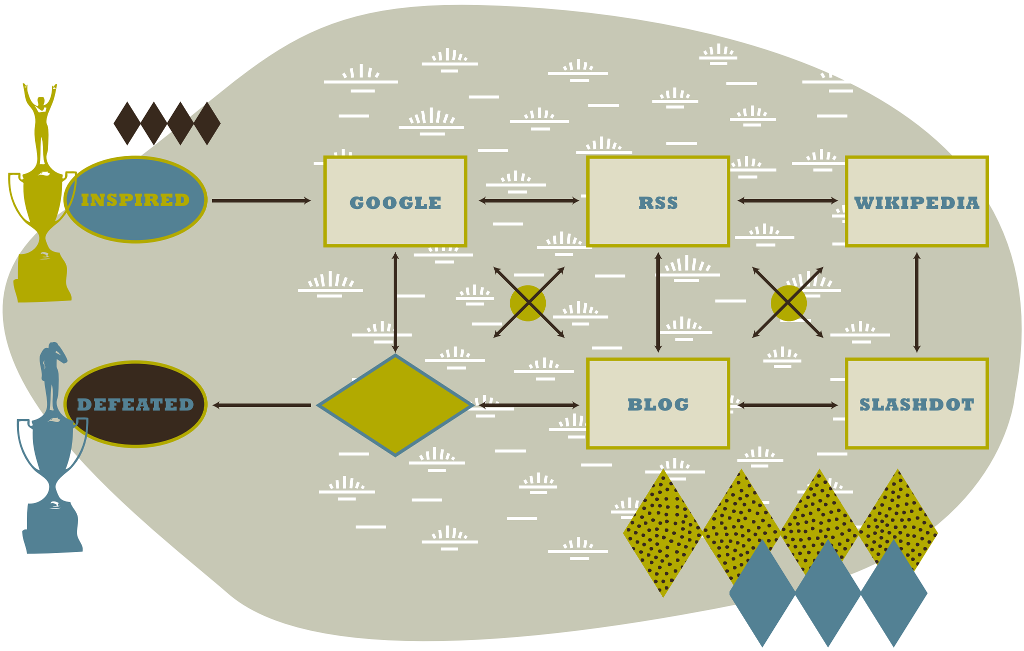


Illustration by Jemma Hostetler

GLENN DAVIS, THE GUY WHO FOUNDED Cool Site of the Day, once told Danny what he thought made the net great. He said, "Suppose there's this young kid in Podunk, Connecticut. He runs a site about a niche, weaving wicker baskets, or naked piano-tuning, or what have you. In another age, that kid would probably have toiled in obscurity, but now he can discover that he is the best wicker-weaver or nude piano-tuner in the world. And he learns, as the rest of the world learns, through his website."

Now, to Glenn, that was a good thing. Such was the youthful optimism of the net.

Well, we've been monitoring what can slow down a maker, and we're not so sure of this whole "meritocracy equals good" thing. We think it's those kids from Podunk who are keeping you down.

Neat organizing tricks contribute about 30% to efficiency and productivity. The other 70% is about motivation. And, frankly, constant exposure to all the world's most wonderful hackers can act as a great demotivator to even the most iron-hearted beginner. How many times have you had a cool idea, googled it, realized that about 50 other people have implemented something similar, so didn't bother to take it any further?

The problem is that over time, the web has become a Massively Parallel Distributed Network of Kids in Podunk. Everywhere you look, people are doing things of such great coolness that you hardly feel you can keep up. This magazine is full of these sorts of things. Your RSS aggregator is dripping with such excitement.

Depending on your mood at the time, the whole idea of a world of excellence might fill you with sickening dread. At those dark moments, the web becomes that horrid machine that Douglas Adams once conjectured, the "total perspective vortex" where, at any one time, you know exactly how many people were ahead of you in the queue when God gave out the ability to play poker, learn the accordion, hack Xboxes, or lip-sync to Romanian pop songs.

Well, speaking as the 43rd and 72nd world experts in cheering up dispirited geeks, respectively, allow us to speak to your horror, and thereby lift your spirits.

First, let's add some perspective of our own. As part of the Life Hacks research, we met and talked to some of these paragons of productivity. Let us reassure you, they're precisely as screwed up as you are. Possibly more so, actually.

Behind every successful geek is a trail of barely mentioned (yet spectacular) failures. We never see this, because most of us, even in our most confessional bloggings, put a little bit of shine on the work that's being done.

Don't try to compete with the entire internet. Your RSS aggregator is called that for a reason — it's glomming together the best of millions. You don't have to be as good as all of them.

If you're ever frozen into inaction by the kids from Podunk, here are a couple of practical tips to switch your "spectator/participant" toggle switch.

First: Hack the net's tendency to catch both the good and bad. Don't try and learn from your geek heroes as they are now. Almost certainly, they'll be less intimidating if you look at their work from five or ten years ago, when they were blundering around as much as you and had their own heroes that they could never live up to.

Back in Glenn's time, the kids from Podunk didn't have a history on the net. But now we all do, and the Internet Archive's Wayback Machine is your friend. So, if you're awed by Tim Berners-Lee, Glenn Davis, Dave Winer, Guido van Rossum, or anyone in the contents of this magazine, do a little exploring. Find out how they started and emulate that — if you can.

Second: Hack your awe of someone else for your own use. A friend of ours really wanted to get into Linux Kernel development but had no idea how. Rather than just file a bug he found in the kernel, he included a request asking where he should start if he wanted to fix it. Alan Cox, who plays deputy to Linus Torvalds, emailed back with a short, sweet suggestion. It wasn't much, but our friend was so in awe of Cox that it made his week and kickstarted his coding.

As long as you're prepared to take on a share of the work (rather than just fawning or drive-by flaming), the heroes and heroines of the net are happy to point you in the right direction. And the narrower your hero's focus might be, the more impressed he'll be that anyone is paying any attention to him. You never know, you might become his hero for being so interested in his hobby. We've seen it happen. Kids from Podunk are just looking for other kids to play with.

Learn how to reel in your mind at Danny O'Brien's lifehacks.com and Merlin Mann's 43folders.com.

HIGH-DEFINITION EQUALS HIGHLY DEADLY

By Cory Doctorow

WHO KNEW THAT HIGH-DEFINITION television would prove so deadly? The way I see it, HD could precipitate great harm to open source (and the tinkerers who love it), competition, free speech, and the right to remix, not to mention the bottom lines for the studios and today's TV stars.

Standard-def TV might be a little fugly (NTSC: Never Twice Same Color!), but it has this virtue: anyone can implement it. There are no patents lurking in SD, no copyrights, no license agreements. In 1979, I plugged an Apple II+ into a standard TV set. Today, I can connect a Slingbox to it. The world is full of these cheap and dirty displays, and innumerable revolutions owe their success to this fact, from Pong to the PC.

High-def is different. Between DRM and patents, it's nearly impossible to make an HD set that receives content from the widest pool of HD devices — like DVD-HD and Blu-Ray players, and many HD consoles — without a lot of butt-kissing. If you want to go near this stuff, prepare to build neutered devices that won't upset anyone's apple cart. You have to please media executives who think that skipping commercials should be a crime.

It gets worse. The studios are bent on bringing something called the Broadcast Flag (in the U.S. and Canada) and DVB-CPCM (in the rest of the world) to HD. This would require anyone building an HD receiver to ensure that it couldn't be used in connection with open source ("user modifiable") software, and that any implementers must license an "approved" anti-copying system that will come loaded with all sorts of conditions about how you can and can't build a device. Forget plugging in a PC, Pong console, or even a Slingbox.

Because PCs are potential HD tuners, this rule will encourage manufacturers of commodity components — like hard drives and video cards — to follow the same rules so that their products can be used in HDTV. Goodbye open platforms, hello monopoly lockware.

But will the public buy HD sets in large numbers? Maybe not. After all, contemporary programming looks pretty weird in high-def. Check out an HD episode of *Friends* — Courteney Cox does not improve at higher resolutions. Every pore gapes, the hair-sprayed coiffure looks as stiff and unnatural as a corset, and the standard-def cute moues and pouts become grotesque comedy masks at high-res.

If HDTV has a future, it's in the invention of a new art form that exploits the inherent characteristics of the medium. Rather than trying to bridge the "uncanny valley" in HD, a savvy director might instead stick several low-res pictures on the screen at once, overlapping them and bringing parts of them forward and back, like the hyperactive display on a customized *World of Warcraft* environment or your own PC desktop.

Forget plugging in a PC, Pong Console, or Slingbox. Goodbye open platforms, hello monopoly lockware.

And if that's too weird, there's plenty of room at the bottom: tiny HD screens forgive many of the sins that are starkly revealed by wall-hogging monster TVs.

Cory Doctorow (craphound.com) is a science fiction novelist, blogger, and technology activist. He is co-editor of the popular weblog Boing Boing (boingboing.net), and a contributor to *Wired*, *Popular Science*, and *The New York Times*.

1+2+3 Custom Travel-Game Mod

By Harry Miller

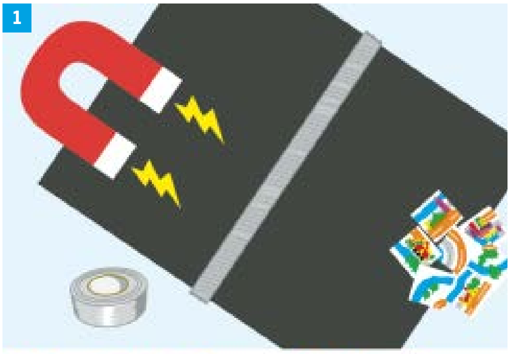
Make a travel edition of your favorite, and otherwise housebound, board game.

You will need: Magnetic metal boards (available at office supply stores), clear Contact paper, duct tape, adhesive magnetic paper or magnets, plastic clips (to hold cards or paper money together)

Can you take your favorite board game with you on a trip? If not, follow my instructions to make your own travel edition. I made a travel version of Rivers, Roads and Rails (by Ravensburger). The original version has to be played on the floor or on a table. You can take mine in a plane, a car, or a boat. When choosing your game, keep in mind that the fewer the pieces the better.

1. Make a magnetic board.

Rivers, Roads and Rails is composed of 140 2"×2" cardboard tiles, on which are drawn a river, a road, a railroad, or a combination of any of the three. The pieces for a travel edition need to be able to move without disrupting the game. Also, the playing space needs to be more confined. I found that 2 magnetic metal boards (about 9"×14") held together by a piece of duct tape were a small-enough space to play on if I shrunk the tiles down by half.

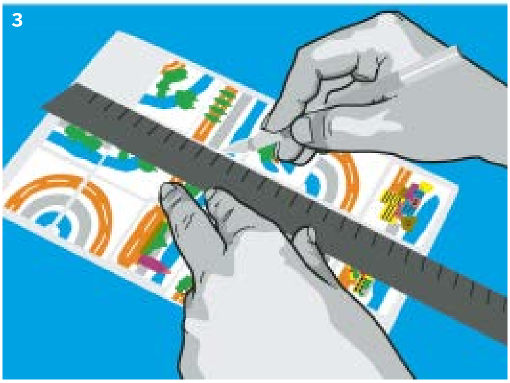


2. Shrink game pieces and playing field.

I used my printer/copier to shrink the tiles down by half to 1"×1" squares. If your game has an illustrated playing field, you'll have to do the same thing for the game board, and then stick it to the magnetic boards.

3. Make the game pieces magnetic.

Take a sheet of flexible adhesive magnet paper and stick the tiles onto them. Then cover them with clear Contact paper and cut them apart using a cutting board. (My mom helped a bit.) I sent a letter to Ravensburger with my design plans, hoping they will produce it. (Maybe I can even get some credit.)



For extra credit

+ A zip-lock plastic bag might work just fine as the travel bag, and some plastic potato-chip clips can keep your game cards together. On the other hand, a hand-sewn bag of vintage fabric and an old silver cigarette case may be a more elegant card holder.

You're done! Play the game to find any flaws. If there are problems, go back and make necessary adjustments until it's perfect!

Harry Miller is a 12-year-old home-schooler who loves to invent, build, and destroy things. On sunny days he can be found terrorizing plastic soldiers with a magnifying glass.

Illustrations by Dustin Hostetler

MADEONEARTH

Report from the world of backyard technology

Mr. Cranky

After you've made what George Lucas called his favorite *Star Wars* parody, how do you keep turning culture on its ear? Retired filmmaker **Ernie Fosselius** (*Hardware Wars*) has been cranking out a wonderful menagerie of mechanical woodcarvings.

Like his hit 1977 movie spoof, which turned eggbeaters into spaceships and crusty rolls into Princess Leia's braids, Fosselius' sculptures poke fun with quick, broad strokes. The face of *Bi-Polar Bear* changes from happy to sad with the turn of a crank; when you turn the crank on *The Politician*, the smirking statuette does ... nothing.

Part of the joy is watching the clever mechanisms Fosselius puts in plain sight, like the spinning drill bit that simulates a stream of coffee. "I like to be the magician who reveals all his secrets, so you want to go home and try it yourself," he explains.

He takes that same exploratory approach as a maker. "I just keep myself open to what [a piece] wants to do," he says. "I never have a blueprint, only a rough cartoon. It's really that *process* of building and tinkering and refining that's the most interesting, rewarding, and fun part. Finishing is anticlimactic."

Fosselius crafts his characters out of basswood, doing the initial shaping on a band saw and then whittling them down with a pocketknife, a carving knife, and palm gouges. "If you look closely at the boxes and bases, you'll see that I'm not much of a woodworker," he claims. "I don't like rulers. And I hate to sand. If you can put the joke over in the simplest way, why bother? Use that time to make another piece.

"I feel that I'm still making movies. I'm creating little characters, situations, and stories that hopefully make people laugh. But it's *direct* entertainment. Unlike films, I get to be there when people experience it."

—David Battino

Read an interview with Ernie Fosselius at makezine.com/08/made_fossel

Ernie Fosselius: contraptions@msn.com
en.wikipedia.org/wiki/Ernie_Fosselius

Photography by Mark Frauenfelder

Photograph courtesy of Theo Jansen

Belly of the Beast

It's not often that studying physics leads to the creation of huge, self-propelled sand walkers that seem more like the living skeletons in *Jason and the Argonauts* than sculptures made of conduits and wire. But for **Theo Jansen**, science has a long, bony arm. He never finished that physics degree, becoming a painter instead.

"In the 80s the physics came back again," he says, and he started tossing around more sculptural ideas. He launched *UFO*, a 14-foot black disc, over the town of Delft, Netherlands. He dabbled in performance and photography, creating light sculptures of the track of an ultralight flight and of a drill suspended high over the street, swinging back and forth.

Then, in 1990, he came across some cheap conduits in a store, started playing around with them, and has been playing ever since. Called the *Strandbeesten* ("beach creatures"), his creations are built from yellow plastic tubing, recycled wood, string, plastic sheeting, and vast amounts of imagination. Each creature can take up to a year to build. Propelled by wind and inertia, they stumble, creak, and race across the ground.

Jansen has displayed his sculptures in galleries (and, more recently, in London's Trafalgar Square), but their native home is clearly the beach. While some look more like giant armored spiders or mechanical, many-legged rhinos, others are elegant spiral skeletons that sweep along the sand with surprising agility. Sometimes huge, fan-like sails catch the wind and start the motion, lending the entire scene the look of a futuristic pirate fleet. Or soda bottles pumped full of air will jump-start the creatures, like some sort of elaborate, earthbound bottle rocket.

Extremely low-tech, futuristic, and visionary (Jansen's CAD drawings look like the cockroaches that would survive Armageddon), the creatures have an aesthetic that is humble and handmade, and at the same time sophisticated and highly technical. Clearly a lot of time and effort goes into each *Strandbeest*, but when asked about the plans for his next sculpture, Jansen says: "Theo must survive. So I am thinking very functional." *—Arwen O'Reilly*

Theo Jansen's website: strandbeest.com

Camera-on-Wheels

Famed landscape photographer Ansel Adams once said, "You don't take a photograph, you make it." According to San Francisco photographer-sculptor **Jo Babcock**, that's not good enough. Babcock isn't satisfied unless he's also made the camera itself.

During the last 25 years, he's crafted more than 200 of them, turning everything from coffee pots to suitcases into the DIY darlings commonly known as pinhole cameras. But the most ambitious of Babcock's creations are the contraptions he's fashioned from motor vehicles, including a VW van and an Airstream motor home. What's next, a 747?

The van-cam works on the same general principle as Babcock's other pinholes, except that it's on wheels. A needle-sized hole in the side wall acts as a mini aperture. Light pours in, projecting an image onto photo paper (you can't find film that large) taped to the opposite wall. No lenses required. But the van also doubles as a proper camera obscura ("dark room" in Latin), thanks to the addition of a lens and mirror on the roof. Because of the tiny aperture, the first van-cam took four hours to expose a pinhole pic. Using the lens, Babcock can send an image to the vehicle's floor and develop a paper negative in a fraction of the time.

Babcock, who taught photography at the San Francisco Art Institute and the University of California, Santa Cruz, among other institutions, is a firm believer in the merits of creating his tools from found objects. "You don't necessarily need newer or high-tech equipment to make better art," he says.

Fittingly, Babcock's new book, *The Invented Camera*, which chronicles his "symbiotic" photos over the years (the coffee-pot pinhole shoots a dreamy coffee shop sign, the suitcase a fuzzy bus station, etc.), mirrors his autonomous approach. To get the book out there, Babcock learned Quark and Adobe Photoshop, worked through the night for weeks assembling the digital page files, then raised the money to print the books by working as an electrician. Up next? A clicker converted from a 2005 Scion xB.

—Megan Mansell Williams

Jo Babcock's website: jobabcock.com

Photography by Jo Babcock

Open Source Open Water

Those with doctorates in artificial intelligence are never the best stewards of houseplants. Programmer **Bryan Horling** says he's killed whole swaths of greenery inside and outside his rural western Massachusetts home. But at least one plant will survive, thanks to a computer-controlled plant watering system — a simple network of plastic tubing and an aquarium pump to keep the Wandering Jew plant in his living room alive.

"You can do this project even if you're too lazy to water your own plants," Horling says. His computer activates an aquarium air pump, which displaces water in a soda bottle, sending it to the plant. He started with an X10 appliance controller from RadioShack, an aquarium pump, length of tubing, 2-liter plastic soda bottle, and aquarium check valve. He drilled two holes in the soda bottle cap, inserted the tubing, and sealed them with a glue gun. A metal binder clip holds the tube in place, and the check valve keeps the water from backing up the pipe after the plant is watered.

Horling, 30, uses hobby projects as a release from his difficult studies. His research on multi-agent systems is funded by the U.S. Army, which wants to use software agents to help filter and analyze information received by commanders in the field. To take a break from his thesis, he created a recipe for baby wipes that involves paper towels, no-tears shampoo, and a table saw.

In this case, the houseplant waterer is controlled by a Linux PC in his den. A freeware application for Linux allows the computer to control the X10 device. Then Cron, a built-in application in Linux, lets him run scheduled tasks. The script tells the air pump to turn on for five seconds every day.

A 2-liter bottle holds enough water to keep the plants happy for two weeks. Originally, he got it because his wife Maura and he traveled constantly. Now it comes in handy because they're distracted by a new baby. "It created a whole other problem," says Horling. "It's just enlarged the scope of our forgetfulness. Now we forget to fill the water bottle."

—Bob Parks

Computer-controlled watering: makezine.com/go/plant

Photograph courtesy of Bryan Horling

Photograph courtesy of Matt Jones

The Secret Life of Death Clouds

Matt Jones contemplates life by building moving sculptures that fail to replicate it. A graduate student in art at Stanford University, his investigations have led him, among other things, to use an air compressor to animate a respiratory system fashioned from old bicycle inner tubes, and to motorize a carpet of zip ties laced with LEDs to approximate a pulsing, gently respiring, furry hide. His goal: to tease out the vital essence that makes the living live.

It took a giant garbage bag full of hot air to teach him to appreciate the life coursing through his creations. To create the grandiose piece *Black Cloud* for a death-themed Land Art show in the cactus-studded desert of central New Mexico, Jones needed little more than a pair of scissors and a lot of tape.

He cut out black garbage bags, sealed their edges to each other, and then rigged a squirrel cage fan with ducting to fill the vessel with sun-heated air, floating it several feet above the ground. Once aloft, the Suburban-sized balloon seemed to find a mind of its own in even the gentlest breeze. Trying to steer the cloud with fishing line before a crowd of spectators, says Jones, was "like trying to drag in an orca — an orca that insists on jumping into cacti." Long patching sessions followed each brief and otherworldly flight.

Despite the difficulties and constraints inherent in making kinetic sculpture (it has to work, after all), Jones says it pleases him more than traditional media. "Besides color, line, and solid shapes," he explains, "there are entire regions [of the brain] devoted to detection of movement, areas untouched by static art."

Certainly, Jones' kinetic works breathe life into many regions of the mind — especially when they're cooperating. "After the showdown in the desert," he says, "I came to cherish those moments when my work wasn't broken."

—Eric Smillie

Matt Jones' website: ojdingo.com

Blue Spark

"A custom-made life is better than a Wal-Mart world," says **Sean Barrow**. Tall, dark, and tattooed, Barrow looks more like a rock star than the avid eco-design aficionado he is.

His post-apocalyptic appearance at first glance seems at odds with the elegant, minimal, Japanese-inspired aesthetic he studies and employs in his sustainable furniture making. But both display his practical approach to 21st-century salvage: to reveal rare beauty and utility from former chaos.

Case in point: the sleek *Electron Monument*, a bewitching handmade side table that hides an array of outlets for electronic devices and their chargers. "'Charging station' sounds so unsexy — hence the name," laughs Barrow, who installed six outlets, capable of handling power blisters as well as standard plugs, in the table's inside base.

Sitting high on salvaged metal legs, the box is made from spalted pin oak that Barrow snagged from a dying tree (which creates the zigzagged black segments in the wood grain), and held together by wooden finger joints. The removable top is reclaimed and sanded zebrawood and rosewood, with sides angled in at 13 degrees (a favorite angle he uses in much of his furniture), finished with nontoxic Osmo oil.

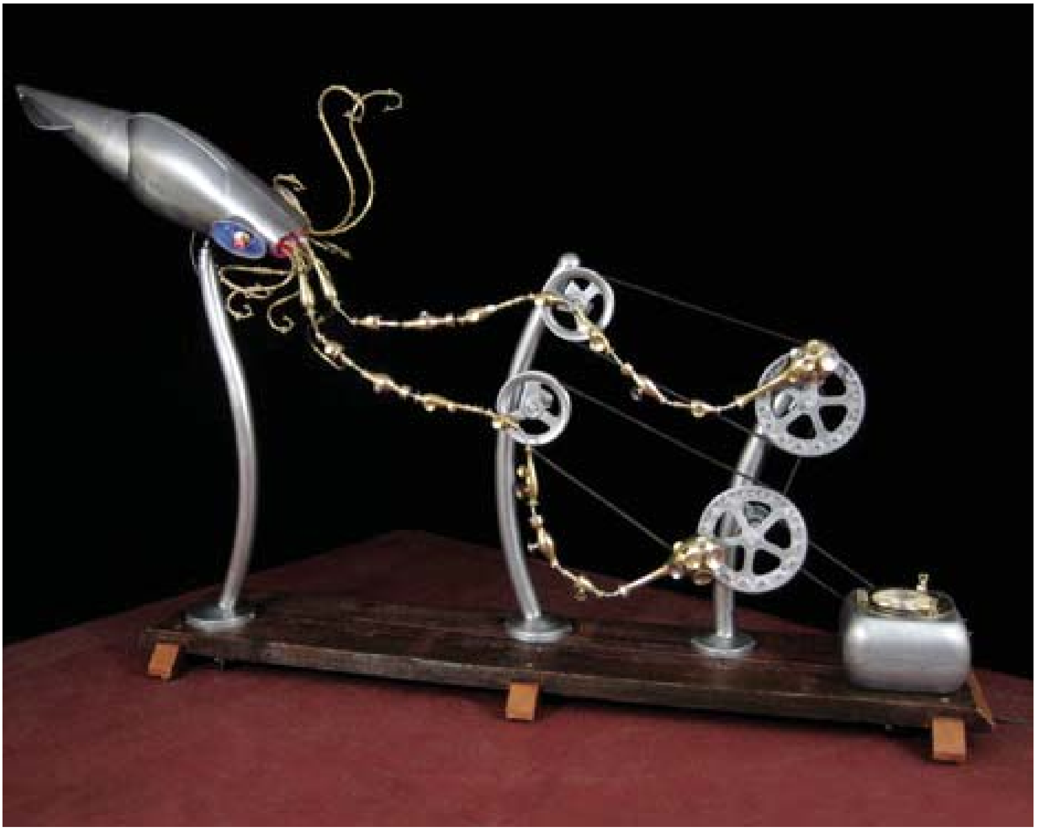
The most compelling feature of the *Monument* is the hypnotic, softly glowing cobalt light in the front of the box, with machined metal pieces added to create an abstract power-outlet motif. Using almost no energy, it is illuminated with an LED plucked from an old night light.

The combination of traditional Asian design, sustainable resources, and the sci-fi hieroglyph glowing from within the *Electron Monument* make it a perfect example of Barrow's work, and one of the coolest ways to hide your electronic clutter.

—Kirsten Anderson

Sean Barrow: skrewgun.com

Photograph by Sean Barrow



Photograph by Gould Nemo

Kinetic Fauxbot Sculptures

Raised by two artists, **Gould Nemo** started drawing as a young child and received a traditional art school education. But once he started creating art with the heaps of scraps and junk he collects, drawing became unsatisfying and there was no turning back. Now Nemo creates a wide range of robot-like sculptures out of recycled materials that move and gyrate in interesting ways.

Nemo calls them "fauxbots" because they don't really count as robots, at least not to the more technical robotics crowd. And he's fine with that; he readily acknowledges that his creations are sculptures first. While many of them are inspired by robots, Nemo admits they are not necessarily helpful or useful in any practical sense.

Nemo's sculptures are made almost entirely from recycled materials. He only purchases a few technical components, like LEDs and bearings. To find parts, Nemo haunts a favorite local salvage yard and relies on garage sales, curbside finds, and the occasional dumpster dive.

One of Nemo's more notorious creations, a 10-foot-tall robot sculpture named *Goliath*, resides famously in San Francisco's ultra-ritzy Pacific Heights neighborhood, where it has attracted neighborhood scorn, the attention of vandals, and delighted tourists. *Goliath* is now a popular fixture on the local tour bus route. The gasoline-pump nozzle that serves as Goliath's male appendage is one of his more attention-getting features.

Not all of Nemo's creations are based on your typical robot. His latest and most challenging sculpture is a truly giant mechanical squid (more than 6 feet tall and 10 feet long) that writhes and undulates in a variety of ways.

"I am really fond of curved lines and surfaces. Aligning belt wheels, bearings, motors, and non-essential squid-looking stuff in an organic form that does not simply fall apart was a real thrill."

—*Bruce Stewart*

Fauxbots: nemomatic.com

Hands On

EGGHEAD

INVENTOR NIKOLA TESLA SAW REALITY IN HIS OWN WAY.

By Bruce Sterling

IT'S A TOY IN A MUSEUM: AN EGG IN A bowl. The egg shifts restlessly. It rocks and it rolls. The wandering egg explores the bowl's limits. It dances arcs within the bowl's tall rim.

Then, just when it seems about to free itself and fly out of the bowl toward its viewers, the egg hesitates. Somehow, mystically, the egg wriggles upright onto one of its ends.

The egg is spinning like a top. It has achieved some kind of post-chaotic feat of stability, and now drifts smoothly back to the spot where it started: the center of the bowl. There, dead center, it spins like crazy, self-contained and untouchable, defying gravity, friction, and common sense.

On its aging shelf inside Belgrade's Nikola Tesla Museum, the *Egg of Columbus* spins like a turbine. The egg *is* a turbine — the conceptual ancestor of pretty much every electrical motor in the world.

Technologists tinker. They engage with the grain of the material, testing empirical realities, pushing for higher performance. Scientists seek out unifying laws and principles that make sense of the natural world. Nikola Tesla, an inventor, did neither of these things. He saw reality in his own way.

Tesla's testament, *My Inventions*, written in later years when he was drifting through fleabag New York hotels and feeding pigeons, is a painfully sincere account of what life felt like for him. The work is intensely psychedelic: visual hallucinations were always the most exciting and significant things that happened to Tesla. A true visionary, Tesla experienced mind-bending flashes of insight, sometimes accompanied by tongues of fire.

Tall, good-looking, and sturdy, Tesla was capable of handling various and sundry tools: he could wire a ship, fix a fire engine, and dig a ditch. But Tesla did not hack; he didn't tinker. He invented through his immensely detailed and vivid mental visions.

Although Tesla blew through college in mere months, absently memorizing entire books and deftly speaking multiple languages, he didn't consider himself a genius. Tesla had an older brother who was much brighter, more capable, and more ambitious than himself, but who (maybe luckily for the human race) died young.

There may not be adequate words to describe the extreme events that took place within Tesla's skull. The shattering flashes of light that paralyzed him were likely migraines. The childish bedtime trips into imaginary Oz-like cities, where he befriended

> Tesla could visualize imaginary machines down to the last detail, even the rust and wear-marks.

strange people and flew through the air, were lucid dreams. His existential loathing for pearls was probably a phobia. Tesla forced himself to read all 100 volumes of Voltaire's complete works, in French, which indicates that he likely suffered from obsessive-compulsive disorder. He had hallucinations on tap as an everyday mental utility. Tesla could visualize imaginary machines down to the last detail, even the rust and wear-marks.

Except for his invention of the alternating-current induction motor, a huge advance that transformed civilization and later contributed to what is known today as the greenhouse effect, Tesla's genius was mostly a personal matter. Wizards prize spiritual advancement over mere cash and power. Poverty and privation were an adventure for Tesla. Even when his pockets were brimming with money (rather often), he took a positive pleasure in systematically depriving himself of food, booze, gambling, cigarettes, and women. In the long decades of his adult life, Tesla never changed weight: he liked to volumetrically

Photograph by Bruce Sterling

The Serbian 100-dinar bill features Nikola Tesla, his favorite motor, and the equation that defines the scientific unit of measurement, the "tesla."

measure his food and stop when he had eaten enough cubic centimeters. Tesla never married, probably because he could never find a girl like dear old Mom — an illiterate genius who could hand-tie three knots in a human eyelash.

This year — 150 years after his birth — Tesla still enjoys the reputation of a man ahead of his time. Tesla's sesquicentennial finds him a 21st-century household name. Tesla coils, transformer coils that beautifully spit giant writhing sparks, are his signature mad-science toy. The tesla (T) is an international scientific unit of measurement, good for the ages. A sports car and a rock band carry Tesla's name, while about a million goofy New Age cranks are still enthralled by Tesla's musings.

Tesla was certainly a genius, but not a "neglected, forgotten genius" — that is a myth. It seems that almost everybody who met Tesla knew at once, on some deep primal level, that he was freakishly smart. It took people a while to figure out that Tesla was beyond the aid and comfort they could offer.

Although he was a paranoid hypochondriac, Tesla lived until his mid-80s. And he wasn't the picture of misery. Tesla always had an excellent opinion of himself and his own doings. He had little money because he was basically unemployable. He ignored the profit motive and never did boring grunt-work under duress. Medals, honors, doctorates, banquets, publications, and patents arrived in heaps for Tesla.

Romance had no relevance for him. Besides his mother, brother, and maybe his father, no human being ever impressed him much. Though he may well have invented the remote-control drone, Tesla was no robot: he was a living being of wild passions and eerie psychic extremities. Tesla had a sense of humor — enough of one to recognize that Mark Twain was a genius and a man he could befriend.

Tesla was not recklessly improvident. He was probably as good at finance as most engineers, but World War I wrecked his prospects for attaining great wealth. It seems the war proved to Tesla that the human race was crazy. In the darker years after the Great War, Tesla scarcely pretended to be normal. He still dressed in his Broadway-dandy uniform — his tailored black Prince Albert coat, top hat, and spotless white gloves — but his tics, phobias, and delusions took free rein. In the real world, he simply went through the motions. Tesla gave some pronouncements in the press, he opened his fan mail, but he could no longer be bothered to construct huge wireless power-towers on Long Island, create death rays for the U.S. Navy, or build magnetically levitating ultra-high-speed global airships.

Tesla could still see these wonders in his mind's eye, probably down to the paint flecks and serial numbers. But spinning deep within his own mental bowl, he no longer bothered to climb over the rim.

Tesla's spinning egg toy is a truly superb proof of concept. It came from a time in Tesla's existence when he had a pressing need to prove his concepts to the outside world. With the passing of years, that need passed. There is one other smooth bronze egg in the Tesla Museum in Belgrade. It is entirely spherical, polished and unblemished, stagily lit, and poised on a pedestal. Some siftings are sealed inside of it — black ashes. That's Nikola Tesla, egghead inventor. He's still in there.

Bruce Sterling (bruce@well.com) is a science fiction writer and part-time design professor.

Maker

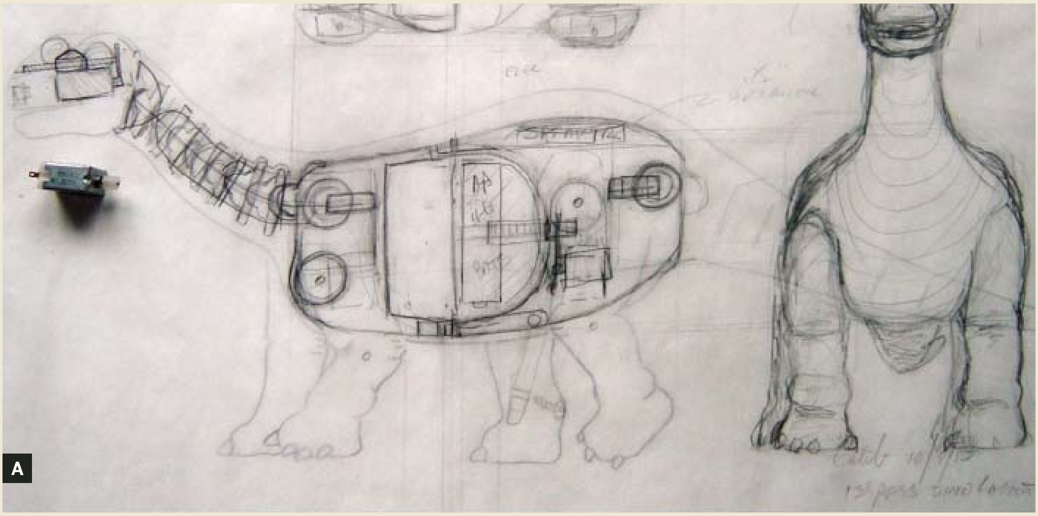
I, PLEO

How Caleb Chung went from street mime to toy-robot maven.

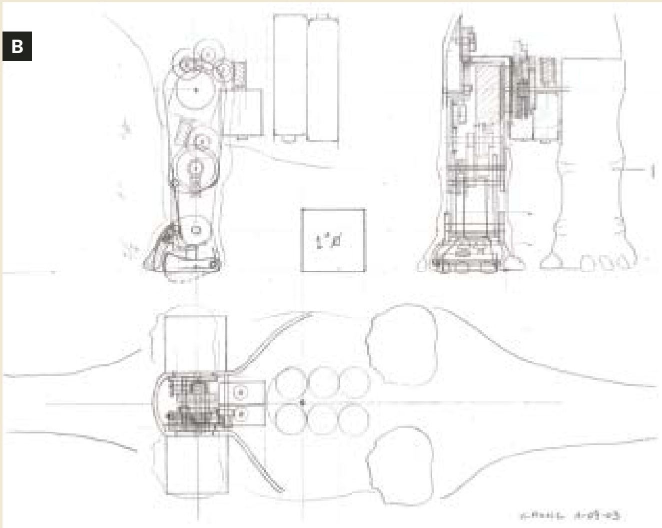
INTERVIEW & PHOTOGRAPHY BY ROBERT LUHN

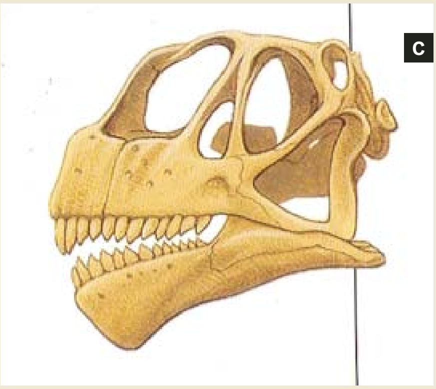
Can a machine have a soul? Can it think? Can it laugh and cry, bug you for a snack, tease you, or curl up on your couch and dream robotic dreams? Can you build such a machine? And can you sell it for $250?

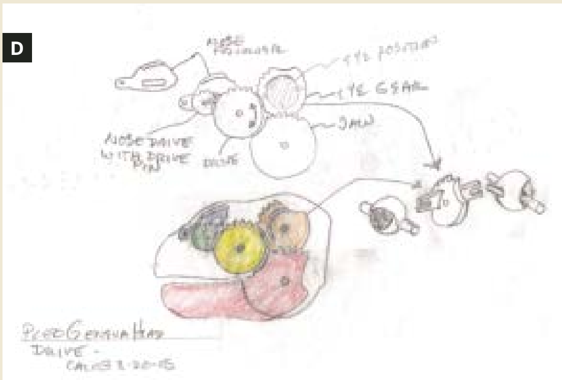
It's alive! Puppet master and puppet — or rather, Caleb Chung and his autonomous robot companion, Pleo.



A. Pleo is the size of a week-old baby camarasaurus, a dinosaur from the late Jurassic period. **B.** A camarasaurus' naturally stocky legs are perfect for containing motors and gears. **C.** Chung and his colleagues studied camarasaurus fossils to create an accurate model for Pleo. **D.** The head contains an IR communication device, an object detector, a light sensor, a mouth object sensor, and a motor to control jaw, nose, and mouth movement.







Those are just some of the challenges facing Caleb Chung and his cohorts at Ugobe, Inc. ("*You! Go and be!*" Get it?) Chung doesn't need the tsuris or the money. As one of the developers of the Furby, which has sold an estimated 40 million units since 1998, Chung never has to work again. But there's something gnawing at Chung, something beyond conquering the toy world again or making enough money to buy his own country.

"Humans have a fundamental need to nurture — it makes you a better person," says Chung. "And one of the roles of digital life forms is to bring out the best in people."

The embodiment of Chung's passion? An unassuming baby dinosaur — the size of a cocker spaniel — called Pleo. Inside this camouflage-green camarasaurus is a ton of technology: 14 servo joints; 38 touch, sound, and light sensors; a half-dozen digital signal processors; a gaggle of electric motors; a camera installed in its nose; an infrared transmitter for communicating with other Pleos; a flash-card slot; and a real-time operating system that oversees Pleo's lifelike movements and its personality.

Outside, Pleo is sheer experience, performance art combined with emotional sleight of hand — just what you'd expect from Chung, a former mime. Pleo ambles along in amazingly lifelike fashion, smiles and shrugs, frowns when he's unhappy, and yowls for "food." According to Chung, Pleo is not only autonomous, but evolves over time based on your interactions with him. Unlike his robotic brethren, Pleo isn't a battle bot; he's a love bot, designed to be your pal and to summon your latent (or overactive) nurturing instincts.

But something more primal drives Chung: the desire not only to manipulate life, but to create it from scratch. To create a robotic companion that thinks and, maybe, even feels. Call it the Geppetto Syndrome.

It's Alive! (Kind Of)

To meet the puppet and the puppet master, I fly up to Chung's lab in Boise, Idaho. As I stride out of the spacious new terminal and behold the stunning mountains in the distance, a worn, white Lexus pulls up to the curb. Out jump Chung and John Sosoka (chief technology officer and key artificial intelligence guru), both clad in Hawaiian shirts and flip-flops — standard high-tech attire in Boise. After a jovial exchange of handshakes and jokes, we're off — and so are Chung and Sosoka, chatting animatedly about the joys of Boise, the nature of robotic emotions, synthetic versus organic life, and more. A fancy lunch follows, and then we're off to the lab.

Alas, there are no bubbling beakers, giant sparking electric generators, or even a tiny tar pit for Pleo to play in. The "lab" is a nondescript box in a faceless office park, manned by a handful of engineers and designers. I meet the staff and poke around, examining Pleos in various stages of undress. One Pleo has returned from a demo in China in tatters, apparently chewed by a jealous panda. Another is stripped down to its motor/gear/wire skivvies, as three engineers fiddle with a locomotion problem. I snap pictures of Caleb in silly poses with Pleo and talk with one of the engineers about the joys of QA testing Pleo's tail.

Later, at a local cafe, I chew the robotic fat with Chung and Sosoka and finally meet a more-or-less working Pleo face-to-face. To say I'm skeptical is an understatement. The company's website and literature make some mighty big claims: "[Pleo is the] genesis of a whole new era in robotics. If you can imagine it, Ugobe can create it," "Pleo is the first truly autonomous Life Form capable of emotions that allow personal engagement," and "Pleo ... can feel joy and sorrow, anger and annoyance ... even dream." The Pleo I meet runs a six-minute script that showcases his range of motions and emotions, but it's hardly autonomous.

Still, for a construction of rubber, gear trains, CPUs, and wire, Pleo is pretty engaging, with a sly smile on his face that's pure Chung. Chung puts Pleo through his paces, the baby dino showing fear (complete with trembling), happiness (wagging tail, dancing, little yippy sounds), groaning for food, playing dead (like a kid, dramatically falling over with a clunk), sneezing, and more. Pleo's motions aren't perfect, but that's the idea.

Illustrations courtesy of Ugobe

"Pleo's movement has 'noise'," says Chung. "That's what makes it organic. And because he moves naturally, his movement becomes invisible — and that's when you become interested in what Pleo can do, what he's thinking."

Thinking Pleo

The question is, what can Pleo do or think about? At this point, it's a little theoretical because Pleo is still a prototype. But according to Chung and Sosoka, Pleo will be autonomous first and foremost — which means no remote control.

"When you leave for work in the morning, your dog doesn't sit by the door all day. He explores; he does stuff. Pleo will be doing something when you're gone because he's alive", says Sosoka, without a trace of irony.

Pleo will also remember and adjust his behavior accordingly; in other words, he will learn. If you twist Pleo's leg, he'll know you're abusing him. He'll cry out and limp, and you won't be able to play with him for a while. He'll store that grudge, cataloging the event and assigning it a value. The next time you try to play with him, he may snap at you. Conversely, the more you reassure and nurture Pleo, the quicker his naturally sunny nature will reappear.

As you'd expect, Pleo is programmed with strategies for solving certain problems, such as finding food. But ultimately, says Chung, you can't program every possibility. "You have to let him choose. Pleo keeps a record of what works and what doesn't — filtering experience the way all living things do."

Like his Furby forebears, Pleo will be able to communicate with his kin, although Pleos will do more than swap colds. "When two or more Pleos get together, there'll be some kind of meeting ritual and they'll pick the 'alpha' — and that Pleo will transmit behaviors and tricks and moods to the others," says Chung. But that's just a start.

You can plug Pleo into your PC via USB, run a little program, and adjust Pleo's personality by moving sliders or writing scripts akin to JavaScript or Logo. Want to really hack Pleo? In the future, there may be a C/C+-style developer's kit that lets you mod the dino to the max. Whatever personality you create, you'll be able to back it up and share it with others.

"Pleo is not a closed product. At every step we ask, 'How can other people play with Pleo, modify it, personalize it?'" says Sosoka. Eventually, users will upload new personalities and tricks to Ugobe's site that others can use. "Pleo is ultimately a platform, and creating new Pleo personalities is like making a movie." Pleo, in short, is as much art form as life form.

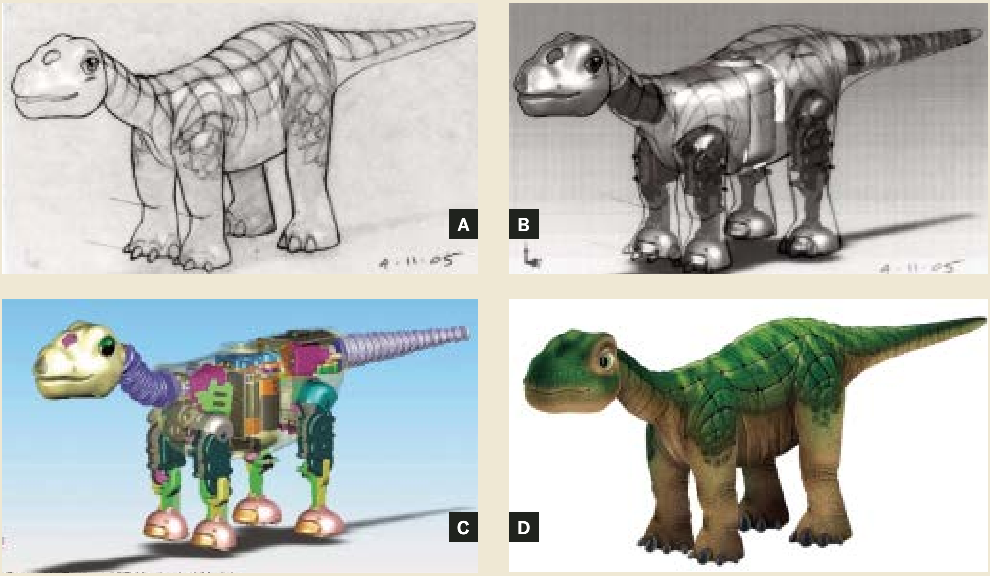
Making Pleo

Building that art form, however, involved some real-world tradeoffs. For example, why build a robotic baby dinosaur? Why not a popular computer-game character?

It was a sound business decision, says Sosoka. "Dinosaurs are great, they're already a brand, and you don't have to pay royalties on them." More important, says Chung, is that you'd never be afraid of a baby dinosaur like Pleo — he's small enough to sit on your desk. And a baby anything is easier to animate. Adult creatures have sublime, complex movements; babies falter and stumble, and they have a smaller emotional palette. One plus even a baby camarasaurus offers: big, blocky legs, perfect for holding motors and gears.

And these motors and gears have been notable headaches. "Exotic magnets that go all the way around a motor are really powerful, really efficient, and really expensive," says Sosoka. The solution? Write a sophisticated control program that makes cheaper, less accurate motors work better. Slap a 12-cent 6502 processor on the motor, says Sosoka, and you've got a smart servo that knows force feedback, self-clutching, and self-calibration. "We do a lot of localized intelligence, just like your body," he adds. Off-the-shelf gearboxes were noisy, so the company turned to an "unrelated" industry for custom units.

Ugobe won't disclose much about its real-time "Life OS" that oversees Pleo's movements and cognition. Basically, Pleo is built around a simple, one-layer neural net; something happens and the event is weighted and remembered. Over time, the connection strength between a stimulus



A. **Pleo is a proportionately correct baby camarasaurus robot. B.** **An exoskeleton provides support. C.** **Motors, gears, and linkages provide realistic movement. D.** **Sight, sound, and touch sensors are hidden under the hide.**

Illustrations courtesy of Ugobe (A, B, C). Illustration courtesy of Mack Fraga Studios (D)

(like turning Pleo upside down) and a response (Pleo laughing or crying) changes. “It’s almost like muscle memory,” says Sosoka. It doesn’t dictate how Pleo will react every time an event occurs, but Pleo’s past experience will influence his future choices.

The other key factor in Pleo’s reactions? Emotions. (Well, what passes for emotions in a $250 robot.) The factors that really control Pleo are his drives — hunger, bonding, fatigue — and the goals associated with them. If Pleo’s hungry, the goal is food, and the preprogrammed strategy Pleo picks to meet this goal is based on which one worked best in the past. It’s kind of like fuzzy logic: rules combined with sophisticated probability with a little sloppiness allowed. In an unusual situation, emotions — colored by Pleo’s success or failure, someone hitting or petting him, etc. — act as a secondary control system. It’s why Pleo should have many different reactions to a given stimulus over time.

From Mime to Machine

Pleo’s ultimate stimulus, of course, is Caleb Chung. Chung has pushed, prodded, and pulled Pleo into existence with a scary singlemindedness. “He’s a character — a mad scientist,” says Ivy Ross, a former Mattel executive who worked with him on the Miracle Moves Baby doll. “He has a vision and relentless drive to bring something alive.”

Gary Schwartz, longtime friend and Chung’s mime partner, says simply, “He’s the irrepressible kid, the incarnation of Tom Hanks in *Big*, pure inspiration, pure yin, but with the emotional savvy of a 50-year-old.”

How did Chung get from street mime to toy-robot maven? At first glance, Chung’s resume looks like a hodgepodge of careers. He went from performing mime (as part of the Schwartz & Chung comedy team in the 70s and early 80s), to voicing live-action TV cartoon characters (he was QT the Orangutan in *Dumbo’s Circus*).

By chance, he applied for and got a job devising cutting-edge toys for Mattel’s R&D group. Later, his knack for creating props led to work designing mechanical effects for such films as *Total Recall*. Since the late 90s, he’s consulted with various toy companies, helped develop Furby, and ultimately, decided to tackle Pleo.

"Pleo's movement has 'noise.' That's what makes it organic."

In his years as a performer, Chung became a master of props and mechanics. "We got a gig on the *Queen Mary* in Long Beach to entertain the tourists," says Schwartz. "They couldn't afford animatronics, so they hired mimes." It was here that the duo created their first notable bit, "Caleb 9000." Chung did a spot-on robot routine while Schwartz, offstage, supplied his voice. At the end of the bit, Caleb 9000 says, "Absolutely nothing can go wrong ... wrong ... wrong" and then blows up, courtesy of a remotely triggered explosive pack Chung designed.

So what's the connection between mime and robotics? "Caleb is a superb actor," says Schwartz. "It's a key skill that game and robotics animators need to learn. As a mime, you're also super-aware of your body, of motivated movement, the physical cues to emotion." Chung's ability to tell a story via movement, to play a cartoon character, to suspend disbelief, and to think like a kid is uniquely suited to dreaming up innovative toys or convincing you that an animatronic dinosaur is emotionally aware.

Not surprisingly, the inspiration for all of Chung's work is his fervent belief in, yes, magic. "The first books my mother read to us were Tolkien's," he says. "Fantasy and magic were an integral part of my upbringing. They've become an integral part of my product design. I want to transmit that wonder."

Not just via robots, mind you, but via random acts of surrealism. Take Chung's interest in, um, fairies. On an island near his house, Chung collects sticks and makes little fairy furniture that he leaves all over the island — a little chair, a tiny broom, maybe a bassinet with a walnut "baby" inside. With a diamond-bit drill, he even carves pseudo-hieroglyphics onto stones. "If you actually found one, you'd never think someone put it there, because it's too frickin' obsessive. But I want to change how people view the world."

A Tale of Two Furbys

After visiting Chung and meeting the lovable Pleo, it's easy to take a sip of Ugobe's Kool-Aid. Chung is intelligent, charismatic, and clearly dedicated to making Pleo a breakthrough. The question is, can he deliver? Ugobe expects to release Pleo in March 2007, but the units I saw — only seven months before release — didn't seem very close to prime time. Still, robotic innovation hardly runs like clockwork, so ship dates are always fluid.

But the dispute over Furby — the robotic toy that made Chung's reputation and fortune — casts a shadow over Chung's current efforts. Chung, who was responsible for the design of Furby's mechanics, tells one story about how Furby came to be.

David Hampton, the co-inventor responsible for the programming and electronics, tells a rather different one, which is mostly corroborated by several former executives from Tiger Electronics, the company that licensed Furby. (Tiger was bought by Hasbro the day after Furby's debut at the 1998 International Toy Fair in New York.) The engineer brought in to "save" the project contributes still another angle.

What most everyone (including Chung) agrees on is that 1) the mechanics for the Furby prototype that was going to be demo'd at the Toy Fair didn't work; 2) mechanical engineer Richard Maddocks' last-minute assistance helped get Furby working in time; and 3) after the Toy Fair, Chung was bumped off the project.

The rest of the story has multiple versions as to who did what, when, and why. On one hand, it's clear that Chung bit off more than he could chew. While he was instrumental in developing the Furby concept and designing the mechanics, execution was another thing. Chung couldn't use off-the-shelf parts; the tiny pulleys, gears,

Photography by Robert Luhn; Furby drawing by Kelly Heaton

A


B


C

A. *The Anatomy of the Furby* by artist Kelly Heaton, who once made an interactive Furby wall. **B.** A Ugobe engineer troubleshoots a locomotion problem with Pleo. **C.** Caleb Chung's lab is an unassuming box in a small office park outside of Boise. **D.** A Pleo tail-testing unit. **E.** Pleo in a classic pose.


D


E

cams, and other parts had to be custom made to very fine tolerances. If a part didn't work, Chung modified it until it did — but that introduced friction that could stall Furby's motor. "[Chung's] design was brilliant and sound in principle," says Richard Maddocks, now a senior principal designer at Hasbro. "But there was a huge amount of stuff packed into a very small form factor. No one had ever done this before. I didn't redesign Furby — I just helped it run reliably."

First, Maddocks put in a bigger motor to overcome the friction. Then, he created new parts to replace Chung's oft-modified (and worn) parts. After some final tweaking, he got Furby working reliably enough to debut at the Toy Fair.

Chung also readily admits he was lousy at overseeing his time and that of the engineers and machinists he hired. (At the same time, he sings David Hampton's praises: "He's a virtuoso in digital design and programming — a great talent who, until Furby, never got the credit he deserved.")

Tiger, too, can be faulted for slashing Chung's prototyping budget (from $60,000 to $40,000) and not keeping a closer eye on the progress of Chung's work, which, after all, involved making something that no one had ever made before. "We were undermanaged," says Chung. "God knows, I needed a manager."

What did Chung learn from the Furby?

"I thought I could run the process and manage a group, but I made some bone-headed decisions," says Chung. "I never made that mistake again. At Ugobe, I invent, I come up with ideas — but I let someone else manage and do the tooling and engineering."

Apparently the lesson stuck. Chung's next project, creating the Miracle Moves Baby for Mattel, won high fives all the way around. Ivy Ross, the senior VP in charge at the time, lauds Chung's dedication and ability to execute.

"Caleb really understood the emotional connection [the doll] needed to have with kids. We didn't have this kind of expertise in house. Caleb showed up and collected a whole group of experts who made it happen," he says.

The Soul of a New Machine?

The Great Furby Debate may never be settled. As the old saying goes, "Success has many fathers." The acid test for Chung will come when Pleo hits the market. Will it work as advertised? Will buyers embrace Pleo as their robotic pal, or dismiss it as a novelty? Chung's reputation and his worldview are riding on the results. But Chung is simultaneously bullish and realistic.

"I think we have something magical," says Chung. "When I showed off Pleo at the Demo 2006 show [see makezine.com/go/pleo], I realized this moment in time would be remembered in the history of man-made life-forms. They'll say, 'These people didn't have all the tools, and there were all these restraints, but they tried to do this for real.' Still, I don't have to prove something to the world. Pleo is going to be what it's going to be."

But if Pleo lives up to half its promise (and a fourth of its hype), it will raise a host of intriguing and troubling issues. Is Pleo an autonomous life-form? Is he sentient? Can he feel?

"All that matters is what the user perceives," says Chung. "Once you create organic movement and add just enough emotive cues, people will suspend disbelief — they'll fill in the rest and fall in love with Pleo." Besides, he adds, he's not even sure it is suspension. "I think Pleo really does these things."

But if Pleo or his successors develop even a tincture of self-awareness, don't Chung and company have a huge obligation to these new creatures and their human owners?

"Of course we do — especially for a creature that plays to the human heart," says Chung. "An invention like Pleo can fundamentally change society. That's why we want to be first, to set a responsible tone. These machines are extensions of us, how we think and feel. As much as we're going to get monsters and creatures we don't want around, we'll also get beauty and magic from artists who really know how to create," he says. "Great art tackles the great issues of our time. That's why we're digging here — we're digging in the right place."

Grandpop's Shop

By Robyn Miller

I JUST RETURNED FROM PHILADELPHIA, the city where most of my family was born and raised. Many of them still live there, including Grandmom, who's still sharp as a tack.

My grandfather repaired elevators and dumbwaiters. He was well-loved, and since his death, his machine shop under the house has been kept almost as a shrine to his memory. My uncle uses the shop for small projects, but after ten years, not much has substantially changed: my grandfather's toolbox rests open, his scrawled notes and plans are scattered all around, and even his smell — machine oil — is everywhere.

The shop was always a magical place for us kids. Grandpop would invite us in, show us a strange mechanism (usually his lathe), and begin to create a trinket right before our eyes. A miniature baseball bat, a Plexiglas lightsaber. I'd watch him shape metal as if it were putty. Turn square blocks into curved cylinders. Nothing seemed impossible.

Then he'd invite us to try our hand at it. I was most apprehensive with the lathe, and would stand there thinking: this hunk of spinning wood is definitely going to pop out and smack me right in the forehead. Grandpop always stood directly to my right, encouraging me while I tried to cut my marvelous colonial chair leg. Overambitious plans for a 9-year-old, but I'd just watched him make the same thing with freehand ease!

Now, whenever I visit, I always go down and poke around, but not too much. It almost feels like he's still there.

Robyn Miller is most popularly known as the co-creator of *Myst* and its sequel, *Riven*. He continues to work on a variety of projects and has most recently finished an album titled *1000 Years and 1 Day*. Visit him at tinselman.com.

Photograph by Robyn Miller

Heavy Lifting

Placing huge towers up a mountain is just the start to reaching Troy Caldwell's ski-resort-on-a-budget dream.

By Dale Dougherty

SIXTEEN YEARS AGO, TROY CALDWELL went to buy 10 acres from Southern Pacific and got a sweet deal on 400 acres of land, most of it mountainous, near Lake Tahoe. A ski bum who left college to learn the sport, Caldwell eventually became part of the U.S. Ski Team in the 1970s, and he says he's been part of the ski industry (which he pronounces "SKI-in DUS-TREE") ever since.

Caldwell's dream is to build his own private ski facility. Lacking the big bucks, he decided to build it himself, and he's been working the past six years on designing and constructing his own chairlift. Some of the work has been bartered as "Tahoe trade-outs." He made office cabinets in exchange for the structural engineering of the chairlift.

Last fall, he placed 17 towers up the mountain, with the help of a helicopter and 30 volunteers who hope to ski on the property one day. The towers, which weigh up to 3,000 pounds, were built in his garage using a series of pulleys and hoists. This allowed him to move these heavy objects himself, as he built stairs and platforms and welded them to the large pipe. "You have to do the towers right," Caldwell says, "because you don't ever want to have to do them again."

Caldwell has been challenged by lawsuits that drain his bank account but not his enthusiasm. "You want your mind to be focused on the positive things

Photography by Dale Dougherty

and not the real-world problems that can make you bitter," he says.

Weather has also been an issue. Two early-season snowstorms of 20 inches seemed to wipe out his chance to place the towers last autumn, as the footings were full of snow. However, his volunteer crew encouraged him to continue by offering to dig out the 7-foot-deep holes and make them ready.

Caldwell says that when the helicopter arrived on site to move the towers, he could tell he had a nervous pilot who had worked on forest fires but not this kind of heavy lifting. He had to direct him not to try to drop the tower into the hole but just to hold the weight of the tower and let the ground crew move the tower into place.

One of the volunteers, Ken Gracey, vice president of Parallax (makers of the BASIC Stamp microcontroller), says: "You've seen how large this tower is

"You have to do the towers right because you don't ever want to have to do them again."

on the ground and then you see it coming at you, as the helicopter is lowering it, and you're aware that all you've got to protect you is a hard hat."

Caldwell has tried to leave the mountain close to how he originally found it, not removing trees and boulders. He hopes to have a ski mountain that looks natural without several big scars down the side of it. Of course, doing it this way has its challenges. "Here's a mile-long job site that I can't get any heavy equipment to," he says. "I've had to figure out how to use hand tools to move massive weights, such as lifting a 5,000-pound rock out of its hole. You get to find out what real leverage is." He adds, "The other problem is that if I don't have the right tool with me, it's three hours to go back and get it."

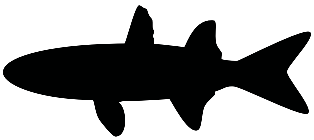
Caldwell's goal is to prove he can create his own ski resort on a low budget in an environmentally sound way. He hopes to be up and running in the winter of 2008. With the eager participation of volunteers, his dream seems about to be realized in the manner of an old-fashioned barn raising.

Dale Dougherty is editor and publisher of MAKE.

Caldwell says you design the towers for the wind load on the cables that run between them, not for the people on the chairlift. The towers are also pitched on the mountain at various degrees of lean. Caldwell welded these towers in his garage, which also houses his snowcat (shown at left).

CHARLIE ASQUITH'S JET DORY

By Tim Anderson



Charlie is 78 years old and he's been fishing for mullet in Hawks Nest, Australia, for over 60 years.

Today, like most days, he's sitting on the beach, watching the water through polarized sunglasses. He hopes to see a dark shadow moving across the bay, a school of mullet coming in from the ocean. Each year the mullet come to spawn in the estuaries that feed the bay. Then he and his son Les will launch their boat to try and catch some in their net.

He calls his boat a "dory." It's a greatly modified runabout with a jet ski power plant. He added a cowling at the front, along with the controls from the jet ski. The engine and water jet impeller drive are in the stern, covered with a smooth housing.

Their truck has a trailer hitch on the front as well as the back. To launch the boat into surf, the boat is put on the trailer as shown (top) and pointed at the water with the skipper on board. At the proper moment, the driver of the truck drives toward the water. He hits the brakes just before getting there. The boat slides off the trailer into the water, and the skipper drives it out through the waves. To get back in through the waves, the skipper rides in just behind a big wave, guns the engine, and runs the boat up the beach to dry sand. A perfect system.

The fishing nets are piled on top and nearly fill the boat. Behind the driver there can be no projections that might snag a net. When the boat reaches the school of fish, he throws out an anchor attached to one end of the net. The anchor starts pulling the long net out over the stern of the boat. As the net is pulled over the stern, he drives the boat around the school of fish, attempting to encircle them.

It's a six-week fishing season here, and then the fish move north. The local fishermen don't follow the fish; they go back to trapping lobster. Charlie and Les built their own lobster trawler as well as fiberglass rowing skiffs, based on traditional shapes, for when the jet dory is overkill.

Tim Anderson, founder of Z Corp., has a home at mit.edu/robot.

1. Charlie Asquith and his jet dory. 2. The jet nozzle and exhaust at the stern of the boat. The boat goes faster than the jet ski did and gets better gas mileage. This jet ski engine is about 100 horsepower. The white truck (left in photo) has a snorkel so the engine can still run while the truck is nearly underwater. 3. The skipper stands in the front with the controls from the jet ski.

Photography by Tim Anderson

UNHINDERED CREATIVITY

ENABLE KIDS TO INVENT THEIR OWN GAMES.

By Saul Griffith

LOOKING BACK AT THE TOYS I LOVED most as a child, I find that the memories that lasted, and the adventures that stuck, were with homemade toys and homemade experiences. I of course remember playing with Legos and a fabulous wooden train set that I was given when I was 5, but few other toys actually stick in my mind.

My parents gave me the luxury of inventing my own toys and games from a very young age; sometimes my games started with a ready-made toy or the odd materials my parents had sitting around. Most were fueled by imagination and sheer curiosity — either that or the particularly delightful boredom that is characteristic of childhood.

Shooting my sister with a water pistol was fun, but the most distinctly proud moment I recall was a game I invented for myself when I was 8 that entertained me for hours. With water pistol in hand I'd shoot a squirt at the very top of a window. The stream would dribble down the window, typically dividing into two or three paths. I'd then shoot the bead of water at the head of each path, which would in turn create two or three more paths.

Quickly, exponentially, the number of paths would increase and I'd be frantically shooting at a fractal of water droplets, trying to score the most direct hits before the first drop dribbled to the bottom of the window. This was analog *Asteroids*, that fabulous Atari video game, only higher resolution and more compelling than its computer counterpart. I can still feel the sense of achievement of having invented a cool game that soon was played by my other friends.

At 9, I became fascinated with grappling hooks. I do not remember which comic book introduced me to the idea, but as soon as I had it in my head that a grappling hook could take me wherever I wanted to go, I simply had to make one. I never made it really work, but I can remember dozens of trees and walls I tried to ascend with the various prototypes. Like an X Prize project, I didn't necessarily reach the end goal, but I learnt lots of other applications on the way.

I had to learn to tie knots. I learnt the material properties of all the hooks I tried (wood, plastic, aluminum, steel). I learnt that falling pieces of steel on the end of string are subject to the laws of gravity, and that sharp points may effectively grip branches, but they also pierce your skin. I learnt that you need a certain diameter of rope to support your weight and not cut into your hands as you try and haul yourself up with it, and I learnt that certain tree branches can't support your weight.

By 10, I was on to inventing jet-powered helicopters. Do you like fire? I like fire. Fireworks were illegal in Australia when I grew up, except for the Queen's Birthday weekend celebrations, which conveniently fell near my sister's birthday, so we always had lots of fireworks (my sister was the princess in my family on her way to being queen). I loved fireworks, not for the colors and noise so much as for the raw materials.

After a few years of making jet-powered Matchbox cars, I realized I could put these precious black powders and cardboard canisters of energy to a better use: a helicopter. I must have spent three days hand-carving and gluing a 3-foot-diameter rotor blade out of balsa and bamboo from the garden. The idea was to redirect all the thrust of the Roman candle out through an aluminum-can-and-electrical-

tape nozzle at the tips of the rotor. Thus spinning, the helicopter would lift off. I'm not going to tell you it worked great, but it did in fact work — getting the two fuses to ignite the two candles simultaneously took hours of hugely fun experimentation. The chopper flew about 8 feet up and about 30 feet sideways until it hit the clothesline. It only singed one bed sheet before I managed to turn the garden hose on it. At least that time I remembered to keep the hose handy.

The thing I find fascinating about these escapades is how strongly etched each of these experiences is in my memory. Not in my parents' memory, of course, as I often went to great lengths to conceal the actual goings-on. It's amazing how many injuries via failed inventions could be passed off as bicycle falls, climbing trees, or another water fight with that nasty kid up the street. Poor kid; more than once my mother castigated his mother for a purported wrongdoing.

This rambling is my plea for encouraging the "other" toys and games, not the ones you buy, not even the ones you learn to build through MAKE. It's by providing the environment (and turning the blind eye) that you enable kids to use their unhindered creativity to invent their own games. Keep an extra box of cardboard around, a jar of screws, a coil of rope. It may not look like invention to you, but for the kid at that moment it is their entire world; it is their idea and inspiration; and their intensity and devotion to it should be celebrated. I took no photos of these things I built, yet they stick as firmly in my memory as anything else I did in my childhood. That sort of recollection can only be attributed to the intensity of pure joy.

If this column helps you recall the triumphant toy inventions of your youth, I'd love to hear about what they were (and are)!

Getting some huge, gnarly air as an 8-year-old using a bike ramp I built myself. Note: I didn't even injure myself ... this time.

Photograph by Dr. Ross Griffith

Saul Griffith thinks about open source hardware while working with the power-nerds at Squid Labs (squid-labs.com).

HOMEBREW MAGNETOMETER

BUILD A TORSION BALANCE TO MEASURE TINY CHANGES IN THE EARTH'S MAGNETIC FIELD.

By Dr. Shawn

MOST OF US ONLY THINK ABOUT THE Earth's magnetism when we need to find our way in the wilderness. When you look at a compass, the Earth's magnetic field appears to be a steady guide. But in reality, the magnetic field fluctuates in response to all sorts of aetheric influences, some of which come from beyond our world.

For example, the sun boils off a steady stream of electrons and protons into outer space, and whenever a large solar prominence erupts from the surface that's facing us, a hot torrent of charged particles rushes outward and eventually slams into our cold and relatively quiescent ionosphere. The collision between these two wispy plasmas sets into motion turbulent oceans of electric currents thousands of miles across, which, in turn, create undulating magnetic fields that stretch down through the atmosphere to reach us here on the ground.

Although huge in scale, these magnetic fields are rarely more than a percent of the strength of the Earth's home magnetic field. Therefore, although these effects are quite common and last from minutes to hours, the magnetic disturbances are notoriously difficult to detect.

Until now, the high cost of tracking these signals meant that professionals had exclusive access to the field. However, anyone can now easily study these magnetic micro-pulsations by building the remarkable magnetometer described here. The simple device requires less than $50 worth of parts and can be built in an afternoon. Yet it can easily capture truly tiny distortions in the Earth's magnetic field, as well as the dramatic effects of a magnetic storm high in the ionosphere.

The magnetometer uses one of the most sensitive instruments in science — a torsion balance. It measures a force by seeing how far it can be made to twist a fine filament. The thread gently resists rotation with a torque (a twisting force) that grows as the fiber twists, until it just balances the torque created by the applied force. The resulting angle of deflection, which is found by bouncing a light beam off a tiny mirror attached to the filament, is proportional to the force under study. With the beam from a laser pointer and a match-head-size mirror, you can, in principle, resolve deflections as small as one ten-millionth of a degree.

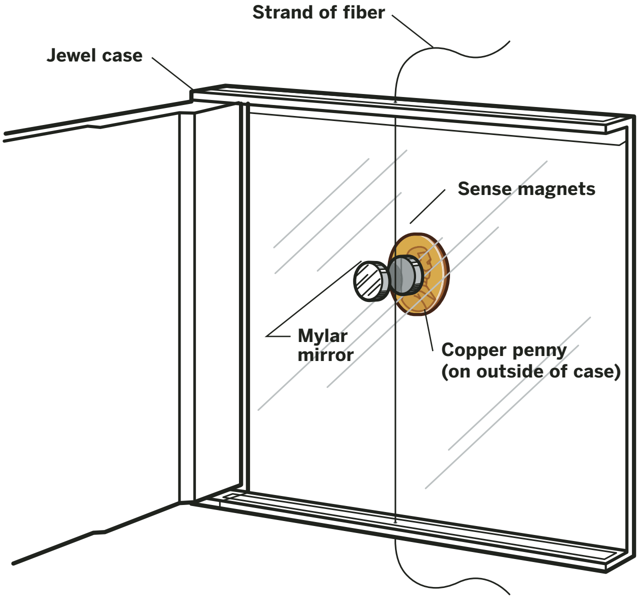
Most torsion balances that you'll find in professional laboratories use fine quartz fibers, which are incredibly strong and insensitive to changes in humidity and temperature. Sadly, quartz fibers are difficult for ordinary mortals to come by. But nylon fibers work almost as well as quartz and can be easily extracted from any soft nylon cord.

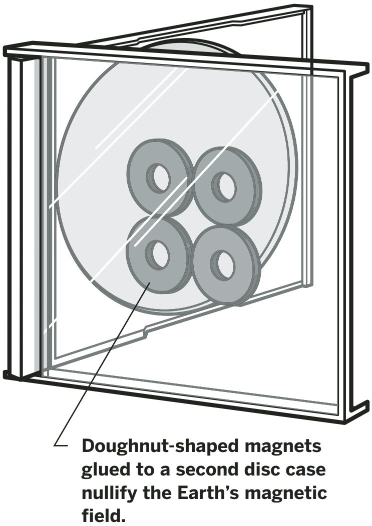
BUILDING THE SENSOR

If you want to use carbon fiber, check your local hobby stores; I prefer nylon because it's much easier to get. To use nylon, start with silky, multi-filamented nylon cord — which you can purchase at any hardware, craft, or boating store — and cut one cord

YOU WILL NEED:

Multi-filamented soft nylon cord
5-minute epoxy
Small piece of aluminized Mylar **At least 5mm thick**
Spring pin (clothespin)
Clear plastic DVD cases (2)
Penny, minted prior to 1982
Sheet of corrugated cardboard or particleboard
Rare-earth magnets (2 packages)
RadioShack part #64-1895
Doughnut-shaped magnets (4)
RadioShack part #64-1888
Laser pointer





The nylon fiber (left) should be between the 2 round magnets. A copper penny glued to the outside of the disc case cancels unwanted currents generated by the magnets.

30cm (1 ft) in length. Next, gently unravel it and use tweezers to select the finest strands, which should be about 25 microns (0.001 in) thick. A slow and steady pull will drag one fiber away from the others. But be careful: these individual minute miracles of modern chemistry are almost impossible to see, and, when left in the open, they often disappear as if by magic. So, if you need to set it down, make sure to secure your harvest in a plastic sandwich bag so you can find the fiber when you need it.

Your next task is to install the nylon filament into a case that is impervious to changes in humidity and isn't too sensitive to shifts in temperature. A clear plastic DVD jewel case works great. DVD cases come in several thicknesses, and you want to get the deepest case you can find. Look for a plastic insert that holds the DVD, or a jewel case made for two DVDs at a time. Pop out the inner plastic DVD holder and keep just the outer case.

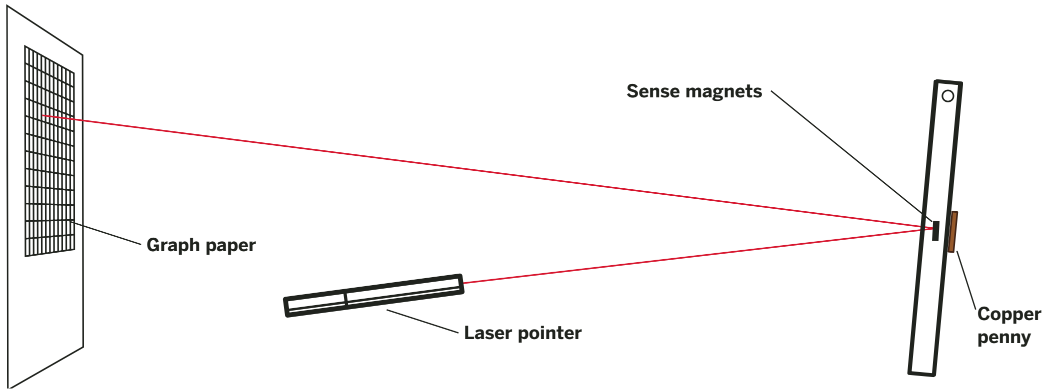
With the case standing on its side, install the nylon fiber so that it runs vertically through the exact center. To do so, you'll need to create 2 tiny holes, with the finest drill bit you own, on exact opposite edges to thread the fiber through.

Working with the nearly invisible fiber takes a great deal of care and persistence. First, delicately thread the fiber through the eye of a fine sewing needle using tweezers and a steady hand. Then, pass the needle up through the bottom of the case and out the top. Tape the top end of the fiber to the outside of the case and use a toothpick to completely fill the hole with a dollop of 5-minute epoxy. Smear some on the fiber that lies against the case for good measure. To provide the necessary tension, tape 2 quarters to the other end, which is threaded through the bottom of the case, and lay the case flat on the edge of a table with the coins hanging free. Now, completely fill the lower hole with epoxy and smear some on the fiber on the outside of the case. Let the epoxy cure thoroughly. Then, use a pair of tweezers to break off the ends of the fiber at the epoxy.

To coax the nylon to twist in response to minute changes in the ambient field, you need to affix a powerful magnet to the fiber. Because a massive magnet would respond sluggishly, the ideal attractor would possess a powerful field and yet be extremely lightweight. Such magnetic miracles exist; they are called rare-earth magnets. These marvels are tiny and yet harbor magnetic fields at their surface that are 10,000 times stronger than the Earth's. Best of all, you can pick up a pair of them at many RadioShack stores for less than $2. In fact, buy 2 pairs because you'll need to use one pair to position the other pair on the fiber.

But first you'll need to install a tiny mirror on one of your tiny magnets. To do so, dollop a smidgen of 5-minute epoxy on the face of one of the magnets.

Illustrations by Damien Scogin



Next, place the doped side against a small square of aluminized Mylar, at least 5mm thick, and then clamp it in place by snapping a second rare-earth magnet to it on the other side of the Mylar sheet. After the epoxy has thoroughly cured, use a pair of nail clippers to trim the Mylar neatly against the magnets. You can then separate the magnets using your fingernail. A quick swab with a Q-tip dipped in rubbing alcohol should provide a clean surface that will adequately reflect a laser beam for this project. If the spot size is too diffuse for your liking, it can be made smaller by delicately darkening the perimeter of the mirror with a fine-point Sharpie pen.

The magnetometer uses one of the most sensitive instruments in science — a torsion balance.

Now it's time to connect your magnets to the fiber (see diagram, previous page). First, to get them both correctly oriented, snap a magnet onto the back of your mirrored magnet. These will be your 2 sense magnets. Then, separate them and, making sure not to turn the back magnet over, position it so that it is directly centered on the fiber. Next, clamp this magnet against the plastic case by positioning your other 2 rare-earth magnets directly behind it. By tweaking the location of these 2 exterior magnets, you can make whatever fine adjustments you need to the position of the sense magnet. When it is perfectly centered on the fiber, carefully lower the mirrored magnet — mirror side up, of course — directly down on top of the back magnet until they snap together. Just remove the exterior magnets and you'll have yourself a working magnetometer.

Now test it. Pick up the apparatus and slowly rotate it 180 degrees and back again. The magnets should remain fixed on the Earth's magnetic field as the case moves around them. Note: It is vital that the magnets be free to rotate completely without ever touching the case. If your magnets wedge themselves against the walls, you need a wider jewel case.

Next, glue a solid copper penny — minted before 1982, when the purity of the copper was still high — on the outside of the case, just behind the magnets. Whenever the magnets move, they induce electrical currents (called eddy currents) in the metal to produce their own magnetic fields, which oppose the motion of the magnets. This clever trick quickly damps unwanted oscillations, making the magnetometer much easier to read.

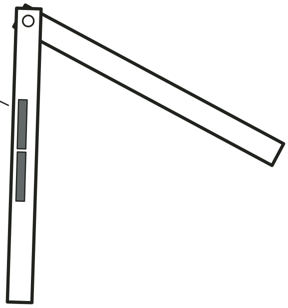
Now, mount the entire assembly vertically to a smooth flat base. For example, you can epoxy the device to a piece of corrugated cardboard or particleboard.

Your sensor is now an accurate compass. As you walk around, the magnets should align to magnetic north and display little oscillation.

NULL IT GOOD!

Because the Earth's relatively large magnetic field absolutely overwhelms our coveted micro-pulsations, you must first null the instrument, or cancel out the Earth's field, before it will register the faint signals we are looking for. For that, you'll need 4 doughnut-shaped magnets.

Epoxy the 4 doughnut-shaped magnets side by side to the center of the second DVD case so that their magnetic fields are all facing the same way. That's easy to do. Just place 2 magnets side by side. If they repel each other, their magnetic poles are facing the same way. Make sure each magnet repels the other magnets as you glue it down and hold it in place while the epoxy sets. Just make



The final magnetometer setup, as viewed from above. Place the disc cases on the floor, pinch the laser pointer with a clothespin, and set it on a book. Position the laser at an angle so you can measure the reflection on a wall.

certain that the center of the assembly is at exactly the same height as the sense magnets in your magnetometer. If you open the jewel case a little and set it on its edge as shown, it will stand up and stay put wherever you want it.

Nulling out the Earth's field is easily done. First, put the nulling magnets far away (like in the next room) and note the orientation of the magnetometer magnets. They will be aligned with the Earth's magnetic field; that is, one will face magnetic north and the other will face magnetic south. Then, position the nulling magnets about 3 feet away, directly behind the sense magnets along the north-south line. Slowly move the nulling magnets in toward the sense magnets. Watch carefully for the moment that the sense magnets start to rotate toward the nulling magnets. (If it doesn't happen, flip the nulling magnets around and do it again.) This is the instant that the pull of the nulling magnets cancels the pull of the Earth's magnetic field.

With the nulling magnets at this exact location, your magnetometer will be exquisitely sensitive. For example, you will find that any small twists of the nulling magnets will be perfectly tracked by the sense magnets. A rare-earth magnet can be detected from many feet away.

WATCHING THE MAGNETIC WORLD GO BY

The bright beam of a laser pointer completes the instrument. Position the laser so the beam shines through the plastic case and bounces off the mirror and onto a distant wall. A clothespin will not only hold the pointer in place, it will pinch the button into the on position for totally hands-free operation.

Ripples in the Earth's magnetic field will show up as deflections of the beam. I think of my own magnetometer as a work of art as much as I do a scientific instrument, like a brass barometer set in teak. The bright laser spot makes an elegant display of a fundamental phenomenon of nature. However, if you should feel the urge to quantify your observations, tape a piece of graph paper to the wall, centered wherever the beam happens to fall, and mark the beam's location.

Watch the beam as it slowly shifts about the paper. As it starts to drift, mark its location with a number, 1, 2, 3, etc., at regular intervals ranging from seconds to minutes, depending on how fast things are evolving. By using a ruler to measure the distance from each of these numbers to the starting point, you'll be able to graph the displacement versus time. Over time, you can identify the relative strength of these micro-pulsations in the Earth's magnetic field.

Although it's exciting to watch the spot of light dance about as it responds to what are often extraterrestrial influences, this sort of hand operation quickly becomes tedious. Fortunately, serious makers — who want to use their home computers to continuously monitor the dynamic nature of the Earth's magnetic field — can learn how to do so from a CD-ROM I publish: *The Amateur Scientist*.

It contains more than 1,000 cutting-edge science projects taken from the pages of *Scientific American*'s now defunct "Amateur Science" column (I wrote that column from 1995 to 2001). My explanation of how to connect this style of magnetometer to a PC to create a professional-grade magnetometer observatory at home can be found in the March 2000 article. (The CD is available from brightscience.com.)

Dr. Shawn (Shawn Carlson, Ph.D.) is the founder and executive director of the Society for Amateur Scientists (sas.org). He won a MacArthur Fellowship for his work helping ordinary people do extraordinary science.

1+2+3 Shaker Flashlight Modification

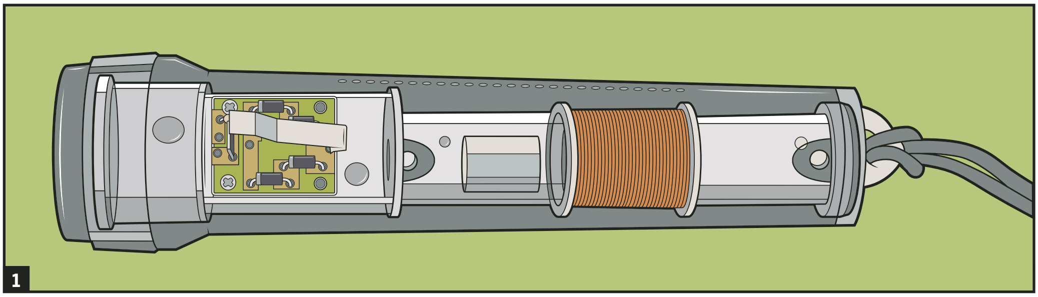
By Cy Tymony

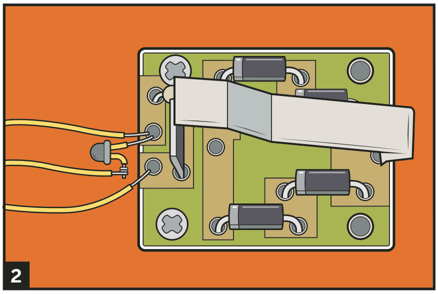
Powering small electronics with your muscles.

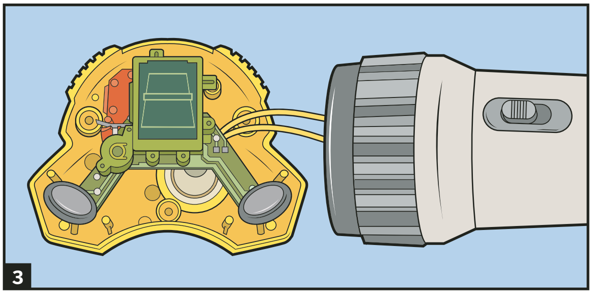
You will need: Shaker flashlight, wire, small Phillips screwdriver, soldering iron, solder

How a Shaker Flashlight Works

A shaker flashlight has a bright LED, a NiCad battery, and an electrical generator made from a coil of wire and a cylindrical magnet. When you shake the flashlight, the magnet slides within the coil to charge the battery. Shaker flashlights provide about 2 to 4.5 volts but produce a very low output current, so there will be limits on their ability to supply power to devices. Recently Walgreens stores offered one for just $5.







1. Modify the flashlight.

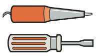
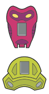


Figure 1 shows the basic parts of the flashlight — the case, coil, magnet, battery, and printed circuit board. Unscrew the lens assembly and remove the screws that secure the PC board to the case. Remove an LED lead and solder 3 wires in place (Figure 2), so you can still use the flashlight normally when you're through powering other devices.

To power a device, connect the 2 wires attached to the flashlight's PC board, with the correct polarity, to the device's battery clips. When you need to use the flashlight normally, connect the LED wire and one of the PC board wires together (use color-coded wire or labels for easy identification).

2. Adapt a device to connect to flashlight.

Select a device that requires 1½ to 3 volts at low current, like a small electronic LCD video game. (I'm an avid collector of the free handheld games that fast food outlets supply with kids' meals. They require very little power if you turn off their sound option.) Wrap the bare ends of 2 wires tightly around the clips. Figure 3 shows the electronic game connected to your shaker power supply.



3. Go further.

A larger NiCad battery can be substituted for more capacity. You should be able to power other low-current devices such as a small Walkman-type AM radio, travel clock, or micro radio-control car. You might also (possibly) use the modified flashlight as an emergency cellphone power supply.

Illustrations by Timmy Kucynda

Cy Tymony (sneakyuses.com) is a Los Angeles-based writer and is the author of *Sneakier Uses for Everyday Things*.

Make: TOYS & GAMES

A challenging and exciting collection of articles and projects that's fun for the entire family! (Batteries not included.)

THE FIRST ANNUAL

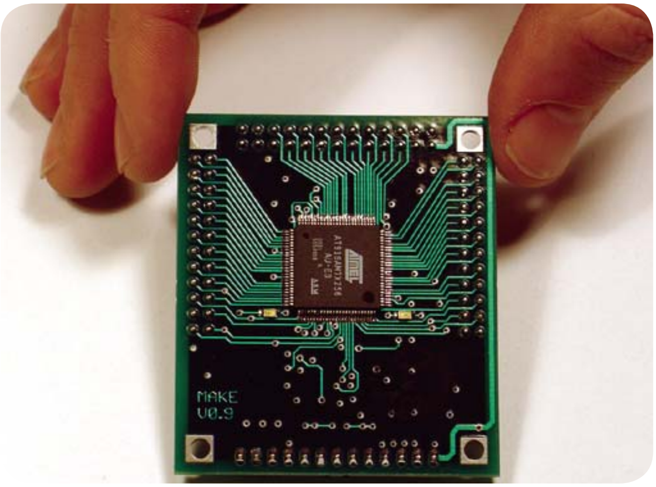
Make:

HOLIDAY GIFT GUIDE

Gift Ideas for Incorrigible Makers and Inquisitive Tinkerers

All Ages

MAKE KITS



The MAKE Controller

$149.99
makezine.com/controller

Born in the fire and smoke issuing from Survival Research Labs' ramshackle compound near Potrero Hill in San Francisco, the MAKE Microcontroller traces its lineage to the digital controllers used to control SRL's robots and artistic weaponry.

Engineers Michael Shiloh and David Williams designed the hardware and software that controls SRL's robots and gives them savage intelligence. While brainstorming ideas for something more powerful and easier to use than available microcontrollers, they came up with what evolved into the MAKE Controller.

The MAKE Controller is a microprocessor unit, a computer-on-a-chip designed to handle a small set of related tasks. But the MAKE Controller has a more powerful processor than typically available on most microprocessors, plus built-in networking capabilities, an onboard USB port, and large memory. With the MAKE Controller, the maker's world opens up, enabling unlimited opportunities for automation, motion control, and artistic expression.

Straight out of the box, the controller is ready to connect to sensors, motors, and your own killer robot. It comes with common functions preprogrammed for immediate experimentation.

Daisy MP3 Player

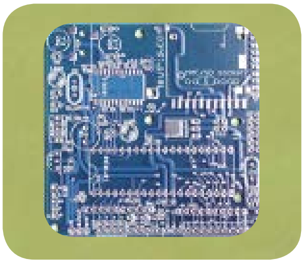
$114.95
makezine.com/daisy

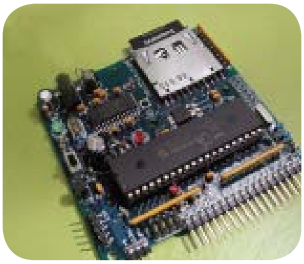
In 2001, artist and designer Raphael Abrams went looking for a new challenge. After some long and careful consideration, he came upon the idea of designing and building his own open source MP3 player kit.

His criteria? First, it had to be easy to build. Second, it had to be open source. Finally, and most importantly, it had to be more than just a handheld device — it had to connect easily to many interfaces, everything from simple button-pushing to parallel ports to very powerful serial modes.

It took several iterations, but eventually he came up with the Daisy, an easy-to-build, pocket-sized MP3 player. Daisy sounds as good as an iPod, can access 65,000 tracks, and plays 48kHz WAV files as well as MP3s. And, unlike an iPod, you can change its battery.

But the big thing about Daisy is the ease with which it interfaces with so many devices, including the MAKE Controller. It is the perfect MP3 kit for makers, for it is easily integrated into kiosks, displays, art installations, or just about anything else.





MiniPOV2

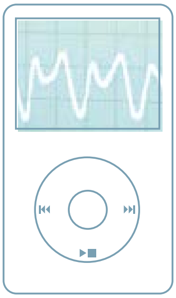
$17.99
makezine.com/minipov2

The MiniPOV2 is a persistence-of-vision device that rapidly blinks eight LEDs on and off so that when waved through the air, an image or message appears to float in front of the viewer.

MIT engineer Limor Fried originally cooked up the MiniPOV2 as an easy-to-build demonstration showing how microcontrollers work. She wanted something that was easy to make, inexpensive, and simple. This little kit, says Fried, teaches several not-so-little lessons:

- **How to solder**
- **How to assemble simple kits**
- **How to program microcontrollers**

The kit includes a microcontroller, sockets, resistors, LEDs, connectors, a battery case, and a printed circuit board. Add some basic tools, a PC with a parallel port, and a little programming, and the MiniPOV is ready to blink out your deepest thoughts.



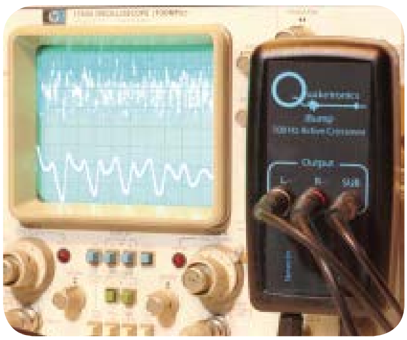
The iBump

$99.95
makezine.com/ibump

"Freshman volume" is the sound level metric introduced to college students in their first year — it's the highest sound level possible at which there is nobody screaming at you to turn the music down. When Ben Anderson made his first attempt at freshman volume, he used his iPod, several guitar amps, and a regular stereo. Although loud, the sound fidelity was surprisingly low. What was wrong?

Big speakers work best with low notes; little speakers work best with high notes. Ben needed a way to separate lows from highs before amplifying his music.

Designed by Ben's dad, Wendell, the iBump is an audiophile-quality active crossover (which separates the highs from the lows). It is inserted between the source (iPod) and the amplifiers. Routing the iBump subwoofer output to a bass amp enables clear, earthmoving low notes. The iBump left and right channels provide high, undistorted volume.



Now, Ben uses an iBump to make sure his neighbors understand the true concept of freshman volume. So can you.

Minty Boost

$19.99
makezine.com/mintyboost

"People put a lot of interesting stuff in Altoids tins," says one maker. "Usually, it's either drugs or condoms." But besides such pedestrian uses, Altoids tins have been used in electronics projects for decades.

At Maker Faire last April, Limor Fried gave her latest spin on the Altoid box project concept. The Minty Boost is a small, simple, but powerful USB charger for MP3 players, cameras, cellphones, and other gadgets that plug into a USB port to charge.

The AA-cell-powered Minty Boost is the Cadillac of battery-powered USB chargers, lasting twice as long as most other Altoid tin chargers. Plus, it's a simple project requiring only easy soldering. All materials (except the Altoids box and batteries) are included.

Game of Life Board

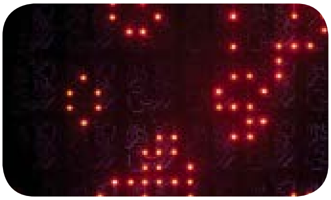
$19.99
makezine.com/gol

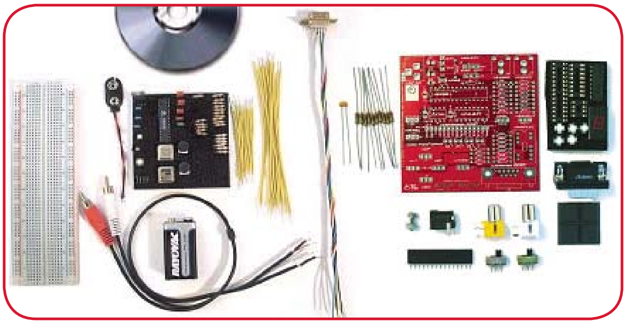
In 2005 a group of brainy MIT students, the Dropout Design Team, decided to try something really novel and clever. They wanted to invent an electronics kit that would look cool, be simple to build, and be accessible to everyone.

At the time, some of them were toying around with the idea of "cellular automata" — a collection of cells on a grid whose colors change according to what's going on in adjacent cells. (The prime example is British math whiz John Conway's Game of Life, in which a collection of cells lives, dies, or multiplies based on a few mathematical rules.)

"Hey, let's build a huge wall of LEDs that would enact the Conway Game of Life rules," they said one night. "The wall could be split into identical modules, and each freshman could assemble their own module, then add the module to the collective wall."

DDT designed an easy-to-solder kit that is cheap and scalable. Each Game of Life board contains 16 LEDs in a 4×4 grid, a microcontroller, and a communications and power distribution network. Boards can act alone, or can be plugged together, border to border, to create a larger display.





XGameStation Pico Edition 2.0

$79.95
makezine.com/xgamestation

Twenty years ago, says Andre LaMonthe, game programming was a real art. LaMonthe, a programming maven, remembers when 32 kilobytes on machines with clock speeds of 1 MHz was state-of-the-art. Yet those programmers of the 1980s created classic video games with perfectly tuned mechanics and unbelievable details.

LaMonthe's XGameStation is a hardware platform developed for educating a new generation of hardware and software hackers in the nitty-gritty, low-level world of hardcore game development.

Combining modern technology with the bedrock-solid design philosophies of the past, the XGameStation Pico Edition 2.0 is a build-it-yourself game development kit based on the technologies of its bigger brother, the XGameStation Micro Edition.

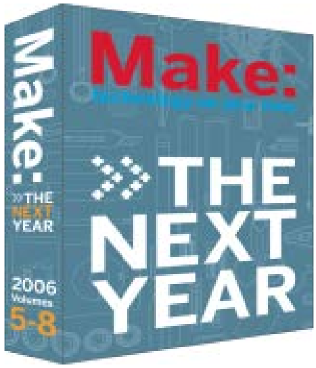
Solder your unit together and you'll have a completely portable and reprogrammable embedded game system. Complete instructions covering assembly, architecture, and programming of the Pico Edition are included on CD.

The Pico Edition includes an 80MHz Ubicom SX28 microcontroller, a solderless breadboard, a 7-segment readout, 15-pin interface, A/V jacks, and a built-in directional game pad for a completely portable mini game console.

If you have a spare evening, weekend, or even an hour, there are projects here for you. No doubt about it, a year's worth of MAKE is a lot of information, discovery, and fun.

HOLIDAY GIFT GUIDE

MAKE BOOKS



MAKE Magazine Collector's Edition Boxed Sets

$59.95 Each
MAKE Year 01 (Volumes 01-04)
MAKE Year 02 (Volumes 05-08)
makezine.com/store

With the publication of Volume 08, MAKE magazine has two full years under its belt. MAKE's famed projects run from practical to whimsical, to maybe even a little scary.

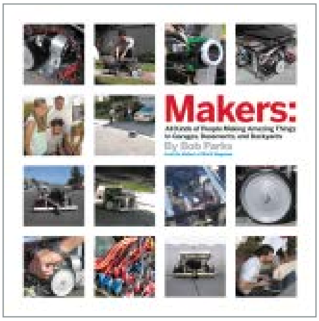
In each of the eight issues, we've showcased the great things people are making in their basements, garages, and backyards with the technology at hand. But most importantly, each issue contains hands-on instructions on how to build stuff yourself — practical or whimsical or scary, but always cool.

MAKE Pocket Reference

$12.95
makezine.com/pocketreference

The perfect stocking stuffer for the workshop warrior, the *MAKE Pocket Reference* is both fun and useful.

Page through and you'll find data on everything from physical constants to bolt specifications to resistor color codes. Add in cool stuff such as first aid, crane hand signals, and the encyclopedia of knots, and you can see why it might take up permanent residence in your shirt pocket.



Makers: The Book

$24.95 *MAKERS: All Kinds of People Making Amazing Things in Backyards, Garages, and Basements*
makezine.com/makers

For more than ten years, Bob Parks has explored the world of the technology addicted, the gadget fetishists, the personalities behind the latest technologies.

In his book *Makers*, Parks profiles a brigade of citizen engineers and inventors, men and women who make their own HERF (High Energy Radio Frequency) guns, fusion reactors, night-vision scopes, and tree houses.

Makers celebrates digital tinkering, hardware hacks, and DIY of all stripes, profiling 100 people and their homebrew projects, in a handsome hardcover perfect for coffee breaks or coffee tables.

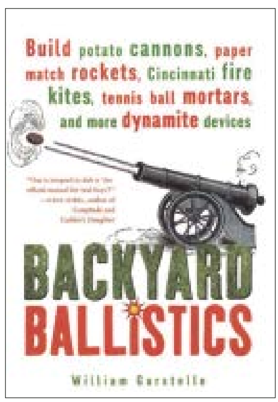
Backyard Ballistics

$16.95 *Backyard Ballistics: Build Potato Cannons, Paper Match Rockets, Cincinnati Fire Kites, Tennis Ball Mortars, and More Dynamite Devices*
makezine.com/backyardballistics

Sure, electronics projects are cool, but sometimes you just want to make something go ka-boom.

Well, *Backyard Ballistics* was written for just those times. William Gurstelle has been collecting information on build-it-yourself projects that go whoosh, boom, or splat for 20 years. From his trove comes this selection of 13 ballistic devices that people can build in their garage or basement workshops.

Instructions, diagrams, and photographs show how to build projects simple (a match-powered rocket), complex (a scale-model tabletop catapult), and wonderful (a combustion potato cannon). With an emphasis on safety, the book explains the physics behind the projects, and profiles experimenters such as Alfred Nobel, Robert Goddard, and Isaac Newton.



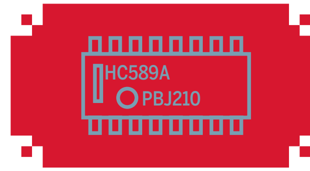
High-Speed Photography Kit

$99
makezine.com/flashkit

Back in 1972, when light shows were all the rage, Tom Anderson visited the Edmund Scientific Company. At the time, Edmund had a terrific light-show display, with mirrored balls, black lights, fiber optics, color wheels, and strobe lights.

Inspired, Anderson's dad, a prototypical maker, designed and built a strobe light for him, adding an external trigger that fired the strobe via a microphone. Using his Polaroid, Anderson and his dad took lots of high-speed photos in their basement: popping balloons, splashing water drops, and breaking glass.

Thirty years later, Anderson shared his secrets in a MAKE Volume 04 article describing the technique and materials for high-speed flash photography. The key is the Flash Controller, a circuit board with the requisite sensors, amplifiers, and timers. The unit includes a high-speed flash, and a flash trigger that synchronizes the flash with the high-speed event. The Flash Controller comes fully assembled and includes a 6-foot connector cable and disposable camera.

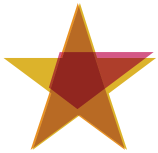


Build Your Own Electronic Game Kit

$39.95 U.S., $49.95 International
makezine.com/gamekit

Originally designed for the Maker Faire by Grand Idea Studio, the Build Your Own Electronic Game Kit is a custom-created kit intended to introduce you to the world of electronics and soldering. When successfully assembled, the kit becomes a version of the popular memory game, Simon, with a few optional twists.

Homebrew Game Design



Turning wacky ideas into fun board games.

By James Ernest

SO, YOU'D LIKE TO INVENT YOUR OWN board game? Great idea! Here's how to do it — or how I do it, anyway.

1. Determine Who Your Audience Is

Know your audience. If you're making a game to play with your family and friends, that's great! That's the best way to start. But if you aim to sell to a game publisher, it's never too early to think about how to position your game in the marketplace.

For example, when I started Cheapass Games in 1996, I knew I wanted to target "core hobby gamers" like my friends and me — college-age males who frequent game stores. Because gamers already have their own dice and game pieces, I knew we could have fun just with new sets of rules and cards or a board. This simplicity meant that games could be sold cheap, in plain envelopes, and displayed near the cash register of the game store to serve as impulse purchases. That's how Cheapass was born.

2. Outline the Story

My games sell on story, so the first thing I do is try to come up with a good one: zombie fast-food workers fight over a single brain (*Give Me the Brain*) or infected mad cows graze fields to discover unexploded landmines (*Unexploded Cow*). A game's theme is the first impression a new player will have of the game, so it's important to nail it.

Once you choose the theme, think about what game mechanics will fit it — things like turns, dice rolls, and auctions. Some designers base their games around the mechanics, but for me, "Do you want to play a game about pirates?" is more compelling than "Do you want to play a game with a unique movement point system?"

3. Imagine the Ideal Experience

What is the playing experience? What are players "doing," and how do they win? For example, in a space-mining game, do you want to spend more time flying spaceships or managing inventory?

How much luck, skill, or complexity do you want? "Skill factor" games have no luck at all, just pure intellectual competition, as with chess. At the opposite end, other games let players passively follow where the cards or dice take them, don't make you work too hard, and with a little luck, let anyone win.

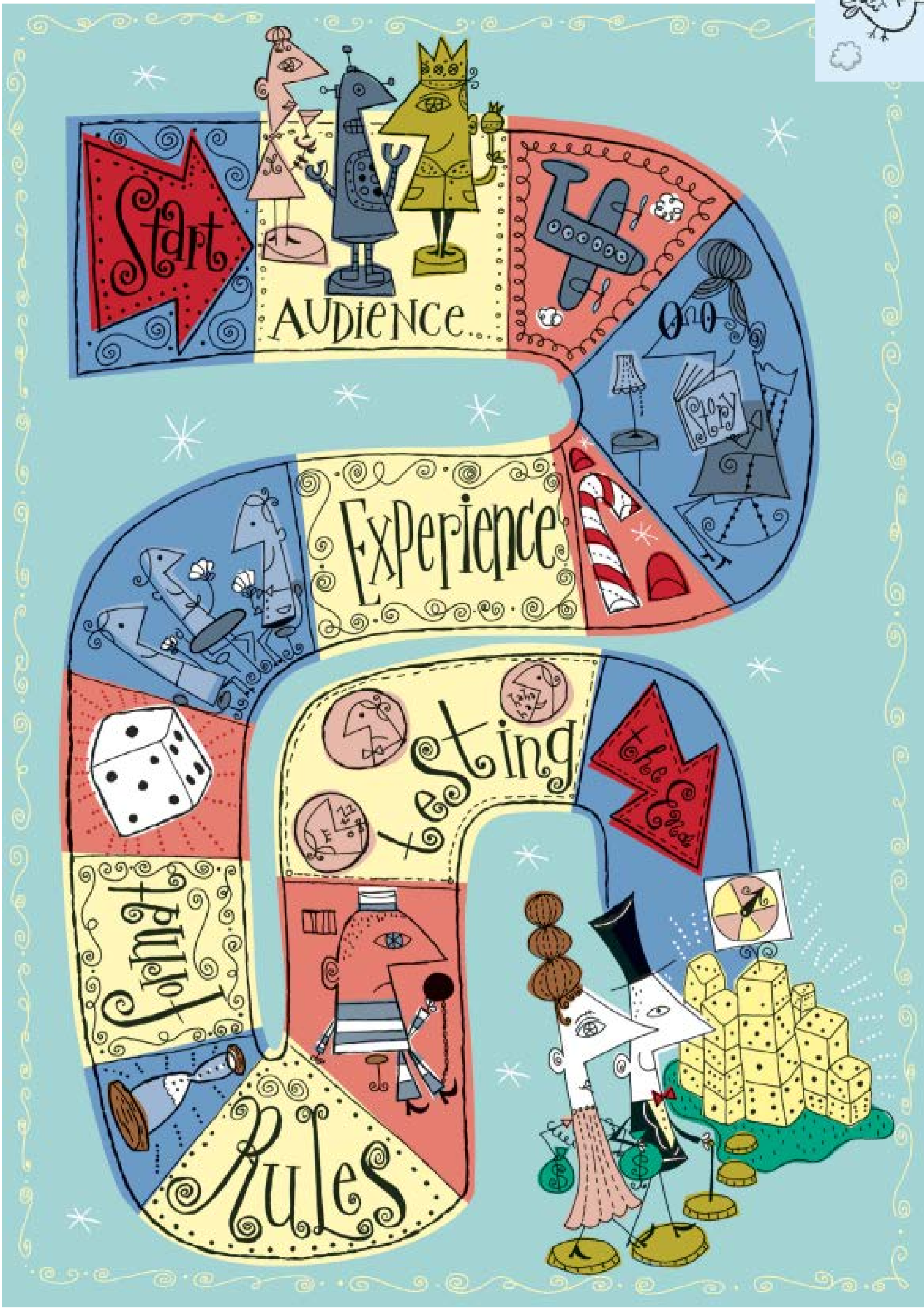
4. Decide on the Format

The next choice is the overall format of the game. Do you want to design a card game? A board game? Something else? Here is a quick rundown of the most common formats. There are other formats, too, and you can always invent your own.

Board games: Games like Monopoly, Scrabble, or chess, that use a central board for static, common information, such as a map, or for tracking game progress, such as score, army size, and so on.

Card games: Cards handle randomizable, quantized, or secret information. Randomizable means that the cards can be shuffled; quantized means that the game content is broken down into pieces rather than being presented all at once; and secret means that players can hold information that isn't known by everyone. Card games tend to be simpler

Illustration by Melinda Beck; Flipbook illustrations by Brian Biggs


Start
AUDIENCE...
Story
Experience
Testing
the End
Format
Rules

and quicker than board games, though not always.

Collectible card games like Magic: The Gathering and Pokemon can be complex because the card sets are huge. As randomizers, cards work well if you want hidden results, complex information, or control over how often a particular result shows up.

Dice games: Dice are another randomizer and are better than cards for outcomes that are openly visible and statistically independent from one another. Some games rely purely on dice (Yahtzee), while others use them within a larger game (Monopoly). Spinners and wheels can function in the same way.

Role-playing games (RPG): A paper-based RPG is an adventure-style game in which one player (the gamemaster) leads the others through a campaign setting that he controls. It's not a competition between the gamemaster and the other players; he just wants to give the players a fun experience.

Party games: Party or "parlor" games are simple games such as charades that can be played by a large group. Party games usually don't need much equipment, but mass-market party games (Pictionary, Balderdash, Time's Up) include cards and other components so that there's something in the box. With so few rules and minimal equipment, these may seem easy to design, but simple games are often the hardest to get right.

> A good game is a road made of doors, with a clear goal and multiple ways to achieve it.

5. Sketch Out Some Rules

Write an outline of the game rules. Even if they all change, you need a place to start. Explain the number of players, the game components, setting up, and the order of play. Describe what you are doing, game length, and how you win.

Also, remember to make the game fair. This is one of the reasons we like games — they're a sanctuary, perhaps, from an unfair world.

I like to say that there are two kinds of novice game designers: those who make houses out of doors, and those who make roads out of walls. The "house made of doors" game has no clear goal but offers many ways to get there. The "road made of walls" has a clear objective, the end of the road, with obstacles along the way. But a good game combines these two — a road made of doors, with a clear goal and multiple ways to achieve it.

First-timers also get "first game syndrome," which is like making a salad with every ingredient in the kitchen. They include all the rules they can think of, and the game bogs down. So, after writing down all the rules you want to try, pare them down until there are just enough to make a playable game.

If you're stuck for game mechanics, consider your story and what it suggests. To help you along, here are three basic types of mechanics, based on the "road made of doors" metaphor. Robust games mix these together to produce complex choices.

Two doors (random): A player is offered two identical doors, side by side. One leads forward, the other leads back, and that player has no way of

BUILDING A PROTOTYPE

At some point, you will want to build a prototype. When you should start building it depends on the game. For example, real-time games with a speed component need art designed early and made very legible because readability is important. Here are a few pointers:

Artwork: There's a huge assortment of clip art online. For homemade games, or even prototypes for game companies, you don't need to buy your art. And for a game you want to sell, licensing clip art costs next to nothing.

Cards: These can be hand-cut from paper or made from index cards, but if they will be shuffled a lot, use sturdy, flexible paper and cut them to exact dimensions with a decent cutter. Rounded corners also help.

You can also make them out of existing playing cards, which are printed on laminated card stock — a plastic-coated paper that you unfortunately can't buy in an art store. Your local card room probably gives away old poker decks for free, and any game store probably also has a huge stack of common, low-value cards from the latest collectible card game on their way to the trash.

For cards with black and white artwork, I laser print on 110 lb. index, a smooth card stock that comes in lots of colors. For color cards, I print label sheets and stick them on old poker decks after cutting the labels down to fit. This gives you custom color artwork on a very sturdy deck. You can also print on normal paper, and insert it into plastic card-collector sleeves, available at game stores, along with a playing card as a backing sheet.

knowing or influencing which is which. Such luck-based mechanics can paradoxically make a game both less challenging and more entertaining.

Hurdle and mud pit (statistical): You have a choice in how to move ahead: you can try to jump the hurdle or walk through the mud pit. The hurdle requires a die roll — if you roll a six, you clear it and move on; otherwise, you make no progress. The mud pit, on the other hand, takes exactly four turns to cross.

This type of choice is interesting because the "right" answer varies with the situation. Statistically, both choices are about the same (you have about a 52% chance of rolling a six within four turns), so the optimal strategy changes based on the game state. For example, if everyone else is already in the mud and you absolutely have to be the first player across, you need to take your chances with the hurdle.

Taxicabs (political): Several taxicabs are available, but sharing a ride with another player is better than traveling alone. A game mechanic like this gets players to negotiate with each other to their mutual benefit, while still trying to win the game individually.

6. Play-Testing (Repeat)

Game design is an iterative process that needs testing with real people, who won't always act the way you expect! In the first tests, be prepared to make sweeping changes. If a game isn't working, abandon it mid-game, fix the problem, and start again.

In a game with secret information, it helps to start play-testing "open handed," where players show their secrets and talk about what they are doing, explaining their reasoning along the way.

When something doesn't work, resist the urge to add a new rule to fix it. Rules for special cases are hard to remember and tend to create new problems. It's better to change the underlying cause. For inspiration, look back at your story and try to identify other aspects that you can bring out.

Here's an example: Suppose you're writing a dice-based horse-racing game, and you find that halfway through, the player in the front almost always wins. (In a random race, odds strongly favor the early leader.) You might be tempted to introduce a "headwind," the code name for a kludgy rule that arbitrarily slows down the front-runner.

But horse races aren't about the weather. The real problem is that random races are too predictable and have no strategy. What if instead of moving the horses, the dice gave them "energy" that players could spend early to sprint ahead or conserve for later? Using the dice in this way makes the game state more complex, and lets players come from behind, thanks to wise resource management instead of a patchy and artificial rule.

For play-test groups, it's good to mix casual gamers with experienced game mechanics people. Naive users are useful for judging overall fun, and the hardcore gamers are good at analyzing the rules and coming up with fixes. Sometimes an astute gamer will suggest debugging a rule in a way that no one else understands. In this case, try playing the suggested way and see if it works.

The last step in the play-testing process is blind-testing, in which you give the rule book and components to a group that's never seen the game before, and watch them play. If the group understands the rules and has fun, you've got a winner!

James Ernest is the president and lead designer for Cheapass Games (cheapass.com) in Seattle. His portfolio includes Kill Doctor Lucky, Give Me the Brain, and Unexploded Cow.

Cards should be easy to read. Don't handwrite them unless your handwriting is very good. If players will be holding a hand of these cards, "index" them by putting key information in the upper-left corners (held both ways) so that it's visible when the cards are fanned.

Boards: Mass-produced game boards are made of a printed label stuck to a sheet of cardboard. You can get the same effect by printing on full-sheet labels or using spray glue on matte board or other heavy cardboard. For larger boards, print your graphics as several sheets and tile them together, or find a large-format printer.

To waterproof your board (inkjet prints run if they get wet!), cover it with a sheet of clear contact paper, and then trim the contact paper, print paper, and backing all at once for a clean edge. Make the board foldable by cutting it in half and reattaching the back seam with packing tape or cloth tape. For a four-fold board, pre-cut the board along one dimension before you add the contact paper, which will form the forward-folding seam. Then finish the board, cut it in half the other way, and use backing tape for the backward-folding seams.

Other components: Game components can be salvaged from other games you own or from games at the local thrift shop. Things like dice, play money, counters, and chips are widely available, and game stores also sell other components. You may have to make some pieces by hand. I frequently use Lego to build prototypes, but that's just because I have a lot of it.

The Secret History of *MYST*

Co-creator Robyn Miller reveals why it became the best-selling adventure game of all time.

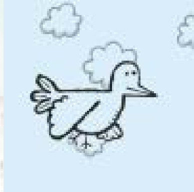
"**HOW DID YOU MAKE *MYST*?"** This has to be the question we still hear the most. So we begin to talk about the production: how we created mountains out of grayscale grids, or how we attempted to create a sense of detail using textures instead of geometry. But typically people are not overly interested in these things. What people usually want to know is, "How did you come up with the ideas for a game like *Myst*?"

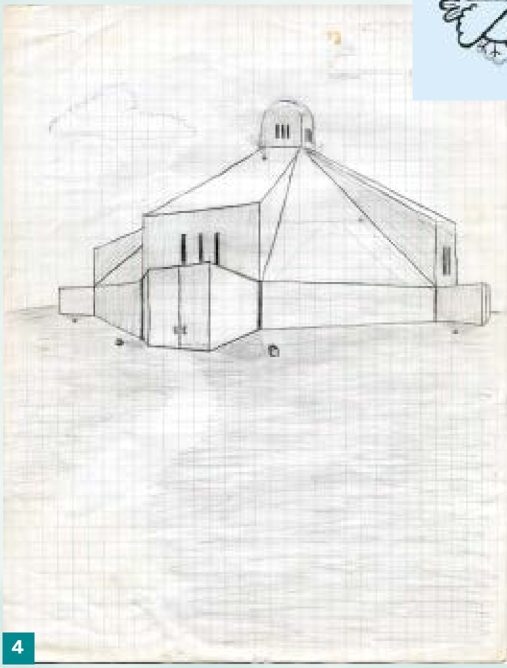
I'm always left fumbling for a sound-bite answer to this question. Something quick and easy like, "Designing a world like this is largely an intuitive process ... we made decisions because they felt right." And although this is true, practically speaking, it explains nothing.

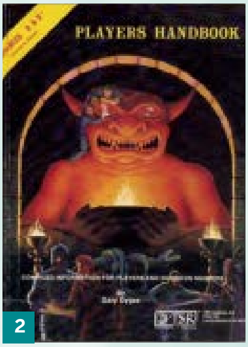
In fact, there was an evolution to many of the concepts behind *Myst*. Some seemingly odd sources gave birth to core *Myst* ideas (some of which we almost took for granted). And all these years later, it's relatively easy for me to look back and see the enormous impact these sources had on *Myst*.

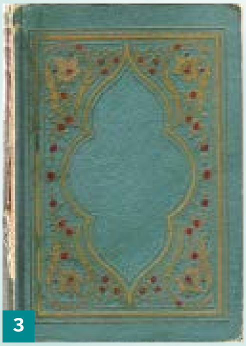
First, we have to go back number of years. Maybe to 1981-82, when I was doing time at Henderson High in rural east Texas, and my brother Rod routinely got together with friends to slip into the skin of a Wizard — or a Paladin. They'd sit around a big table and pretend to have adventures in trap-ridden dungeons where some horrifyingly grotesque monster or demon hides behind each corner. This role-playing game, called Dungeons & Dragons, was growing in popularity around that time (and still has quite a following).

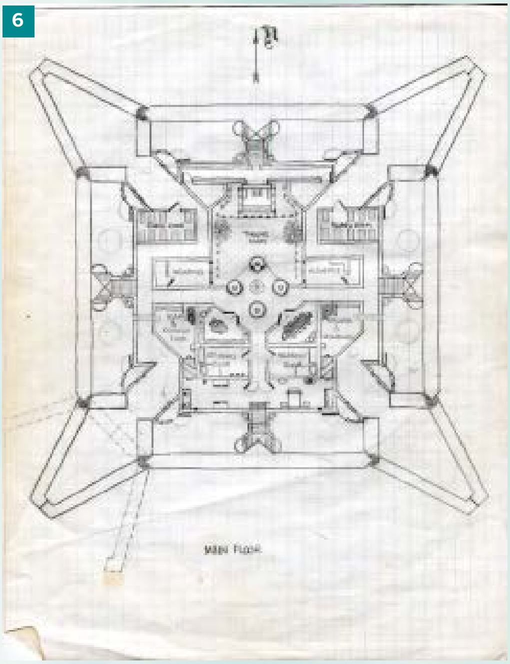
Every once in a while, I'd sit in on one of these games. They were curious. And fun. These times I played D&D were something like mini-vacations, or in some ways, even better. I could explore ancient castles. Or dig through the ruins of some futuristic city, long dead. Hey, this wasn't half bad! Especially when Jeff Zandi (who was later immortalized in the *Myst*-related *Uru*) acted as Dungeon Master. He told a lot of jokes, ignored dice rolls that weren't in the players' favor, and generally kept things moving along expeditiously. This was all vital because usually the game moved like molasses, and the rules were so numerous that they filled up three heavy books (faithfully brought to every game). A bad Dungeon Master spent half the game looking through his books; a good Dungeon Master (like Jeff) would just confidently pretend to have it all memorized.











Images courtesy Robyn Miller

1. Rand delights in torturing Robyn, in Dallas. 2. This was one of the oft-referenced rule books of D&D: the *Players Handbook*. These rule books presented another hurdle to losing oneself completely in the fantastic D&D environments. 3. Many of the books used in *Myst* were scanned directly out of my personal library, like this copy of Robert Louis Stevenson stories (which most notably contained *Treasure Island*). 4. Rand's D&D fortress worked shockingly well. He'd even show the players the occasional drawing, like the one above, as a way of placing them more powerfully in the world. 5. Rand teaches Robyn how to mow the lawn, in Philadelphia. 6. Rand's fortress, which he tested as a D&D-like game back when I was in high school, ended up having a direct impact on the game play of the Mechanical Age in *Myst*.

> "From the moment that closed manhole appeared on the monitor, I was dying to know what would happen when I lifted the cover. What kind of world was down below?"

No Dice, No Avatars

My oldest brother Rand also sat in on a few of these sessions, and later, he and I enjoyed discussing what we saw as D&D's various successes and failures. The good stuff was obvious: the adventure and the sense of escapism. But we'd also talk about how we disliked the slow speed and endless rules. We felt it was a poor interface that only the most devoted fans would ever bother to commit to memory. One of the qualities that especially seemed to hinder the experience was the assignment of a false persona, or avatar, to every player. The player's avatar would even be given characteristics that were wholly not his own: dexterity, intelligence, strength, and so on. To us, this detracted from the sense of escapism the game offered. These puppet-like characters were nothing like us, so we were left with a sense that they were the ones having the adventure in that environment.

Lastly, one had to ignore the poor "visual design" of the typical D&D environment, which rarely rose above the level of a second-rate fantasy novel. It almost never attempted to be provoking or original. Each dim hallway looked the same. Each ghoul or gargoyle died exactly the same way as the last ghoul or gargoyle.

It was right around this time that Rand, wanting to test an improvement of D&D, created his own intriguing and complex D&D castle. He then hosted Rod's group of friends through it. Rand played by none of the tired D&D rules: no dice rolls, no predetermined characters, no hit points or rolling for damages. Instead, all the players had to do was collectively decipher their way through what was essentially a *Myst*-like world. I sat in for the first session and just watched. I'd never seen them have so much fun. His test was completely successful! A D&D without the rules and avatars worked better than the D&D with them.

This successful test of Rand's D&D game was the first step in the evolution toward *Myst*. The second step came a few years later, in my parent's basement.

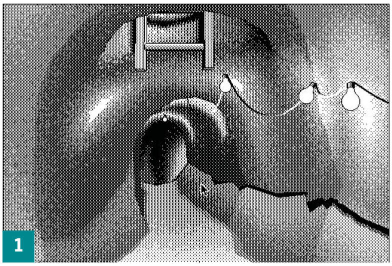
The First-Person Interface

I was married now. My stunning wife and I lived in Seattle, where I attended the University of Washington and freelanced the occasional illustration and design job. Rand called from Texas to tell me he had discovered a development environment that would allow a programming novice (like myself) to create relatively complex applications (or "stacks," as they were called). The name of this environment was HyperCard.[1] As Rand began to explain its simple structure of "links" between "cards," I had to stop him in the midst of his excitement to remind him that I didn't own a Mac.

And this is where my parents' basement comes in. They lived close by, so a couple of weeks later, I found myself sitting in their basement, taking HyperCard out of its shiny white packaging (it's beautiful!) and slipping it into their recently upgraded Mac SE30. A few moments later, I discovered the HyperCard drawing tools and began to sketch a manhole cover.

Rand had proposed a multipage children's book with interactive "hot spots" on every virtual page, but as soon as I began to sketch, it became obvious that there was a more appropriate model. From the moment that closed manhole appeared on the monitor, I was dying to know what would happen when I lifted the cover. What kind of world was

1. HyperCard was the brainchild of Bill Atkinson, one of the early designers of the original Macintosh team. The tool he and his team created was phenomenal because it was simple enough for a child to use, and yet it could also create relatively complex applications (such as *Myst*). But HyperCard didn't seem to fit into any known software "category," and this is probably why Apple left this revolutionary hypermedia construction set to flounder and disappear (instead of evolving it into a simple and highly intuitive web-media application).



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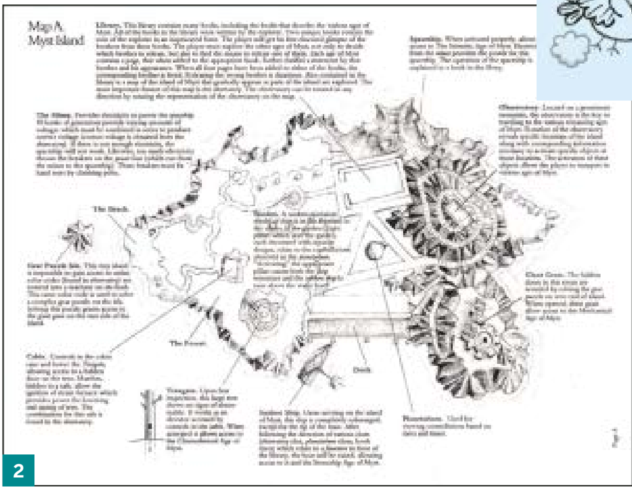


2

1. A drawing from a long-discontinued children's product called Cosmic Osmo and the Worlds Beyond the Mackerel. 2. A page from our *Myst* proposal to Broderbund, the company that published *Myst* in the United States. Our successful meeting with them was one of the first hints we had that *Myst* might be something different.

down below? And to how many different places was this going to lead me? All at once it was a world and not a linear book.

This later became the beginning of our first children's product, called simply *The Manhole*. Within a matter of a few hours, I created a navigable segment of that world, which operated using the same basic first-person interface. The interface wasn't a matter of conscious thought; it simply sprung to mind as if it were a necessity of the medium, and I'm now convinced that our history with D&D inspired it. In other words, our vision of an ideal interface had already been floating around in our heads for some time. We'd even tested it with Rand's D&D castle. So now, presented with a tool like HyperCard, that non-avatar interface could not help but resurface (for our style of interactive world).

After that initial project, we applied the same first-person interface to all our children's products, and with each one of them, attempted incremental improvements. We tried to keep those products as free as possible of keystrokes or graphical embellishments — windows, menus, maps, packs, avatars — anything that might create a barrier between our users and the virtual environments we were creating. Our goal was for players to lose themselves in these self-contained "worlds" in the same way we'd so often been lost in the self-contained worlds of films or books. And there was no obvious interface interrupting a film or a book (though both have beautifully evolved interfaces), so, as much as possible, we pushed to strip away all computer-like interface elements, leaving nothing but the navigable world of sight and sound. We felt that this was not only the route to achieving a more cinematic experience, but also the player's most uninterrupted and direct link to our visual/aural environments (especially for new users or children).

Around this time I began picking up old Jules Verne novels. I enjoyed his writing, not just because of his predictions (though they were often astonishing) but because the environments he created were weird — fantastic yet believable. And better yet, all of this was couched in the unique aesthetic sensibilities of the Victorian age! Jules Verne had never visited many of the places about which he wrote, so he tended to let his imagination run wild when describing places like the ocean floor or the surface of the moon. And not surprisingly, the ocean he described is the one I found myself wanting to explore. Verne had never journeyed to the center of the Earth, but his endless caverns would be more enticing to almost any explorer than a mere Mammoth Cave or Carlsbad Caverns.

My interest in Verne didn't seem to fit with anything we were doing. Certainly not yet, and certainly not with the kids' stuff. But when I read his *Journey to the Center of the Earth*, I was inspired, and I began to write a novel in my spare time about a boy named Matt Dunny.

The gist of it was this: Matt lives in a gigantic shack in the middle of nowhere with his eccentric family and his insane grandfather. Through a strange series of events, he discovers that the shack sits atop a trapdoor. He's attracted to the trapdoor for whatever reason, so down he goes. He eventually discovers an entire kingdom far underground called Dunny. The enlightened Matt now

> We pushed to strip away all computer-like interface elements, leaving nothing but the navigable world of sight and sound.

realizes he's always been a citizen of this kingdom (and he has amazing adventures in Dunny). I had no idea that this story would end up saving us enormous amounts of time during our *Myst* development, and, along with Jules Verne's influence, would become an integral piece of the *Myst* game and the larger *Myst* "universe."

A Call from Japan, a Blank Slate, and a Side-Room in a Mobile Home

Around 1991, a Japanese company we hadn't heard of, Sunsoft[2], called us out of the blue. They wanted to know if we had ever considered putting together something a bit more sophisticated and larger-scaled. Something along the lines of what we'd already been doing, but goal-oriented and aimed at an older audience. We could barely contain ourselves! A couple of years earlier, we'd proposed an almost identical concept to the young Activision, but had been turned down. Now we were getting a chance to attempt that very thing: a world with a goal and a story.

So here it is: the blank slate. Of course this always entails a certain amount of trepidation. However, at this point, much of that blank slate was already filled. We'd been slowly growing large chunks of that blank slate, and we saw *Myst* as just another step in our slow evolution.

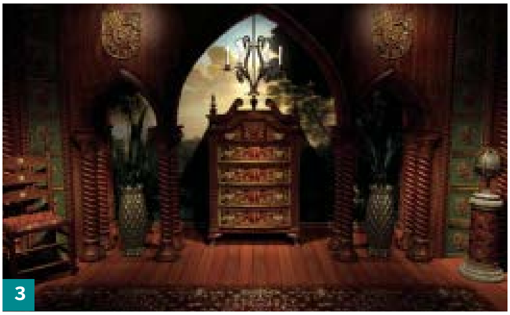
We began designing *Myst* at Rand's office, a side-room of the mobile home (talk about luxury!) where he and his wife lived. It was not so much a discussion as a vomiting of ideas. Being brothers helped during these sessions because we not only had the freedom to tell one another when an idea worked, but we could also lambaste one another (in our special brotherly way) when an idea was hopelessly bad. So we talked and talked and sketched and sketched, and slowly, *Myst* began to take shape.

2. A division of Sun Electronics from Nagoya, Japan, Sunsoft was a complete delight to work with throughout the *Myst* project, and we remain friends to this day.

It was a very rare and exciting experience — working together like that and watching those ideas form. We never could have predicted that *Myst* would be such a "big deal," so we had the freedom to make substantial decisions in a seemingly off-the-cuff way, not necessarily focusing on "the consumer" or "the fans" (because there were none), but only on whether we reacted in a positive way (one that we often couldn't even articulate to each other).

It didn't take long for us to affirm the assumptions we'd made about our first-person interface. Even though we were aiming for a more adult audience, we still felt that the first-person interface we used for *The Manhole* — an interface with few computer graphic elements — would also work for *Myst*. We wanted *Myst* to be as cinematic as possible, so we naturally kept anything at bay that would take players out of the world and place them in front of their computer screens. The *Myst* world had to be believable; a player had to know that he or she was really walking around Myst Island — listening to the waves in the distance, peering through the lonely mist — and any "computer-like" elements might easily destroy that believability.

In addition, Rand and I were not "gamers," so we were naturally distracted by the same style of adventure-game graphic elements: avatars, packs, maps, etc. We believed that non-gamers would face a small hurdle learning and adjusting to graphics like this, and many would find them unappealing or downright distracting. An audience of gamers did not seem to mind deciphering the rules for a new game, but we never imagined that *Myst* was specifically for gamers. We never dwelled on who the *Myst* audience might be, but we ourselves were non-gamers and usually didn't bother learning the latest interface for the latest computer game. There had to be others like us. An adventure game should feel like a world, immediately obvious from a sensory point of view with no barriers to learning it — even for the most inexperienced computer user.



1. Our concept and our hope was that even a non-game-playing public could be dropped into the *Myst* world without any rules, directions, or explanations, yet would be immediately able to intuit their way forward. 2. An example of one of *Myst's* "puzzles": this generator powered an antiquated battery.

3. This luxurious hidden bedroom in *Myst* displays a Verne-like visual influence. 4. During *Riven's* development, Richard Vander Wende and I were inspired by a slew of visual sources, but Verne's presence filtered through from the original *Myst*.

The First Game for Non-Gamers

So the decision to go with the first-person interface was almost automatic. And it proved to be the right one. The transparency of the interface was a feature that (unexpectedly) helped to transform *Myst* into a best-selling piece of software by opening the doors to an entirely new computer-game-playing population. Non-gamers, many of whom had very little patience or time to learn how to play a game, turned out to be the vast majority of our audience and enjoyed the almost instant learning curve that *Myst* offered. We were even surprised and very pleased to learn that our growing *Myst* audience contained a number of people who'd never even touched a computer; *Myst* was their introduction!

When it was time to design the actual game-play, we had no experience under our belts. Even so, after letting our D&D background percolate for all those years, we had a good idea of what we were after. Between us, we had one real desire for game-play: we didn't want anything to feel like a clever mind puzzle or an arbitrary trick. We simply wanted to build impediments into the environment. Stumbling blocks. We hoped that puzzles would feel nothing like puzzles, but would instead seem to belong in the *Myst* world. If we did our job right, simple observation would suffice. The only thing players would have to do is pretend they were really there.

We invented most of these logical "impediments" as we sat around in Rand's office (probably gorging ourselves on chips). But we began scratching our heads after awhile; it wasn't so easy and we were quickly running out of ideas. So at a certain point, we went ahead and got out Rand's old D&D dungeon. We began looking through his notes and maps, thinking, "Where can we use some of this stuff? These great puzzles? Hmm ...." We eventually took the whole layout, shifted it around a bit, made it spin, added and took away some things, and called it Mechanical Age. This was D&D's most direct influence on *Myst*; it only takes a quick glance at Rand's castle map to spy a clear correspondence to the rotating Mechanical Age.

As it turned out, we were relatively successful with the game-play in *Myst*, although a number of arbitrary-feeling puzzles slipped through the cracks — even when we attempted to hold them at bay. Later on, during *Riven*'s development, we did a

An adventure game should feel like a world, immediately obvious from a sensory point of view: no barriers to learning that world — even for the most inexperienced computer user.

better job in this respect, though the puzzles were often so difficult that the vast majority of players lost patience with the game and gave up far before they could reach any of the endings (it's a difficult balance).

It never occurred to us to allow our players to die. This would have destroyed their experience. One does not die in reality and then get a second chance. That was not believable, so it was never considered. Incidentally, along the same lines, we initially were not going to allow the player to "save game." This also felt like a break from the believability we were trying to establish. Instead, we'd originally reasoned, the game would simply be saved every time the player moved forward. If he quit (or if the computer bombed), he could easily return to the exact spot in which he'd last been playing. By taking away any convenient option to save, we thought that players would feel a much greater story tension and would therefore not make any decision lightly. Eventually, we were talked into adding a "save game" feature, but I'm not sure I'd do the same thing again.

Most of our goals didn't seem impossible. We were almost positive we could carry off an environment with little or no learning curve. We felt it would be a bit more difficult to successfully place non-arbitrary "puzzles" into that environment. We had a clear approach, yet there was one lingering obstacle that was still a complete *Myst*ery to us: story. Rand and I thought it might be possible to create a user-driven story within the realm of the "computer game." Not just a story in which the player moved from A to B, but one that also moved its players, provoking them intellectually or emotionally in some small way.

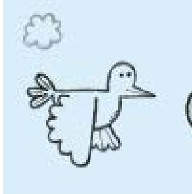
Could we do this? Could we create an interactive work that evoked similar emotions to the more linear games our audience was already familiar with? Attempting this was largely an experiment, and we went to great lengths to set up scenarios in which the player would be forced to make crucial choices at set story junctures, many of which grew more climactic as the player's adventure progressed. We kept it simple. And we hoped our audience might feel something more than the typical computer game.

Myst did provoke. But not in the way we expected! The story we created seemed to have a fleeting impact compared to the islands themselves. The *Myst* audience surprised us by expressing a bond with the islands. The Island Ages became, in a manner of speaking, the "characters," and players felt the impact of these characters in ways Rand and I could never have imagined! I came to recognize the more linear story of the brothers and their father as almost ancillary, as another vehicle simply to distract players from what was much more vital to the *Myst* experience — the landscapes.

Jules Verne's Contribution

As Rand and I designed, the look of those islands evolved. Our inspirations probably came from a wide gamut of outside sources ranging from *Star Wars* (of course) to Disneyland, but on *Myst* I was finally free to let my current favorite, Jules Verne, run a bit amok. Verne's fantastic Victorian aesthetic had been piling up in my brain for a while and, before I knew it, his peculiar imagination had seeped its way into our design. This was most obvious in the way that Victorian-era mechanical technology was contrasted against small pockets of finery. Odd metal spaceships against pipe organs. Underground rail cars against lavish bedrooms. Of course,

3. The name "*Myst*" was indirectly taken from the Verne book *Mysterious Island*, about a group of men who are essentially dropped out of the sky onto a strange, unexplored island. Rand and I hit on the name over a phone call while discussing the book.



we could never begin to equal Verne's imagination, but the *Myst* world did take on that flavor. Like another Nemo, our main character had constructed his own small kingdom of weird wonders, replete with touches of luxury (and even a Nemo-esque library of books).[3]

Finally, we had all our sketches and designs in hand and were almost ready to get to work when we realized we were missing a key part of the *Myst* universe: backstory. We hadn't built a *Myst* history into our world; it felt incomplete. We needed a backstory and we needed it fast. Fortunately, we had a story sitting around, waiting to be used — my unfinished novel about Matt Dunny.

We took that story and, in a matter of a few minutes, our "Dunny" history was complete. "Fire-marbles" stayed; they were an excellent source of power. The idea for a separate Dunny language continued, though we annihilated the thriving Dunny kingdom and ecosystem, leaving it empty of both people and plant life.[4] At the time, we felt that the Dunny kingdom would remain nothing more than an insignificant backstory. We were very wrong.

So, as far as I can tell, that's how we came up with the ideas for *Myst*. It didn't come to us in some great moment of inspiration. It didn't form itself out of the ether. It grew out of our shared experience over the course of many years. The ideas for *Myst* evolved. And now that we had all our designs, sketched and scattered in a few yellow legal pads, we were ready to move into production (which would end up being a completely different story).

The Spreading *Myst*

But none of these ideas seemed like a big deal. None of it hit like a bolt of lightning. Perhaps that's why we were shocked by the overwhelming success of *Myst*. We hoped to make a small profit. Instead, *Myst* became the best-selling computer game of all time (though this record has since been broken by *The Sims*). We had expected *Myst* to enjoy a level of success similar to our previous products — in other words, just enough to fund our next thing. But instead, *Myst* fired a large enough spark to start something of a domino effect (which, I assure you, is a surreal thing to observe from the inside looking out).

It's still exciting for me to see how the *Myst* world continues to evolve, now in even more unexpected ways. During the development of *Riven*, Matt's hut became the desert "cleft," and his grandfather became a grandmother. The Dunny name was changed to D'ni, and after that, the convoluted history of the thing began to evolve, expand, and seemingly take on a life of its own.

This has to be one of the oddest yet best parts of my *Myst* experience: to witness a broad community become so interested in an alternate reality that many of them know it more intimately than Rand and I do. And yet saying they "know" it is not nearly enough; D'ni has become too large a concept to be conveniently controlled.

What started out in the form of one game and one novel is now scattered throughout thousands of websites. And this broad web community, in pondering a fictional reality, often begins to fill in gaps about which its creators have not yet begun to think. They conjecture. They join D'ni "guilds." They write D'ni stories. They create their own words using the D'ni language. They draw D'ni art. In so doing, they too have become not only participants but creators of the *Myst* universe. *Myst* is no longer any one computer game — it's a community. In this respect, D'ni and *Myst* now belong to their users.

Which is the best idea of all!

Resources:

You can see the entire proposal for *Myst* on Robyn Miller's blog, which includes renditions of every island in readable resolution:
makezine.com/go/mystproposal

Here's a *Myst* spaceship built in Second Life:
makezine.com/go/SLrocketship

4. My Matt Dunny story was inspired both by Verne's *Journey to the Center of the Earth* and by *The Lord of the Rings*, and I had ambitions for it to be "epic." After we used it for *Myst*, I trashed my only copy, my outlines, and my map of the world. No big loss: as far as I can remember, it was mediocre and it found a much better place in *Myst*.

Robyn Miller is best known as the co-creator of *Myst*. After his work on *Riven* (the sequel to *Myst*), he left Cyan, the company he founded with his brother Rand, to pursue independent projects.

1966: A Big Year for Video Games

An afternoon with Ralph Baer, the "Father of Video Games."

By Joe Grand

I MET RALPH BAER A FEW YEARS AGO. I had just finished writing my book *Game Console Hacking*, and, given that Ralph is regarded as the "Father of Video Games," he was an obvious choice to seek out to write the foreword. To my surprise, Ralph accepted the challenge and we've been friends, co-inventors, and business partners ever since.

At 84 years of age, Ralph's thirst for inventing shows no sign of being quenched. He has invented hundreds of video games and toys, including the Magnavox Odyssey, Simon, and Computer Perfection.

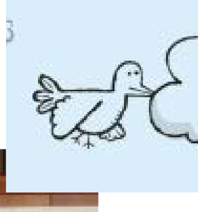
What follows are selected questions and answers from an afternoon I spent with Ralph in his Manchester, N.H., home in June 2006. For the story of how video games were invented and developed in the early age of computing, along with pictures and schematics, be sure to check out Ralph's recent book *Videogames: In the Beginning* (Rolenta Press), and his website ralphbaer.com.

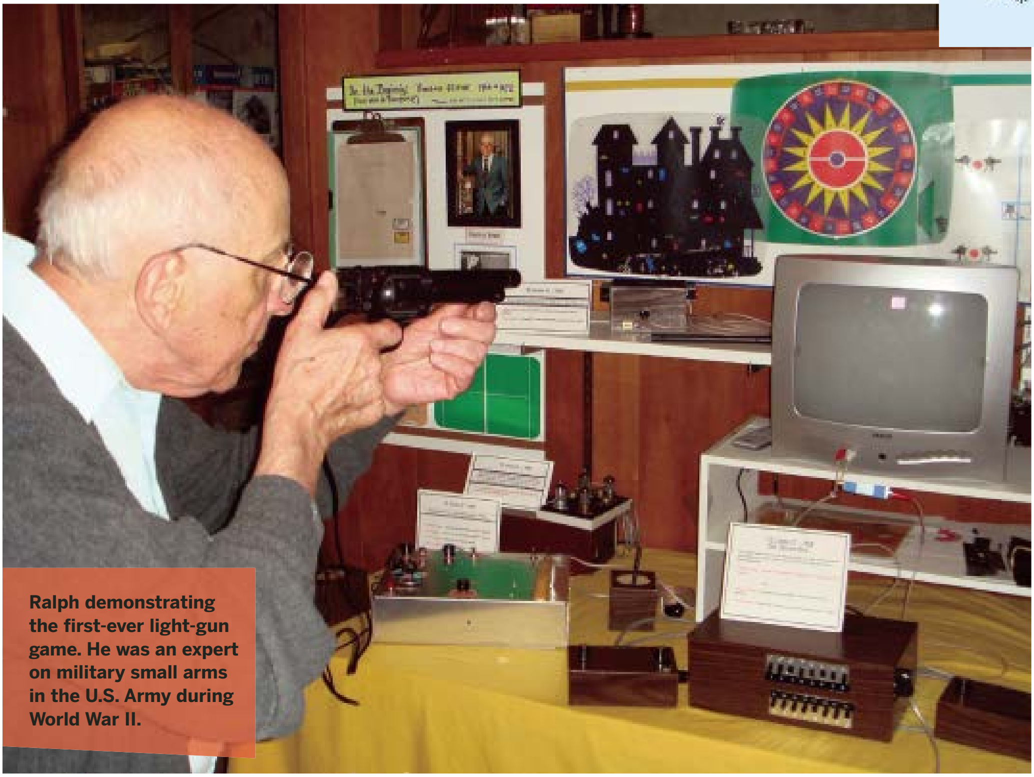
Can you give us some background on where you grew up and how you got involved in electronics?
The short story of a long story: born 1922 in Germany, left Germany in 1938 because of the Nazis. I came to New York and worked in a factory. Started studying correspondence course for radio and television services and graduated as a radio service technician from the National Radio Institute. Got drafted in 1943 and wound up in the same old place that I came from [Germany].

After I came out of the service in 1946, I worked for Emerson Radio in Long Island fixing broken radio sets as they came off of the production line (which was almost every one). I eventually ended up at Sanders Associates in 1956, a defense electronics company. We developed systems such as radar and electronic countermeasure equipment. In 1966, I came up with something that had nothing to do with my job, namely the concept of using a television set for playing games.

That was the year you designed *Chase Game*, your first television video game prototype. Can you describe it?
A simple device in which two spots on the screen could be controlled by two players, the object being for one spot to chase the other, catch up with it, and wipe it out. We also had light-gun, target-shooting games right from the start.

This led to the development of a game console in 1968, called the Brown Box (after the fake wood-grain contact paper you applied to the metal case), which was the basis for the Magnavox Odyssey. What are some challenges you faced in licensing this novel invention?
The biggest challenge was, "What the hell do we do with it?" What did I know about licensing at the time? I was running an engineering department and building radar systems. Then, it dawned on me: the components inside our Brown Box were identical to





Ralph demonstrating the first-ever light-gun game. He was an expert on military small arms in the U.S. Army during World War II.

Photograph by Joe Grand

those inside of television sets, so obviously television manufacturers could make this thing.

We started ringing bells at all the TV manufacturers we could find in the U.S. (and there were a lot at the time). RCA was interested but came back with an inch-thick licensing contract, so we walked away. At Magnavox, we faced a bunch of engineers, marketing people, and management sitting around a long, wooden boardroom table looking very glum, like they weren't too happy about getting involved in this. But when Gerry Martin, the VP of marketing, saw the demonstration he instantly said it was a "Go!" and that started a whole year of futzing around written agreements between us.

Ultimately, the Magnavox Odyssey wasn't released until 1972, four years after the Brown Box had been built, but it was a great success.

Editor's Note: 100,000 units were sold in the first year and more than 350,000 Odysseys were sold by early 1975.

You also invented the smash hit Simon, in the late 1970s, and many other successful games for Marvin Glass Associates (the famous game design studio). What sorts of projects are you working on now?

The recreation of early cable games [using the cable television system to display a graphical overlay on the screen in a time before computer-generated graphics were available] and building some replica Brown Boxes for use in museums.

Do you have any final words for aspiring inventors, makers, hackers, builders, artists, or other do-it-yourself enthusiasts?

Get born to rich parents so you can afford to become a hacker and play around and have a real good time without having to worry about making money. Otherwise, reality sets in real soon because you find out that creativity and talented engineering capabilities and all that are only a small part of the big picture. There's always all this nasty stuff [like sales and marketing] that can get in the way.

When not inventing new consumer electronics, toys, and video-game accessories for his company, Grand Idea Studio, Inc. (grandideastudio.com), Joe Grand collects classic video games and plays ping-pong on his Magnavox Odyssey.

Photos from the Inside

Toys sent through the X-ray machine give new insights. By Shawn Connally

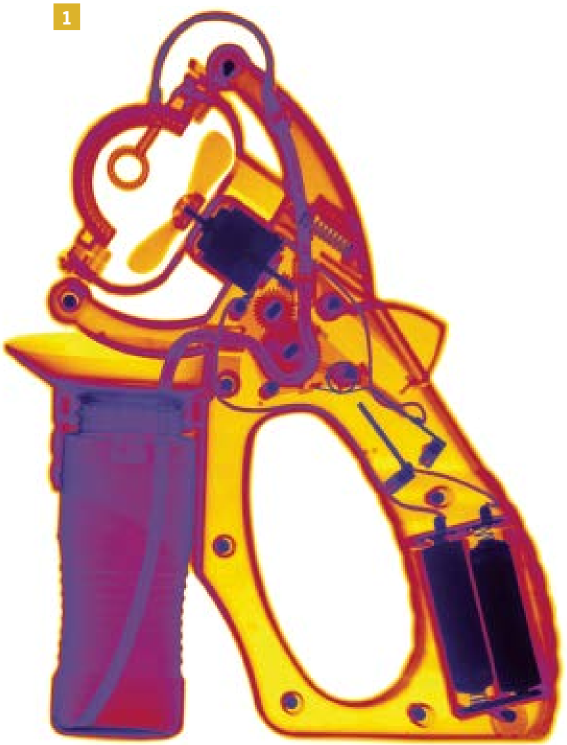
TED KINSMAN MADE THE DECISION MORE than a dozen years ago to take photos of stuff that's "sciencey" and sell it to the general population. He's accomplished this by using a variety of techniques — close-up macros of snowflakes, infrared and time-lapse photography, even X-rays — and he says, "I always break even ... or lose money."

His time-lapse images are seen in many nature documentaries, and he's one of a handful of people doing serious infrared photography. If you're watching a flower bloom, there's a good chance Kinsman took the images. With two or three cameras working for him at home, he goes off to his *other* full-time job as a high school physics teacher. "I have a lot of fun with it," he says. "I want to teach young kids that science is out there and it's cool. And I think I'm doing pretty well."

Kinsman's X-ray photos recently traveled from his home in Rochester, N.Y., to Alameda, Calif., for a special exhibit. Of particular interest to Kinsman are the plastic toy guns. "When you look at the X-rays, whoa, it looks exactly like a gun. Some of the toys are quite graphic and look like something else," he says.

"I like showing people what's inside this object or that object. Seed pods, shoes, duck decoys. So people can see exactly what's inside — the defects, recycled materials. It becomes a totally wide-open world."

1



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Photography by Ted Kinsman

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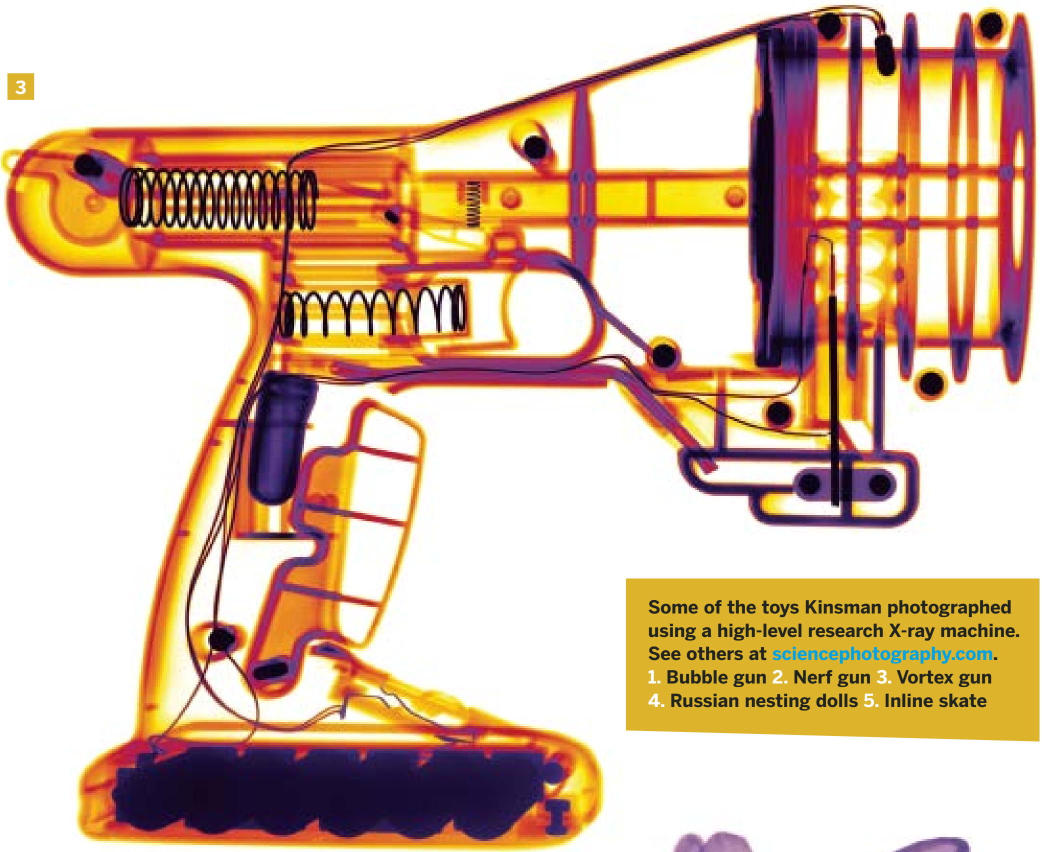


Some of the toys Kinsman photographed using a high-level research X-ray machine. See others at sciencephotography.com.
1. Bubble gun 2. Nerf gun 3. Vortex gun
4. Russian nesting dolls 5. Inline skate

4

5

Pinball, Resurrected

Restoring a crusty, beat up *Cyclone*.

By Bill Bumgarner

THE FLIPPER'S SWEET SPOT STRIKES THE steel sphere, sending it through a gantlet of colorful obstacles. Electrical relays fire, bells ring, lights blink, sounds play, and the world vibrates with a dizzying barrage that only sharpens your focus. You parse the steel ball's trajectory, then adjust its course by nudging the 300-pound machine underneath; there's nothing "virtual" here. You are playing pinball, and it envelops you in a sense-filling physicality that video games can't begin to approach.

Even though the once-ubiquitous pinball machine is a rare sight in arcades and bars today, you can still fulfill your wildest pinball dreams by buying and restoring one yourself. The machines and the parts are out there, and many games in good or reparable condition are collecting dust, waiting for a loving home. Old pinball machines are tough, designed to survive with little maintenance in rowdy, smoky roadhouses. They're also built for repair; different models share many of the same mechanical and electrical subsystems, which you can easily swap around. I've enjoyed restoring several pinball machines, and my most recent adoption was a Williams *Cyclone*, a great solid-state pinball machine from 1988. Here's how I did it, along with more general advice on pinball restoration.

Find a Machine

Pinball machines can cost anywhere from $100 for an as-is electromechanical to nearly $10,000 for a particularly collectable game in good condition. Prices vary wildly, so unless you absolutely must have a particular, hard-to-find game, you should be prepared to look at many before finding a good one to buy. For first-timers, even those with backgrounds in electronics or mechanics, I recommend spending the extra dollars to buy a machine that's at least in decent shape. There will still be plenty of things to tune.

You can buy pinball machines in better condition from restorers, who range from hobbyists to full-time professionals. The most pristine are "home use only" machines, which were never operated in public places. You can also pick up machines from arcade operators and "route operators" who place them in bars and restaurants. In my experience, you should be more careful with these. I have seen evidence of numerous dubious ad hoc "repairs" done to on-route machines in order to avoid the effort and expense of taking them off-location for proper maintenance. The worst offense is the use of spray lubricants such as WD-40. Pinball machines were designed as sealed boxes with mechanical systems that don't require oiling, so they could work maintenance-free in smoke-filled bars for months. Extraneous lubricant sucks up dust and smoke, and turns into a thick, damaging sludge.

To find machines for sale, I scanned craigslist.org, the rec.games.pinball forum, and *Mr. Pinball* classifieds (see makezine.com/08/pinball for more resources). I prefer late-80s and 90s Williams/Bally pinball machines, and my search led to Thursday Night Pinball (pinballnight.org), a group in San Jose that meets in a battery shop. The group's organizer had a Williams *Cyclone* for sale for $1,000. *Cyclone* is one of my favorites; it's a brilliant machine from

Photography by Bill Bumgarner


CYCLONE
JACK POT
MYSTERY WHEEL
Williams
PINBALL AMUSEMENT PARK
EXTRAVAGANZA

1988 with a fairgrounds roller-coaster theme, a kitschy midway soundtrack and voice-overs, ramps, a Ferris wheel, and a spinning wheel of chance on the backglass.

I played the machine and found no catastrophic problems. All parts were present, though extremely dirty, and the playfield had minimal paint cracking and no bare spots. But the machine would still need a lot of work. The Ferris wheel didn't spin, rubber bumper bits were broken or missing, one string of lights flickered intermittently, the flippers were weak, and the Player #3 scoring display didn't work. Pretty typical for a machine that had spent time on route.

I handed over the cash, and readied the machine for transport by folding the backbox down and unscrewing the legs. Like this, it measured 53" by 29" square, and just fit into my Subaru Forester.

Initial Play Test

After transferring the machine safely to my garage, the first step was to play it for a few days and note any problem areas — which is also a good way to meet the neighbors and their kids. When play-testing a neglected machine, you should watch for any relay coils that are energized all the time.

Pinball machines have dozens of these coils, which are what make playfield objects move. Any feature that's stuck in the wrong position — like a bumper always popped out, a flipper stuck up, or a target that won't drop — indicates an always-energized coil underneath, which will also typically buzz and be warm to the touch.

If you find one, it probably means either a short circuit or a blown transistor is leading to the coil. You should turn the machine off immediately and try to locate the problem using the schematic and a multimeter (*see "Special Tools," page 73*). Pinball machine coils are not designed to be on all the time; when they are, they overheat, strain the power supply, and can damage other components or scorch the playfield.

As you play-test, learn the rhythm of your machine. If you feel something change — like a flipper or bumper losing strength, or a ramp starting to wiggle — this is often the initial symptom of something that could grow to become a major problem later.

Get Documentation

Before going further, you need the manual and schematic for the game you're restoring. Fortunately, my *Cyclone* came with both. If it hadn't, I would have looked for a printable copy online, at Marvin's Marvelous Mechanical Museum or the Internet Pinball Database, or else ordered a reproduction manual from Pinball Resource or Bay Area Amusements (see makezine.com/08/pinball). Marvin's site is a fantastic resource in general; it has saved me countless hours with its repair guides and other helpful info.

You will refer to the schematic often during restoration, but, unfortunately, it isn't always the gospel truth. A game's circuitry may be tweaked during its manufacture run, making it differ in small ways from the published schematic.

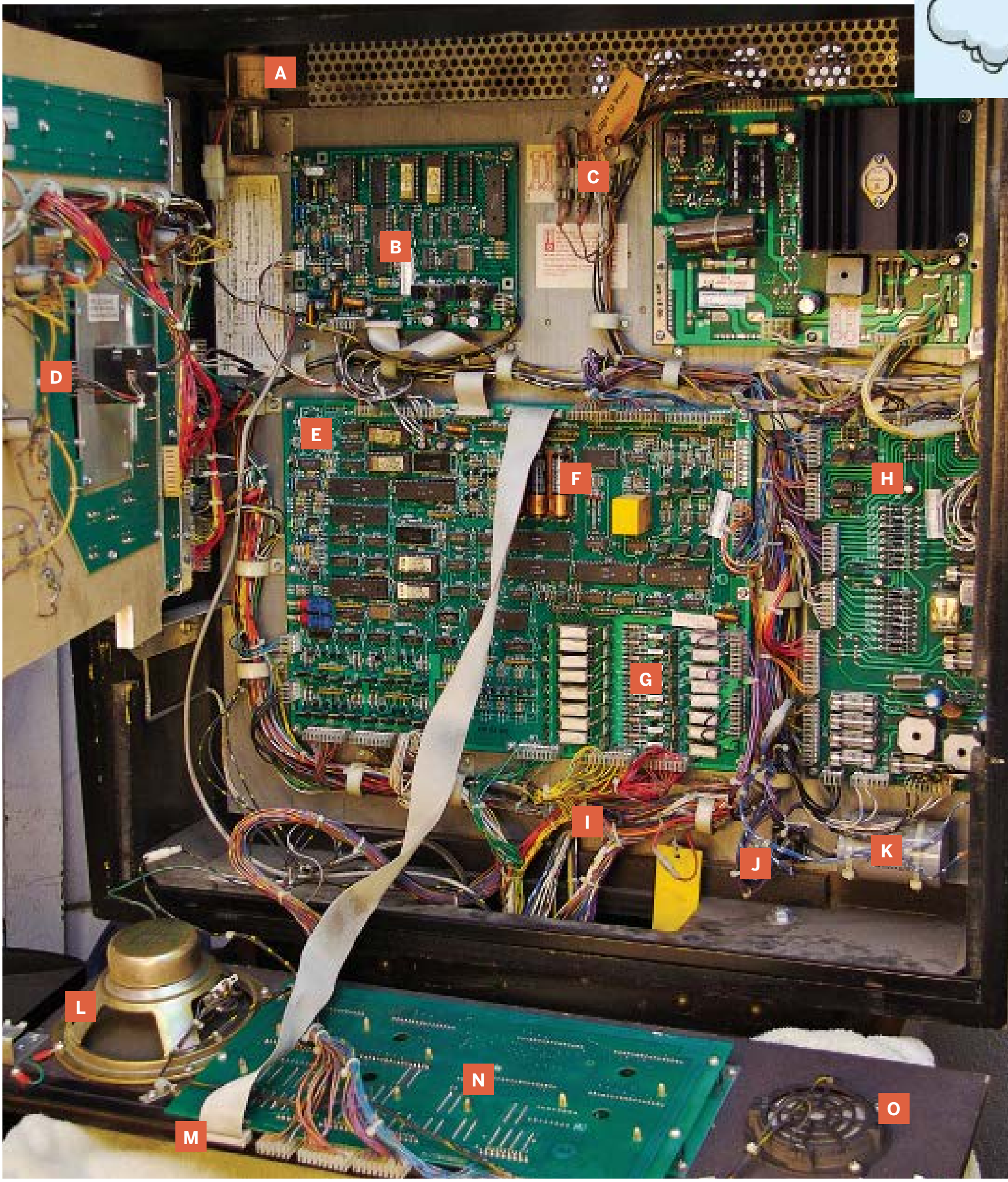
Run Diagnostics and Check Components

Check the manual or repair guide for how to run your machine's diagnostic routines. Every solid-state machine has these. On *Cyclone* and other solid-state Bally/Williams machines, a single dot appearing after the number of game credits indicates that the diagnostics software has found a problem. Switches inside the coin door let you enter diagnostic mode, and from there you can navigate menus to identify what's wrong.

Diagnostic mode also lets you test individual subsystems of the game, all the way down to individual lights and coils. With multimeter and schematic in hand, you can use the diagnostic mode to check everything out. Whether or not you are taking guidance from the diagnostic software, you'll want to check for proper voltages from the power supplies (there are several), check for bad bulbs, bad diodes on coils, or shorted/broken coils.

For the rectifiers, probe the output voltage of that rectifier's power supply section. With the multimeter in continuity testing mode, put one lead on ground (metal strap in the backbox is easiest) and touch the metal tab on each transistor. Any transistor that reads 0 ohms or causes the meter to buzz is bad, dead shorted, and will cause the corresponding coil to be energized all the time. Coils will typically have a diode across their two contacts and this diode will need to be unsoldered for full testing of the coil and diode, something I only do for coils that look particularly beat.

NOTE: Like any device that plugs into a wall, pinball machines can bite. Be careful when working inside the machine. Some electrical components may remain live while the machine is not in play, or even while it's turned off! Also, ground faults are common, so things that should not shock you



INSIDE THE CYCLONE

[A] Knocker that fires when you win a free game

[B] Sound board

[C] Fuse holder

[D] Mystery Wheel (spinning wheel of chance in the backglass)

[E] MPU/driver board. Contains CPU, software, switch matrix input, and driver output.

[F] Evil batteries that leak all over the main board. Moved to external battery holder in a Ziploc bag.

[G] Driver transistors that control the coils and flashlamps on the playfield. Flippers are not controlled by these in this model of machine.

[H] Auxiliary power board

[I] Wiring harness that connects the playfield to the MPU

[J] Bridge rectifier. One of many, but this one runs particularly hot.

[K] Big fat power supply capacitor

[L] Left speaker (midrange). Bass is in bottom cabinet.

[M] Display cable. Don't plug this one in backwards.

[N] Display board

[O] Right speaker (tweeter). Stereo effects are achieved by pitch, not true stereo.

sometimes will. Mechanically, pinball machines move a very heavy steel ball at high speed, so you can imagine what they will do to your finger.

Replace the Batteries
Like other solid-state pinball machines, *Cyclone* has batteries in the backglass that save settings and high scores when the machine is off. These batteries can leak acid and damage the CPU board. With the machine unplugged, our first task is to unscrew the backglass, open it up, and replace the batteries.

In my *Cyclone*, the battery holder was damaged from an acid leak, but the CPU board was still OK. I ripped the holder off the board and soldered in the wires of a new, off-board battery holder. I enclosed the new holder in a Ziploc bag and zip-tied it to a screw I drove into one interior side of the backbox. This arrangement will prevent any future acid-related damage, and I recommend it for any arcade machines that have batteries on their CPU boards.

Raise the Playfield
Remove the playfield glass by opening the coin door on the front of the machine and sliding the little lever inside that is just above and to the left. This unlatches the lock-down bar that spans the glass at the front of the machine. The glass will then slide out of the machine easily. Lean it out of the way, with the bottom edge resting on something soft like a towel.

It's important to remove the balls before flipping the playfield up all the way, lest they drop and break lamps and other components. To do this, lift the playfield a little, reach underneath, and flip the metal bit that kicks the balls into the launcher. With all the balls removed, you can swing the playfield up until it leans vertically against the backglass.

Initial Breakdown and Cleaning
I start cleaning at the bottom of the playfield, the flipper end, and work my way to the top. The bottom is simpler, and addressing it first gives me a feel for what kind of grime and other recurrent issues I'll be facing. With *Cyclone*, I quickly encountered a number of stuck screws, and it was better to practice handling these in a simple, open area.

With all the dirt, it soon became clear that I would need to remove every component from *Cyclone*'s playfield. I grabbed my digital camera and took over 100 pictures of the playfield and various assemblies in close-up, to help me reassemble everything later.

After documenting, I started by stripping the lower-left quarter of the playfield, the simplest quadrant. Using warm water and cotton rags, I gently took up a thick layer of dust and grime, only to reveal a more difficult cleaning problem underneath: the playfield was covered in thousands of tiny paint blobs, probable evidence of an old spray-painting mishap. No major discoloration, but definitely noticeable.

For the components themselves, I used warm water. I treated especially grungy plastic parts with Novus #1 or #2. If you don't completely replace the rubber rings, treat the grimy ones with rubber cleaner.

Playfield Detail
There are three kinds of pinball playfields: painted wood, Mylar, and Diamondplate. Each requires a slightly different cleaning technique. With a painted wood playfield, artwork is screened onto the wood with paint that's quite tough, but that steadily wears down under the abrasive powers of a rusty pinball or dragging flippers. To prevent this, some manufacturers began protecting the playfield with clear, adhesive-backed Mylar. And as of about 1990, Bally/Williams began covering the entire painted wood playfield with a thick coating of Varathane, branding it Diamondplate.

My *Cyclone* had plain painted wood, and happily the paint was still firmly bonded to the playfield. This let me remove most of the grime and spray paint with plain water. I used Wildcat Playfield Cleaner for my initial cleaning, followed by Mill Wax and Playfield Cleaner, a less harsh wax-based cleaner.

Note that Wildcat destroys plastics, so it should not be used to clean ramps or used near plastic parts. Mylar playfields become cloudy if you clean them with harsh cleaners like Wildcat. Diamondplate requires a good plastic polisher like Novus #1 or #2. All cleaners mentioned here are available from pinball parts suppliers.

New Lamps and Rings
While the playfield was stripped of parts, I replaced all the burned-out bulbs and changed all of the "general illumination" lamps (the ones that are on all the time) from #44 to #47. The latter use less current, which eases stress on the power supply. Cleaning the machine makes up for the slight decrease in light. Using brighter #44 lamps for the computer-controlled illumination makes special lighting effects stand out more.

After cleaning each section of the playfield surface and its resident components, I reassembled them, substituting new rubber rings from the replacement kit for the old ones.

The art, playfield, and mechanics of *Cyclone*, mid-restoration. Every pinball machine is an antique model never to be made again. 1. Cameo appearance by Nancy and Ronald Reagan on back-glass. 2. Left flipper exposed for cleaning. 3. Flipper mechanism with flipper shaft removed. 4. Newly cleaned playfield under removed left flipper.

Upper Playfield

Cleaning the upper playfield was just like with the lower playfield, but with more features to remove. *Cyclone* has a network of clear plastic ramps in its top half, many of which have integrated switches. Some of the switch leads disconnect under the playfield, which lets you remove sections of ramp with their switches attached. But they don't all work like that. Along with three separate ramp assemblies, I removed the ball launching assembly and several plastic-on-posts assemblies. Underneath these toys I found a mess of rubber bits, lots of dirt, and even a few seed pods (no idea).

After cleaning and reassembling, I readjusted the ramps. With the playfield down, I took a ball, rolled it around the ramps, and fine-tuned their positions so that it wouldn't get stuck between the upper and lower ramp.

Next came the Ferris wheel. I found that it didn't spin because its drive belt was broken. Simple enough, but at $6, this special rubber belt turned out to be considerably more expensive than any other rubber pieces. Installation wasn't easy, either; I had to disassemble the wheel completely to put the belt around its hub, then pass the belt around a piece of metal that prevents the ball from falling out under the playfield, and finally attach it to the motor underneath.

Clean Underneath

The underside of the playfield is pretty straightforward to clean. On *Cyclone*, a ball guide connects the various under-the-playfield features together. It is made from the same plastic as the topside ramps, and it should be clear, though mine was close to opaque when I first opened the machine. A bit of Novus #2 cleared that up.

If my *Cyclone*'s paint were in better shape, I would have stripped the playfield bare on both sides and coated it with an automotive clear coat. As it was, this wasn't worth doing, but I am on the lookout for an NOS (New Old Stock) bare playfield that I can clear-coat and swap in for that gleaming-perfection look.

> A pinball machine is like a mid-70s British roadster: it may play just fine, but there is always something you can fix, clean, or tweak to make it work better.

Flipper Rebuild

Every time a flipper flips, a metal pawl is pulled through a relay coil and slams against a stop. After thousands of repetitions, the end of the pawl and the stop both change shape; and if the pawl isn't replaced, it eventually mushrooms and fragments around the edges. This can rip apart the coil, causing a short and possibly a power-supply failure. Also, *Cyclone* uses "Fliptronics I" flippers, in which the buttons directly switch on the 50V DC coil current. This results in considerable arcing and wear on the switches, which need to be replaced as frequently as the mechanical components. It is possible to upgrade Flip I's to software-controlled Fliptronics II, which use low-voltage switches, but that's another project.

Rebuilding a flipper involves taking it apart and replacing all of the components that wear out with new ones, usually from a flipper rebuild kit. The tricky part is putting the flippers back together so that they're both at the same correct angle when in the "down" position and never grind against the playfield surface. My *Cyclone* machine showed some wear around the clown's mouth from improperly adjusted flippers, but it didn't go through the paint entirely, and I touched up the damage with some paint pens.

Finally, it was time to put the playfield back together, install the ball, and fire up the game. It's good to do this before replacing the glass because there's invariably something else that you need to tweak before you seal it all back up.

I have yet to figure out why *Cyclone*'s Player #3 display is dead, but the machine is otherwise in great condition: bright, responsive, and fully playable. Frankly, given that the machine works so well, fixing the display was bumped down the priority list.

Ongoing Maintenance

A pinball machine is like a mid-70s British roadster: it may play just fine, but there is always something you can fix, clean, or tweak to make it work better.

Maintaining a restored pinball machine is easy. Clean the playfield regularly with the proper cleaning compounds. Grime builds up in a pinball machine, and if a metal flake ever gets stuck in the grime, it can easily be driven into the playfield, creating a seed for more significant damage later. On a clean playfield, they just vibrate out of harm's way.

Conventions, Modifications, and Upgrades

There are pinball swap meets, conventions, and competitions held around the world. See the *Pinball News* site for upcoming events. There is also a huge pinball community online, including many of the original game designers. Pinball hackers have even produced an open source pinball emulator and control board, PinMame and PinMame-HW, that let a PC control a long list of pinballs — an easier way to restore if an original board is missing or trashed.

A lot of machines also have relatively easy hacks and upgrades. In some cases, the original machine design included extra switches and coils that offered more advanced play or special effects. These were sometimes removed during manufacturing to reduce costs, but the software was typically left untouched.

Custom versions of software also add features to some popular hobbyist machines. For example, a popular home version of *Twilight Zone*'s software adds a "pause" feature: if you catch the ball on a flipper and hit a certain button, the machine will go silent and hold the ball until you are ready to resume the game! With a bit of research, you can find what additional features your game might support.

Because pinball machines are so modular, many of their control circuits and mechanical systems can be broken out to do real-world tasks. You can also buy these at reasonable prices, and full schematics and documentation are online. Pinball machine subsystems can perform some powerful tasks in the real world, as I hope to describe in another MAKE article.

You can spice up a machine quite a bit even without making any functional or permanent modifications; for example, many an *Addams Family* owner puts a funny character in the game's electric chair.

Bill Bumgarner plays with high voltage, cooks with fire, hacks code, corrals bugs with his son, and tries to make stuff do things that were never intended. See friday.com/bbum.

SPECIAL TOOLS

A multi-bit magnetic screwdriver, preferably with a telescoping pick-up tool. This is your most important tool by far. Pinball machines have countless screws in hard-to-reach locations. Worse, if you drop one while the playfield is rotated up, it will invariably "pachinko" its way through the maze of wires and parts, only to fall in some tiny crevice.

A multimeter that can handle both low and high voltages. Modern pinball machines use 5V DC to handle the logic and sensors, 18-50V DC to drive lamps and coils, and upwards of 400 volts to drive the gas-plasma scoring displays.

A big box of slow- and quick-blow 5×20mm glass fuses, of many different amperages. Pinball machines run within tight power consumption parameters, so you should never substitute fuse types or deviate from the proper amperages.

A full rubber ring kit for the machine you are restoring (pictured above). Many rubber rings are buried under hardware, making them difficult to access. Replacing them during restoration will save frustration later.

Flipper rebuild kit for the machine you are restoring. As with the rubber ring kit, these are available from pinball parts retailers. See makezine.com/08/pinball.

Pinheads in Oddball Places

Inside the electromechanical underground.

By Dale Dougherty

MICHAEL SCHIESS / LUCKY JU JU

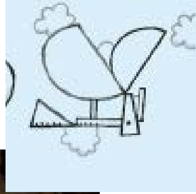
Seventy-five years ago, in the city of Alameda on the San Francisco Bay, an amusement park called Neptune Beach was a rival to Coney Island. Now all that's left of it are some post-cards hanging in the Neptune Beach Amusement Museum, also known as Lucky Ju Ju Pinball.

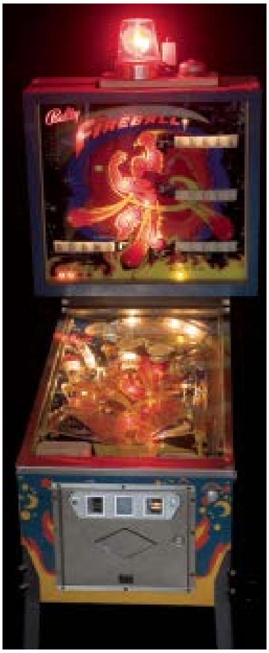
In this oddball headquarters, 20-some pinball machines crowd a two-room space that shares an off-street entrance with a beauty salon. Proprietor Michael Schiess calls Lucky Ju Ju an "Arcadium," short for Arcade Museum, but it's also an art gallery. It's only open on weekends, and Schiess charges $10 at the door, with all the machines on freeplay.

In his early 50s with a gap-toothed grin, Schiess is an affable caretaker and willing custodian. Before establishing Ju Ju, he composed electronic music and worked at the San Francisco Exploratorium as an exhibit builder and maintainer. But his long-time love of pinball art led him to start collecting machines. While taking me on an informal museum tour, Schiess explains that he prefers the art of Christian Marche, whose prolific output included many science-fiction-themed machines; he also admires Jerry Kelly's work, such as in the Beatles-themed *Beat Time*. Schiess calls attention to Dave Christiansen's *Captain Fantastic and the Brown Dirt Cowboy*, the artwork of which was censored in mid-production by the manufacturer. This led to an X-rated follow-on story that I won't repeat.

Schiess is particularly proud of *Fireball*, a 1971 machine that he says is "everyone's favorite" because it integrates superhero art by Christiansen with deft skill shots and a whirlwind spinner that

Photography by Steve Double





Lucky Ju Ju's ***Fireball***, ***Teacher's Pet***, ***Beat Time***, and the guts of ***Faces***, a 1976 machine from Spanish manufacturer Sonic.

changes the ball's direction as it approaches the flippers. "This is such a well-themed machine," says Schiess. "On the backglass, it's got this guy throwing balls at you, and that's just what it does on the playfield. The function follows the art, which is rare."

Schiess hopes his collection of classic pinball machines will be the centerpiece of a larger vision that restores the old Ferris wheel from Neptune Beach, and invites kids to have fun while learning how these wonderful machines work. With his combined pinball and Exploratorium experience, Schiess may understand the educational possibilities of amusement machines better than anyone. "What I like about pinball machines," he sums up, "is how they bring together art, history, and science."

TIM ARNOLD / PINBALL HALL OF FAME

A mile or two east of the bright lights of Las Vegas, there's a dimly lit strip mall with an aging movie theater, some ethnic restaurants, and the Pinball Hall of Fame. Inside this darkened space filled with pinball machines, I found owner Tim Arnold making his nightly rounds, caring for the machines he loves. The glass is off the one he is working on, the fully electromechanical *Gold Rush*. Arnold replaces a bulb, then wipes down the playfield before replacing the glass and testing the machine. He is as quiet as a monk, but soon the machine's chimes are ringing — a good sign.

With thick glasses and ageless blond hair pulled back in a pony tail, Arnold mirrors the hybrid personality of pinball itself: part idealistic hippy, part road-hardened truck driver, and part nerd. Arnold sees every pinball machine as a hooker with a heart of gold — a storyline from the West that could be a pinball game itself. "These machines don't belong in the home; they belong where people come to hang out and have fun," he explains.

Years ago, Arnold worked as a route operator, selling and servicing amusement machines throughout the Midwest. He sold his business, moved to Vegas, and set up the Pinball Hall of Fame. Arnold runs it as a nonprofit, with extra revenue going to the Salvation Army. One day, Arnold hopes his Pinball Hall of Fame will become a popular oddball Las Vegas attraction like the Liberace Museum down the street.

Michael Schiess and Tim Arnold know each other. "Beware of Mr. Schiess," Arnold tells me jokingly. "He's charging you a flat price for all you can play but when you are done, how do you know it is ALL YOU CAN PLAY?"

Schiess stays with Arnold when he visits Las Vegas. "Tim's been around pinball machines a lot longer than me," Schiess explains. "He keeps telling me that I'm still in the romantic phase, and I'll get over it."

♪ Hear an audio tour of Lucky Ju Ju Pinball Arcadium at makezine.com/08/pinball.

Chris Ware's ACME Papercraft

Comics you can build! By Gareth Branwyn

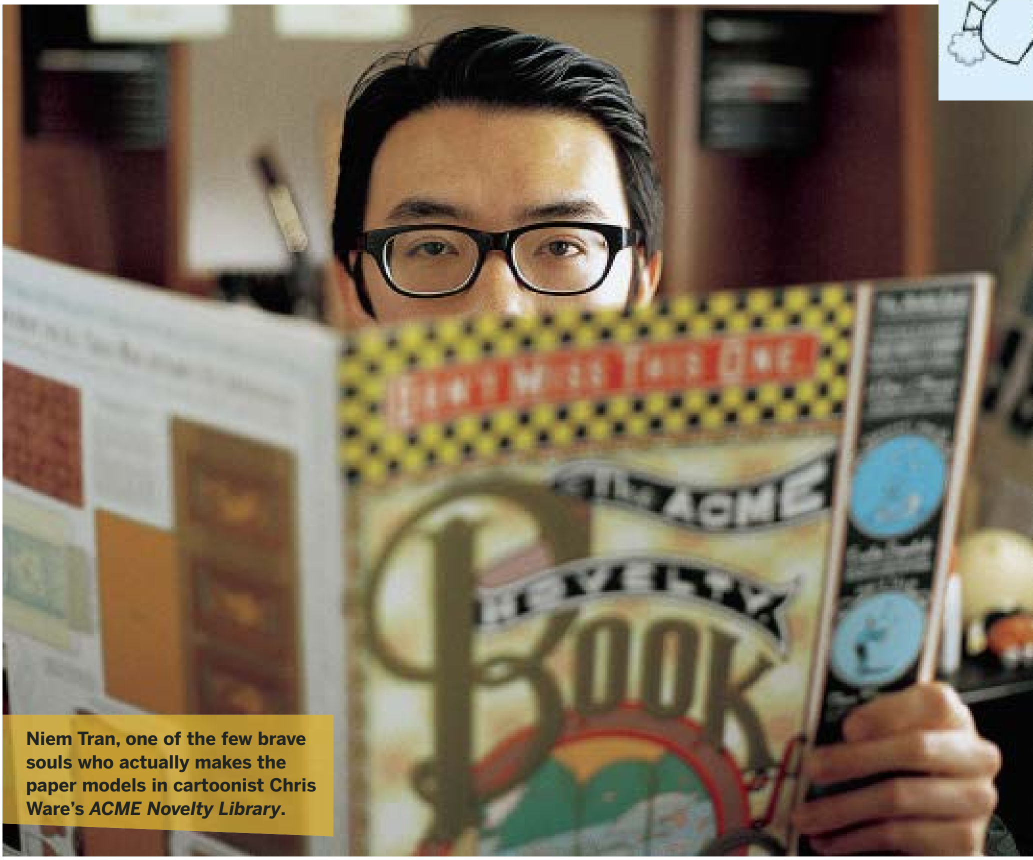
WHEN YOU PICK UP A CHRIS WARE "comic book," such as his critically acclaimed *ACME Novelty Library* series, you know you're about to encounter something extraordinary, even before you crack it open. The covers themselves immediately work to tickle our too frequently jaded fancies. Ware's books are usually oversized or off-sized and sport evocative art and snazzy embellishments (such as foil stamping, paper banding, and pockets hiding mini-comics) designed to communicate difference: this is not your ordinary comic book.

Peering *inside* a Ware comic is when the psychoactivity begins to peg your novelty meter. As one reviewer put it, "You don't read a Chris Ware book so much as open it up and fall into it." The unique landscape onto which you tumble is populated by a weird and wonderful cast of characters, whose often breathtakingly mundane or tortured lives are meticulously rendered in strips such as *Rusty Brown*, *Jimmy Corrigan: the Smartest Kid on Earth*, *Quimby the Mouse*, *Rocket Sam*, and *Tales of Tomorrow*. The look and feel of the strips are very much a throwback to *Krazy Kat*, *Little Nemo*, and other early comic strips. The breathtaking neglect, alienation, existential cravings, and the sense of sensory overload are decidedly modern themes.

There is a profound tension between the pristine virtuosity of Ware's renderings — which feel like they exist in a kind of Zen garden quiet — and the almost dizzying density of all the content he packs into each of these books. There's stuff going on everywhere: multiple strips per page, mock comic book advertising, corporate reports from the ACME Novelty Company, bizarre essays (e.g., a field guide to "The Collector"), actual glow-in-the-dark star maps, animated flip book frames. It all seems to beg for interactivity. To consume a Ware book, you end up turning it in every possible direction to not miss a single graphic or buried treasure. On the cover of the *ACME Novelty Library* anthology, published last year by Pantheon, there was even a comic strip printed on the cardboard-thin leading edges of the cover (billed as the "World's Smallest Comic Strip").

One of the most delightful features of Chris Ware's *ACME Novelty Library* books has always been the inclusion of do-it-yourself activities, namely the cut-and-fold toy models. Looking at these projects, reading the thoroughly detailed teeny-font instructions, one can't help the temptation to actually try putting them together. You too can build a model of Rocket Sam's retro ship, a Lilliputian library of Ware comic books, complete with an ornate book cabinet to store them in, and even a working, hand-cranked 3D movie viewer.

Like everything Ware does, the project plans look so well designed and drawn out that they appear as though they'd really work. Are we supposed to actually put them together? Is this an image of a project — another painstaking put-on, like the fake ads, the fake ACME company histories, the fake coupons and contests — or a real DIY project? While few readers have likely gone beyond questioning the integrity of these models, a handful of hardy souls have actually put scissors to the hallowed pages of *ACME Novelty Library* in a devoted effort to bring



Niem Tran, one of the few brave souls who actually makes the paper models in cartoonist Chris Ware's *ACME Novelty Library*.

Ware's work into the third dimension.

"I don't know of too many people who've built the actual models," says Niem Tran, one of the few fans who's actually done it. He's built them all, in fact, and shows off his efforts on his website (niemworks.com). So why did he take on the challenge? "I'd been collecting Chris Ware's comics for a while and really loved them, including the paper toy designs. The models looked like they'd be fun to build, but I never really gave too much thought to actually constructing them myself.

> **"The covers themselves immediately work to tickle our too frequently jaded fancies."**

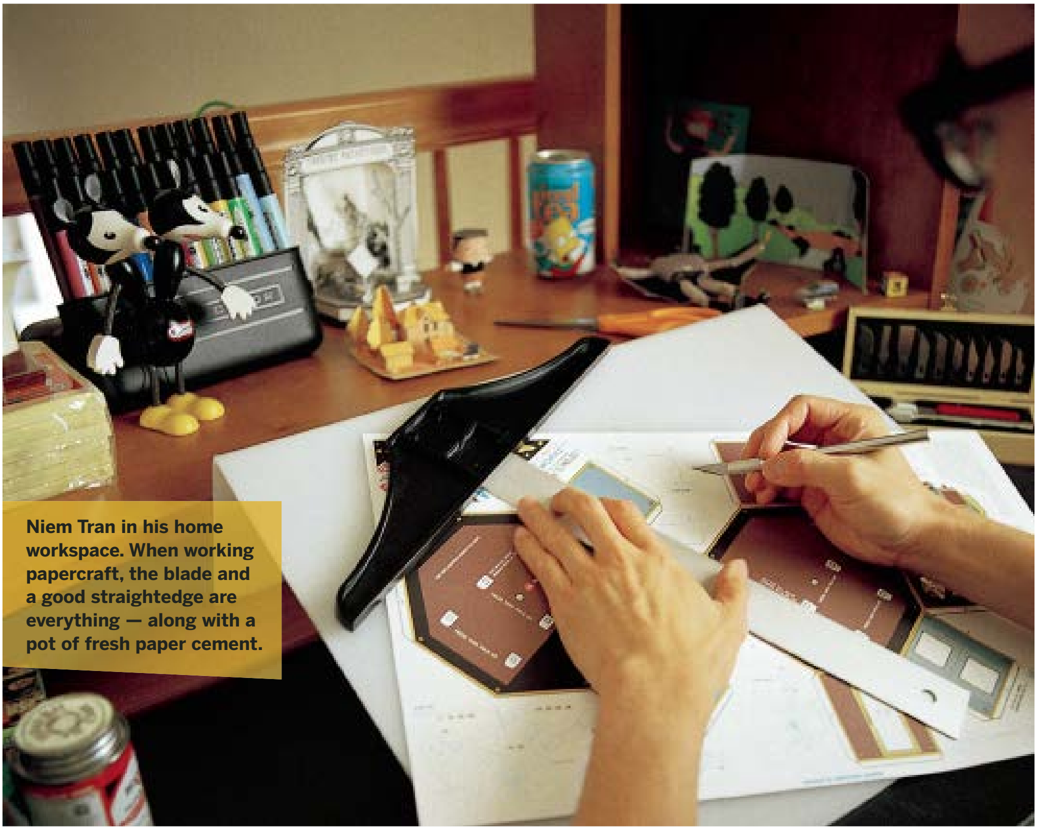
Over the years, as my appreciation for Ware's work grew, so did my curiosity about assembling the models. After fruitless net searches for photos of others' attempts, I decided to try making them myself. One project led to the next, and now I've made just about all of them from the *ACME* series."

Another builder of Ware's often tricky papercraft is Dan Raeburn, author of *Chris Ware*, the 2004 Yale Monographics edition about Ware and his work.

"I built the models in order to get more intimate with his work," says Raeburn. "By building them, I hoped to feel some of what he felt making them. I'm not sure if it worked, but it provided a great way to procrastinate from working on the book itself. It was 'research.'" Like Tran, Raeburn knows of few other readers who've actually built the models. "Of all the people I know, I think only Niem and I are geeky enough to try," he jokes.

Believe it or not, Chris Ware himself doesn't even build the models he so scrupulously designs, draws, and then instructs readers on how to properly construct and display. "I've only ever built a prototype for one of the models," says Ware. "For the rest of them, I simply draw them out on the page and hope

Photography by Jen Siska



Niem Tran in his home workspace. When working papercraft, the blade and a good straightedge are everything — along with a pot of fresh paper cement.

that they function if anyone actually ever tries to cut them out and put them together."

When asked if he created the models with the expectation that anyone would actually construct them, he replies: "I suppose I'd hoped that someone might, but one never has any idea what kind of reaction one's work is going to get, let alone when it requires the use of scissors, tape, and glue."

For devoted fans of Ware's books, the cringe-worthy question to ask builders like Tran and Raeburn is: Do you actually cut up the books or make color photocopies? They both say they've cut up actual copies of the books, but then this was years ago, before decent scanner and printer technology, making it somewhat of a necessity. "If I were to make the models today," offers Tran, "I'd try printing them directly onto Epson Matte Paper Heavyweight."

So, what other words of advice would these pioneering papercrafters offer those who'd like to attempt building Ware's *ACME* models? "Be patient and have plenty of time to spare," cautions Tran. The 3D Movie Machine (the most challenging and impressive model, found in *ACME* #15) took him about 24 hours of build time. Most of the others took between 2 and 12 hours of concentrated work. If you just want to get your feet wet, Rocket Sam's ship from *ACME* #7 is a good model to start with. "I like the rocket ship the most," says Raeburn, "mainly because it was relatively easy to build and reminded me of the toys I made as a child."

+ CHRIS WARE'S *ACME* MODELS AND OTHER PAPERCRAFT RESOURCES:

Niemworks niemworks.com/else/acmetoys.html

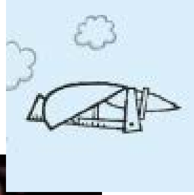
The *ACME* Novelty Archive kempa.com/blog/archives/000120.html

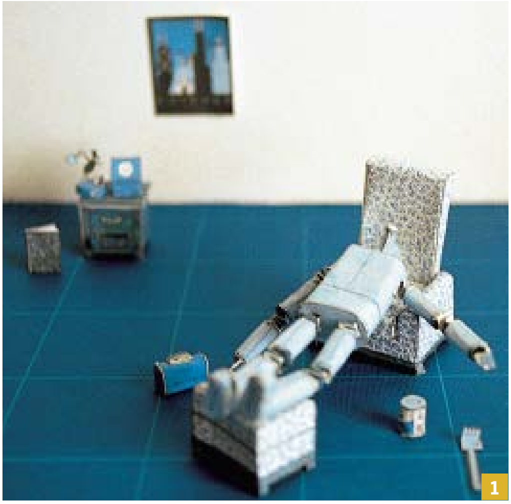
The *ACME* Novelty Warehouse quimby.gnus.org/warehouse

Chris Ware's Flipbook Images as GIF Animations davidcihla.com/ware.htm

Iceberg Paper Model Links www.peterjvisser.demon.nl/indexe.html

In the Studio: Visits with Contemporary Cartoonists, by Todd Hignite (Yale), chapter on Ware and his work studio





1. The Robot from *ACME* #1. 2. The elaborate 3D Movie Machine from *ACME* #15. 3. The Lilliputian library of Ware books, complete with ornate book cabinet, from *ACME* #7. 4. The house from *ACME* #13, also reprinted in it. All from Niem Tran's collection.

SPECIAL TOOLS

Tran and Raeburn offer these additional papercrafter tips for *ACME* builders:

- Use a self-healing cutting mat and have fresh hobby knife (X-Acto) blades handy.
- Use a metal ruler when cutting. Don't press too hard.
- Score all lines before folding. Use a metal ruler and a blunt sewing pin, applying slight pressure as you trace the lines.
- Make all your folds before applying any glue.
- Don't squeeze the white glue out directly from the container onto the tabs. Instead, place a puddle of it onto a dish or scrap sheet of cardstock and dip a sewing pin into it. Use that pin as your applicator, and you'll have more control over the application.
- On larger models, such as the Rocket Ship, use 3M Spray Mount or Spra-Ment and mount the parts onto card stock.

Dan Raeburn adds: "Glue your models to bases or at least keep them away from drafts, especially in the summertime when the windows are open."

Is it just me, or does the image of a collection of pretty paper toys, lovingly constructed by some doting fanboy, flying away on a indifferent current of air, have a decidedly Chris Ware beauty to it?

Tabletop Terrains

That's no pile of trash; it's my asteroid mining colony! By Gareth Branwyn

SAY THE WORD "GAMING" AND MOST people these days will think of the first-person shooting and role playing that takes place on a computer screen. Or maybe a family board game. But to a relatively small and dedicated cadre of players, "gaming" brings to mind a rich and diverse skill set and activities including carpentry, painting, sculpting, mold-making and casting, scale modeling, and environmental simulation. This is the realm of the tabletop miniature wargamer.

There are tabletop wargames based in many genres, but the most common are historical, fantasy, or science fiction. The process for making terrain boards and pieces is basically the same across the genres, but in this article, I'll talk about sci-fi terrain — the type with which I've had a lot of personal experience.

What Is Tabletop Miniature Wargaming?

Before we talk about the terrain making, we need to understand what the terrain is for. The mechanics of each tabletop wargame are different, but play basically boils down to "fire and movement": moving your toy soldiers ... er ... troops into position (how far you can move is determined by dice rolls and measured with a tape) and firing your weapons at your opponent's models (determined by dice rolls and the rules for the weapons depicted on the model). Nearly all tabletop wargames are WYSIWYG (What You See Is What You Get), so the models must actually show the weapons and defenses they are using in play (e.g., you can't have a model holding a projectile weapon and claim that it's a plasma pistol). Terrain (woods, swamps, mountains) becomes very important because it affects movement rates and "line of sight" rules. So, the buildings that gamers spend dozens of hours constructing — sometimes to nearly museum display quality — are not just for ambiance and the cool factor. They also provide much-welcomed cover when your ground forces need a place to duck behind, or your sniper team needs high points in which to nest.

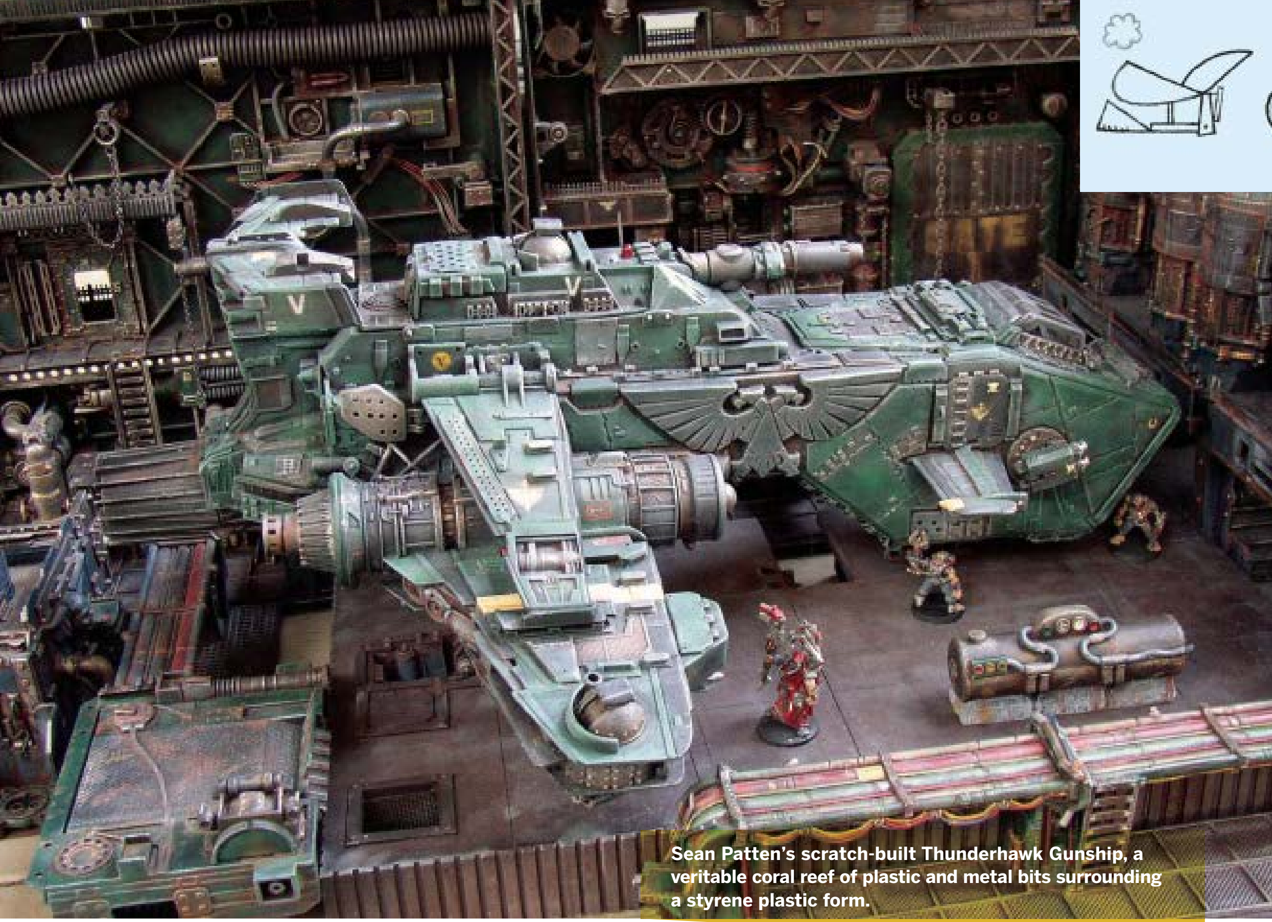
Terrain for Beginners

Getting started in miniature wargaming can be an expensive and time-consuming proposition. Like paper-and-pencil role-playing games and map-based wargames, the rules can be very intimidating to newcomers. There are lots of hit, wound, and save tables to memorize, terrain and other dice modifiers to understand, special rules to remember. On top of that, miniatures mean toy soldiers: dozens, even hundreds, of little plastic and metal soldiers to buy, assemble, paint, and base.

Once all of that's done, the last thing you want to do before playing is to spend months more building a terrain board and scratch-building dozens of buildings, barricades, rubble piles, and the like.

Luckily, you can get away with some pretty groovy-looking terrain made from little more than kitchen trash. The trick is developing a terrain builder's eye. Look carefully at what goes into your trash can. Any metal can, turned over, can become a storage tank of some sort. A bunch of them together can serve as a fuel depot, a worthy objective for a game. A cut-up egg carton becomes a field of alien gestation pods. The plastic dividers in boxes of cookies, crackers, and candy, flipped over, can serve as futuristic army barracks, power stations, command bunkers, and anything else your imagination can dream up.

Of course, none of this stuff is going to look very



Sean Patten's scratch-built Thunderhawk Gunship, a veritable coral reef of plastic and metal bits surrounding a styrene plastic form.

believable in its native packaging colors. This is quickly and easily dealt with by spraying everything with matte black paint and then drybrushing it to bring out details. Drybrushing is when you put paint on a brush, remove most of it on a rag or paper towel, and then work the "dry" brush over the target area. Any raised details on the piece pick up some of the drybrushed color, adding texture and dimension. For concrete and rock effects, drybrush successive layers of darker to lighter gray and then white. For a metal look, use metallic paints from darker to lighter shades. You'll be amazed at how effective this technique is once you get the hang of it.

Meet the *Gomi No Sensei* of Terrain Makers

In William Gibson's collection *Burning Chrome*, he describes the character Rubin as "a master, a teacher, what the Japanese call a sensei ... he's the master of ... garbage, kipple, refuse, the sea of cast-off goods our century floats on. *Gomi no sensei*. Master of Junk."

The masters of terrain building have an uncanny ability to look at the mundane objects around us and visualize what they'd look like turned upside down, twisted sideways, glued to some other piece of detritus, cut, improvisationally embellished with bits of plastic at hand, painted, and lit by twinkle lights and some AA batteries.

One such venerated master is Sean Patten. A computer game designer by day, he got into tabletop wargaming in college. At first, the terrain was an afterthought, with cardboard boxes sheathed in building façades photocopied from books serving the utilitarian need. When Games Workshop came out with *Warhammer 40,000* (aka WH40K), their tabletop miniatures sci-fi game, in 1987, Patten says he was "immediately attracted to its gritty art style and dark gothic-industrial setting."

It is this dense, baroque junkyard world — where a far-future dark age sits on top of the strata of all periods of history — that serves so many of the *gomi no sensei* of terrain, like Patten. He's built terrain for other game systems, such as *Mage Knight* (where he was commissioned to build a couple of boards for its maker, Wiz Kids), *Mechwarrior*, *Mordheim*, and others, but he's most in his element plying his trade in the 41st century. He became something of a legend in the

Photograph by Sean Patten

WH40K community years ago when he built a Thunderhawk Gunship, an iconic vehicle in that game universe, which, at that point, had rarely been seen in three dimensions. His version of the ship took three months to build and used hundreds of parts, including *Star Wars* toys and models, other sci-fi and army toys, sheet plastic and lead, clothes pins, belt buckles, and spent printer cartridges.

Mark Zimmer is another master of the terrain maker's art. Like Patten, he got on board with WH40K in 1987, but wasn't that interested in terrain until he got back into the hobby years later and discovered amazing online resources for terrain crafting, such as the venerable TerraGenesis. "Discovering Gary James's excellent do-it-yourself site got me really excited about the idea of building my own terrain."

Zimmer now runs Parasitic Studios, a site where he shows off his work, offers pointers, and sells his terrain. Like most accomplished builders, he sells pieces via eBay and does commission work. "My original goal was to get this hobby to pay for itself. Over the last few years, I've done considerably better than that," says Zimmer. Like Patten's Thunderhawk, Zimmer also has at least one project that got away from him. "I built this massive, modular, 35-square-foot *Space Hulk* table (a WH40K game that takes place on a derelict spaceship). It was comprised of 88 individual pieces. The rooms and passageways could be arranged in different layouts (like a big puzzle). It was insane."

> "Look carefully at what goes into your trash can. A metal can, turned over, becomes a storage tank. A cut-up egg carton becomes a field of alien gestation pods."

Terrain Making Tips

Here are some words of wisdom on getting into making tabletop terrain, gleaned from my own terrain-making experience and that of Patten and Zimmer.

Start a collection of plastic and metal containers and packaging rescued from the trash. Save stuff that looks even mildly interesting.

Keep a "bitz box," a collection of smaller parts, pieces from old scale models, jewelry, junked toys, wargame miniatures, etc. Buy any and all models at yard sales. It may be a car or a plane or goofy *Battlefield Earth* toy *now*, but repurposed and painted properly, it can become almost *anything*.

Learn the way of the blueboard. Blueboard (aka insulation foam, or pink insulation foam) is used in construction. You can get it at any home/building supply place. It is, literally, the ground upon which most terrain projects sit. You can cut it with a hot wire, sculpt it, sand it, paint it, and turn it into nearly any shape you want. Take a few pieces of this board, tape them together, cover with glue and dyed-green sawdust, and you've got yourself a gaming board.

Get some specialty tools. Besides the usual building and hobby tools, you'll want a hot-wire foam cutter (you can get these cheaply at a craft store), a hot glue gun, and a Dremel rotary tool.

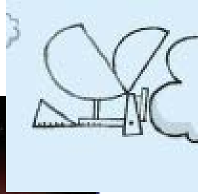
One of Patten's secret ingredients for great terrain is Pre-Mixed Concrete Patch (found at building supply stores). "You can use it for adding texture, filling gaps in terrain pieces, and building up ground surfaces."

Zimmer is partial to kitty litter. "By mixing kitty litter with white glue, you get a chunky, spreadable cement mixture that makes incredible-looking rubble/debris when it dries. Be sure you buy the cheap clay litter."

Zimmer also recommends what's known as "granny grating" in the trade: "These lightweight plastic grids are actually designed for use in cross-stitching, but are excellent for making fencing and floor grating."

+ More resources at makezine.com/08/terrain.

Gareth Branwyn writes about the intersection of technology and culture and is a member of MAKE's Advisory Board.



Making Your Own Video Game

Microsoft's XNA Game Studio Express opens up game development.

By Dean Johnson

ALMOST ANYONE WHO'S EVER PICKED up a joystick or controller to play a video game has thought about creating a game. When I was very young, I drew out levels for Super Mario Brothers with crayons and construction paper. As I progressed through school, I taught myself a lot about programming. I knew I wanted to create games. The problem was that I was a one-man show. When video games first emerged around 1961 (the year Steve Russell created *Spacewar* while attending MIT), it was possible for a single programmer to create a simple yet engaging game. But now expectations are much higher. A professional game development company must hire dozens of people in order to create a single console game.

Where does this leave students and hobbyist developers like me? Behind a mountain of barriers. But there's good news: in late August, Microsoft released the beta version of XNA Game Studio Express, a framework for creating games. With very little knowledge of programming, you can create games for Windows (and, in later versions, for the Xbox 360).

Included in Game Studio is an updated 3D *Spacewar* game, along with its source code. Right away, you can pull apart the code to see how it works. Then, you can start modding the game. One of the first changes I made was to add triple shot to the ship; the ship can now send a wave of bullets toward the enemy. Having a full game right out of the gate allows you to see the results of your programming quickly.

After you play around with *Spacewar*, you might want to start creating your own games. I suggest starting with some of the classics. One of the first games I ever wrote was a clone of *Pong*. Creating a full game such as *Pong* will allow you to learn all of the aspects of programming necessary to create games, including graphics, input, sound, collision, and AI. After *Pong*, try creating other classics, such as *Arkanoid/Breakout*, *Asteroids*, *Space Invaders*, and *Tetris*. Once you've finished creating a few of the classics, begin working on your dream game.

To get started with XNA Game Studio, visit msdn.microsoft.com/xna and download your free copy. I also suggest signing up for the forums and posting any questions you might have. You can view some starter tutorials and samples at a community site I helped create: xnaspot.com.

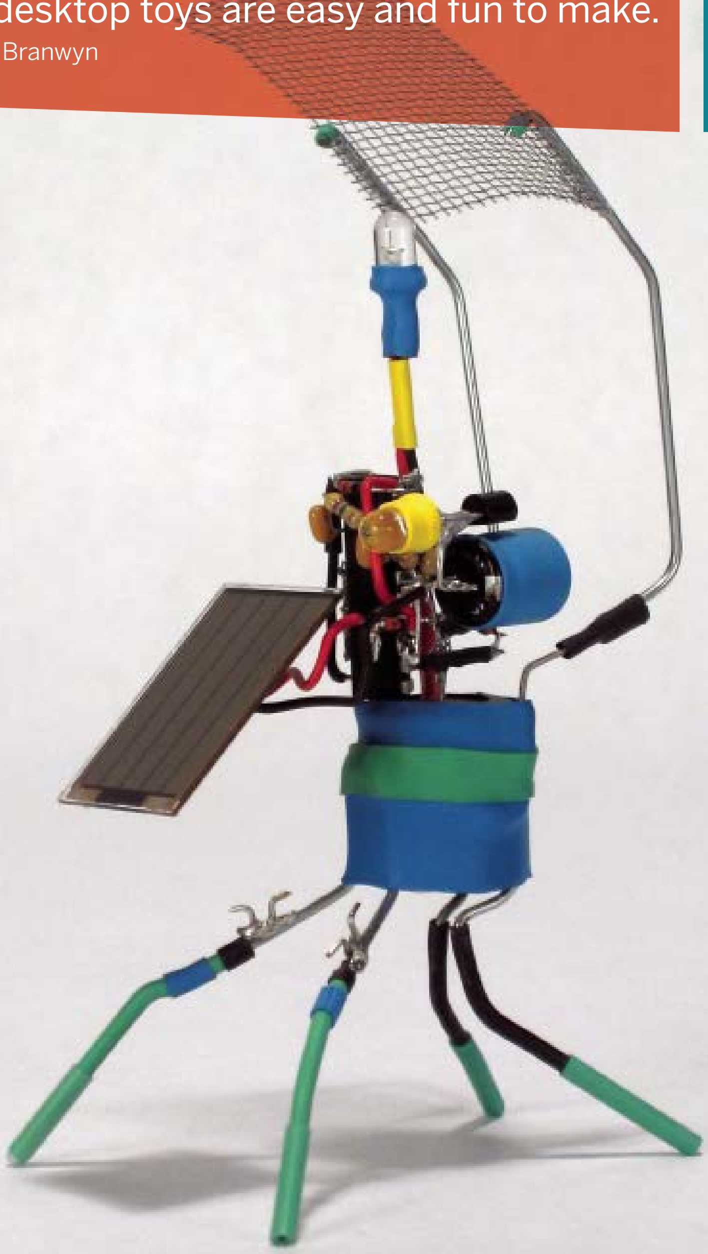
Dean Johnson created his first game using BASIC on his parents' PC. He now attends Full Sail in Orlando, Fla., studying game development.

Image courtesy of Dean Johnson

Pummer, Dude!

Part robotic plant life, part techno-sculpture, these desktop toys are easy and fun to make.

By Gareth Branwyn



Photography by Zach DeBord/M27.com

IN MAKE VOLUME 06, I WROTE ABOUT BEAM, a branch of robotics built on low-end, mainly analog electronics that is inspired by biology. I described how to build two types of bots in the BEAM taxonomy: Solarrollers and Symets. One of the more obscure members of the BEAM family tree is the Sitter, an immobile robot with few or no moving parts.

One of my favorite types of Sitters is the Pummer, a nocturnal, robotic plant that soaks up the sun during the day; stores that energy in batteries or capacitors; and then, when it senses darkness, feeds power to a light which pulses, or "pumms," away in the dark. Since the electronics are simple and minimal, you can have fun with the design of your Pummer, creating a swanky piece of high-tech art that will intrigue everyone who sees it adorning your geekosphere.

MATERIALS

To build this Pummer circuit, you'll need:

Solar cell that can deliver 3V at 20mA (I recommend the SCC2433a from Solarbotics)
74AC240 Octal Inverting Buffer IC
AAA NiCad batteries (2) or you can use 10F "gold" capacitors (2)
0.22μF capacitors (2) often marked with "224" on the cap
1000μF capacitor or 3300μF for a longer fade-away
1kΩ resistor
4.7MΩ resistor
LED any color, high-intensity LED recommended
Diode A low-voltage type, such as the 1N5818 Schottky or a germanium diode, is best, but a silicon one works too.

How a Pummer Works

In "A Beginner's Guide to BEAM" (*MAKE, Volume 06, page 54*), we talked about different types of Solarengines (SE), which are simple power circuits for actuating miniature robots. We mentioned the nocturnal type of Solarengine. This is the variety of SE used in many Pummers. All SE circuits work in much the same way: the solar cell captures light energy, converts it to electrical energy, and sends it to storage, either in capacitors or rechargeable batteries. When a trigger value is reached, the stored energy gets sent off to do some sort of work. In a voltage-triggered SE, the trigger is a set voltage ceiling. In a nocturnal SE, the trigger is a threshold value of light.

Looking at the circuit diagram on the following page, you might be asking yourself: where is the sensor that tells the Pummer that it's lights out and time to get with the pummin'? Ingeniously, the solar cell and the circuit itself serve this purpose.

During the day, when light hits the cell and the cell is sending juice to storage, the diode in the circuit keeps the enable line set to high. When the level of light/current reaching the cell/circuit falls below a certain value (as set by the value of the parallel resistor), the enable goes low, triggering the discharge cycle and the pumming of the LED(s). The diode, being a sort of one-way valve in a circuit, prevents the current from flowing back into the charging part of the circuit; it has no place else to go but along the discharge path.

Pummer Circuits

There are a number of different Pummer circuits you can use, from simple ones that power a single LED, to more sophisticated ones designed to maximize power collecting and discharging, and ones that can power multiple LEDs. The one shown here, used in the Solarbotics Bicore Experimenters BCP Applications Project (see makezine.com/08/pummer), balances simplicity with circuit efficiency and bang-for-buck; i.e., it makes a pretty damn cool Pummer without too many building headaches.

This nocturnal SE circuit makes use of another hallmark BEAM circuit, the bicore, which is the basic "neuron" of BEAM "intelligence" (*see MAKE, Volume 06, page 54 and page 58*). Here, the two-state oscillator is used to create the flashing/pumming behavior. The C1 and C2 caps are used to set the blink/pause rates, and C3 handles the "decay" rate of the pumms. You can play around with these rates by trying different capacitor values on a breadboard.

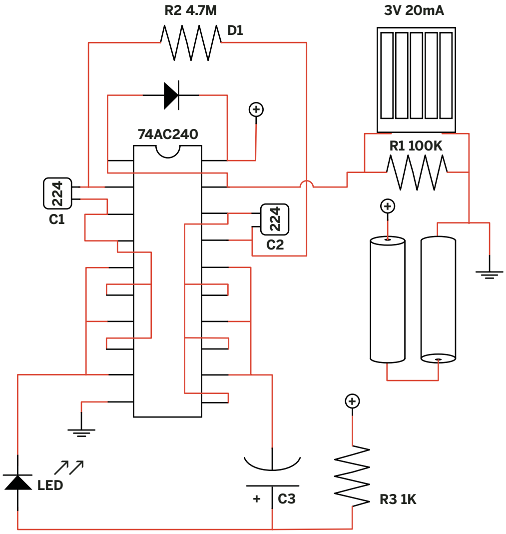
Other Pummer circuits, including those that can handle multiple LEDs, can be found on Solarbotics.net, in */library/circuits*. Costa Rica BEAM (costaricabeam.solarbotics.net) has a fairly thorough library of schematics for Pummers, including a circuit for making a Type 1 Solarengine (which uses a 1381 voltage trigger) into a darkness-activated power circuit.

Pummer Designs

One of the cooler aspects of a Pummer is that, because it's a Sitter and has no moving parts and no concerns over weight, etc., the design and aesthetics of the robot can take center stage. You can build Pummers to look any way you want. A lot of builders, inspired by the idea of Pummers being a sort of robotic plant life, put the LED(s) on a long stalk or on multiple stalks. But Pummers have also been built in the shape of modern sculptures, hexagons, triangles, cubes, even a dragon with solar

Zach DeBord's collection of Pummers made from paper clips, guitar strings, rubber bands, heat-shrink tubing, and a dash of imagination.

Single-LED High-Efficiency Pummer



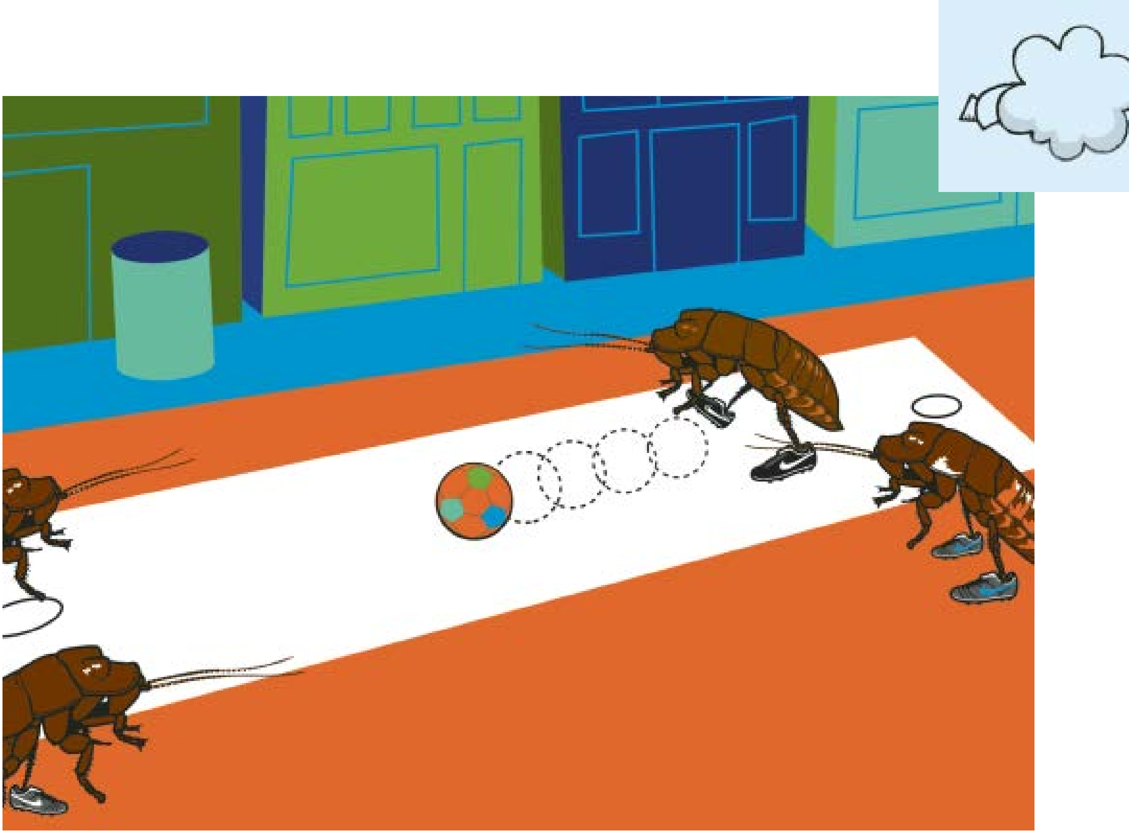
cells on the wings and glowing LED eyes. Really, your imagination and building skills are the only limitations.

A large majority of Pummers are built using paperclips as the main building component. Zach DeBord, a BEAM builder from Chicago (whose Pummers are pictured here) writes: "Buy a pack of jumbo and regular sized paper clips. For the $2 you spend, you'll be able to build a whole fleet of robots. I almost exclusively use paper clips and guitar strings for my creations."

Other common structural components are rubber bands and heat-shrink tubing. "An assortment pack of heat shrink (available at RadioShack and other places) goes a long way," says DeBord. "Not only are your bots more interesting looking, but you can use tubing in key places to reinforce weak joints."

+ For more Pummer resources visit makezine.com/08/pummer.

Gareth Branwyn writes about the intersection of technology and culture for *Wired* and other publications, and is a member of MAKE's Advisory Board. He is also "Cyborg-in-Chief" of Streettech.com.



Roachball Goes Open Source

In this fast-paced lunch-hour sport, changing the rules is part of the game. By Mike Kuniavsky

JASON WILSON DIDN'T START OUT TRYING to invent an open source sport. While living in Brooklyn, he and some friends wanted an incentive to go outside during the cold months, so they formed a winter kickball league. One game day, only five people showed up (because it's winter in New York), which is not enough to make two kickball teams. Not wanting to give up on their original idea of getting out of the house, the group started wandering around Brooklyn. Walking through the snowy streets, they found a bocce ball court. Putting the court and the kickball together, they improvised a new game, which they called Roachball (because, well, it's Brooklyn).

They started playing standard kickball on the bocce court but quickly had to modify the traditional rules. The bocce court was too small for three bases, so they appropriated cricket's two-base system (but kept kickball's baseball-inspired system of strikes, outs, and innings). From soccer, they borrowed the idea of throwing the ball back in when it goes out of bounds, which led to another important change. As Wilson says, "you can [really] bean somebody" when you throw a ball in the close quarters of the bocce court, so they introduced rules from dodgeball.

Borrowing ideas and adapting the rules became part of playing the game. With spring, bocce season started and the courts were in use on the weekends, but the bank drive-through wasn't, so it became a legitimate court, and the rules changed again to accommodate it. As Wilson puts it, "It was

Illustration by Dustin Hostetler

never declared that it was going to have a collaborative rule-making process, but that's what it was."

Fast-forward a couple of years. Wilson moved to Portland, Ore., was working long hours and blowing off steam playing Roachball with his co-workers. They noticed the resemblance of the collaborative, improvisational nature of open source software to Roachball, and decided to rename it OSBall (pronounced "ossball" or "ozball"). They created an OSS-like structure for modifying the game.

Wilson is OSBall's project leader and serves as the editor of the rules wiki (osball.org). Although the attitude is lighthearted, he sees OSBall as a serious alternative sport, with advantages over other sports.

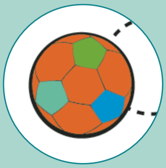
"The challenge," he says, "is motivating enough people to play existing ball games." OSBall can be played with a smaller number of people than other sports, so it's easier to get a group together. It's fast-paced, so you can play a couple of innings over lunch. It's a little dangerous because of the close quarters ("But not too bad," Wilson says). And, like skateboarding or parkour (a freestyle urban-navigation activity), the rules encompass available terrain, so you don't need formal playfields, and it can be played in crowded cities.

OSBall players are encouraged to wear funny costumes during a game.

In addition, the OSBall team hopes to take the ideas beyond a ball game. They're planning a library of ideas for collaborative, improvisational activities they've had, and creating "a packet of stuff that you can use for something totally different."

Mike Kuniavsky is a San Francisco- and Portland-based ubiquitous computing and user-experience consultant and writer who blogs at orangecone.com.

OSBall: Game Play and Rules



OSBall borrows from existing sports. From cricket it borrows the two-base system of running and scoring. From soccer it borrows the idea that hands can only be used while throwing into the court from the sidelines. From kickball it borrows the notion of a pitcher who rolls the ball to a kicker. From dodgeball it borrows the ability to get someone "out" by hitting them with the ball. From bocce ball it borrows the court.

- Two teams of 3 players.
- Play a set number of innings (3 innings is a good introductory length, 6 is a fairly intense game, 9 is tournament length).
- Flip for offense or defense choice.
- All players must be in the court at all times.
  ➡ Defense team can position anywhere, but it's advised to have one pitcher, one catcher, and one outfielder (1 team member at each end and 1 in the center).
  ➡ Offense team congregates around home base.
- The ball is pitched, hands OK.
- Kicked ball must remain inside court; if it goes out this is a strike.
- If the kicked ball goes out of bounds and hasn't touched the ground yet (airball) a defense player can catch it (outside the court) for a catch-out.
  ➡ 3 strikes you are out.
  ➡ 3 outs = 1/2 inning (switch offense to defense).
- Kicker runs to other base, avoiding any contact with the ball.
- Physical blocking of the runner is prohibited.
- Runner may not step outside the court, and may not step on top of the court's retaining wall.
- Defense players can exit the court during play only if the ball has already left the court.
  ➡ Defense players can use their hands while outside the court to throw the ball at runners.
- If any body part is touching the base "end" wall (home base or other base) runner is safe.
- The runner may decide to return to home base in the same turn (home run), but this is purely optional.
- When the second player kicks, the first runner has the option to stay put (2 runners can share a base, but 3 cannot, as this would cause a lack of a kicker).
- A point is scored for every player returning home before the moment of the third out.

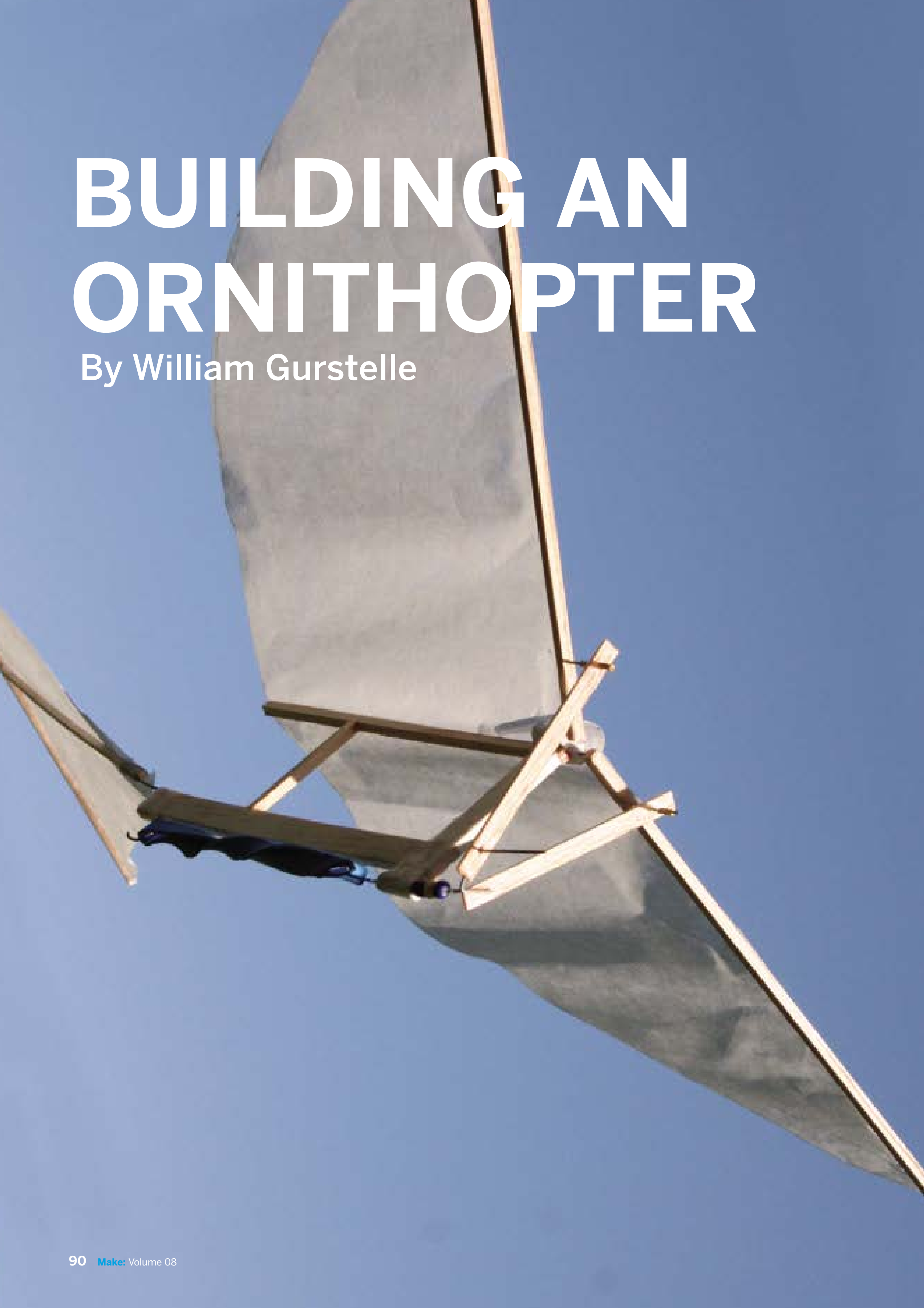
Photograph by Jason Wilson

Make: Projects

Find your angle of attack and get your flap on when you construct a winged flying machine. Then give yourself something to wake up for by connecting a toy gun to your alarm clock. Or check out our "java script" and experience the bliss of true homebrew.

BUILDING AN ORNITHOPTER

By William Gurstelle



FLIP, FLAP, FLY

For millennia, men and women have studied birds, bats, and beetles, observing and experimenting, attempting to determine what humans must do to fly by flapping.

But people can't fly by flapping: not with wings covering their arms; not with pedaled, chain-driven wings; and, so far, not with internal-combustion engines, either. Nonetheless, the concept of manned ornithopters continues to hover on the periphery of aeronautical engineering. This project shows you how to build a small, rubber band-powered ornithopter we call Orly.

There are many types of ornithopter designs. Orly is a simple monoplane, meaning there is a single wing mounted above the motor-stick, and its motion is similar to a bird in flight.

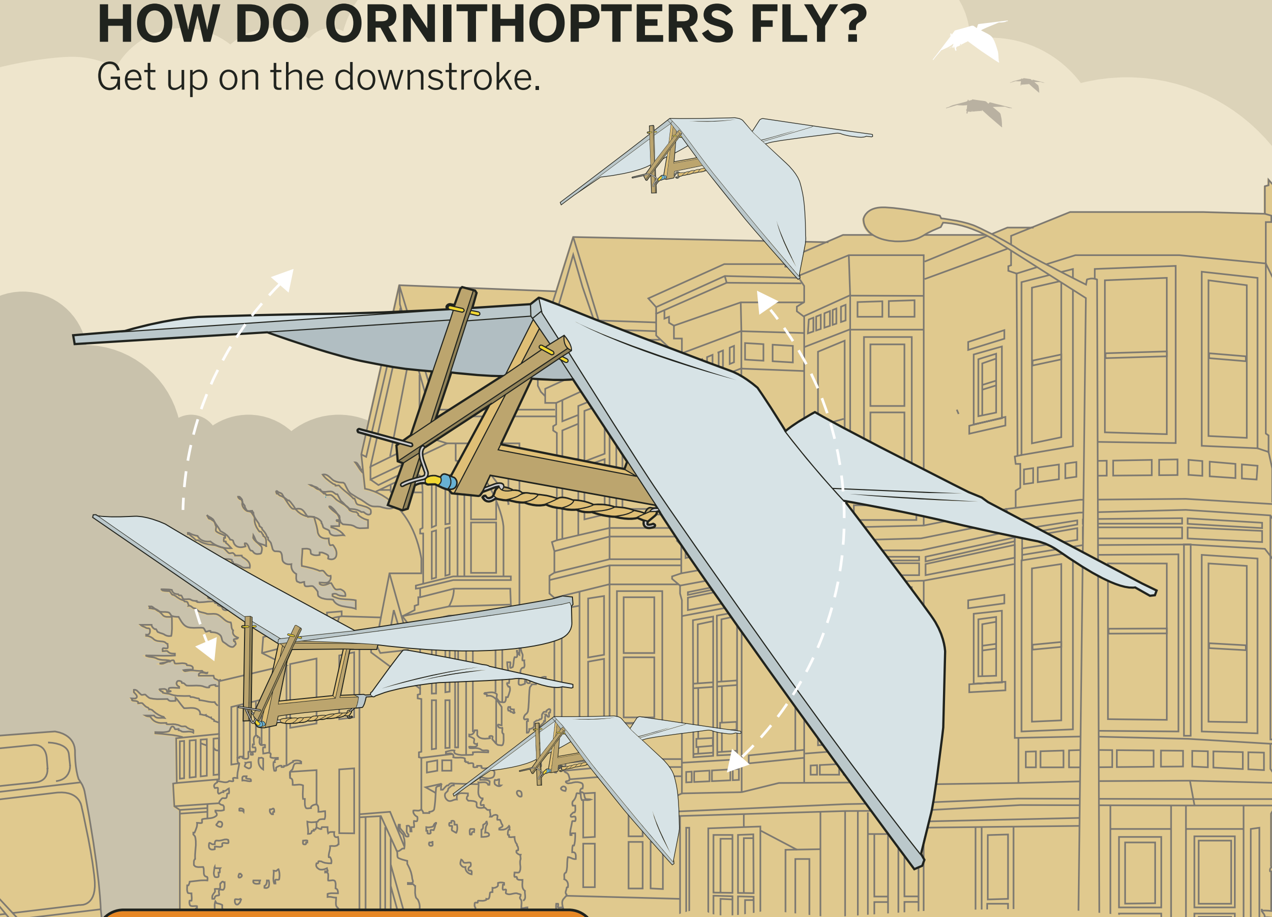
Photograph by Gerry Arrington

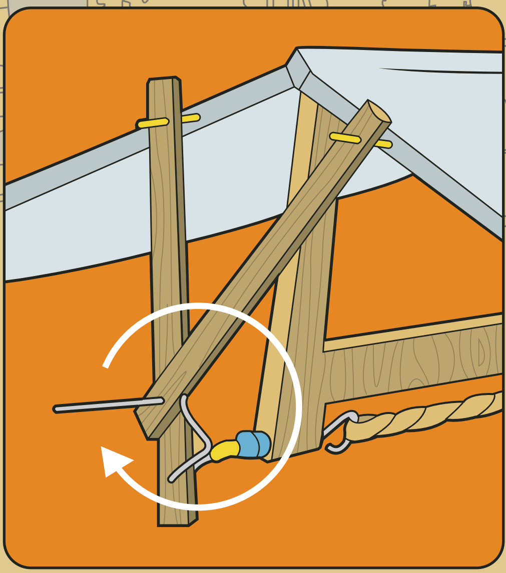
Set up: p.94 **Make it:** p.95 **Use it:** p.99

William Gurstelle is a contributing editor of MAKE and is the author of *Backyard Balistics* and *Adventures from the Technology Underground*.

HOW DO ORNITHOPTERS FLY?

Get up on the downstroke.





How do ornithopters fly? According to Nathan Chronister of the online Ornithopter Zone, "The ornithopter wing is attached to the body at a slight angle, which is called the angle of attack. The downward stroke of the wing deflects air downward and backward, generating lift and thrust.

"Also, the wing surface is flexible. This causes the wing to flex to the correct angle of attack we need in order to produce the forces that we want to achieve flight."

The mechanics of flapping flight are far more complicated than that of fixed-wing flight. For an aircraft with fixed wings, only forward motion is necessary to induce aerodynamic lift. But for flapping flight, the wing not only has to have a forward motion, but also must travel up and down. This additional dimension means the wing constantly changes shape during flight.

Illustration by Timmy Kucynda

FROM ICARUS TO ORLY: A SHORT HISTORY OF ORNITHOPTERS

Without doubt, even the earliest humans watched birds fly past and felt, well, rather envious. Thus when Thag, a Pleistocene caveman, looked up and saw flocks of ducks and geese soaring above, he might have gathered together a few palm fronds, lashed them around his arms with a vine, and leapt off a tree. Poor Thag never got airborne, or at least he didn't live to record the episode in petroglyphs on his cave wall.

Later, from ancient Greece, comes the legend of Daedalus and Icarus. Daedalus was a skilled engineer who angered King Minos. Minos ordered him imprisoned in a tower.

According to *Bulfinch's Mythology*, "Daedalus contrived to make his escape from his prison, but could not leave the island by sea, as the king kept strict watch on all the vessels.

"So he set to work to fabricate wings for himself and his young son Icarus. He wrought feathers together, beginning with the smallest and adding larger, so as to form an increasing surface. The larger ones he secured with thread and the smaller with wax, and gave the whole a gentle curvature like the wings of a bird."

Unfortunately for Daedalus, the attempt at flight didn't entirely work. His son, Icarus, flew too near the sun, melting the wax that held the wings together. Icarus fell out of the sky and drowned in the ocean.

To a large extent, that's been the typical outcome of human flapping flight experiments, right up to modern times.

The New York Times has run many stories over the years:

» "Ornithopter Somersaults — Captain White Hurt in Crash" (June 1928)
» "Inventor Tries to Soar Like a Bird; Narrowly Escapes Drowning" (March 1932)
» "100,000 See French Birdman Die in 9,000 Foot Fall" (May 1956)
» "[University researchers] named their ornithopter 'Mr. Bill' after the perpetually maimed character on the television show *Saturday Night Live*." (May 1992)

Around 1490, Leonardo da Vinci was carefully studying the mechanics of avian flight. From his bird-watching came perhaps the first blueprint for a human-carrying ornithopter. More of a theoretician than a true maker, Leonardo never got his flying machine off the paper in his notebooks. Had it been built, it likely would not have flown. Still, experts say his design is clever, and embodies modern aerodynamic principles developed hundreds of years later.

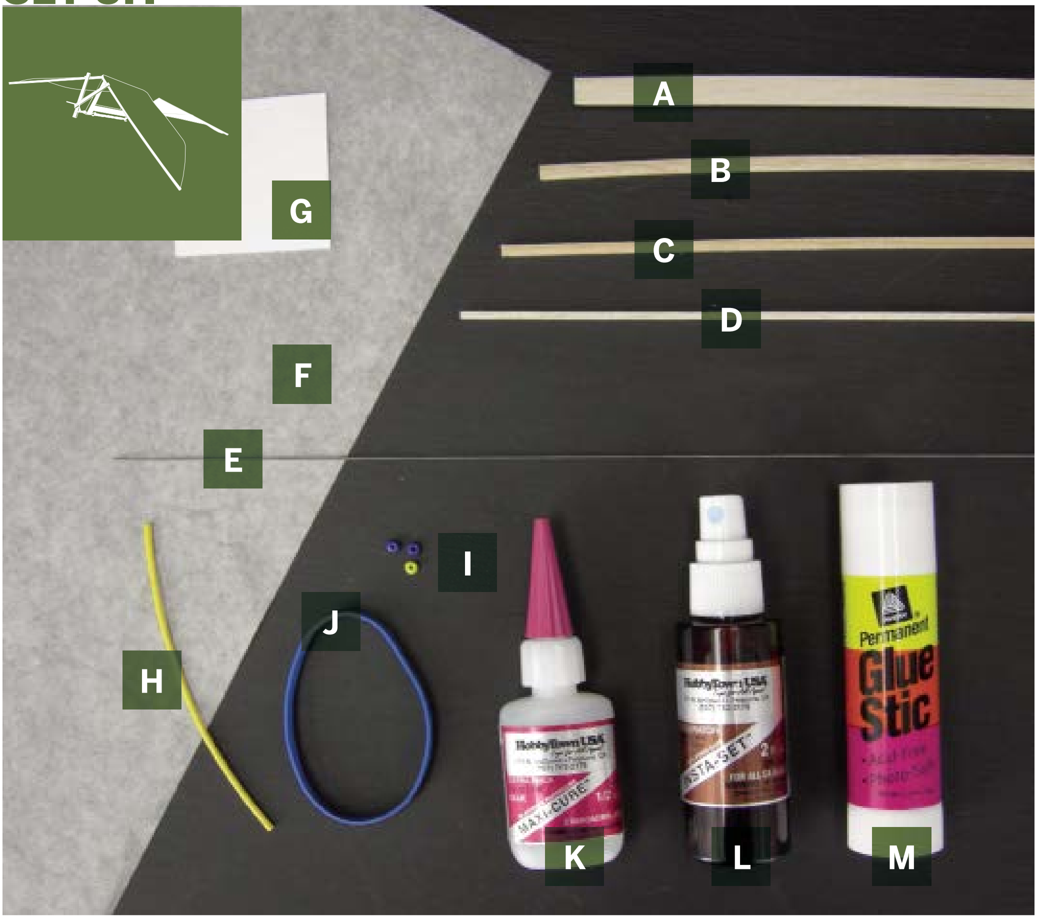
Interest in flapping flight took off again in the 1870s. Building model ornithopters became fashionable in Europe, and a number of enthusiasts — among them Alphonse Penaud, Hureau de Villeneuve, and Gustave Trouvé — built internally powered birds that soared over the fields of France and Flanders. Soon, ornithopters powered by rubber bands, gasoline, electricity, and even gunpowder were flapping away, but as scale models, not people-carrying aircraft.

Since then, many people have tried to build a manned ornithopter, but none have yet succeeded. There are unconfirmed reports that the Germans made one during World War II and that the Soviets flew one during the Cold War, but solid evidence is lacking. Today the University of Toronto is making a game attempt.

Why bother with ornithopters at all? Because flappers can do things other aircraft cannot. They probably have the best maneuverability of any aircraft. Unlike fixed-wing drones, ornithopters, at least in theory, can stop and hover like a hummingbird, which makes them extremely versatile, and they need less space to maneuver than a helicopter. Couple all that with their ability to fly at very slow speeds, and ornithopters may be the perfect surveillance vehicles. The military applications for unmanned ornithopters are numerous.

Ornithopters have practical applications in civilian life, as well. For instance, the Colorado Division of Wildlife uses an ornithopter to research a hard-to-capture endangered species called the Gunnison sage grouse. This skittish bird flies away at the first sign of danger but will stay on the ground if it sees a hawk flying above. So state biologists use a motorized, radio-controlled ornithopter painted like a hawk to keep the flighty grouse on the ground long enough for them to capture it.

SET UP.



MATERIALS

[A] Balsa rod ⁵⁄₁₆"×⅛", 7 inches Cut into lengths of:
- 5" motor stick
- 1½" front vertical connector

[B] Balsa rod ³⁄₁₆"×¹⁄₁₆", 6 inches Cut into lengths of:
- 2¾" connecting rods (2)

[C] Balsa rod ⅛" square, 24 inches
Cut into lengths of:
- 8" wing spars (2)
- 5" top wing attachment member
- 1½" back vertical connector
- ½" crank standoff

[D] Balsa rod ³⁄₃₂" square, 14 inches
Cut into lengths of:
- 7" tail members (2)

[E] Music wire .032" diameter, 10 inches
Thicker wire is too heavy and can adversely affect Orly's performance.
Cut into lengths of:
- 3" tail/rear motor attachment wire
- 2½" crank/front motor attachment wire
- 2" wing spar wires (2)

[F] Sheet of tissue paper, about 18"×18" Made specifically for modeling, about .04 ounces per 100 square inches. Regular tissue paper is comparatively heavy.

[G] Square of 16 lb. paper, 2"×2"

[H] Heat-shrinkable tubing, ¹⁄₁₆" diameter Cut into 3 pieces each ⅛" long

[I] Small beads (2) With inside diameter just large enough to accommodate the .032" diameter music wire. From bead or craft stores.

[J] Model airplane rubber 12" long Tied in a loop to make a big rubber band. From hobby shops.

[K] Cyanoacrylate (CA) glue

[L] Cyanoacrylate drying accelerator

[M] Glue stick

Vegetable oil (not shown)

TOOLS
(not shown)

Needle-nose pliers (2)

Utility knife To cut the balsa wood to size

Ruler

Scissors

Photography by Matthew Dalton and Ty Nowotny

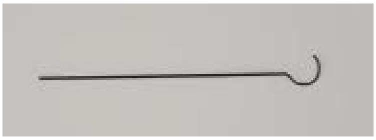
MAKE IT.

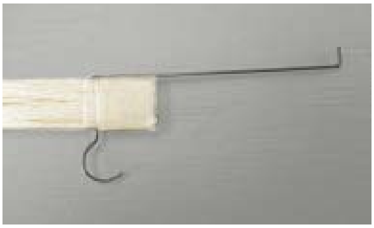
BUILDING ORLY THE ORNITHOPTER

START **Time:** **A Day** **Complexity:** **Medium**

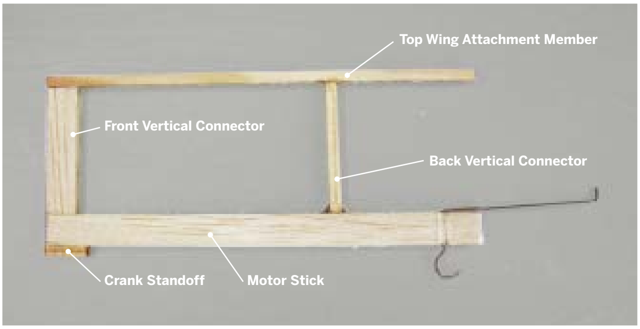
1. MAKE THE FUSELAGE

1a. Form a hook in the tail/rear motor attachment wire as shown. Carefully push the wire through the center of the motor stick at a point ⅜" from the tall end. Then make two 90-degree bends in the wire as shown, and glue into place using CA adhesive. Reinforce the wire-to-balsa joint by placing a tissue paper cover over it. Dab the joint with a thin layer of CA. Spraying CA drying accelerator on the joint makes the process faster and less messy.



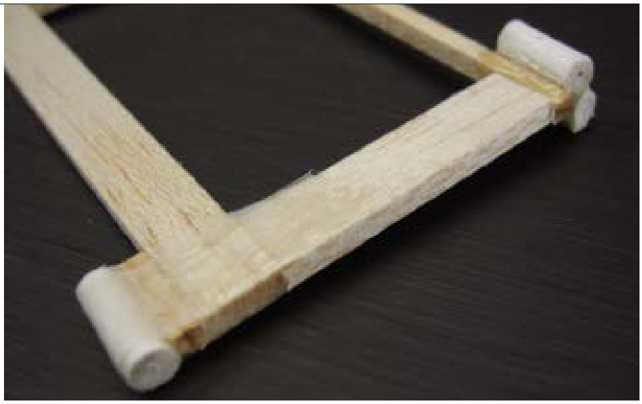


1b. Glue the fuselage together as shown.

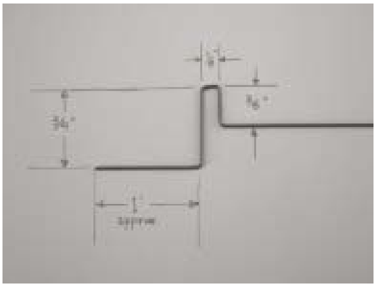


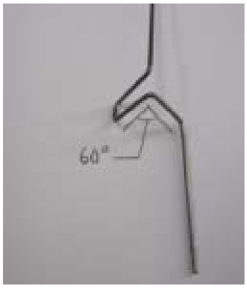
1c. Roll the 2"×2" paper into a narrow tube using the music wire for a mandrel. Remove the music wire and carefully daub the tube with CA, taking care to maintain the tube's openings. Spray with CA accelerator. Cut into three ½" long tubes and discard the remainder.

1d. Attach the 3 tubes to the fuselage as shown, with CA and accelerator. Make certain the tubes are aligned with the long axis of the fuselage.



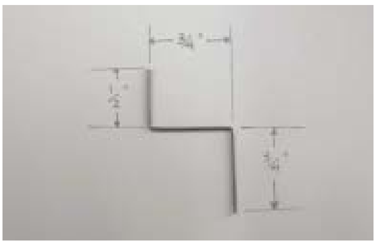
1e. Use the needlenose pliers to bend the wire so the crank appears as shown. Insert the crank wire through the paper tube glued to the crank standoff. Place the 2 beads on the wire. Create a bend in the back end of the wire to serve as the motor hook.





2. MAKE THE WING SPARS

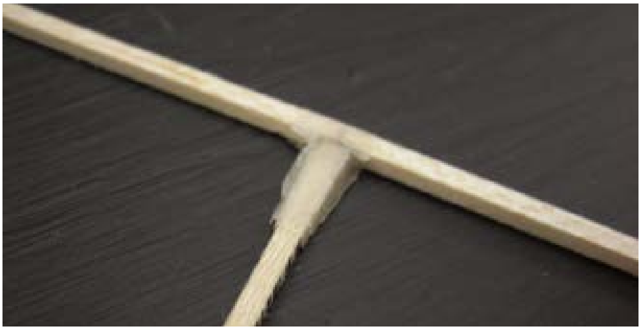
2a. Bend the music wire as shown. Carefully push the wire through the wing spar at a point ¾" from one end. Glue into place using CA. Reinforce the joint by wrapping a layer of tissue paper around the joint and coating with CA.



3. MAKE THE TAIL

3a. Use CA adhesive to glue the balsa rods into a T shape. Reinforce the joint by covering it with tissue paper soaked with a thin layer of CA.

3b. Poke the end of the fuselage tail attachment wire into the balsa tail member; then glue the assembly with CA. Reinforce by wrapping with tissue and CA.



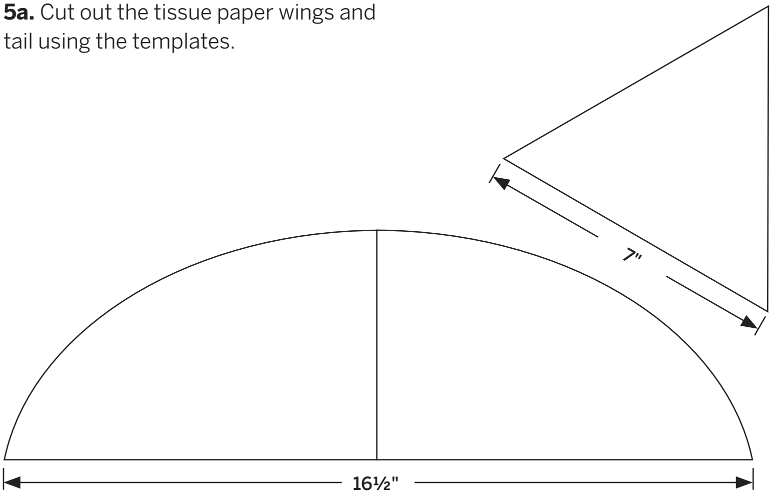
4. MAKE THE CONNECTING RODS (CONRODS)

4a. The conrods undergo considerable stress. Harden the rods by coating the last ½" of each end with CA.

4b. Make 2 holes for the music wire in each conrod, ¼" from each end.

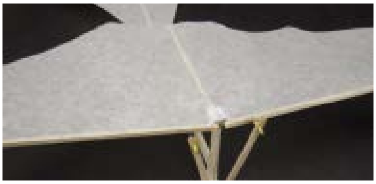
5. FINAL ASSEMBLY

5a. Cut out the tissue paper wings and tail using the templates.

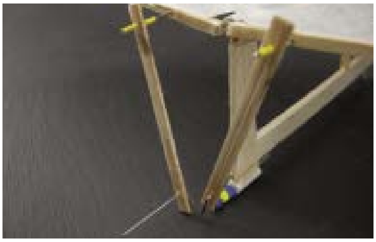


NOTE: Full-scale templates are posted at makezine.com/08/orly.

5b. Glue the tissue paper wing to the wing spars and the top wing attachment member. Glue the tissue paper tail to the balsa T frame with a glue stick.



5c. Connect the conrods to the wing-spar attachment wires and the crank. Adjust the spacing of the conrods so the crank turns smoothly. Place heat-shrinkable tubing over the crank and wing spar wires to maintain alignment, and carefully heat with a match to shrink the tubing.

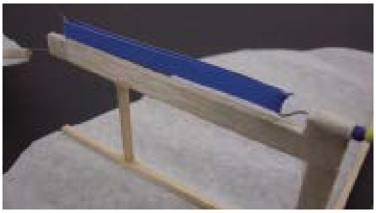


WARNING: The tissue paper, the balsa wood, and the CA catch fire easily! Use great care in this step.

5d. Bend the tail up so it is at about 15 degrees from the plane of the motor stick.

6. SENDING ORLY AIRBORNE

6a. Double the rubber band and place it over the front and rear motor attachment hooks.



NOTE: To accommodate a longer rubber band, double it into 2 loops and place it over the front and rear attachment hooks.

6b. Rub the band with a little vegetable oil for lubrication.

6c. Wind up the rubber band motor by turning the crank at least 35 turns.

6d. Angle Orly's nose up slightly and release gently.

FINISH X

NOW GO USE IT »

USE IT.

FLY, BE FREE!

TROUBLESHOOTING

Ornithopters can be difficult to fly. Common problems include stalling, nosediving, and veering, in various combinations. If your ornithopter doesn't fly well, try the following:

1. If the ornithopter dives and veers, winding the motor in the opposite direction may help.

2. Balance is important. Make certain the action of each wing is the same. Make the conrods and crank carefully to ensure balanced wing operation.

3. If Orly has a tendency to flip or roll in flight, you need to improve your craft's stability. Try lengthening the distance between the motor stick and the tail, or adding a rudder (a vertical stabilizing surface on the tail).

4. If the ornithopter veers consistently in one direction and then nose-dives, add a small wire weight to the end of the wing tip on the side opposite the direction of the veer.

5. The angle of the tail is important. Bend it slightly up if the flapper nose-dives, and bend it down if it stalls.

6. If Orly goes through a series of stalls before ultimately diving into the ground, your tail may be mismatched to the rest of the aircraft. Fix this by decreasing the size of the tail. If that doesn't help, extend the length of the tail boom — that is, increase the distance between the wing flappers and the tail.

7. A direct head first plunge to the ground may be a signal to increase the size of the tail stabilizer.

8. If your ornithopter flaps vigorously but won't gain altitude but lowers into the ground tail first, try to move the center of gravity forward. It is best to make the rear lighter instead of making the front heavier.

9. Bank and spiraling problems are common in ornithopters, and can be tough to correct. If your ornithopter starts out with few good looking flaps, but suddenly banks or rotates around its longitudinal axis and then spirals down, try the following:

• Reapply the tissue paper to the wings, making sure the paper is not applied too loosely or too tightly stretched. Both wings should have the same amount of tension.

• Bend a small rotation in the tail plane relative to the longitudinal axis of the ornithopter.

• Add a small weight to the outside of the wingspar opposite the direction of the bank.

Fixing the bank and spiral problem can be difficult. You may need to try a number of fixes in combination before the problem clears.

EXPERIMENT!

You may be able to extend the duration of flight by making a few changes to Orly's design. For instance, you can experiment with rubber bands of differing lengths and thickness. You can also vary the shape, sweep angle, and size of the wing.

Sometimes, adding wing gussets made from a thin piece of transparent tape improves performance. Finally, experiment with the length and width of the tail.

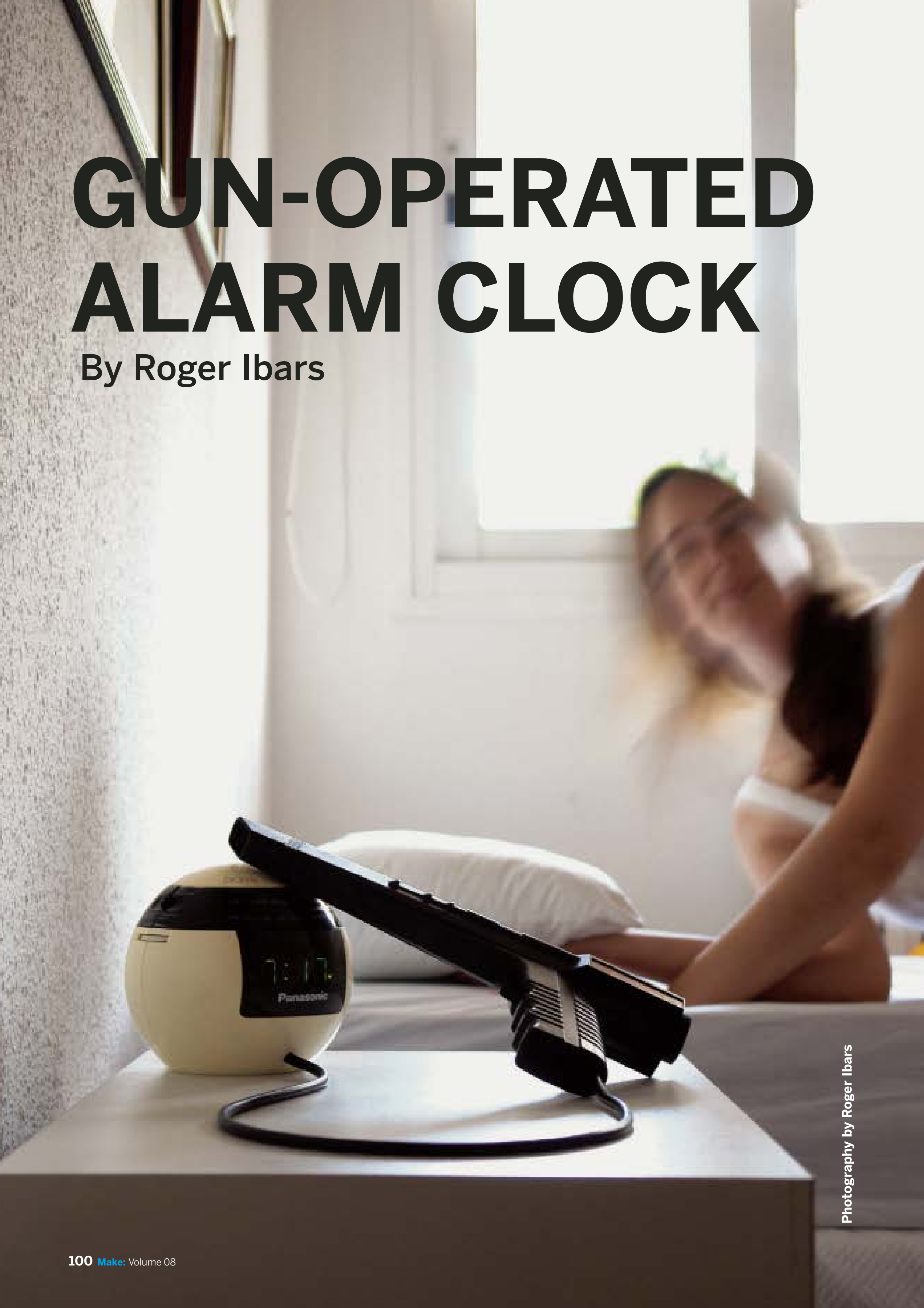
RESOURCES

There is an active community of ornithopter enthusiasts, with a lively online forum at ornithopter.org. This excellent site also provides plans, kits, motorized models, and advice.

For the latest news on the University of Toronto manned ornithopter project, visit ornithopter.net.

GUN-OPERATED ALARM CLOCK

By Roger Ibars



Photography by Roger Ibars

KILLING TIME

Hack a retro gaming light gun with some tilt switches to control a vintage digital clock radio. After the alarm wakes you up, you can grab the gun and kill it off. Isn't that what you've always dreamed of doing?

Clock radios are everyday hated devices that designers seem to ignore, judging by how little their features and user interfaces have changed. This project adds a new capability, letting would-be sleepyheads enjoy a human-machine interaction of a different sort. Don't worry, we're not going to connect your clock to an MP3 player and play mellow New Age sounds. We're going to shoot the alarm off. With a gun. Wake-up time is now payback time.

We'll base the project around a digital clock radio and a light gun for gaming; huge selections of both of these are available inexpensively second-hand, with many beautiful and well-designed examples. To enable our FPSI (First Person Shooter Interface), we'll outfit the gun with five tilt sensors, arranged at different angles on a small circuit board. A cable tethers the gun to the clock and carries your tilt and trigger signals to the clock's time and alarm control button contacts.

Set up: p.103 Make it: p.104 Use it: p.109

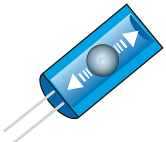
Roger Ibars lives and works as an Interaction Designer in London. He is interested in how people understand technology and how technology understands people. See more of his work at **selfmadeobjects.net**.

IMPLEMENTING GUN CONTROL

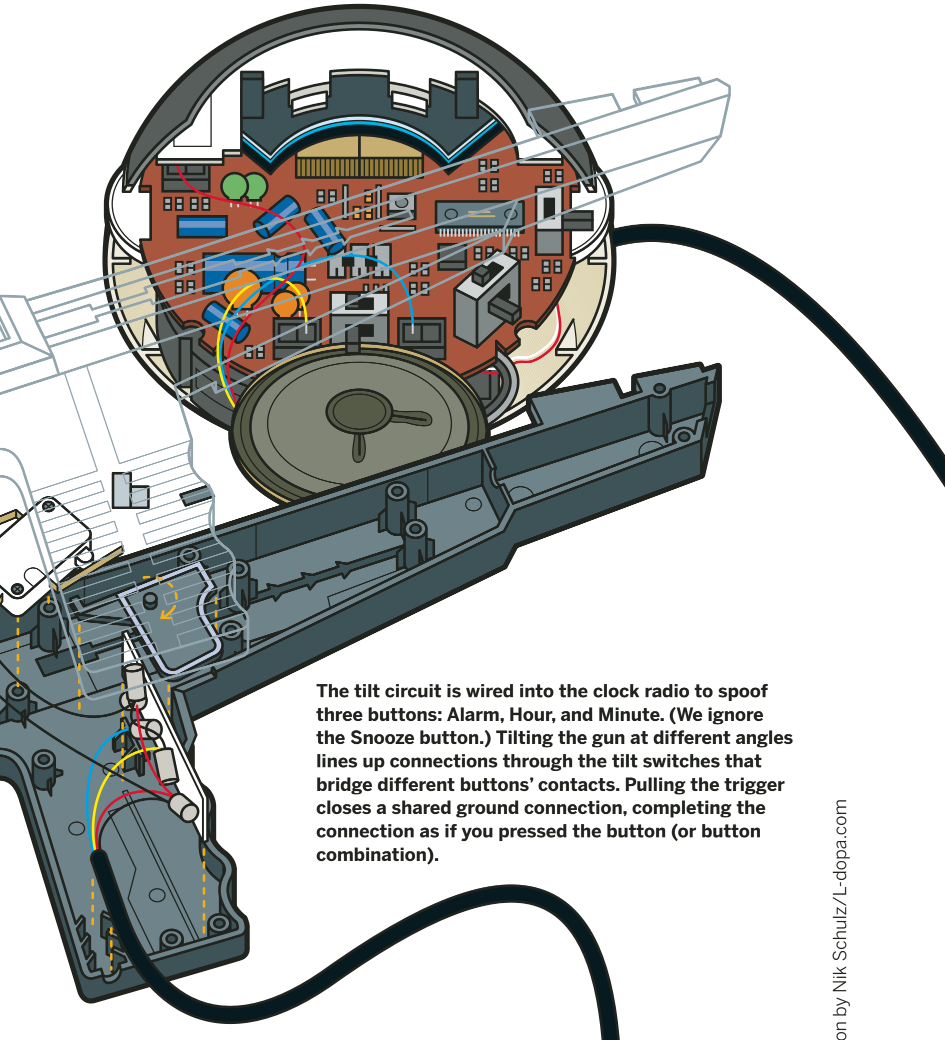
Our control circuit uses tilt switches to detect the gun's position.

Tilt switches contain a metal ball or a conductive liquid (such as mercury) that rolls inside a small capsule. When the switch's contacts point downward, the conductor bridges the contacts, closing the switch. Turn the switch upside down, and the conductor falls away from the contacts, opening the connection.

The tilt switches are arranged in a plane perpendicular to the gun's barrel, to detect the approximate rotation of the handle when the gun is aimed forward (its "roll" in aeronautical terms). The gun doesn't need to point at the clock to work (but it's more satisfying that way).



Tilt switch: A rolling ball (or some mercury) makes or breaks the connection.

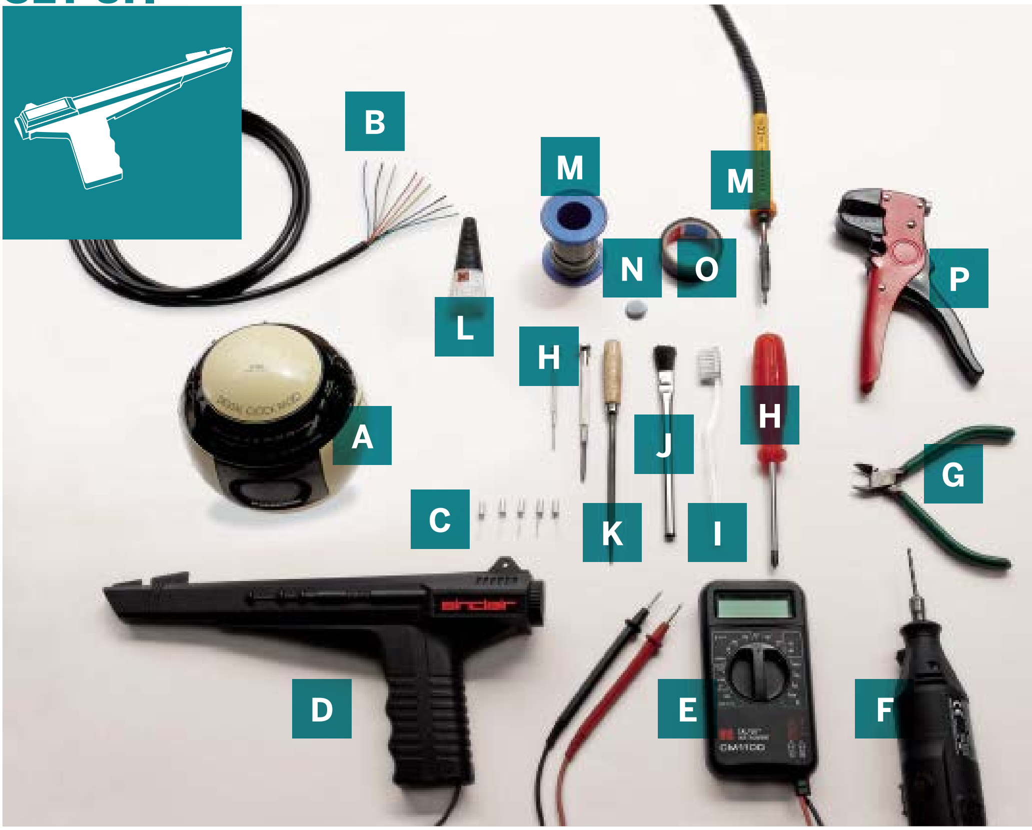


The tilt circuit is wired into the clock radio to spoof three buttons: Alarm, Hour, and Minute. (We ignore the Snooze button.) Tilting the gun at different angles lines up connections through the tilt switches that bridge different buttons' contacts. Pulling the trigger closes a shared ground connection, completing the connection as if you pressed the button (or button combination).

Illustration by Nik Schulz/L-dopa.com

WARNING: Do not work on the alarm clock while it is plugged in, or you risk serious and possibly fatal electric shock.

SET UP.



MATERIALS

[A] Digital clock radio
Almost all of these operate the same way and will work. If you go retro, don't go too far back; 15 years old is a good limit. Make sure all the buttons, the alarm, and the screen still function. Check for cracks in the case, and inspect the underside to see how much the color of the plastic has yellowed or faded. Finally, play with the radio's volume to make sure it doesn't sound like frying eggs. I chose a vintage, spherical Panasonic RC-70.

[B] Multi-way cable with at least four conductors, about 5' long I used a fancy SCART cable consisting of 9 color-coded, stranded wires wrapped in a grounded, metallic Mylar screen, all sheathed in black PVC to an overall diameter of 6mm. This top-quality choice can be found in hi-fi stores and will give you a nice curvature of the cable.

[C] Small tilt switches (5)
I recommend non-mercury switches for environmental reasons. These cost about $1 each, and are available from electronics suppliers such as Farnell (farnell.com), Newark InOne (newark.com), Rapid (rapidonline.com), and RS (rswww.com). For models with just one lead, the case works as the other contact.

[D] Light gun Many are available secondhand. I particularly like the Nintendo Zapper, the SEGA Light Phaser, the Atari G1, the Konami Justifier, and the Sinclair Magnum (my choice). Make sure there's enough space inside the grip to fit the circuit that we are going to build.

Small perfboard Available from electronics suppliers, including RadioShack (not shown).

TOOLS

[E] Multimeter

[F] Rotary tool and bits

[G] Side cutter

[H] Screwdrivers

[I] Toothbrush

[J] Artist paintbrush

[K] Round metal file, no more than 5mm thick

[L] Strong glue (or glue gun and hot glue)

[M] Soldering equipment

[N] Poster putty

[O] Electrical tape

[P] Wire stripper

[NOT SHOWN]

Spray plastic polish
The kind used to shine your car dashboard works perfectly.

Kitchen soap

Cotton cloth

MAKE IT.

BUILD YOUR GUN ALARM CLOCK

START **Time:** An Afternoon **Complexity:** Medium

1. OPEN THE CLOCK RADIO

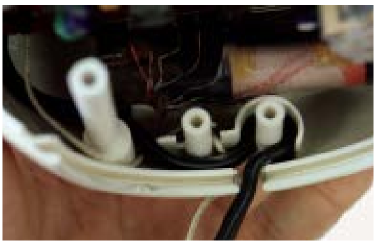
1a. Unplug the clock radio.

1b. Disassemble the case. Carefully unscrew the four screws concealed by wells on the back, and separate the electronics from the plastic parts. To avoid damaging the plastic, choose a screwdriver that fits well, press down firmly, and turn slowly.

Marvel at the design details and quality! The shell is extremely well-crafted, with neat cavities for the screws and an elegant, raised icon for the power cord. The controls even resemble a face. This clock is full of design generosity, which is quite rare nowadays.

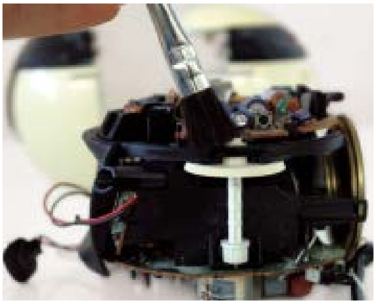
1c. Untie the electric cable, and separate the electronic parts from the plastic shell.

Remember exactly how you took apart the electronics block and untied the electric cable, so you can put it all back together later.

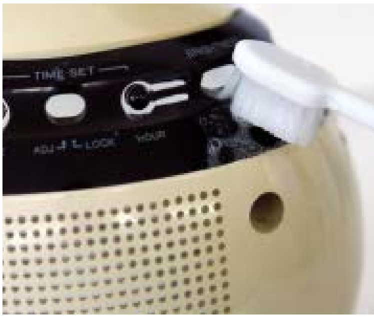


2. CLEAN AND SHINE IT

2a. Use the paintbrush to clean the dust accumulated on the electronics.



2b. Clean the plastic case with the toothbrush and kitchen soap. The bristles won't damage or scratch the surface. Take your time to enjoy cleaning every corner! Let all pieces dry thoroughly.



NOTE: After the pieces dry, spray them with plastic polish, following the instructions on the can.

Wait a few minutes after spraying, then polish the surfaces with a clean cotton cloth.

You'll be amazed how new they'll look! Now your alarm clock is ready for more serious work.

3. DRILL THE HOLES

3a. On the front half of the plastic shell, measure and mark a point to drill near the base and centered below the display. Protect the surface around the hole area with electrical tape, in case your drill skips away from its proper destination.

3b. Find a drill bit that's a bit thinner than your multi-conductor cable and drill the hole.

NOTE: This is the riskiest part of the work: drilling holes for the cable through the clock's case. (I see some vintage collectors out there raising their hands in objection.)

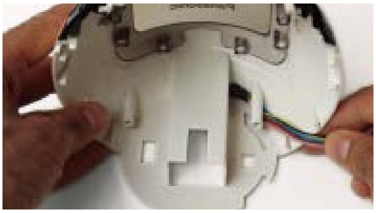
3c. Widen the hole with the round file. Keep widening slowly until the cable can just go through the hole with a bit of pressure. We don't want a hole bigger than the cable.

3d. Drill and widen a second hole in the plastic shell about 1" to the left and slightly back from the first hole, in the interior wall that holds the battery case (see picture below right). The cable will enter the first hole and make a sharp left turn into this hidden hole as it routes its wires around to the back of the clock.

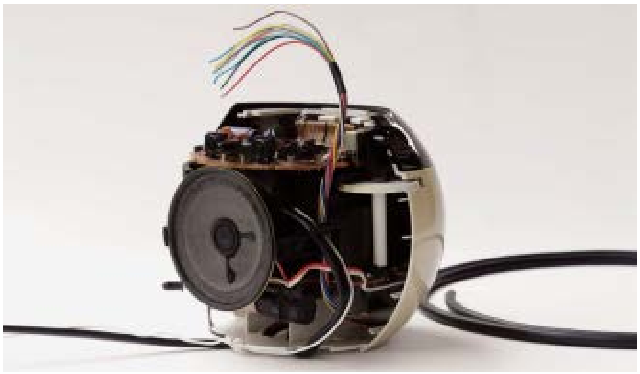
4. ATTACH THE CABLE

4a. Strip about 16" of sheathing off of each end of the cable, to reveal the color-coded wires inside. Pass one end of the cable through the holes you just drilled.

4b. Use hot glue or another strong adhesive to fix the cable firmly in place, keeping the individual wires free inside the main compartment. Leave it neat and strong since this cable is going to be used.



4c. Put the electronics block back into the front half of the case. Now we are ready to hard-wire the color cables to the clock switches.



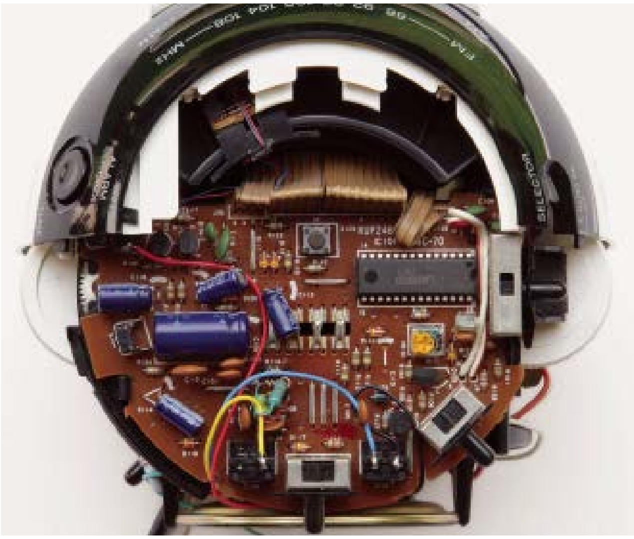
5. HARD-WIRE THE CLOCK

If you aren't modding a Panasonic RC-70, don't worry, because almost 99% of digital clocks work the same way. Just remember that each button has 2 connections, which come into contact with each other when you press the button. You want to extend these connections so that, instead of closing the circuit with the button, you'll be using the light gun.

5a. Find the buttons that control the essential functions: set time and alarm (hours and minutes), and alarm off. The RC-70 uses just 3 buttons for these: Alarm, Hour, and Minute. The Alarm button does double duty, shutting off the alarm and switching the Hour and Minute buttons from "time-set mode" (the default) to "alarm-set." Some clock radios use a switch instead of a button to change between time-set and alarm-set modes.

5b. Locate the essential buttons' contacts, 2 per button, and use a multimeter to follow each of them out to a solderable connection point. With the RC-70, all 3 buttons shared a common ground, so I needed to find a total of 4 connection points.

5c. Solder wires from your cable to the contact points, using the color coding to track what goes where. Following convention, I connected the cable's black wire to the shared ground, and designated colors for the 3 button-specific connections.



5d. Organize and fix all the color cables between the free spaces of the clock. Trim extraneous cables to get them out of the way. Avoid placing cables near parts that get warm, such as the power converter.

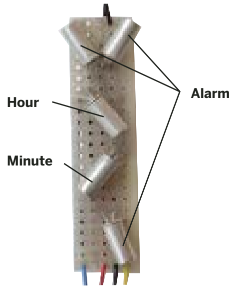
5e. Reassemble the clock and screw it back together.

5f. Test the clock by plugging it in and touching together the other ends of the cable wires you just soldered. Confirm that bridging the wires mimics the functions of the buttons you connected them to.

If you didn't make any big mistakes, everything should work! Don't worry about touching the wires going to the buttons with your fingers, because the current going through them is very low. Once it's working, unplug it again.

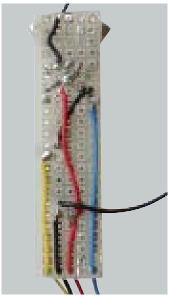
6. HARD-WIRE THE LIGHT GUN

6a. Take the light gun apart, and clean and shine it up the way you did with the clock radio in Step 2.



6b. Cut a rectangle of perfboard that's big enough to carry the 5 tilt switches flat, but narrow enough to fit facing backward inside the handle. For my Sinclair Magnum, my board was about ⅝"×2⅜".

6c. If your clock radio is an RC-70 or work-alike, arrange the tilt switches on the perfboard as shown at right. Leave some extra room around each switch to let you bend and fine-tune their positions later.



6d. Following the wiring diagram online (makezine.com/08/alarmgun), solder the tilt switches into place and connect them to the cable wires. Don't worry about which sides you connect; the switches are functionally symmetrical.

6e. Connect the ground to each sensor section and route it through the trigger switch contacts in the gun. To make my circuit more readable, I routed all wiring from the cable and trigger through the front of the board, at the edges. I also split 1 ground coming from the trigger and connected it in 2 places.

6f. Use poster putty to hold the tilt circuit in position inside the gun-half with the trigger. Plug in the clock radio, and test the interface by tilting and firing. Experiment with different firing angles, and bend the tilt switches around to refine their operation.

6g. When the tilt switches work together properly, glue them in place, and then glue the circuit board into the gun handle. Re-assemble the gun.

6h. Set the time, set the alarm to +1 minute, wait a minute, and FIRE!

Now send a photo of your design to roger.ibars@gmail.com, and I'll send you back an exclusive preview of my latest projects.

FINISH X

NOW GO USE IT »

USE IT.

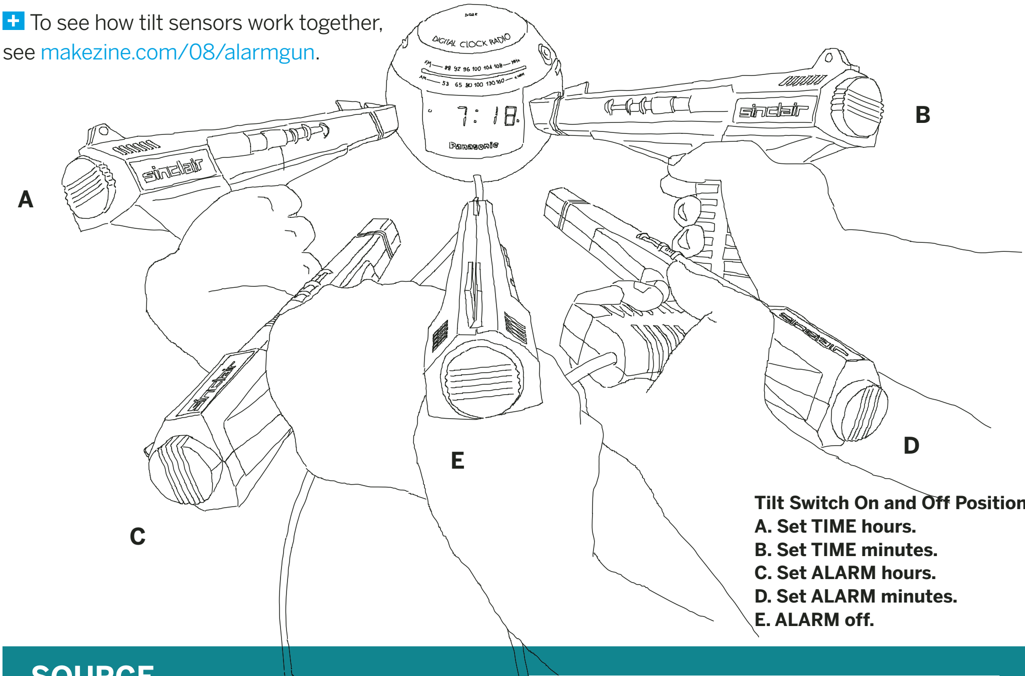
DO YOU FEEL LUCKY? WELL, DO YA CLOCK?

OPERATION

The Panasonic RC-70 has a switch that locks the time set and disables the Hour and Minute buttons from changing the time. For our gun to work, this switch needs to be in the unlocked position.

To use this new hard-wired device, imagine that the clock is a circle of degrees (not difficult with a spherical clock). A straight up-and-down shot kills the alarm. Tilting left sets hours, and tilting right sets minutes. Small tilts set the time, and big tilts, below the horizon, set the alarm.

+ To see how tilt sensors work together, see makezine.com/08/alarmgun.



Tilt Switch On and Off Positions
A. Set TIME hours.
B. Set TIME minutes.
C. Set ALARM hours.
D. Set ALARM minutes.
E. ALARM off.

SOURCE

HARD-WIRED DEVICES BY ROGER IBARS

This project comes from my Hard-wired Devices collection, which pays tribute to great consumer electronics designs from the 70s and 80s. They are remanufactured vintage devices that blend two cultures of interface: computer games and household appliance design.

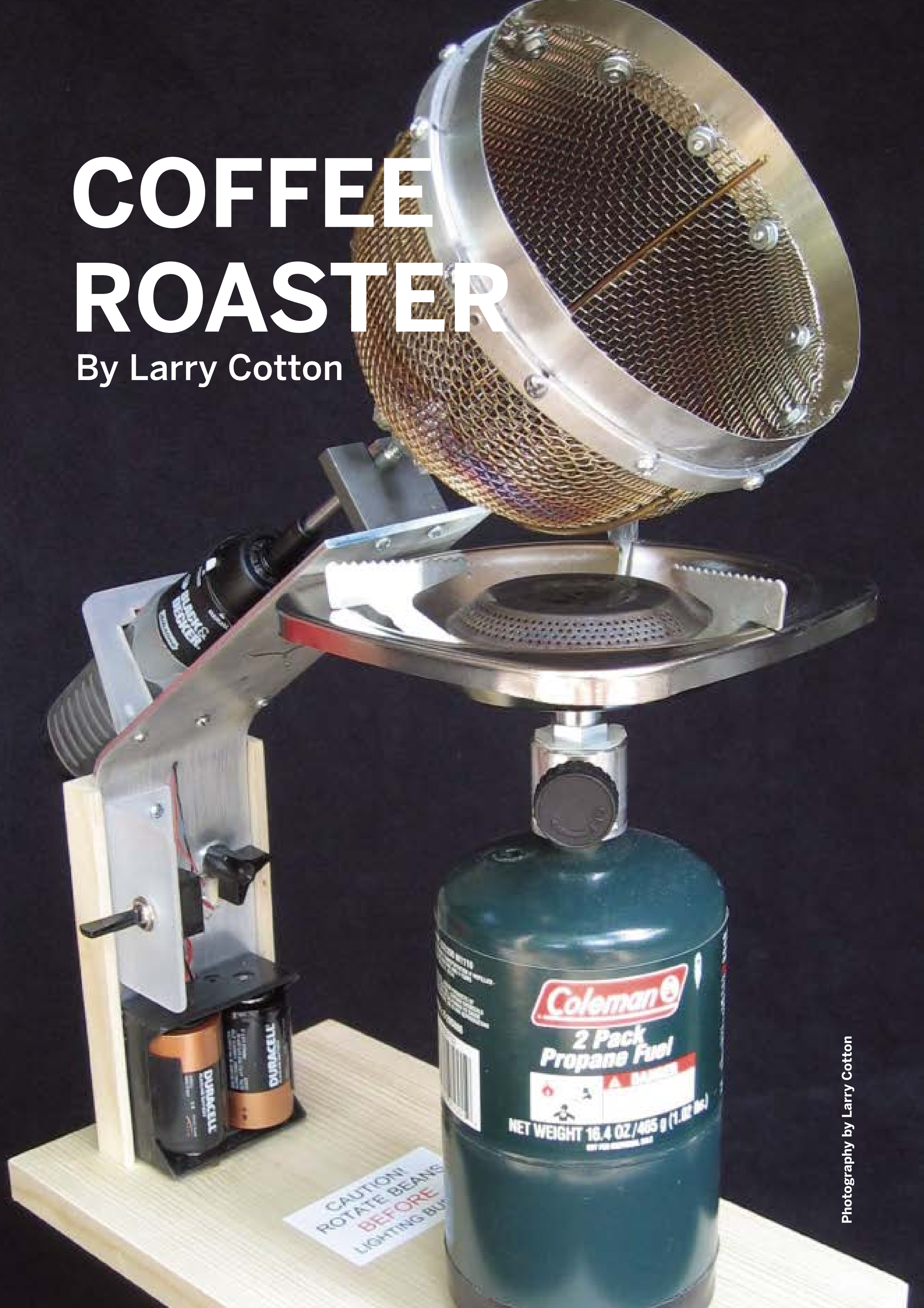
In these pieces joysticks, light guns, and controller pads from the classic age of computer games connect actively via cable to digital alarm clocks and other iconic devices.

You can see the full collection of hard-wired devices at selfmadeobjects.net.

Illustration by Roger Ibars

COFFEE ROASTER

By Larry Cotton



Photography by Larry Cotton

THE NIRVANA MACHINE

Lots of folks think that quaffing a cup of coffee from boutique beans comes close to nirvana, but roasting your own beans will bring you even closer. That's why I call this roaster the Nirvana Machine.

I didn't drink coffee for most of my life, and I even survived without it in the Navy. But when my son introduced me to a cup of legendary West Coast java (OK, Peet's), I began to understand what all the fuss was about. Soon, I too became fussy about excellent coffee.

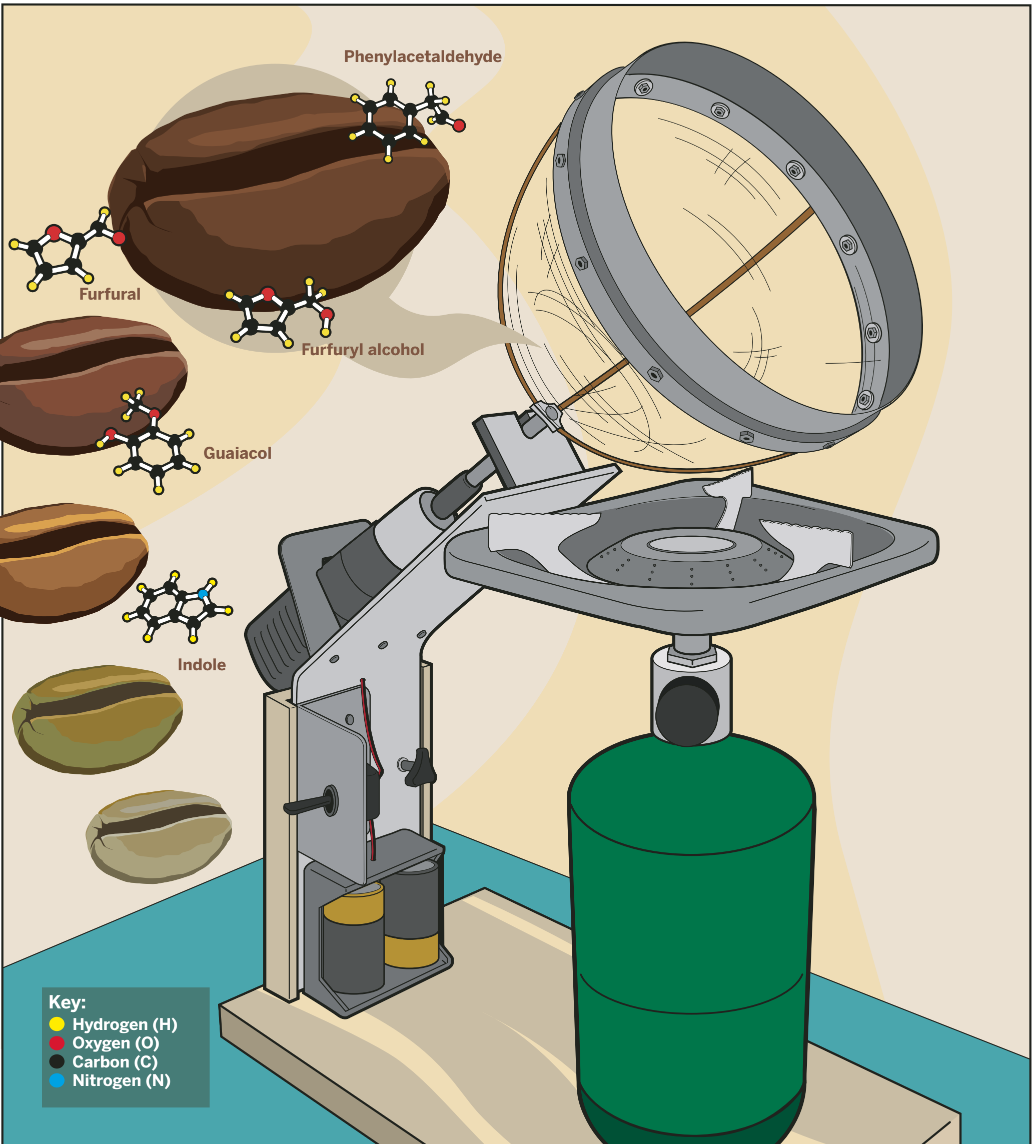
Beans lose flavor after they're roasted because all of those delicious but volatile aromatic compounds dissipate and break down. Roasting your own beans guarantees ultimate freshness, putting all the flavor into the cup; you will not drink a fresher, more satisfying cup of coffee!

Home roasting is easy and inexpensive. Top-quality green beans cost less than roasted beans and have a much longer shelf life. You can have fun fine-tuning your roast's darkness and developing your own blends. Indeed, a growing selection of countertop roasting appliances are now sold, but they're pricey, non-portable, and very noisy.

Set up: p.113 Make it: p.114 Use it: p.121

Larry Cotton is a retired power-tool engineer, musician, part-time math teacher, and full-time coffee devotee who lives in eastern North Carolina.

JAVA IMPLEMENTATION



The Nirvana Machine uses a battery screwdriver to tumble beans over a camp stove. Unlike commercial machines, the basket is tilted and open-ended, which makes it easier to load the beans and to see and smell their progress during roasting.

When you roast coffee, sugars caramelize, water vaporizes and makes the beans expand, and aromatic compounds are produced, including the ones shown above. The compounds develop at different rates, so varying the roasting time and temperature lets you balance which you want more or less of, to determine the resulting flavor.

The Version 1 basket was a cheap strainer, but the beans broke through that and caused a fire!

Illustrations by Tim Lillis

SET UP.

MATERIALS

[A] 1' square stainless steel wire cloth, .025" wire diameter Do not substitute. McMaster-Carr part #9238T523 mcmaster.com

[B] Unpainted aluminum flashing 10'×10"×.010"

[C] Battery-powered screwdriver I used a Black & Decker AS600.

[D] 1½"×¼" piece of aluminum, at least 4" long Cut from McMaster-Carr part #6023K231

[E] 3"×⅛" aluminum bar, 3' long Cut from McMaster-Carr part #8975K833

[F] A few inches of adhesive foam weatherstripping

[G] Single-burner propane camp stove The Century 2058 Trail Scout is best.

[H] Simple on-off (SPST) switch RadioShack part #275-701

[I] 2' insulated wire, 22-gauge minimum Telephone cable wire works well.

[J] Twin D-cell battery holder RadioShack #270-386

[K] D-cell alkaline batteries (2)

[L] Two pieces of acrylic or other hard plastic, at least 3" square each, one ⅛" thick and the other ¼" thick Cut from McMaster-Carr part #8589K41 and #8589K81

[M] 3'×3/32" brass brazing rod From a welding supply house

[N] Scrap plywood 8"×8"

[O] Matching 1" long carriage bolt, washer, and knob, ¼" threaded

[P] Matching ⅜" long machine screws, washers, and nuts, 6-32 threaded (16)

[Q] Matching 3½" long hex-head bolt and nut, ¼" threaded

[R] Uninsulated wire, 24-gauge solid McMaster-Carr part #8870K16

[NOT SHOWN] Standard 16.4 oz disposable propane cylinder

¼" long machine screws, 6-32 threaded (4)

Wood screws, ½" long flathead #10 (2) and ½" long #6 (8)

Scrap 1×8 lumber or plywood At least 18" long

Scrap wood block About 6" cube

8" wood or plastic dowel, ¼" diameter

Wood glue or 5-minute epoxy

Paper For templates and caution label

See a list of tools for this project at makezine.com/08/roaster.

MAKE IT.

BUILD YOUR COFFEE ROASTER

START **Time:** **A Weekend** **Complexity:** **Medium**

1. MAKE THE METAL PARTS

This project has blueprints with complete measurements of all the parts at makezine.com/08/coffeeroaster. Start by downloading and printing them all. Then you can easily follow along and make the metal parts, the wood and plastic parts, and the bean basket.

1a. For the support plate, saw a 14⅛" piece off of the 3' aluminum bar and drill and tap 12 holes as shown in the support plate blueprint. File the cut surface smooth after this and all other cuts.

1b. Clamp the plate in the vise between two 2×4s and use the C-clamp to bend it widthwise, 6⅞" from the bottom, to an angle of about 127°.

NOTE: You could also start by making the basket (Step 3, page 117). That's the hard part, and then you can go back and make the other parts to fit afterward.

1c. To cut the height adjustment slot, drill four or five ¼" or 5/16" holes as close together as possible, then saw or file the slot until it's even.

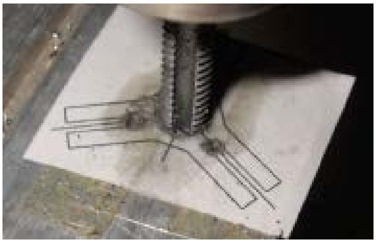
1d. Make the drive shaft bearing. Drill a ¼" hole in one end of 1½"×¼" aluminum bar, then saw or drill and file the slot in from the end. Saw the piece off the bar to measure 1¼" — it's easier to machine the slot before trimming the bearing down to final size. File the cut end smooth, and drill and tap two 6-32 holes.

NOTE: Refer to bearing blueprint.

1e. The trickiest bit of metalwork is the triangle piece, which connects the basket to the driveshaft. To start, I drew a paper template with the dimensions shown on the blueprint, and taped it to the leftover ¼" thick aluminum bar.

NOTE: Refer to triangle blueprint.

1f. Drill 4 holes in the aluminum, tap the large one, and saw the 3 slots to the small holes before cutting the triangle to shape. This piece is small and fairly precise, so go slowly and be safe. Then saw the triangle shape, file smooth, and put it in a vise to drill and tap the 3 clamping-screw holes.



1g. Thread 3 screws into the part and check its clamping action on small pieces of the 3/32" brazing rod. It should hold the rods parallel and tight.

NOTE: Hold the triangle in a vise for drilling and tapping.

1h. For the reinforcing ring, draw a 5¼" circle as a template. Cut a strip of the ⅛" aluminum bar, about ⅜" wide and 19" long, and slowly hand-bend it into a circle, comparing against the template as you go.

NOTE: Use a vise to get a good grip for bending the very ends.

1i. Saw or file an overlapping joint at the ends, then drill a ⅛" hole and use a pop rivet tool and a short rivet to join the ends together.

1j. Using a compass, mark at least 6 evenly spaced hole locations in the reinforcing ring. Drill the holes to 9/64".

1k. For the appearance ring, use metal snips to cut a strip of the aluminum flashing about 20" long and 1" wide, or wider to make the basket hold more beans. Mark the strip to match the locations of the holes on the reinforcing ring, and snip pairs of ¼" notches to flank each hole. Bend the metal back and forth in the notches until the tabs break out.

2. MAKE THE WOOD AND PLASTIC PIECES

2a. For the base, cut a 13" length of the 1×8 and drill and countersink two 3⁄16" holes 2½" apart and 1⅛" from one end, with one hole 1 13⁄16" from one side.

NOTE: Refer to base blueprint.

2b. For the height adjustment block, cut down another piece of the 1×8 to 6⅝"×3½". Use a table saw or router to cut a 3" channel ¼" deep down the block, to just fit around the support plate.

NOTE: Refer to height adj block blueprint

2c. Nest the support plate in the height adjustment block, stand them up together on their bottom ends, and mark the very top of the slot on the block by tracing through plate. Drill a ¼" hole through the block at this mark, for the height adjustment bolt.

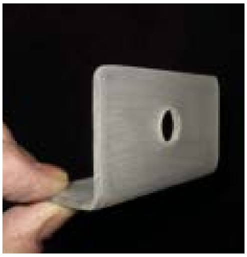
2d. On a piece of ¼" thick plastic, trace the screwdriver hold-down shape from the blueprint online, and saw it down to shape. The interior dimensions are fairly critical, to securely hold the screwdriver. Clamp it in a vise, and drill and tap two 6-32 holes matching the pair of holes at the top of the support plate.

NOTE: Refer to hold-down blueprint.

2e. For the switch bracket, cut a 3"×3" square of ⅛" thick plastic. Saw or file 2 edges round, and drill two 5⁄32" holes matching the holes near the slot on the support plate, and a larger hole on the other side to fit your switch.

NOTE: Refer to switch bracket blueprint.

2f. For the bracket, wrap foil around the plastic to shield all but a ⅛"–3⁄16" wide bend-line. Holding the plastic with a gloved hand, heat it gradually over a stove. Press on it periodically, and when it's soft enough, remove it from the heat, bend and hold it at a right angle, then run cold water over the bend to harden the plastic again.



2g. Remove the battery chamber of the powered screwdriver and drill a clearance hole in the end, angled to miss all internal parts. Thread two 1' lengths of insulated wire through the hole and solder one to each battery contact. Note the polarity of the wires and replace the battery chamber. Test the connections by touching the wires to one or two 1.5V batteries in series and switching the screwdriver on.

2h. For the drive shaft, carefully mark the edges of the bolt's head with a marker, then use a grinding or cutting wheel to cut it down so that it fits the chuck of the screwdriver, about ¼" across. The new hex-head must be concentric with the shank of the bolt.

3. CONSTRUCT THE BEAN BASKET

3a. Make the pressing ring tool using the circular template from Step 1h. Cut a 5¼" diameter circle out of plywood by drilling in the center and then sawing out. File the inside edge of the ring on one side to make it round and smooth.

Then make a round form out of a wood block, 5" diameter and approximately spherical or hemispherical. You can turn the form on a lathe, but the shape doesn't have to be perfect, so you could also just cut down and shape it with a saw and a coarse rasp.

NOTE: The form also needs something in the bottom that you can clamp in a vise. I epoxied a ¼" dowel into the hole in its flat face.

3b. Draw an X in the exact center of the 1' square wire cloth. Mark the front tip of the form, then drill a hole and screw the center of the cloth to the tip of the form with a ½" #6 wood screw.

3c. Center the pressing ring, rounded edge down, above the form and wire cloth square. Apply downward pressure until the cloth looks like a bean basket. This is easier said than done, Gradually push a little, guide a little, and compress the wire cloth a little below the ring to help it go down.

NOTE: The square holes in the wire cloth will deform into diamonds of various size and shape; this is as it should be.

3d. Towards the end of pressing the wire cloth, it will help to have a friend drive more small #6 screws in along the way, to hold the screen against the form. It also helps to cut off some of the excess material at the bottom with metal snips, but leave about 1" all around, past the flat end of the form. Now take a break!

3e. Remove all the shape-holding screws, leaving just the one at the tip. It's OK if your basket is distorted at this point; the reinforcing ring will circularize it. Lay the pressing ring and reinforcing ring on top of wide-open vise jaws. Flip the form and wire cloth assembly upside down and re-press it through the rings. Attach the reinforcing ring to the bean basket with 6-32×⅜" machine screws, washers, and nuts.

For each attachment point, wedge a piece of scrap wood between the form and the basket and drill a 9⁄64" hole through both the reinforcing ring and the basket before installing the screws. The basket should be a minimum of 4" deep, tip to ring.

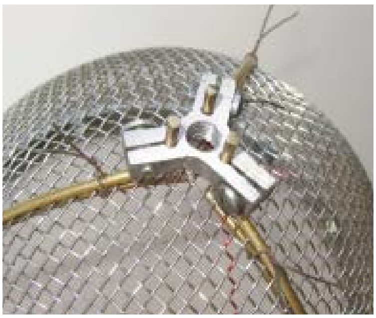
NOTE: With all screws tight, trim the excess wire cloth as close as possible to the ring.

3f. Cut and bend the 3⁄32" brazing rod into 3 pairs of ribs that reinforce the basket, extending out from its center point inside and out. On the 3 outer pieces, leave an extra bend as shown, to fit into the aluminum triangle piece.

Attach the rod pairs to the basket and each other by twist-tying them together with short lengths of uninsulated wire. Use at least 3 wire loops per pair. The pairs should converge close to the center inside and out, forming three 120° angles.

NOTE: Refer to the brazing rod piece blueprint.

3g. Push the 3 outside pieces into the triangle, and tighten the 3 clamping screws securely. Make sure the bean basket assembly cannot be pulled off! Cut and file the ends of the rods flush with the face of the triangle.



3h. Thread the ¼" nut onto the driveshaft bolt until at least ¼" of thread protrudes. Using pliers to keep the nut from turning, thread the triangle onto the driveshaft until it jams tightly against the nut.

3i. Loosen (but do not remove) all the reinforcing ring screws, and insert the appearance ring between the reinforcing ring and the raw edge of the wirecloth. You may need to shorten it first. Re-tighten the screws.

4. FINAL ASSEMBLY

4a. Stain, paint, or varnish the base as you wish, then attach 4 small feet cut from adhesive foam weatherstripping under the corners.

4b. Make a caution label (or print out the one online), and glue it to the base.

4c. Screw the height adjustment block to the base with two #10 ½" long flathead wood screws.

4d. Attach the D-cell battery holder, wires pointing upward, to the bottom end of the support plate with two ¼" machine screws. You may have to enlarge the holder's mounting screws.

4e. Mount the switch in the switch bracket, and mount the bracket to the support plate with two ¼" machine screws.

4f. File off any screw threads that protrude from the back of the support plate.

4g. Mount the bearing to the support plate with two ⅜" machine screws.

4h. Attach the support plate assembly to the height adjustment block with the carriage bolt, washer, and knob.

4i. Thread the 2 screwdriver wires through the hole in the support plate's bend. Use the hold-down and two ⅜" screws to mount the screwdriver to the plate, with its chuck pointing up. Make sure the sleeve adjacent to the screwdriver chuck is set to "Power" position.

4j. Thread a ⅜" screw into the bottom of the support plate, under the screwdriver's central switch button. Tighten it enough to fully depress the button. This screw keeps the screwdriver switched on internally, and helps hold the tool. Briefly touch the 2 screwdriver's power wires to a battery to make sure that it runs.

4k. Slide the bean basket's shaft through the slot in the bearing and into the screwdriver chuck until it stops. You may have to adjust the bearing's position slightly so the shaft doesn't bind.

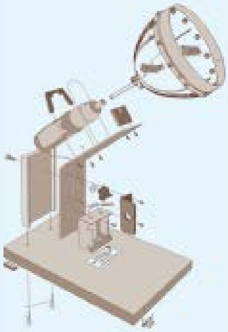
4l. Thread a piece of uninsulated wire through the support plate and wrap it around the screwdriver near the chuck. There's even a convenient groove for this. Finger-twist and trim the wire ends. Avoid over-tightening, which would put an extra load on the motor.

4m. Lean the assembly on its back and, noting the wires' polarity, solder the switch in series with the battery holder and the screwdriver wires.

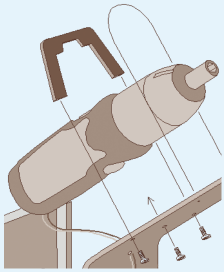
4n. Put 2 fresh D-cell alkaline batteries in the holder.

4o. Make sure the camp stove is off, then screw it onto a standard 16.4-oz. disposable propane cylinder and center it onto the base with one of the burner's flat sides toward the support plate. Position the propane flow-control knob so you can reach it easily.

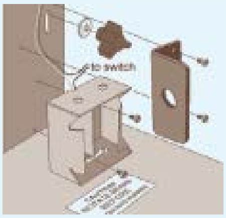
4p. Flip the switch on, and check that the bean basket rotates freely, doesn't wobble, and seems sturdy and safe. Use the height adjustment knob to position the basket at 1" above the burner. Your Nirvana Machine is ready to roast!



Support plate holds assembly together and slides along the height adjustment block attached to base in back.



Plastic hold-down and wire loop secure the screwdriver while another screw keeps its On button pushed in.



Knob adjusts basket height while switch (not shown) turns the screwdriver on/off to rotate the basket.

Illustrations by Larry Cotton

FINISH X

NOW GO USE IT »

USE IT.

ROAST YOUR COFFEE BEANS

PROPER NIRVANA PROCEDURE

1. Take the Nirvana Machine to a well-ventilated place, preferably outdoors.
2. Make sure the batteries are fresh, and put a drop of oil on the shaft bearing.
3. Load up to ½ cup of green coffee beans into the bean basket.
4. With the burner off, switch the screwdriver on and observe the beans' rotation pattern. The 3 ribs inside should cause the beans to tumble nicely. The bulk of the tumbling beans should be centered above the burner. Green beans expand as they roast, so they should stay well away from the opening, to leave room for expansion.
5. If the beans tumble properly, light the propane burner and set the gas-flow knob on low. The beans should begin to yellow in a couple of minutes, and should roast in 10 to 15 minutes.
NOTE: Never roast coffee unattended, keep kids at a safe distance, and use plain old common sense.

As the beans darken, they will make cracking sounds and shed thin, parchment-like chaff, which drifts out of the opening, making somewhat of a mess. To me, this just adds charm to the experience, but your significant other's opinion may vary.

If you roast outdoors in cool or breezy weather, you may have to crank up the heat, reduce the clearance between the flame and the basket or shield the basket from the elements. I've used aluminum flashing, but any windbreak should do.

As the beans turn even darker, you'll hear lighter crackling. This is about when I think the beans are perfectly roasted. If you keep going, the beans smoke more, caused by the oil that seeps from the beans (this oil also makes the beans shinier). The smoke may smell great to you, but the odor can linger, which is another good reason for ventilation. Be careful not to scorch the beans!

When the beans are done to your liking, turn the screwdriver off and remove the burner. Beans like to be cooled fairly rapidly, so let them continue to rotate for a few minutes in the cooler air.

Dump the beans into a container and seal it. Purists say to wait anywhere from 4 to 24 hours before grinding the coffee. You will be amazed at how good it is. Good luck!

RESOURCES

Green bean sources: sweetmarias.com, burmancoffee.com

Coffee and home roasting information: coffeegeek.com, thecoffeefaq.com, homeroaster.com, ineedcoffee.com/roasting

Roasting color guides: sweetmarias.com/roasting-visualguidev2.html, breworganic.com/coffee/vowtoroast.htm

1+2+3

Streamerator 2000

By Professor Greg Arius of The Phenomenauts

This favorite stage prop launches streams of toilet paper into mid-air, or can completely mummify someone in the front row.

You will need:

Leaf blower We use the Toro Power Sweep ($30) in red.
31" length aluminum rod, 3⁄8" diameter
24" length galvanized steel bar, 1 3⁄8" wide, 1⁄16" thick, perforated with 3⁄8" holes
Sheet metal or machine screws (5+) and washers (2)
Rolls of toilet paper
Brackets (2) We used conduit holders, with water heater strap to go around, but any thin bendable metal will do.
Phenomenauts stickers (2) Available from interpunk.com

1. Attach the roll holder.

Bend the aluminum rod at a 90° angle, 23" from one end. This will be the roll holder.

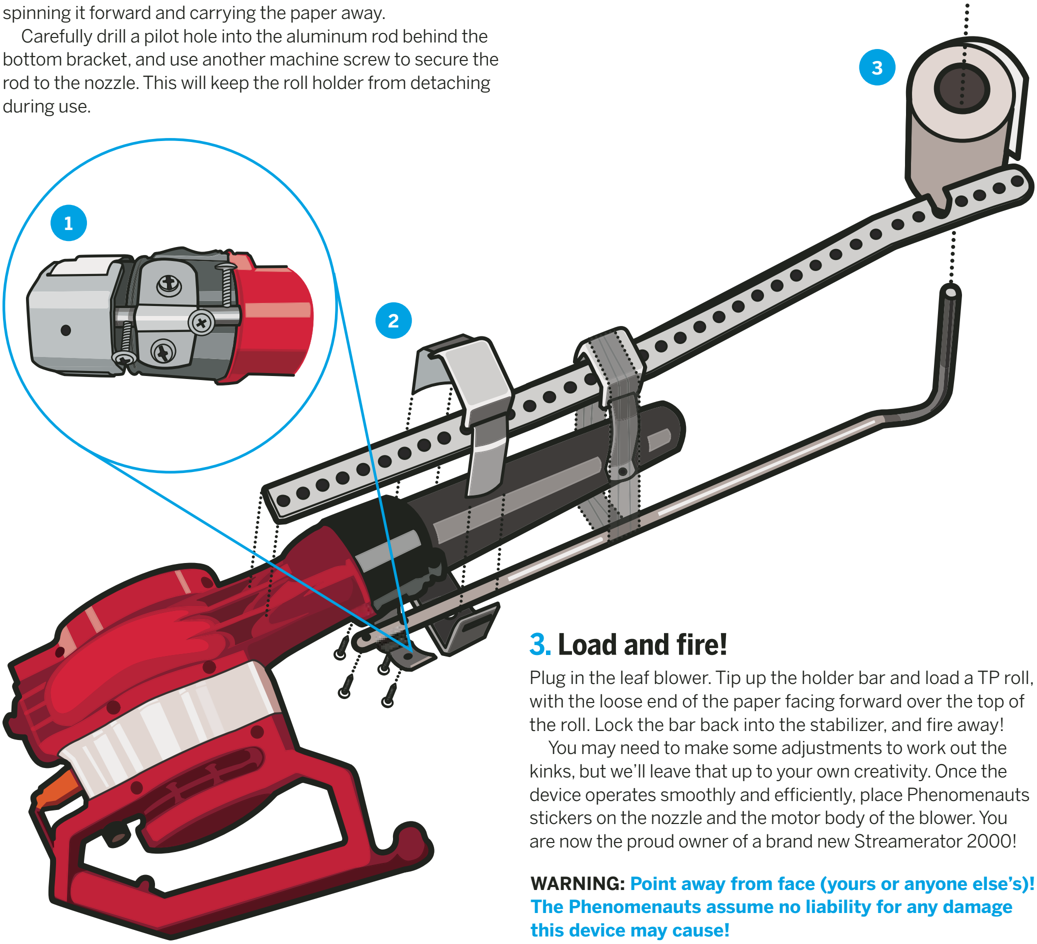
Use 2 brackets and screws to attach the rod to one side of the leaf blower nozzle, screwing directly into the plastic. Attach one bracket about halfway down the nozzle, and the other about 1" from the base. The bend that holds the TP roll should be about 3½" in front of the tip of the nozzle, and aligned with its lower edge so that the air stream hits the top of the roll, spinning it forward and carrying the paper away.

Carefully drill a pilot hole into the aluminum rod behind the bottom bracket, and use another machine screw to secure the rod to the nozzle. This will keep the roll holder from detaching during use.

2. Attach the stabilizer.

On the galvanized steel, cut a channel from the side of the bar into one of the holes 3–4 holes down from one end. It should be wide enough to accommodate the roll holder rod.

Use a couple of screws and washers to attach the steel bar to the other side of the leaf blower nozzle, with the cut-through hole in front. The end of the roll holder should pull back and nestle into the stabilizer's channel and hole, under some tension.



3. Load and fire!

Plug in the leaf blower. Tip up the holder bar and load a TP roll, with the loose end of the paper facing forward over the top of the roll. Lock the bar back into the stabilizer, and fire away!

You may need to make some adjustments to work out the kinks, but we'll leave that up to your own creativity. Once the device operates smoothly and efficiently, place Phenomenauts stickers on the nozzle and the motor body of the blower. You are now the proud owner of a brand new Streamerator 2000!

WARNING: Point away from face (yours or anyone else's)! The Phenomenauts assume no liability for any damage this device may cause!

Illustrations by Damien Scogin

In the amazing year of 2002, Professor Greg Arius was asked to join the Phenomenauts for a special Rocket Roll mission. Upon completion, he became the band's arsenal manager, sound effects engineer, and sometime Science Officer.

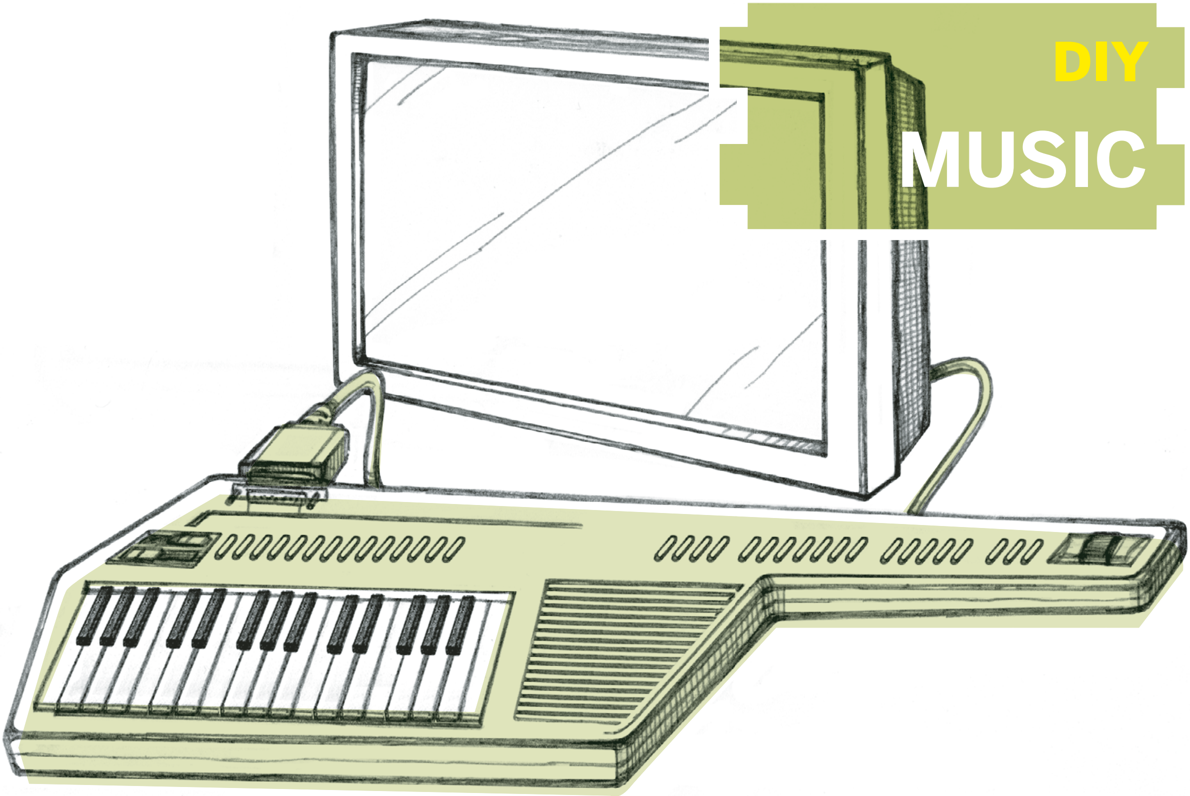


Illustration by Damien Scogin

TV-TO-SYNTH INTERFACE

Triggering sound from video images.

By Tom Zimmerman

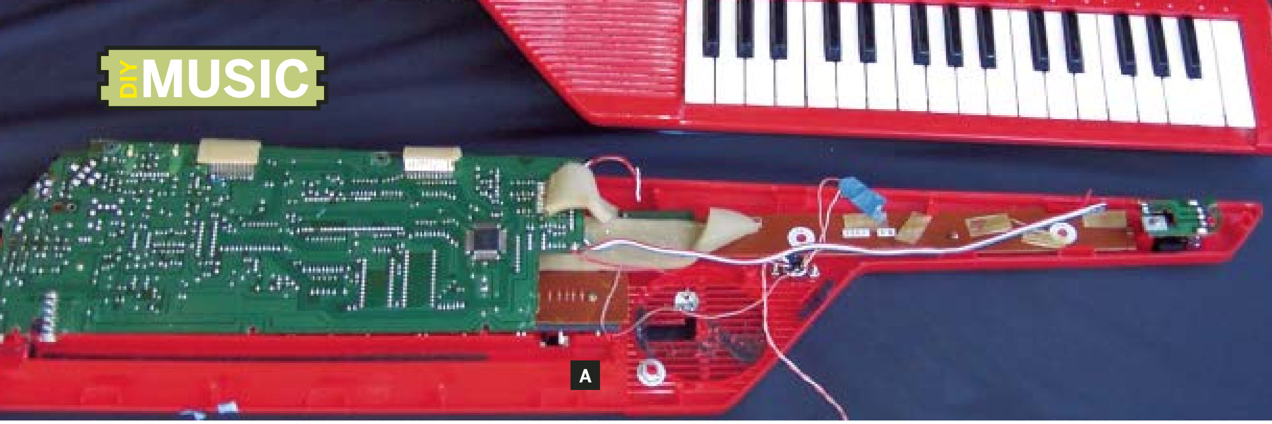
In 1922, a 16-year-old farm boy from Idaho sketched the idea for TV on his high school teacher's blackboard. An avid reader of science fiction (he would have loved *MAKE*), Philo Farnsworth got the idea of scanning an electron beam across a phosphor screen while mowing hay fields.

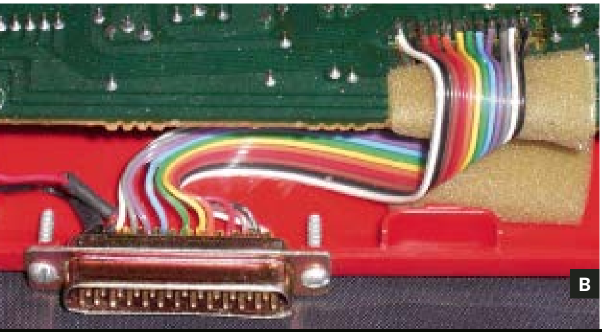
In this project, we'll stick phototransistors to a TV screen to trigger musical notes on a synthesizer. A peak detector circuit removes the 60Hz pulses caused by Farnsworth's scanning technique. When a bright object passes under the phototransistor, a CMOS switch closes, triggering a musical note. Any video source displayed on a CRT or LCD can be used, including movies, TV, live cameras, and computers. I originally built this circuit to generate sound from a recording of dancers that was filmed with a Fisher-Price camcorder. The circuit emulates a mechanical switch, so it can be wired to any low-voltage circuit (like a remote control), allowing movement in a video image to start a CD player or a VCR, for example.

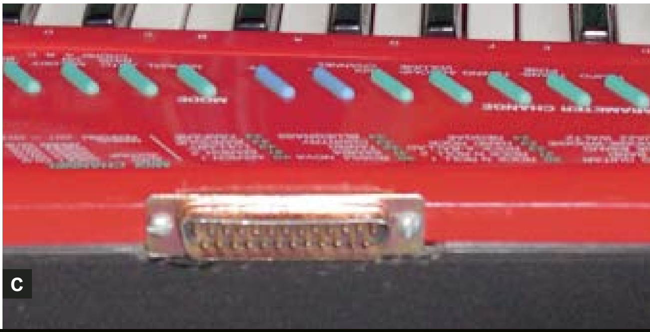
Install a D25 Connector to a Keyboard Circuit Board

Get an inexpensive musical keyboard. Remove all the screws from the back of the keyboard and remove the case, being careful not to pull any wires loose.

Locate the cable that connects the main circuit board to the keyboard. The keys are multiplexes, so the cable should contain about a dozen wires. Prepare a D25 solder-type socket with enough wires to connect to every wire in the cable, plus two for power and ground. Using a Dremel or







Adding a connector to the keyboard. Fig. A: Carefully open the case of any inexpensive keyboard synthesizer. Fig. B: Prepare a D25 solder-type socket with enough wires to connect to every wire in the cable, plus 2 for power and ground. Solder each wire from the D25 connector to the circuit-board pins on top of the keyboard cable. Fig. C: Check the connections, close the case, and attach the D25 connector to the back of the keyboard.

MATERIALS

Label	Value	Comment
R1	100kΩ	Converts phototransistor current into a voltage
R2 pot	10kΩ	Trigger sensitivity — lower voltage means less light is required to turn on CMOS switch
R3	10kΩ-1MΩ	Pulls C1 to supply voltage. Sets hold time: 10k = instant, 1M = 10 sec
R4	220Ω-1kΩ	Sets LED brightness. Use 220Ω for 5V supply, 1k for 12V supply
R5, R6	10kΩ	Sets middle voltage for output comparator
R7	15kΩ	Positive feedback creates hysteresis to remove noise from comparator output
C1	22 µF	Retains voltage for peak tracker
C2	0.1 µF	Filters power supply
C3	10 µF	Filters power supply
D1	1N914	Part of peak tracker
D2 LN85RP	LED	Trigger indicator. Side-view LED (Digi-key #P444-ND)
D3, D4, D5, D6	1N914	Prevents cross-talk among key multiplex lines
Q1	LTR-301	Side-view phototransistor (Digi-key #160-1065)

file, create a hole to mount the D25 solder-type socket to the synth case. Solder each wire from the D25 connector to the circuit-board pins on top of the keyboard cable, starting with pin 1. Be careful not to short pins together with solder or disturb the connection between the keyboard cable and main circuit board. Find a place on the circuit board that has a ground and a switched power (hint: locate a big capacitor), and check it with a meter. Hook the ground to pin 25 and the switched power to pin 24 on the D25 connector.

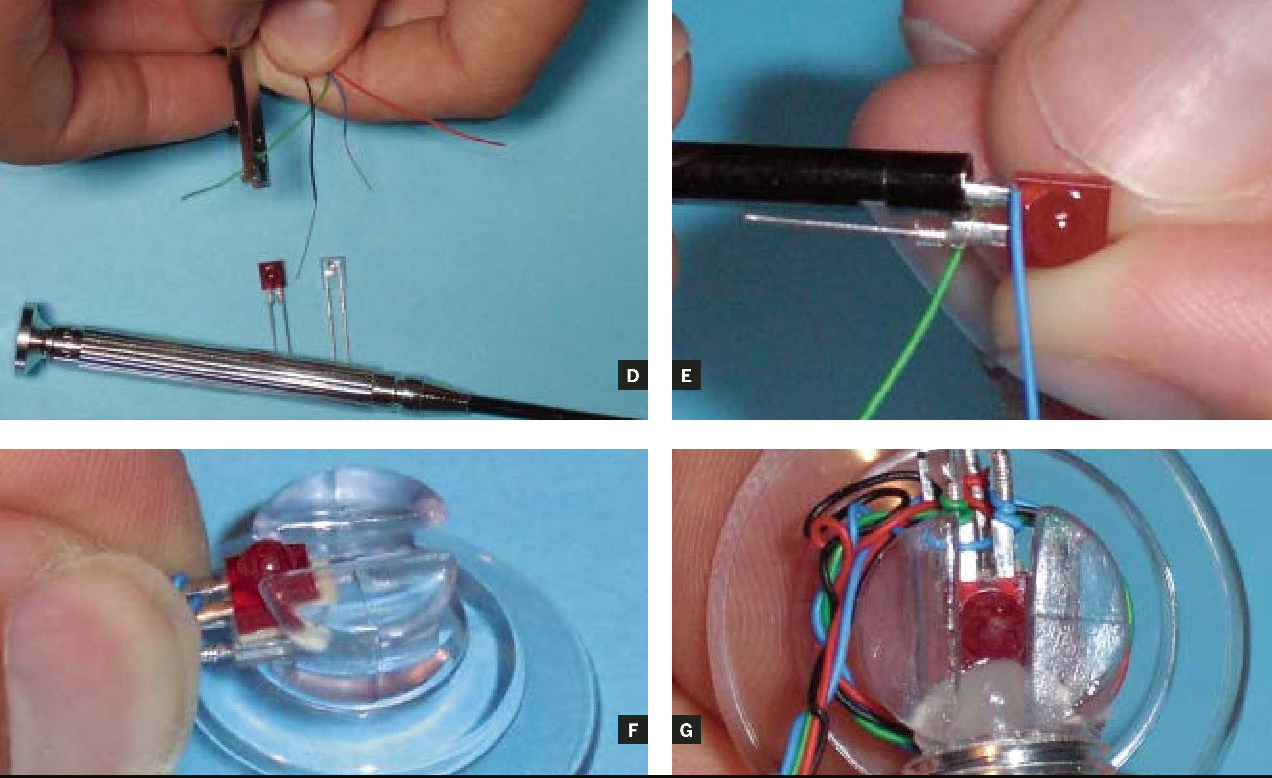
Check your soldering job to make sure you didn't cause any shorts. Turn on the power to confirm that the keyboard still works. Close it up and admire your work.

Decode the Keyboard Matrix

Now comes the fun part. Make a matrix tester with an LED and 1kΩ resistor. See circuit (Figure H).

Attach the resistor to the ground (pin 25) and touch the LED anode (positive end) to every pin (Figure J). Write down which pins light up the LED — these are the scanner Source pins. The other pins are the Sense pins. If the LED never lights, hook the bottom of the 1kΩ resistor to the positive end and search again for Source pins. (If this

Photography by Tom Zimmerman



Assembling a suction cup sensor. Fig. D: Each suction cup sensor consists of an LED and a phototransistor. Fig. E: Use a wire wrap tool to attach connector wires to component leads. Fig. F: Stick LED and phototransistor together with tape and insert into suction cup. Fig. G: Apply silicone glue to the assembly.

works, you'll need to reverse the directions for diodes D3, D4, D5, and D6.)

Touch one side of the 1kΩ resistor to any Source pin and the other end to any Sense pin. You should hear a note play. If you're an organized person, write down what note is played for every combination. Otherwise, just marvel at your ability to play notes by touching a 1kΩ resistor to pins on the connector.

Prepare Side-View LEDs and Phototransistors

A clear suction cup holds the phototransistor to the TV screen. The best suction cups are "Light Holders" from Adams Manufacturing Corporation in Portersville, Pa., available at Home Depot. The suction cup has a molded, slotted socket that is perfect for holding a phototransistor and LED. Phototransistors come in many packages, but a flat side-view package phototransistor sandwiched with a flat side-view LED is ideal. The LED indicates when the phototransistor detects a bright object.

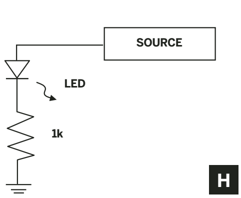
Determine the polarity of the phototransistor with circuit (Figure I). The voltage should be high in the light and decrease to ground in the dark.

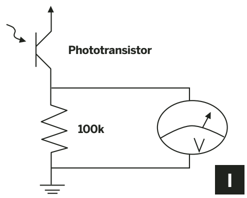
Cut 4 different-colored 3-foot lengths of #30 wire. Bundle the ends of the wires together, twist a loop at one end, and put that end into a drill chuck. While a friend holds the other end, pull tight and spin the wires carefully into a tight, twisted cable. Keep the cable taut while running your hand over it a few times to keep it wrapped and not tangled. You've just made the thinnest four-conductor cable available!

Strip 1 inch of insulation off the 4 wires and use a wire-wrap tool (RadioShack #276-1570) to wrap them around the phototransistor and LED leads. Document the color that goes to each lead, and be consistent.

Cut some double-sided foam tape into tiny squares, slightly larger than the phototransistor. Stick one side to the back of a phototransistor. Peel off the backing tape and stick the other side to the back of an LED, making a phototransistor/LED sandwich. Cut the leads of the phototransistor and LED slightly below the end of the wire and bend them away from each other so they don't touch.

Insert the phototransistor/LED sandwich into a suction cup. Wrap the cable around the suction cup and loop it into a knot to relieve strain. Inject





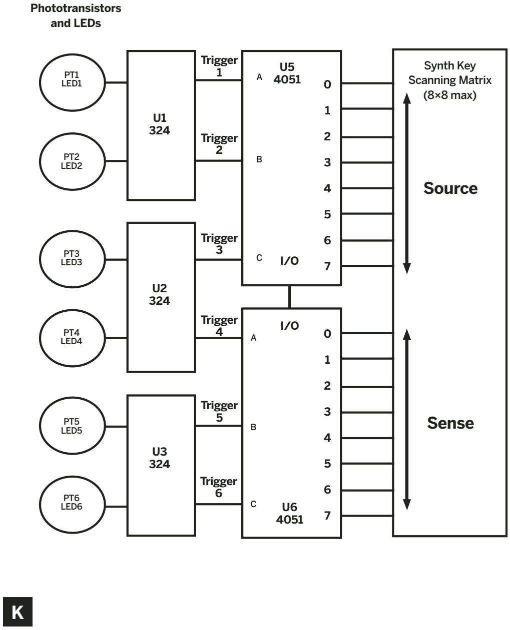


Fig. H: The matrix tester is made from an LED and a 1k resistor. Fig. I: Use this circuit to determine the polarity of the phototransistor. Fig. J: Attach the resistor to the ground pin and touch the LED anode to each pin, writing down the pin numbers that light up the LED. Fig. K: Triggering up to 64 monophonic notes using two 4051 CMOS switches.

clear-silicone sealer glue into both sides of the slotted socket by pushing the tube nozzle against the slot opening. It's OK to get glue on the wires and LED — the light will shine through the clear silicone. Now repeat the process to make a total of 6 suction cup sensors using the same wire-color code, and let them dry overnight. The next day, strip and solder the other end of the 6 cables (24 wires) to a D25 solder-cup plug.

Build the Detector Circuit

Using Figure N, we see that each detector uses half of an LM324 quad op-amp. The op-amps are used as comparators. When the TV screen under the phototransistor (Q1) gets bright enough to exceed the reference voltage set by R2, the output of comparator U1a pulses at 60Hz, thanks to Farnsworth and his scanning electron beam.

This pulls C1 low, which can only rise through R3 due to diode D1. R3 sets the hold time; the larger the resistance, the longer it takes for the trigger output to shut off after the bright object leaves the phototransistor. Using positive-feedback resistor R7, comparator U1b cleans up the output, making sure the trigger is a sharp binary signal (no noise during transition). The LED D2 is mounted on the suction cup next to the phototransistor to indicate when a bright object has been detected.

The circuit operates from 5 to 15 volts and is powered by the synth to avoid batteries and power cubes. If you're going to use batteries, remember to hook the ground of the circuit you're controlling to the batteries, and never hook to anything that plugs into the wall! Wire a battery-powered remote control instead.

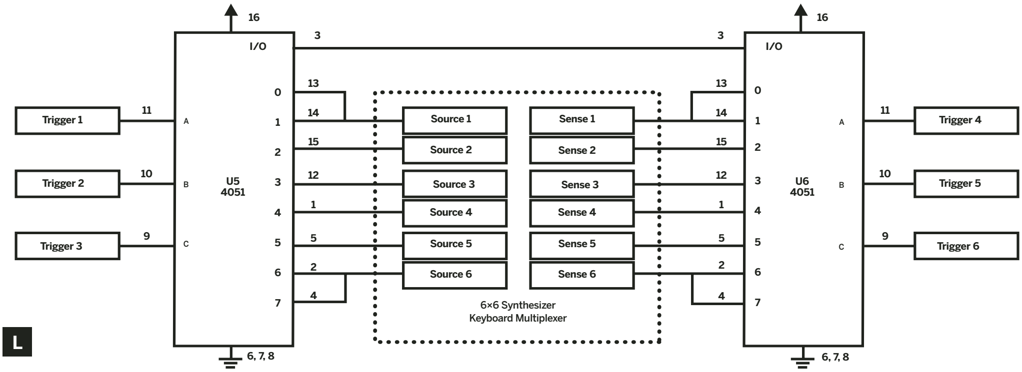
Trigger 4 Polyphonic Notes

Each detector independently triggers a 4066 CMOS switch (see Figure M), providing a polyphonic sound (several notes at once). This is useful if you want a sensor to trigger a specific function, like the Record button on a VCR.

The CMOS switch is electrically equivalent to a mechanical switch. Since we are tapping the keyboard scanner before the keyboard switches, we must include diodes D3 to D6 to prevent switch cross-talking.

Trigger 64 Monophonic Notes

The previous circuit used 4 channels to control 4 notes simultaneously. Now, using two 4051



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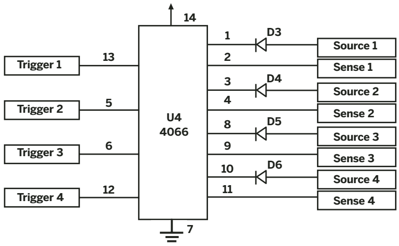

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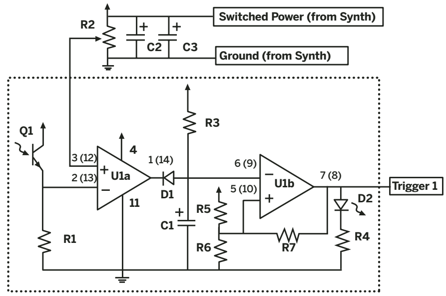


N

Fig. L: Doubling up switches on each 4051 CMOS switch. It's recommended that you wire-wrap this circuit, or make a printed circuit board (See MAKE Vol 2, page 164 for a printed circuit board primer) Fig. M: Triggering 4 notes at once to create a polyphonic sound. Fig. N: The detector circuit. Each detector uses half of an LM324 quad op-amp, which are used as comparators.

CMOS switches (see Figure K), we'll make a circuit that can select up to 64 notes (8×8), one at a time (monophonic).

The synth I use has only 6 Source and 6 Sense lines for a total of 36 notes, so I double up 2 switches on each 4051 (see Figure L). I recommend you wire-wrap the circuit, or, if you are more adventurous, lay out a printed circuit board.

Conclusion

With a video camera and this circuit, you can perform electronic magic, controlling audio/visual equipment by moving your hands into hot spots that correspond to suction cups on the monitor. The circuit can trigger sound effects, perfectly synchronized to video action.

If you're an installation artist, this circuit is an easy way to create an interactive performance space. By applying light sensors directly to the video screen, we avoid all the complications of video-signal processing.

We have Farnsworth to thank for the scanning TV, and now we have suction cups to thank for holding our simple sensors to his ingenious invention.

QUICK WIRE TWISTING

You can use a power drill to quickly and neatly twist wires into lengths of conductor cable.

1. Gather the wires together and make a loop at one end.

2. Put the loop into the drill chuck.

3. Another person can hold the other end tightly while you spin the wires carefully into a tight twisted cable.

4. Keep the cable taut while running your hand up and down the twisted cable a few times to train it to stay wrapped and not twist upon itself.

Tom Zimmerman is an inventor, educator, and researcher at the IBM Almaden Research Center who loves gadgets, LEDs, synthesizers, and hooking people up to computers.

WORLD'S LOUDEST IPOD

iBump crossover lets you crank it up without distortion. By Tom Anderson and Wendell Anderson

Getting a big sound from portable music players should be easier. Fancy new plastic mini-speakers are everywhere, but what if you want to plug into a big old stereo and truly rock the house?

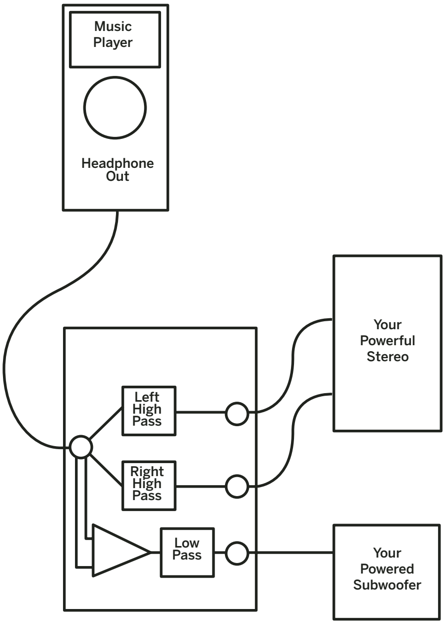
An inexpensive Y adapter cable can split a player's headphone mini-jack into two RCA plugs for left and right channels, but you'll get better sound if you put the low frequencies into a subwoofer and send just the mids and highs to the stereo speakers. That's because the large movements that a speaker cone must make to produce low frequencies will distort the mids and highs — especially at high volume. Our iBump improves this situation with an active crossover circuit, which separates audio into high- and low-frequency channels. Connect the low end to a powered subwoofer, and you'll have proper thump!

The iBump's crossover circuit is based on the classic Linkwitz-Riley audiophile design, which you can read about at Siegfried Linkwitz's site (linkwitzlab.com/filters.htm).

Some newer audio amplifiers include separate outputs for powered subwoofers and filters to keep the lows from the main speakers. We tested these and found that our iBump provides much better sound. Try it and see for yourself. This crossover sounds natural without being boomy or leaving a gap between the highs and lows.

If you don't have a powered subwoofer, you can make one using our article "Resurrecting This Old Amp," (*MAKE, Volume 02, page 110*). Start with an eBay bass amp, add large speakers, and presto: you'll have yourself a 'quake. Or buy powered subwoofers from Klipsch, JBL, and others.

Photograph by Wendell Anderson



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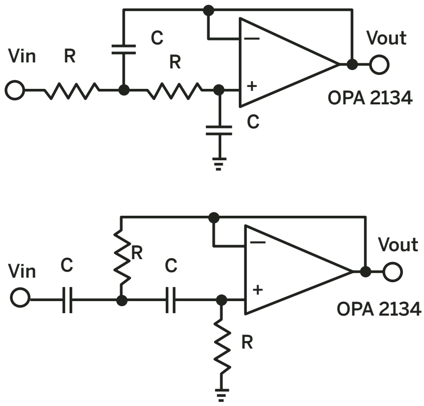

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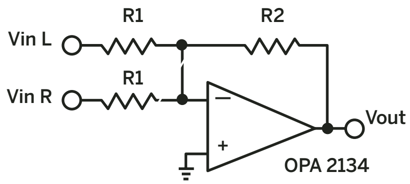


C

Fig. A: iBump splits each input channel in two. One half of each is fed through its own high-pass filter and sent to the stereo speakers. The other halves are summed, routed through a low-pass, and sent to the subwoofer.

Fig. B: The high- and low-pass filters share the same formula for transition frequency and identical layouts, but with resistors and capacitors swapped. Fig. C: The summer circuit combines left and right channels.

Build It

The iBump is an assemble-and-solder project on a single printed circuit board (PCB), with no moving parts. You can build the circuit from our schematic at makezine.com/08/ibump. You can also order the iBump bare PCB, or buy the board pre-assembled and packaged at the same URL. The iBump kit is designed for learning audio electronics, with clear labels and test points that make it easy to probe the circuit with a multimeter or oscilloscope. Once you've assembled the circuitry, enclose the board in a small case.

How It Works

The iBump's all-analog circuitry uses matching high- and low-pass filters to block low and high frequencies. Given resistor value *R* and capacitor value *C*, the formula for where they cross over is: $1/(2\pi RC)$. Our iBump uses 23.7kΩ resistors and 0.068μF caps, which gives a crossover frequency of 99Hz, which is close to a bass guitar's G string.

The summer circuit combines left and right inputs before sending signal through the low-pass and to the subwoofer. Human ears are no good at locating low frequencies, so mono is fine here.

Our circuits are all based on the OPA2134 op-amp from Texas Instruments. This is a great amplifier chip with low noise and 0.00008% distortion. The 5532 op-amp from Philips is a less expensive choice, and the high-end OPA2134 may be overkill, but that's the whole point, right?

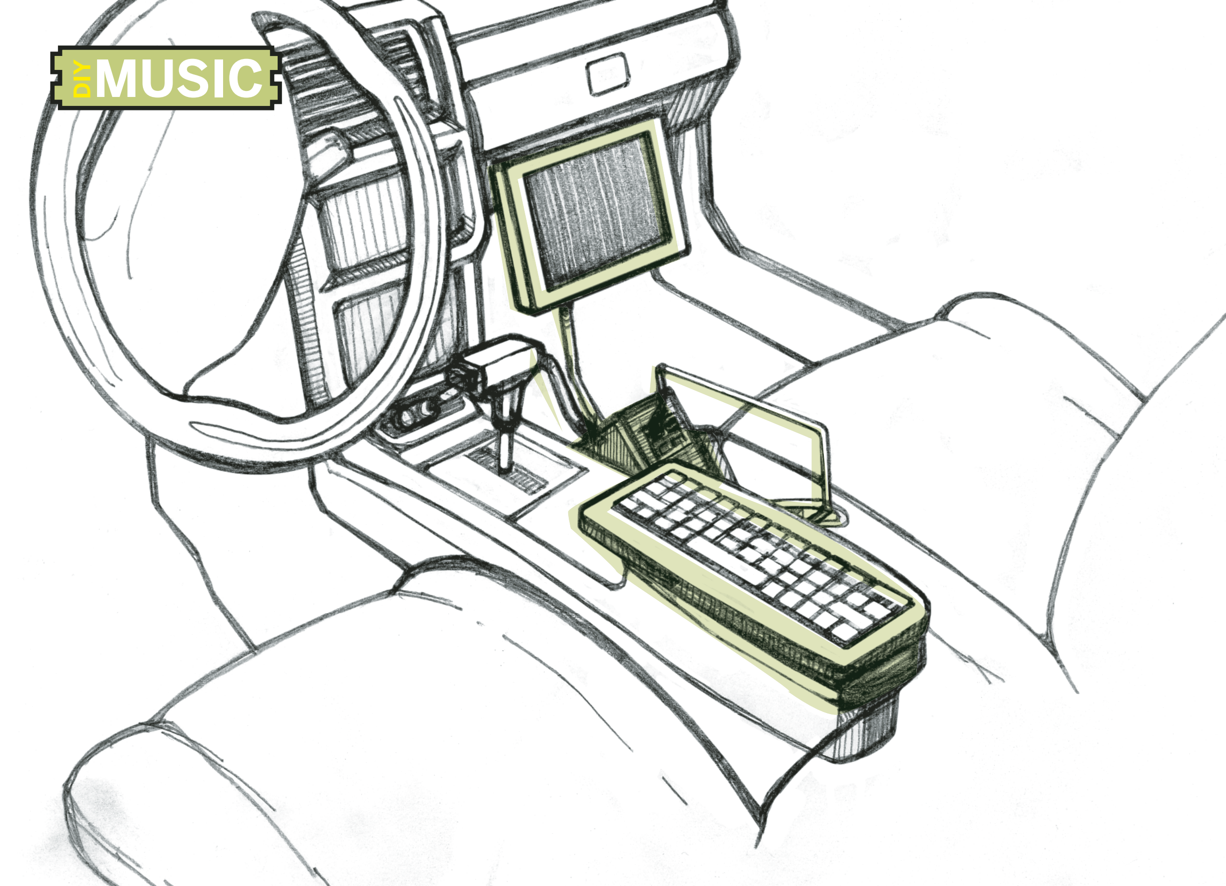
High Volume Fun

CAUTION: Do not deafen yourself or anyone else with the magnificent power of your iBumped stereo. Wear ear protection.

To test and adjust the iBump, download and play the test tones from makezine.com/08/ibump and use a sound-pressure level (SPL) meter. You can be an audiophile and tweak the levels to achieve a flat frequency response. Or you can just crank up the subwoofer until things start falling off your shelves.

Challenge your neighbors to see whose stereo is loudest when you listen from the street. When the police come, prove that you're not exceeding local ordinances by showing measured sound-pressure levels from your SPL meter!

Tom Anderson and Wendell Anderson are engineers who like to develop audio hardware and software projects.



PROJECT REDSHARK

Turn your Xbox into a mobile media monstrosity.

By John Riney

I wanted a system for my car that could play my entire music collection. A sensible human being would have purchased an iPod and plugged it into the tape deck. But I had a dusty Xbox lying around, and I figured I could turn it into the foundation of a powerful car computing environment — something that I could play music with now and add more features to later.

The Xbox is just a PC wrapped up in fancy plastic, and I knew that hackers had gotten Linux working on it. Thus began Project Redshark, named after my old car — which, in turn, was named after the red convertible in *Fear and Loathing in Las Vegas*.

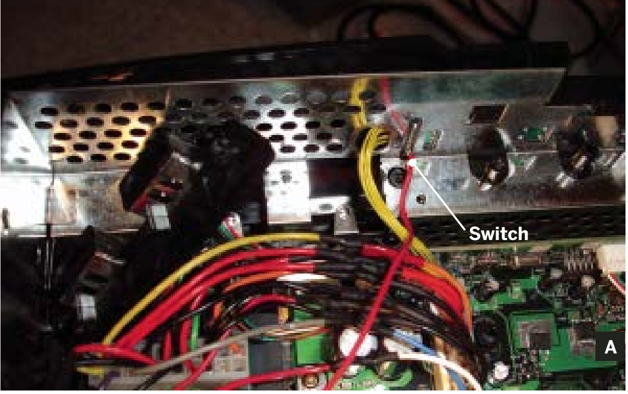
After some beer-assisted research and de-velop-ment, I got it to work. Here's a summary of how I did it, and you can see more details on my website (rineysoft.com/xbox).

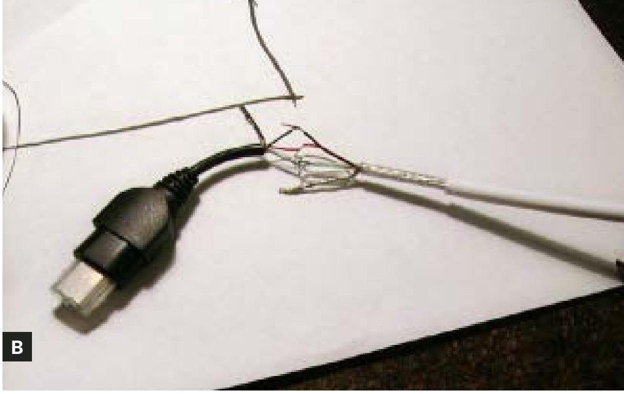
1. Xbox, meet Linux. Linux, meet Xbox. First, I discovered that Microsoft doesn't want people installing other operating systems on their game console! Who knew? Fortunately, the Xbox-Linux project (xbox-linux.org) describes several work-arounds, including one hack that boots Linux on an Xbox without ever cracking its case. Sold!

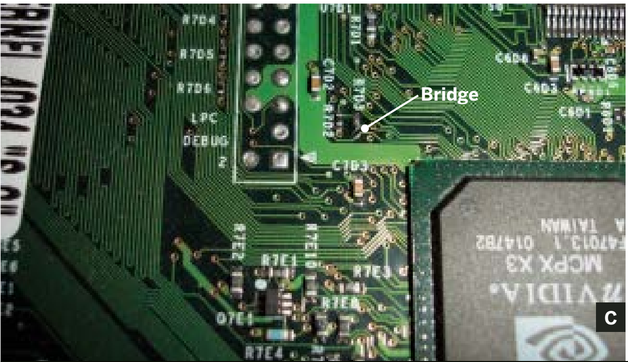
The technique comes from the Xbox game *MechAssault*, the first version of which has an exploitable bug in its load/save code. If you load a properly crafted savegame into *MechAssault* from an Xbox memory cartridge, the box will crash, allowing you to run foreign code. (You can also load the fatal savegame from a USB stick, using an Xbox-to-USB adapter cable.)

The payload of this exploit then runs a Linux kernel from the Xbox's hard drive or from a disc

Photography by John Riney / Illustration by Damien Scogin







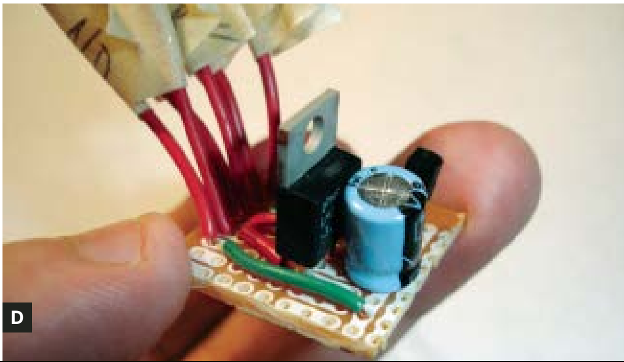


Fig A: Remote switch for Xbox grounds a wire running to the second pin from the bottom of its front panel PCB.
Fig B: Spliced USB-to-Xbox controller adapter cable.
Fig C: Soldering across tiny bridge on main PCB makes Xbox's BIOS chip writeable.
Fig D: Mini board steps 5V down to 3.3V for Xbox power.

in the DVD drive, on top of the Xbox's own BIOS. A minimal Linux running on the Xbox BIOS isn't a very robust combination, but it's a beachhead from which you can continue the Linux takeover.

Note that using Xbox Live closes the *Mech-Assault* loophole. In this case, you must follow a procedure that includes installing a modified chip.

2. Add a keyboard. Xbox doesn't come with a keyboard, which isn't surprising since there's no English composition involved in playing *Burnout 3*. Fortunately, those plastic Xbox controller connectors are just USB ports in disguise — same pins, different shape. So I made my own Xbox-to-USB adapter cable by splicing together an el-cheapo Xbox controller cable and a USB-B cable, matching up the 4 wire colors. (Microsoft must not require Xbox controller manufacturers to scramble cable wire colors.) Attach a USB keyboard with this cable, and you can type!

3. Flash the BIOS. The Xbox's BIOS resides on something called a TSOP chip (I really don't know what that stands for), and you need to overwrite it with a Linux BIOS. To make the chip writeable, you have to open the box, remove the motherboard, and solder across 2 pairs of absurdly tiny points, one on each side. My cheapo soldering iron couldn't cut it, so I purchased a Weller WP35 iron, which has a $1/32$" conical tip, and soldered while looking through a magnifying glass.

With the TSOP chip writeable, you use a flasher utility named Raincoat (rimshot, please) to install a replacement BIOS named Cromwell (thanks — I'll be here all week). Cromwell gives Linux full control of the system (with no Restoration).

4. Upgrade the hard drive. Next, you can slam a new hard drive into the mix. I picked a 200GB Maxtor with a parallel IDE interface that I got cheap. Unscrew the stock drive from the plastic carrier you removed earlier, and screw in the new one. This is the easiest part of the project.

5. Install Linux in full. Now you have to decide which Linux distribution you want for the full, final OS. One minor wrinkle is that depending on what flavor of Xbox you have, its DVD/CD drive may be picky about what recordable media it can read. Mine likes Maxell DVD-Rs; your mileage may vary.

I'm a Gentoo fan, so I went with that, but there are Xbox-specific versions of Fedora Core (called XFedora), Debian (called Xebian), and dyne:bolic, which may streamline your install process. The standard Gentoo install CD knows nothing about booting onto an Xbox, so I burned a Xebian install

Junction box powers and switches Xbox, LCD display, and USB hub from 12VDC cigarette-lighter power. At left, the USB, phone jack (for remote switch), video, and power all connect to a massive "cable snake" that runs to the Xbox in the rear of the vehicle. The 4-port USB hub connects to the Xbox USB, letting you plug a keypad, USB thumb drives, and other fun things into the Xbox.

CD, booted from that, and then ran the Gentoo CD to complete the install.

6. Replace the power supply. An Xbox power supply may look similar to a standard PC ATX power supply, but the Xbox's standby voltage is +3.3 volts rather than +5V. So I got a car ATX power supply and ran its output through a mini board that I built to step it down to 3.3V. I also built a cable to carry +12V in, ground, and an ignition sense signal (not currently used), and ran it out the hole where the Xbox's AC cord used to go.

7. Build the front end. For the user interface, I picked up a 7" color LCD panel from a pawnshop and bought a little numeric keypad. Then I wrote my own little player front-end in Python, using the Pygame library. My app, Redshark Player, is basically a file browser with large type. You can download it from my project website.

8. Install the Xbox. I set the system up so I could hide the Xbox out of the way and keep the LCD and keypad up front. This took a lot of cabling: USB, video, and audio cables, Ethernet cable, and two-conductor wire for power and a remote starter switch. I wired a junction box to handle all the interfaces up front, and then used several bags of zip ties to tie all the cables together into one long snake, to feed the Xbox in back.

I originally planned to mount the Xbox in the trunk, but it gets toasty in operation and needs ventilation. So I ended up just sitting the box on the back seat. I'm glad I don't do this for a living.

Conclusion

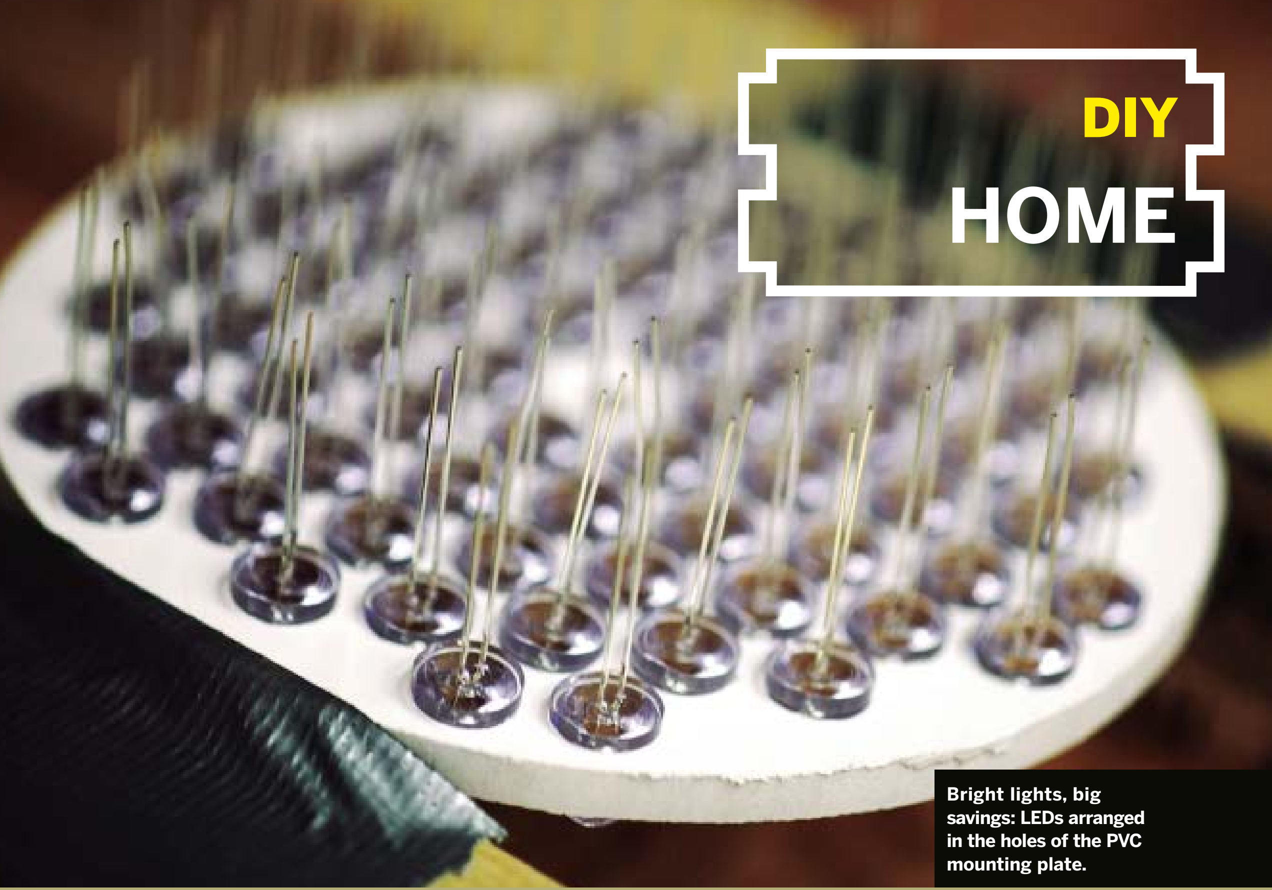
An Xbox is perhaps not the easiest computer to put in a car, but it's rewarding to drive around town, listening to music coming out of a system you put together! That big, black slab of plastic is good for something other than *Halo* after all!

Thanks to Nafees bin Zafar for editorial assistance with this article.

Resources

Project Redshark web page: rineysoft.com/xbox
The Xbox-Linux Project: xbox-linux.org

John Riney is an engineer, writer, and generally nice guy living in Charleston, S.C.



Bright lights, big savings: LEDs arranged in the holes of the PVC mounting plate.

MY LOVE AFFAIR WITH LEDS

Build a bright, low-powered desk lamp.

By Charles Platt

Quartz halogen lamps are more efficient than old-fashioned incandescent bulbs; fluorescents are more efficient than quartz halogens; and white light-emitting diodes (LEDs) are the most efficient of all (if you consider the ballast that is needed by fluorescents). So why haven't white LEDs become as fashionable in homes as a Prius in the driveway?

One reason may be that a white LED isn't quite white. It has an eerie purplish tint. This doesn't seem to bother people when the product is a flashlight, but it has been a barrier to the application of LEDs in domestic settings. Personally, I like freakish technology that looks as if it came straight out of *The Jetsons*, so a purplish tint is fine by me. With this in mind, I set out to be the first on my block to have an LED desk lamp.

After an unproductive attempt to find ultra-high-power LEDs using Froogle, I tried eBay and hit pay dirt. Hong Kong manufacturers are now accepting PayPal for state-of-the-art LEDs ordered by the hundred, and are charging less than 25¢ per diode. Diodes are 1cm in diameter and have a claimed light output of at least 100,000mcd.

Now, you may be wondering what this "mcd" measurement is. It stands for "millicandles," which is confusing, since old-fashioned light bulbs are rated in lumens. A lumen measures the total amount of light emitted in all directions, whereas a millicandle is a measurement of intensity per unit of area — more appropriate for an LED since it has a lens that emits a tightly focused beam, often as narrow as 5 or 10 degrees.

Photography by Charles Platt

Fig. A: The body consists of PVC pipe pieces glued together, sanded, and spray-painted silver. Fig. B: The base is drilled at an angle to accommodate the stem and filled with sand. Fig. C: The stem's other end is glued into a 1" hole in the head. Fig. D: The mounting plate is ABS plastic drilled with 72 holes. Fig. E: The finished lamp, with the head tilted to show the LEDs. Total cost: about $40; total power consumption: about 5W.

It can best be compared with a reflector bulb, but since those aren't rated in millicandles, the only way to evaluate LED brightness conclusively is by buying some and trying them for yourself.

When my Hong Kong package arrived, I opened it and found not only LEDs but also little brown blobs on wires — resistors to be put in series with the lights. Evidently, a common application of raw LEDs is to trick out cars with underbody lights and other effects. So, manufacturers helpfully deliver LEDs with resistors that reduce the 12V from a car battery to the 3.5V preferred by a typical diode.

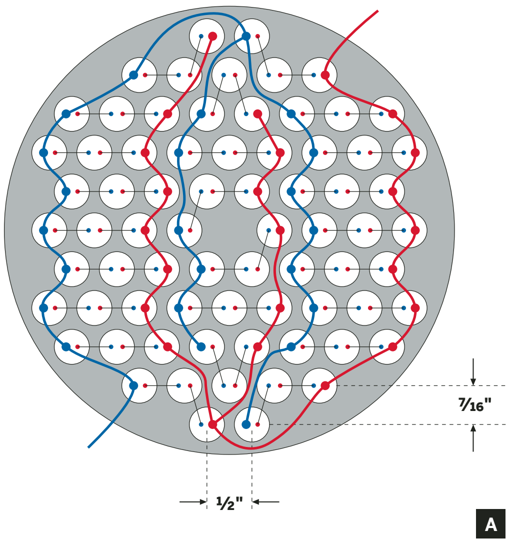
This was not so helpful from my point of view, since a resistor dissipates excess power as heat. Fortunately, there are a couple of ways to avoid using this wasteful device in your ultra-efficient lighting system.

If you want to use an LED light source at home, you can simply buy an AC power adapter that converts house current directly to the 3.5V DC that you need. However, I wanted my lamp to work equally well in an RV, so I wired my LEDs in groups of three. Because each LED has its own internal resistance, you no longer need a wasteful series resistor. When you put three together in series and attach a 12V supply to the ends of the chain, each LED requires 4V. You can add more chains like rungs of a ladder, as shown in Figure B on page 135.

Because LEDs are fussy about getting precisely the correct amount of power, you do still need a very small amount of resistance in order to optimize the voltage. For this purpose, I placed a wire-wound potentiometer (variable resistor) at the bottom of the ladder, to adjust the supply for all of the LEDs simultaneously.

I used a multimeter (available for about $20 from RadioShack) to check the voltage across a few sample LEDs while adjusting the potentiometer to the correct setting. By turning the potentiometer back from this point, I could make it do dual duty as a lamp dimmer.

The natural next question is "How do I wire everything together?" You will need a soldering iron — the low-wattage type designed for electronic components (15W is typical) — which you can find at RadioShack. To avoid roasting the diode, you must apply this to your LED wires very briefly. I place an alligator clip on the wire just



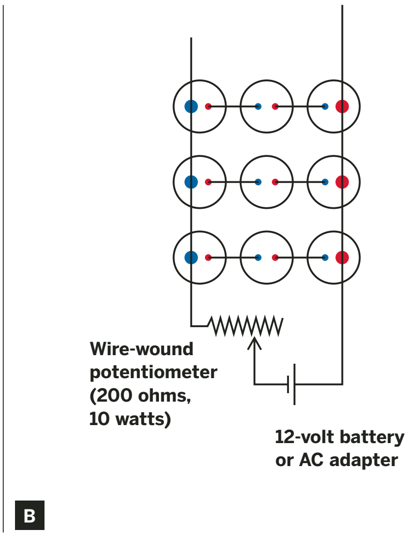


Fig. A: One possible pattern for a lamp using LEDs wired in threes. The result is 24 chains, with a total of 72 LEDs powered by 12V.

Fig. B: Basic schematic for wiring LEDs in chains of three, driven by a 12-volt DC power source and with a potentiometer to fine-tune the voltage (usually 3.5 volts across each LED).

below the soldering iron as a heat sink.

(Soldering guides will tell you that "real solderers don't use heat sinks," but since the difference between a diode that works and a diode that doesn't work can be 6 seconds of soldering time instead of 5, why not take an elementary precaution?)

Most importantly, you will need to remember that the long wire of the LED goes to the positive side of your DC supply, whereas the short wire goes to the negative side. If you wire the LED the other way around, you may burn it out, depending on how much voltage you apply.

With all of these details, you may be wondering whether LEDs are just too much trouble. They're really not. I composed a kind of sunflower pattern for my 72-LED lamp using Adobe Illustrator, then printed it and used it as a template for drilling holes into a piece of ¼"-thick, white ABS plastic.

If you don't happen to have any metric drill bits in the house (I certainly don't), you can use a 25⁄64" bit, which is almost exactly equivalent to the 1cm diameter of the LED. After you drill the holes, poke the LEDs into them, glue them in place (I smothered them with silicone caulking), and solder them together. The whole project took me an afternoon.

If you have a recreational vehicle, you may like the idea of ultra-efficient lighting that won't add to the power drain on your electrical system. In fact, I'm expecting RV owners to go for white LEDs long before homeowners.

Once your system is working, you will enjoy its peculiar economic benefits: a chain of three 100,000mcd LEDs lasts about 100,000 hours and uses a mere 20mA (0.02A) of electricity. If you follow my lamp design, using 24 chains (a total of 72 LEDs) powered by 12V, the whole assembly will consume approximately 5W, while emitting about as much light as a 60W incandescent bulb.

Of course, you will have to get used to that freaky purplish glow, but early adopters should be willing to embrace that kind of thing.

Charles Platt is a freelance journalist who wrote the profile on cold fusion researcher Ed Storms *(MAKE, Volume 03)*.

Direct TV: Motorized rotating stand lets you point the screen to where it's needed most.

TV SPINNER

Motorized lazy Susan aims the screen where it's needed. By Alan Mellovitz

Space can be a precious commodity when you live in a shared dorm room. However, if you allocate space efficiently, you can transform a 10'×10' room from a confining cell to a desirable and pleasurable living area. It can be a challenge on move-in day to create a solution that satisfies the needs of two strangers. More likely than not, the room unintentionally becomes split into two longitudinal sections, and each roommate must try to respect the other's sector, accommodating TVs, computers, video games, tools, wires, large boxes of Dunkaroos, live panda bears, and/or any other strange possessions and hobbies that have the power to annoy.

I know firsthand that the typical hardworking college student vitally needs entertainment. Yet under cramped dormitory circumstances, amusement sacrifices must sometimes be made. To reduce the need for such sacrifices, I recalled that my 10'×10' room had a third dimension: an 8' ceiling. I thought, why not suspend a lightweight flat-screen TV/computer monitor in this unused airspace? And while I was at it, why not make the screen rotate to any viewing angle anywhere in the room, with more than 180 degrees of rotation? That way the screen could generously face the roommate who needed it, wherever and whenever circumstances demanded. Here's how I built my motorized rotary LCD TV mount, after dusting off an old box of Legos.

Selection and Placement

First, consider what piece of equipment you would like to suspend and rotate (computer screen or TV), and where you would want to view it. I bought

Photography by A.J. Kane

MATERIALS
LCD TV or monitor with wall mount
Lazy Susan swivel, steel ball-bearing, 6" diameter
From home and/or hardware store
2×4 lumber: 10' length or (2) 8' lengths
From home and/or hardware store
2×2 lumber: 2' is plenty Find a scrap piece if you can
Adhesive EPDM rubber door and window seal weatherstripping
Small door hinge Strap & T style
L-shaped metal brackets: 6" (2) and 5" (2)
½" particleboard, 2'×2'
¾" plywood, cut to 6¼"×13" or so
Small box of #8 2½" screws
I used some brass ones I had
Small box of #8 ½" screws
4" all-purpose spring With low spring constant
Cable ties
Lego pieces: Medium gears (3); Technic axles (8); Technic gears: 8-tooth, 40-tooth; Technic bush ½ Type I; Technic pins with friction (12); Technic bricks, perforated: 1×4 (4), 1×8 (5), and 1×12 (4); 4×12 plate; 9V motor with gear reduction; electric brick pair 2×2, ⅔" thick with wire; generic bricks to complete assembly
Double-pole double-throw (DPDT) slide switch
From RadioShack
24 gauge Cat5 wire From RadioShack
Electrical tape

TOOLS
Hammer
Screwdriver
Drill and wood drill bits (⅛", ¼", and ½")
Tape measure
Circular saw with adjustable miter angle
Jigsaw
Hacksaw
Carpenter's square/straightedge
Level

a TV especially for this project: a Dell W1900 19" LCD TV, which is wall-hangable and has a built-in TV tuner and both DVI and VGA inputs. Whatever flat-screen you use, this project requires it to be under about 25" wide, including the speakers. As for placement, I cantilevered the TV over the foot of my bed, so I could watch TV and use the computer from the comfort of my cushions and pillows. The stand is attached to the bunk bed itself.

Assemble the Stand

Measure the base height for the stand — the distance between the floor and the bottom of the monitor. Mine was 6' 3". Cut one of the 2×4s to this length, and use the long 2½" screws to attach the 6" L-brackets to the top of the 2×4, leaving ¾" between the top of the L-bracket and the top edge of the 2×4. Drill pilot holes before sinking the screws, and use a hacksaw to trim the points sticking out the other side.

Cut a piece of ¾" plywood to 6¼"×13" or so, a bit more than half of the TV's total width. Use the long screws to attach the plywood to the free side of the L-bracket running perpendicular to the 2×4 the long way. For the angled brace that helps support the plywood shelf, take the leftover piece of 2×4 and measure out the plywood length plus about 3". Then cut the 2×4 to this length (16" in my case), with 2 opposing 45-degree miter cuts. Screw this brace onto the long 2×4 and the plywood shelf. As with all wood-to-wood joins in this project, drill pilot, clearance, and countersink holes before attaching the screws.

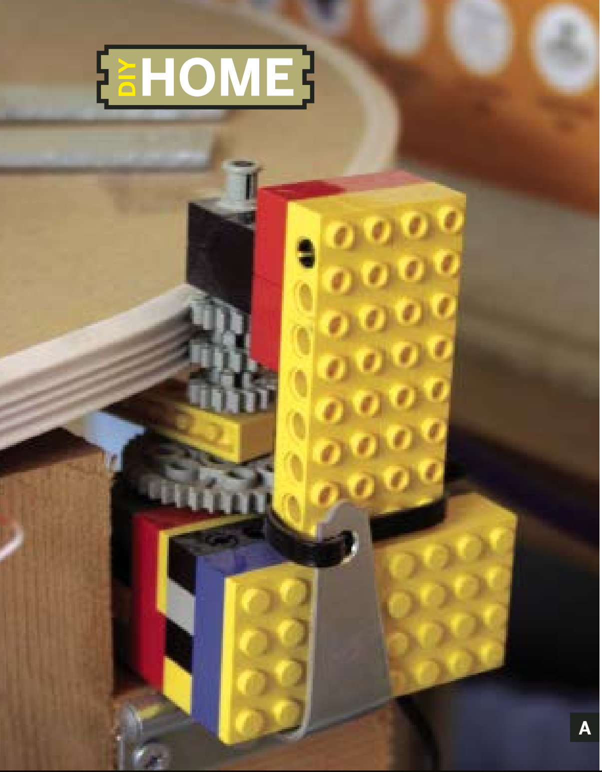
Decide which side of the 2×4 upright you want to mount the motor on (probably the side nearest the wall). Cut a 2×2 to about 1' and screw it onto the 2×4, running parallel up along your motor side and ending flush with the top. Cut a 2½" piece of the 2×2, and toe screw 2 screws partway into this block, angled in to attach one end of the block horizontally to the top of the stand later. This piece will hold the motor, but don't attach it yet.

Build the Rotating Base

The TV base consists of a big circle of particleboard with a 2×4 that points upward, offset from the center, and supports the screen as if it's mounted onto a wall. A larger circle gives the little Lego motor more torque with which to rotate the TV, so its diameter should be at least as big as the total width of the TV. For my Dell LCD TV, that's 24".

Use a screw, string, and pencil to trace a circle on the ½" particle board. Then cut the circle; I used a jigsaw. Once it's cut, draw 2 perpendicular lines through the screw hole. The Lazy Susan swivel should have 4 mounting holes on each half; center the lazy Susan's top half on the circle by positioning all 4 holes so that the perpendicular lines show through, then drill and screw-mount it to the particleboard.

Drill a ⅛" hole through the center mark on the particle board, then measure and mark a point on the top side of the board that's the same distance out from the center as the lazy Susan mounting screws on the underside, but offset from them radially so that there's no metal on the other side.



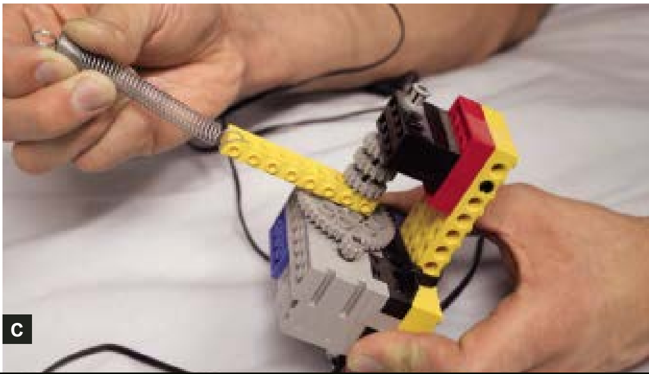


Fig. A: Gear reduction on Lego motor gives sufficient torque while 3 medium gears on the axle engage the rubber weather stripping on the spinner's edge as a friction drive.

Fig. B: Underside of TV spinner, showing lazy Susan, brackets, brace, and motor mount. Fig. C: Tension spring pulls the axle against the edge of the stand.

Drill a ½" hole through this point; this is an access hole that will let you screw the rotating base assembly down onto the stand later.

Mount the TV

Using the top center hole as a reference, figure out where the TV should sit on the base. To minimize stress on the motor, the TV's center of gravity should fall on or near the center of the base. Mark the base directly below the mounting holes on the back of the TV.

Examine and measure the mounting plate and hardware supplied with the TV's wall mount and decide how high you want your TV to be from the particleboard base. Add this height to the height of the mounting plate plus the distance between the bottom mounting holes on the back of the TV and the bottom edge of the screen, and cut another piece of 2×4 to this total height or a little more (mine was 10"). Use the two 5" L-brackets and 2½" screws to attach this piece of 2×4 perpendicular on the base. Then use the heavy-duty hex screws supplied with the TV mount to mount the plate at the proper height onto the 2×4. After the mounting plate is secure, trim any screws sticking out the bottom of the particleboard base.

Clamp the stand to a workbench; this will make things easier. Using ½" screws and working through the ½" access hole, mount the other side of the lazy Susan to the ¾" plywood at the top of the stand so that the circle hangs about ¼" over the back of the main upright 2×4. Wrap around the edge of the particleboard with a strip of door and window seal, and reinforce it with staples for extra durability.

Build and Install the Motor

Use the pictures above as a reference to build the motor out of Lego. It does not have to be exactly like mine, but you do need an 8-tooth gear on the axle driving a 40-tooth gear to step it down, and 3 medium-sized gears on the same rod as the 40 to friction-drive the edge of the TV base. There should also be a 1×8 Technic brick through the axle to attach the tension spring, which will pull the motor against the base.

Once the motor assembly is complete, hold it on top of the 2½" piece of 2×2 and mark where the 2×2 should attach to the stand. Screw the 2×2 block on, and attach the small hinge to the

The author Alan Mellovitz's dorm room at the University of Illinois. It's no wonder Alan thought to use the upper airspace in his room; he spent years living in a three-story tree house before he headed off to college.

back side of the block, opposite the base. Use pliers to make a 90-degree bend in the free side of the hinge to support the motor. Mount the motor to the 2×2 by drilling three ¼" holes in the 4×12 Lego plate and screwing it on with ½" screws. Use a cable tie to anchor the motor to the hinge. Attach the spring to the free end of the 1×8 Technic brick, and sink a ½" screw into the ¾" plywood to anchor the other side of the spring so that it pulls the motor's gears up against the base. Crafting the motor does not have to be exact, just so long as it works.

You can use a slide DPDT switch to control the motor. Install the switch in a convenient location, and wire its 2 middle terminals to the wire pair from the Lego electric brick. Then wire any 9V power supply or battery in both directions on the switch's 4 remaining terminals; solder the (+) and (-) one way on one side of the switch, and in the reverse direction on the other side.

For a fancier solution, you can even build a remote control to run the motor off a relay board. The kit I used for this was the 12 Channel IR Remote w/Relay Board (item #CK1615) from Carl's Electronics (www.electrokits.com).

Install It

Now you can fasten the TV spinner to your bunk bed. Use a level and have someone hold it in place while you make ⅛" pilot holes. Use the 2½" screws to fasten the stand to one of the bed's uprights. Then mount your TV to the mounting plate and connect all the cables. Bind the cables together with cable ties, leaving a large loop of slack to allow the TV to rotate around at least 180 degrees. Then staple the cable ties to the 2×4.

The rotary TV mount can also be useful for attaching other necessities to it, like fans, hooks, or more wires! You have the option to trim off the front edge of the circle in case it blocks your view of the TV, but if it doesn't bother you, it does make a nice nightstand.

+ A schematic for the motor and switch can be found online at makezine.com/08/diyhome_spinner.

Alan Mellovitz is a University of Illinois sophomore studying mechanical engineering. He has his own handyman business, likes to create gadgets, and plays the drums.

SMART HVAC

Energy-efficient A/C knows when you're in the room. By Dave Mabe

When I began working from home, I converted a shed in the backyard into an office. The shed wasn't heated or cooled, and summer was bearing down, so I needed to find an HVAC solution quickly. I didn't want to extend my home's HVAC system because this would have been lot of trouble, quite costly, and wasteful; I knew the office would remain unoccupied much of the time. Being a home automation enthusiast, I saw this as a perfect opportunity, and I came up with a cheap, efficient solution that sets the temperature to different levels depending on whether I'm in the office.

My office is about 20 feet square, so all I needed for cooling was one energy-efficient window-unit air conditioner. As with the main house, I decided to use X10 home automation, which transmits through home electrical wiring. X10 hardware is easy to install: you just plug the controller modules into the wall and then plug your appliances' power cords into the modules.

The peripheral components in my system were the X10 appliance module on the A/C unit, an X10-readable thermometer, and an X10 motion sensor. The thermometer I used was part of a multi-function weather station that takes indoor temperature as one of its readings, but you just need any cheap digital thermometer that can communicate over X10. To control the system, I used the excellent home automation program MisterHouse and a serial adapter that translates between MisterHouse messages on the computer and X10 signals on the power lines. (My weather station connects to a different computer in my network from the one that runs MisterHouse, but you can also plug the thermometer directly into the MisterHouse computer if it has a spare port.)

Photograph by Dave Mabe

MATERIALS

Air conditioning unit Or fan, heater, or other HVAC appliance
X10 appliance module (model A466) One for each appliance, from x10wirelesshome.com, or just click on the company's notoriously ubiquitous pop-up window
Digital thermometer that's readable via X10 I took readings from my Oregon Scientific WM918 weather station via HomeSeer software, but the MisterHouse project site reports that you can also use an iButton DS1920-F5 sensor in a DS1402D reader ibutton.com with an iButtonLink Link12 serial adapter ibuttonlink.com.
X10 motion sensor (model MS14A) x10wirelesshome.com
Wireless transceiver (model TM751) x10wirelesshome.com
X10 serial computer interface Such as an X10 Activehome kit, smarthome.com/1140.html
MisterHouse software Open source project misterhouse.com

I plugged the A/C unit into power through the X10 appliance module and set it to a lowest temperature of 60°F, since my MisterHouse virtual thermostat would be turning it on and off anyway. Once this was set up, the rest of the "thermostat" was some simple Perl code executed by MisterHouse:

```
$office_ac = new X10_Appliance('C1');
# C1 is the X10 code I set on the appliance module
$desired_temperature = 75;
$wiggle_room = 1.5;

if ($Weather{TempIndoor} > ($desired_temperature +
$wiggle_room)) {
 set $office_ac ON;
}

if ($Weather{TempIndoor} < ($desired_temperature
- $wiggle_room)) {
 set $office_ac OFF;
}
```

I placed this code in a file and saved it to the MisterHouse code directory, where it would be executed continuously, several times a second. In the code, `$Weather` is a special variable that MisterHouse sets automatically when it checks for a weather station, and `$wiggle_room` defines some leeway in maintaining the desired temperature. Increasing `$wiggle_room` saves energy by causing the A/C to switch on and off less frequently.

To add an occupancy check, I used a battery-powered X10 motion detector near my desk chair, which talks to an X10 wireless transceiver plugged into the wall. When the office is unoccupied in the summer, the desired temperature gets set higher (for winter, with a heater, it would be the opposite). To accomplish this I added the following code to the same file:

```
$desired_temp_unoccupied = 85;
$desired_temp_occupied = 75;
$office_occupancy_timer = new Timer;
$office_occupancy_timeout = 10;
$office_movement = new X10_Item('N9'); # this is the
motion detector

if (state_now $office_movement eq ON) {
 # motion detected in office!
 $desired_temperature = $desired_temp_occupied;
 set $office_occupancy_timer ($office_occupancy_timeout
* 60);
}

if (expired $office_occupancy_timer) {
 # no motion for 10 minutes
 $desired_temperature = $desired_temp_unoccupied;
}
```

MisterHouse's `Timer` variable type is perfect for this. When the motion detector senses movement, the code sets a timer for 10 minutes and sets the virtual thermostat to 75°F. If no motion is detected after 10 minutes, the timer expires and sets the thermostat to 85°, because I'm not in the office anymore (or maybe I'm just asleep!).

Because all this control is in software, there are limitless opportunities to customize your setup. For example, you could change the desired temperature remotely via MisterHouse's built-in web interface. You could track and determine your A/C's cooling rate at different outdoor temperatures. Even the fanciest "programmable thermostat" hardware would be put to shame by the flexibility you have with this system.

Dave Mabe is the author of *BlackBerry Hacks* from O'Reilly Media, Inc., and lives in Chapel Hill, N.C.

DIY CIRCUITS

Shock the monkey: Sensor-equipped sock monkey changes its tune as it twists and contorts.

MIDI CONTROLLER MONKEY

A/V monkeyshines with flex sensors and a MIDIsense board. By Peter Kirn

Who said input devices have to be hard and mechanical? Here's one that's as soft, bendable, and easy to play with as a plush toy. In my MIDI primer (*MAKE, Volume 07, page 158, "MIDI Control"*), we saw how to use the MIDI data specification, originally designed for music, to interconnect both musical and non-musical hardware and software. Now, we'll use this approach to construct a sock monkey instrument you can use to control visuals and sound.

The monkey has flex sensors sewn into its limbs, and it wears a sensor interface board as a backpack. The sensors detect the monkey's movements, and the board converts the readings into MIDI data. This lets the monkey conduct audio-visual symphonies and perform other MIDI magic.

Circuit Bending

Designers have long used off-the-shelf sensors to translate real-world movements into digital realms. For this project, we'll use one of the most commonly used types: a flex (or bend) sensor. This type of sensor was designed by Abrams/Gentile Entertainment and used in the infamous Mattel PowerGlove (a game controller for the Nintendo Entertainment System), as well as in the more recent Essential Reality P5 gaming glove.

The concept behind a bend sensor is simple: its electrical resistance changes as it bends. This lets it work in a circuit just like other resistive sensors, such as light sensors or potentiometers. Variations in voltage that result from bending can be converted to a digital value and trans-

Photography by Peter Kirn

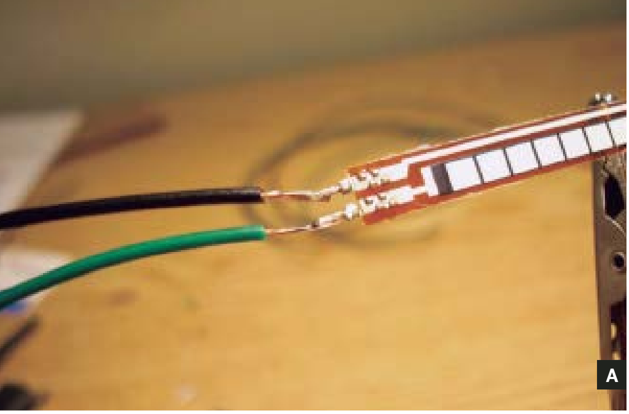


Fig. A: Two leads soldered to the end of the bend sensor.
Fig. B: Bend sensors slip into muslin sleeves sewn onto the insides of the sock monkey's limbs.

Fig. C: Partially assembled sock monkey, with sensor wires and reinforcement sewn at base of monkey's back.
Fig. D: Sensor wires connected to MIDIsense board.

mitted as data to a computer or other device. The typical bend sensor application is a data glove, which uses one bend sensor for each finger. Here, we'll try something different.

Monkey See, Monkey Do MIDI

Constructing sock monkeys is well-documented and easy to do. All we need to add are the bend sensors, some wires, and a way of translating the movements into MIDI. There are several off-the-shelf microcontroller boards that could perform this translation, but Limor Fried's open source MIDIsense board, which we also used in the MIDI Control primer, is ideal for our monkey. It's small, inexpensive, and designed to read sensors and nothing more. The MIDIsense takes input from six resistive sensors and has a MIDI jack output rather than serial or USB. This makes it easy to use the monkey with standard standalone music and video hardware, rather than only with computers.

For this design, I collaborated with my sister Anne Kirn, who has a knack for designing and making durable plush toys. Instructions for making sock monkeys are included in the packaging for Rockford Red Heel socks and are also widely available online, so I'll focus on the elements that are unique to this project.

Make the Monkey

1. Cut up the socks. Follow standard sock monkey instructions for cutting up the 2 socks. Basically, 1 sock forms the legs and body, and pieces of the other are used to form the tail, arms, and mouth.

2. Prep the sensors. For each sensor, cut an 8" length of a two-contact ribbon cable or a pair of hookup wires. Strip the ends and solder 1 end to the sensor contact prongs (Fig. A).

3. Reinforce the connection. Place a small piece of heat-shrink tubing over each connection between the wire and sensor. Make sure you have a size that fits loosely. Use a heat gun or hair dryer to shrink the tubing around each joint, and then reinforce the end of the sensor itself with electrical tape. (We found that all the heat caused some of the backing to peel away from the sensor; the tape made sure it continued to bend properly.)

4. Prepare the appendages and sensor sleeves. Sew the edges of the arms and legs per sock monkey instructions, so you have empty, inside-

MATERIALS

Rockford Red Heel socks 1 pair, men's extra large
Polyester fiberfill Or other stuffing
Muslin fabric For the "sensor sleeves"
Felt To reinforce attachment points
Thread To match sock color
Buttons (2) For eyes
Fleece or other non-raveling fabric, narrow double-fold bias tape, mini anorak/jacket snaps, and snap setter tool For backpack
Bend/flex sensors (6) Jameco part #150551 jameco.com
MIDIsense board Available at ladyada.net/make/midisense
Heat-shrink tubing RadioShack sells an assortment
Electrical tape
Solder Rosin-core/lead-free, any finer size
Insulated copper hook-up wire Or two-contact ribbon

TOOLS

Wire stripper Jameco #159290 is a good size
Wire cutter
"Helping hands" Or vise (optional)
Heat gun Or hair dryer
Soldering iron with a fine tip Weller is a good brand
Soldering stand and de-soldering tool or braid
"Micro" flat-head screwdriver
Computer or other MIDI-to-USB interface Such as the Edirol UM-1EX or M-Audio Uno
Sewing machine (optional)
Needle and scissors

out appendages. Cut 5 sensor-length sleeves out of muslin, and sew them to the outsides of the inside-out legs, arms, and torso. For the torso, turn the uncut sock inside out and attach the sleeve midway between what will become the head (the sock's toe) and waist (just above the heel). You won't need a sleeve for the tail sensor, since the tail is smaller than the other appendages.

5. Insert the sensors. Turn the various parts of the monkey parts outside out as per the sock monkey instructions. Then gently push the sensors and wires into their sleeves (Fig. B). To make it easier later, you can label by body part the wire ends of each sensor.

6. Add the stuffing. Stuff the monkey with the fiberfill. Make sure you add enough so that the monkey feels firm and not floppy, but not so much that he refuses to bend easily.

7. Assemble the parts. At this point, you'll have some stuffed limbs and a lot of loose wires. Follow the sock monkey instructions to finish the assembly. Then cut a hole just large enough for all the wires at the base of the monkey's back, just above the tail. Reinforce the hole by sewing on a small piece of felt (Fig. C).

8. Feed the wires. Label the sensor wires, if you haven't already. Feed the wires out of the base of the monkey's back so they can connect to the sensor board. Pull the wires through the body so they all meet on the way out of the hole, and then pull them out together.

9. Make the sensor-board backpack. Assemble the MIDIsense board according to the enclosed instructions. Then sew together a monkey-sized backpack with a board-sized pouch and a hole in the bottom to allow the wires to feed into the board from the monkey. Small straps let the monkey wear the board snugly. We made a pack with a snap closure out of fleece trimmed with double-fold bias tape.

10. Attach the wires to the sensor board. Strip the wires from the sensors and attach them to the 6 screw terminals on the MIDIsense board. Each terminal has 2 holes, one for each wire. Insert the wires, and screw the terminals down tightly using the micro screwdriver (Fig. D). We found that the wires would sometimes pop out when torquing the screws, so we added a bit of solder to make the connections more permanent. Carefully put the board and wires into the backpack.

11. Add some finishing touches. Eyes give the monkey personality, and using 2 buttons of slightly different size give it even more character. From there, accessorize at will. Now the monkey is ready for action!

Configure the Board

1. Set up the sensors. Connect the monkey to your computer via the MIDI-to-USB interface. Use the MIDIsense software to enable all 6 sensors, and select Control Change (CC) type messages for each of them to transmit. There are many MIDI CC messages, but they all transmit continuous values rather than on/off, which is what we want. For best results, use one of the message types with a range of 0 to 127.

If you're planning to use your monkey with external MIDI hardware rather than computer software, make sure you choose messages that your hardware can interpret; most hardware documentation includes a MIDI Implementation Chart that you can check for this.

2. Calibrate the sensors. Prep each sensor so it will transmit the full range of data it's sensing. To do this, use the MIDIsense application to calibrate the low, middle, and high end of the sensor's values. Bend each sensor to its maximum, then partway, and then fully straighten while tracking the corresponding slider position onscreen. Then set the green, yellow, and red arrows to those locations. You may need to invert the high and low values so that the sensor sends 127 when bent and 0 when unbent.

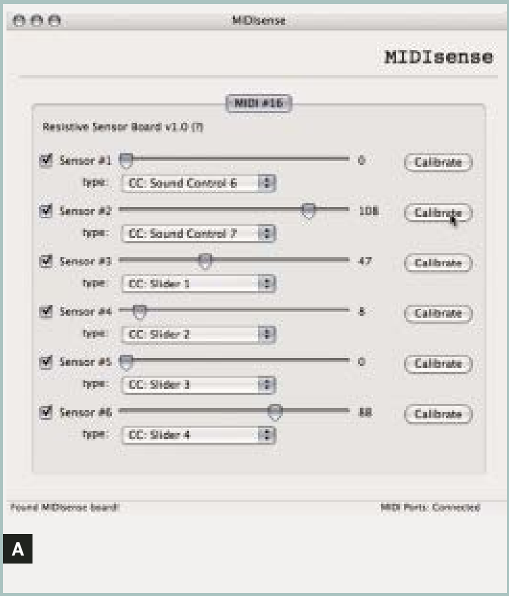
Sample Application

Now our monkey MIDI is all set up. But what can you do with it? The answer, as we saw in the MIDI Primer, is anything you like; you can control music and visuals software as well as any hardware with MIDI ports. Once MIDIsense has configured the ports, you don't even need a computer; you could hook your monkey up to a hardware beatbox and use the monkey in place of the box's own knobs and sliders.

Using the free Quartz Composer tool included in the developer tools that ship with Mac OS X 10.4 and later, I rigged up a simple MIDI-controlled, animated monkey for testing and demonstration purposes.

The Quartz Composer patch I assembled takes an image of a banana and assigns it to a Particle System, which is a way of animating lots of objects onscreen with similar but independent movements. (In this case, the bananas are the "particles," spurting out in clouds of floating fruit.) Quartz Composer translates MIDI input from each of the monkey's limbs into the size of the bananas in the particle system; if the sensors are straightened, the bananas are hidden, and as you flex the sensor, the clusters of floating bananas appear and grow. You could add sound for an audiovisual interactive sock-monkey installation. For more on this patch and the calibration and programming procedures for the monkey, with videos, see makezine.com/08/diycircuits_monkey.

Of course, you can also ignore this monkey business and do your own thing, putting the sensors into another object, or using them to control something else. That's the whole fun of this. But the next time you see a stuffed monkey in a DJ booth, you'll know why he's there.



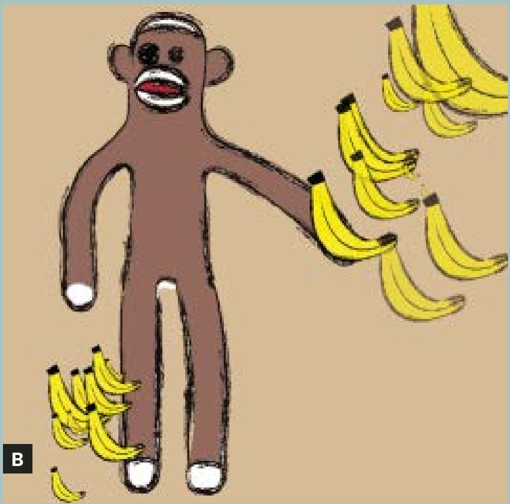


Fig. A: The MIDIsense board supports 6 sensors, which you configure and calibrate through a simple window. Set sensors as MIDI continuous controllers so that they generate a constant, reactive stream of message data.

Fig. B: A patch built in Apple's free Quartz Composer lets the MIDI monkey trigger on-screen bursts of bananas, which are animated via a particle system — delicious!

Composer and media artist Peter Kirn is the author of *Real World Digital Audio* (Peachpit, 2005), and editor of createdigitalmusic.com.

One person's trashed dishwasher is another person's source of treasured components.

CLEAN OUT A DISHWASHER

Salvaging components from unwanted appliances. By Thomas Arey

Nothing looks more forlorn to me than a piece of electronic or mechanical equipment set out to the trash.

I know that many folks who live by the maker philosophy share this view. So when I saw this early 1990s GE dishwasher sitting out for disposal, I thought I might be able to give some of the parts inside a second chance to perform some service. As with most disassembly projects, I not only discovered some neat parts, I also learned something about how things work.

As with any attempt at trash picking, make sure you are not trespassing, and take steps to ensure your personal safety. It doesn't take very long for indigenous flora and fauna to turn a curbside find into a permanent residence. Gloves and safety glasses at a minimum, please!

I began disassembly by turning the unit upside down and having a look-see. I quickly discovered that damaged impeller blades had sent this dishwasher to the curb. Probably repairable, but such parts can be expensive, so the owner sought replacement. His loss, my gain.

That said, a working motor and impeller pump have many uses. My first notion to turn those parts of the unit into a pond fountain was put aside as I began to strip the dishwasher for other future projects.

My first discovery was how simple a device a basic dishwasher is. It performs all of its basic functions by way of a single motor and a pair of solenoid-controlled valves. The single motor/ impeller pump serves to wash the dishes, as well as fill and drain the unit throughout its operating

Photography by Thomas Arey

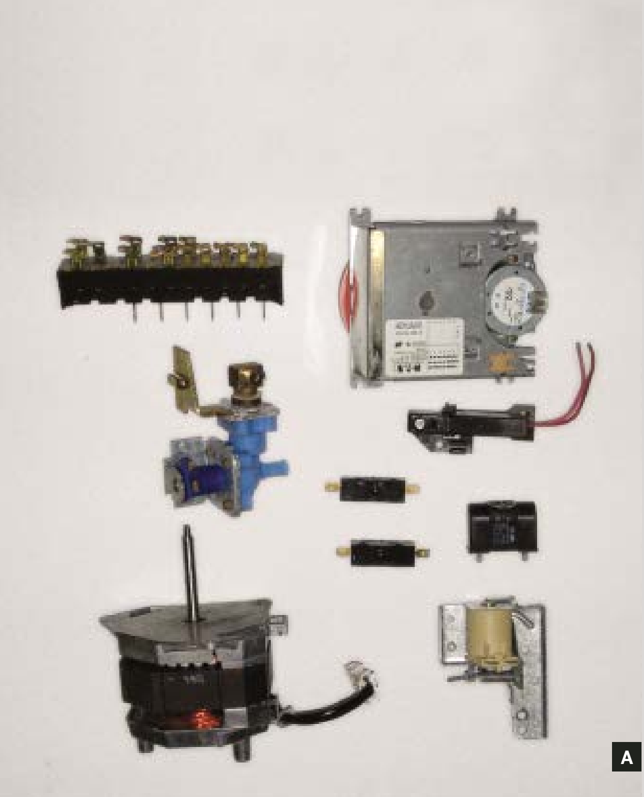


Fig. A: A few minutes' work with common hand tools and a generous application of maker philosophy yields motors, switches, valves, and solenoids, all taken from my curbside find. Fig. B: The "brains" of the dishwasher, a cam stack and 1 rpm synchronous motor. Sturdy, fail-safe electromechanical-timed switching that can be applied to hundreds of possible uses in projects where more complex electronic switching is unnecessary.

cycle. Also, all functions are performed with standard AC house current, so the salvaged parts might be useful in any project meant to be plugged into a wall socket.

The first pass at stripping out the big parts gave me a Siemens thermally protected motor that routinely shows a "Buy Me Now" price of $15 on eBay. Such fractional horsepower AC motors have dozens of practical uses for an experimenter.

The two previously mentioned solenoid-controlled valves will still likely end up in a pond fountain project next summer. But anyone who wants to control fluid flow by remote means will find such devices useful.

The unit also provided three heavy-duty momentary switches and a terminal block containing half a dozen NE-2 style neon lamps and their accompanying current-limiting resistors. Again, there are dozens of potential uses for such ubiquitous components.

The dishwasher contained a 70°C (158°F) thermostatic switch that could serve the same protective function in another project. The unit's intact heating/drying element is an item that someone more adventurous than I might find an application for. I chose to let it go.

The final item in the big parts picture is the switch unit. Control functions on this dishwasher were all electromechanical. Cycling through the unit's functions was performed by a 1 rpm synchronous motor geared to a plastic cam stack.

As the cams turned, they activated a switch assembly consisting of 6 SPDT switches. Of course, the simple 1 rpm motor can be used in many basic timing applications by itself, but since I was in the mood to take things apart, I decided not to stop there with this subassembly.

Further examination of the motor, gearing, switches, and cam stack led me to think of more advanced timing applications. Modification of the existing cam stack or construction of a new stack out of layers of plastic would allow the recovered parts to perform a maximum of 12 switching functions — all conducted without the use of ICs or PIC controllers.

Lots of food for thought there for a dedicated maker. There are many applications in which electronic circuits are not practical and a mechanical switching function is desirable.

C

Fig. C: "Big Box" hardware stores will charge you 10 cents each or more for most common fasteners. Stripping down any appliance will turn up several dollars worth of screws, nuts, and bolts. You will also find specialty hardware including springs and clamps. The dishwasher racks provided 6 small wheels and 8 grooved wheels that can be used as pulleys. All these liberated parts will find their way into future projects.

Of course, more disassembly will always turn up a host of smaller hardware that can be used for future projects.

This dishwasher was no exception. Most of the rubber hoses were too deteriorated for reuse; however, I was able to find one plastic hose that has potential. I also added a number of hose clamps, springs, self-tapping screws, nuts, and bolts to the hardware cans under my workbench.

The main hard plastic tub that lined the inside of the unit, measuring out at over 20 gallons, gave me several ideas. The pond project came to mind once again. Another possibility would be a parts cleaning tub for projects around the garage. My wife added yet another idea: drill the tub liberally with 1" holes and turn it into a composter.

The dishwasher's dish racks also contributed to my future projects in the form of a number of small plastic wheels. When scrounging, almost everything has a potential use and salvaging appliances for future projects is always time well spent. You will not only save many useful parts from your local landfill, but also learn much along the way.

BEGINNER'S SALVAGE TIPS

Wear gloves and goggles when working with salvaged equipment.

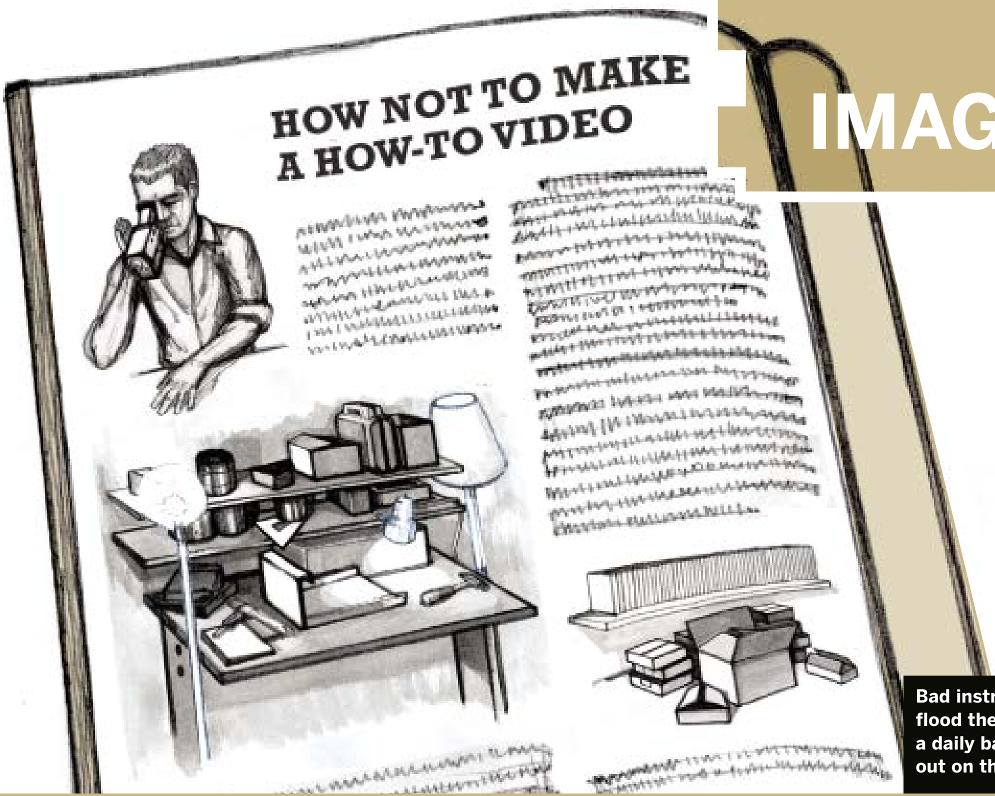
1. Specialty fasteners can be drilled out if you don't own the proper tool.

2. Fasteners are often hidden under moldings. A small pry bar can be your most useful tool.

3. A web search on the model of the unit may turn up information that can help with disassembly and parts identification.

4. If the part ain't broke ... save it or swap it.

T.J. "Skip" Arey N2EI has been a freelance writer to the radio/electronics hobby world for over 25 years and is the author of *Radio Monitoring: A How To Guide*.



Bad instructional videos flood the internet on a daily basis. Don't miss out on the fun!

HOW NOT TO MAKE A HOW-TO VIDEO

Ignore these handy rules and your instructional video will turn out great! By Travis J. I. Corcoran

Many people have noted the collision of the open source/hacker ethic with the growing interest in hands-on projects. Add the declining cost of digital video cameras to the mix, and the result is a huge surge in folks making their own instructional videos.

If you can imagine a project or a skill, there's probably someone who's made a how-to video about it — everything from smelting metal to brewing beer to creating goth cemetery scenes to lifting large stones.

Perhaps you're interested in making your own how-to video. It's a great idea, and there's a huge market! In my job of running a how-to video rental website I've seen lots of good videos, but also lots of bad ones. After watching all these videos, I've developed a list of rules you should definitely break if you want to make a great video.

Let's take a look at some tips from the low-fi playbook, but remember: Use these tips only in reverse!

1. Hold the camera yourself.

Decent quality, consumer-grade tripods can cost as much as $45. Save that money, and have a friend hold the camera for you ... or better yet, hold the camera yourself, as you operate machinery.

2. Film with dim lighting.

Halogen shop lamps can cost as much as $15 each at a big-box retailer, and diffusers and reflectors made out of poster board could cost

Illustration by Damien Scogin

another $6. Skimp on these. Either use only a few small lights to help you cast shadows on your work, or use fluorescents to give everything a greenish, underwater tint.

3. Mumble.

Having good sound means using a decent quality microphone, placing it correctly, and practicing your delivery a few times. It might even mean shooting a scene more than once, to get the delivery and sound right. You want to skip these steps — do one take only, and speak softly.

4. Be poorly organized.

Sometimes when folks tackle projects they're poorly organized — the parts aren't ready, the tools are scattered, and the workbench is cluttered. For an air of verisimilitude, reproduce this in your video. Use a dark-colored bench. Do not lay out your tools and materials cleanly. Do steps out of order. Do not name or explain your tools or techniques.

5. Do not edit.

The process of building something often has long boring stretches, such as waiting for metal to melt, doing dozens of passes on the drill press or table saw, etc. Make sure to document each and every repetitive step in your finished video. If it's boring to do, it should be boring to learn!

6. Reproduce the video yourself.

Bulk duplication services will reproduce your video on DVD for just a few dollars per copy. Save this money by buying blank media, DVD-shaped stickers, and empty DVD cases, and duplicate your videos one at a time on your PC. Your defective DVD rate will be higher this way, and you'll have to process lots of returns from customers, but it gives your product that handmade look.

7. Do your own distribution.

You could sell your video via customflix.com and Amazon, but why should some faceless company have all the fun of putting things in boxes? Instead, sell the video yourself. Buy a roll of stamps and shipping boxes, and do shipping on your kitchen table on the first Tuesday of every month.

8. Keep your video a secret.

Do not use Google Adwords. Do not mention your video on discussion boards or your blog. Do not post excerpts of the video to Google Video, YouTube, or other free video websites — doing so might result in snippets being forwarded around the internet, thus exposing your product to thousands of interested hobbyists.

9. Have a bad website.

Ideally, you would sell your video only by snail-mail. If you must have a website, make it hard to navigate. Offer your video only as part of a package with tools that customers might already own. Use HTML features that do not work in certain browsers. Consider having an archive of "stupid customer" emails, where you ridicule people who wrote to you with questions.

10. Price your DVD too high.

Back in the 1970s, Hollywood sold movies to consumers for $100 each and made millions. Today, DVDs sell for $12 each at Target, and the studios make billions. Your task: Put on a pair of bell-bottoms, turn on the 8-track, and price your video appropriately.

There are lots of other advanced bad-video techniques I didn't cover, but these are the basics. If you reverse every one of these hints, you've got most of what you need to demonstrate your special skill or project to thousands of folks in a well-done video, and have fun doing it.

Travis J.I. Corcoran (known to friends as "TJIC") hacks software, wood, and metal. He is the founder and president of smartflix.com.

Why bother paying for advertising when you can drive around and broadcast your message?

VAN TV

Big sights and sounds hit the streets.

By Ethan O'Toole

Some time ago, I had an idea for a project that would lend itself well to marketing applications. I had previously created a few local websites and needed to promote them. After contacting the traditional media (newspaper, radio, TV, etc.) for advertising rates, I came to the conclusion that I could probably get more bang for my buck with something original. It was time to build "The Truck."

Photography by Joe Legeckis

The Vehicle

First, I needed a suitable vehicle. After looking at a few different models, I stumbled across ex-U.S. Postal Service trucks on the surplus market. These trucks are based on the 1987 Chevy P-30 chassis, which is used by a number of work/utility vehicles and RVs. Of all the step vans, it is definitely my favorite in terms of the body style. It's not too large, and it's fun to drive.

The Sight

I tested various materials for rear projection, settling on translucent plexiglass with a matte texture on one side. The size of plexiglass sheets from the local plastics vendor set the limits on the screen size, so I ended up with a piece measuring 6' wide by 4' high, or 54" diagonal. That doesn't sound very large for an outdoor display, but it fits the truck well and is very impressive in person.

The first step to mounting the screen was to cut a hole out of the side of the van, which I accomplished (after many sweaty hours) with an angle grinder (the Dremel just couldn't hack this

Here's a view of the inside of the van with the back doors closed. I set up both the projector and the mirror installation to be removable so the truck can still be used to move large equipment.

one). I had to be careful of the pocket doors while cutting through the wall of the truck; these are the reason the display is not widescreen. I cut the hole a little smaller than the plexiglass sheet, to allow for easy mounting and sealing. After installing the plexiglass, it turned out that too much light was going through it, which bleached out the picture. So, I used a white sheet stretched behind the plexiglass to act as an added projection surface.

The projector connects to the computer via a VGA cable. My original projector was an older model with a halogen lamp. But after testing a friend's projector that used a metal halide lamp, I knew I needed to upgrade. On eBay I found a 1500-lumen Sony projector with zero hours on the bulb, similar to my friend's, for $300. Its resolution is 800×600, which has fallen out of demand, but it's more than enough for this project.

With the stock lens, the projector required a long throw distance. To facilitate this, I took a mirror from none other than an old rear-projection TV. It's a standard mirror, with coating on the back of the glass, and not a front-surface mirror like those used in laser projection, but it works just fine. I set up both the projector and the mirror installations to be removable, so the truck can still be used to move large equipment.

With truck, screen, computer, and projector, I was off and running. Since then, I have put the van through numerous upgrade cycles, including moving its control to a LAN accessible via touchscreens. Here's a tour of its current, enhanced configuration.

The Sound

The audio is handled by recycled components, including 6"×9" speakers, a subwoofer, a 40-watt, 4-channel amplifier, and an active crossover that ensures that low, potentially damaging frequencies don't reach the 6×9 speakers. The system is quite loud and the sound is clean, although upgrades may take place in the future.

The Brains

The main computer in the rear of the van is a 1GHz white-box PC running the FreeBSD operating system, and it handles many functions. It runs video playback on the projector, using the MPlayer and Video LAN Client video applications. It also stores all the content, along with some scripts that help manage it. For control, it serves a private web page that lets you run everything, hosting it from an Apache web server, and it also runs a browser and XWindows to display the page to touchscreen terminals in the front of the van.

Meanwhile, the PC also hosts other applications including XMMS, which is used for MP3 playback with visualizations, and XScreensaver phosphor module, which displays text on the screen in a retro style.

The Controls

The main control interface to the system is via three touchscreen LCDs in the front. The touchscreens are recycled 486-133MHz point-of-sale terminals that I converted from Windows 98 to the NetBSD operating system. They communicate with the main computer over an Ethernet LAN, and since they aren't powerful enough to run standard browsers themselves at usable speed, they render the control interface by running XWindows to remotely display the browser window executing on the main machine.

In addition to these "cockpit control" touchscreens, a second Ethernet jack on the main computer connects to a wi-fi access point, in order to provide wireless remote control. Apache is configured to serve the private control page over both the Ethernet and wireless networks. With this arrangement, you can control the van's projection and audio via a wireless-capable laptop or PDA; using the two physically separate interfaces for the wired and wireless networks ensures that people can't hack the terminals via wireless.

The Live Feed

For an outdoor concert experience anywhere, you can also wirelessly stream live A/V content to the truck. For this, I connect the camera to an MPEG2 encoder box, which connects to a wireless-enabled, Linux-based laptop via USB. If there's a live music show, the truck can be parked on a nearby street and show video that's happening in the venue. I've tested this in a parking lot but haven't done it at a show yet.

The Power

The truck still maintains its original alternator. Power is fed from the alternator into a dual-battery isolator, which splits it between two separate sets of batteries. The truck itself uses two standard car batteries, and I have three class-24 marine deep-cycle batteries mounted in the rear for the computer and A/V equipment. The deep-cycle batteries in the rear are connected to a low-quality 2200-watt power inverter/charger. I originally tried to power the system with smaller UPS units, but they didn't work well with the projector (and the larger UPSs use 24V, which is incompatible with standard 12-volt vehicle power).

The Ground Effects

The finishing touch was LED ground-effect bars. I originally set out to build my own, but after realizing how much time and effort it would take, I contacted a manufacturer in China named CodeLED and purchased LED tubes and a controller. I am currently working on reverse engineering the communications protocol that the controller uses to signal the tubes. My plan is to integrate it with the computers, so the touchscreens can also manage the ground effects. In the meantime, the supplied controller is fairly flexible in programming and capable of producing many colors by using pulse-width modulation. I hacked them up a bit and am using four long tubes on the truck (which aren't normally available with the factory-shipped kits).

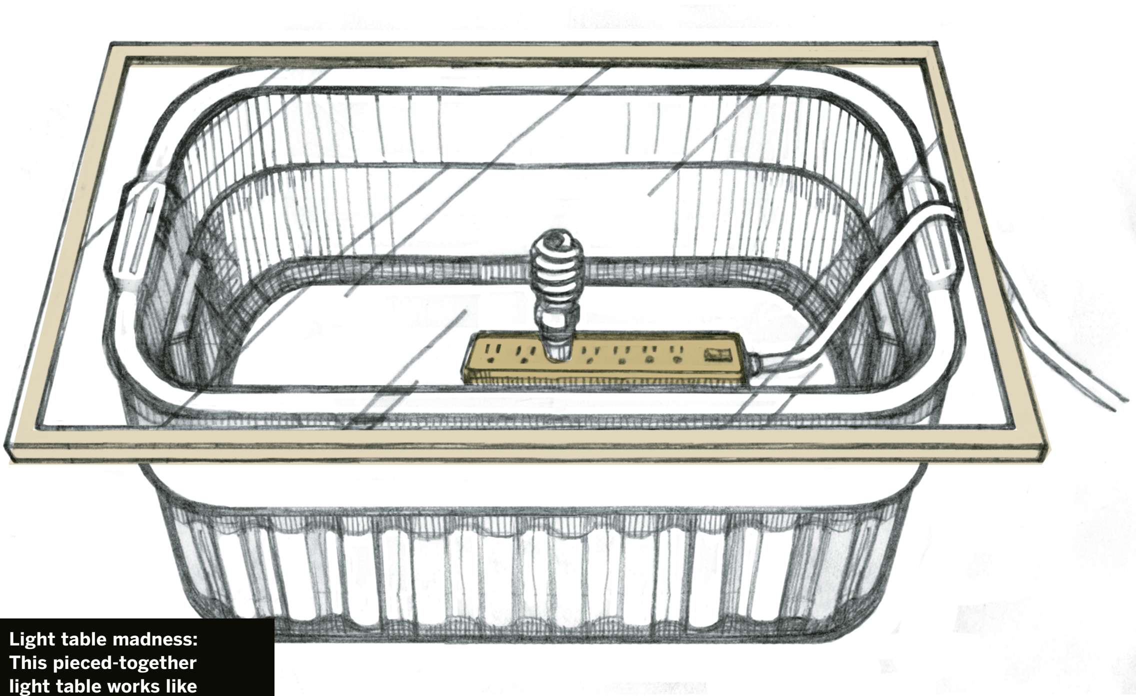
The Future

Future additions planned include a HDTV receiver and a GPRS/SMS card so people may text-message the truck from their mobile phones. I plan to feed the text-message data into the phosphor program.

The truck can often be spotted around southeastern Virginia. I generally take it and park in downtown Norfolk, downtown Virginia Beach, and the Virginia Beach oceanfront.

When parked in a well-lit store parking lot, the display is clearly visible. The truck rides high enough that the screen clears many cars. It gains a good amount of attention in any situation, so I would call the project a success.

Ethan O'Toole is a creative Unix and network admin who lives in Norfolk, Virg., and likes to start lots of projects. (Completing them is often the challenge.)



Light table madness: This pieced-together light table works like a charm.

QUICK AND DIRTY LIGHT TABLE

A storage bin, a pane of glass, and fluorescent light saves hundreds of dollars. By Hiram Cook

A couple of weeks ago my wife asked me to make her a 2-foot by 3-foot poster to display at a retirement party for a friend from work. I created the image on the computer and printed it using a graphics program that sections large, banner- and poster-sized images into pieces that a home printer can handle. But after trying to line up the sections to neatly tape them together, I realized that I needed a light table to get the alignment right.

Necessity is the mother of invention. In a hurry and not wanting to spend big bucks on a light table I might never need again, I looked around for light table makings. For the tabletop, I used the storm window from our back door. It measured 25 by 36 inches — big enough to hold the finished poster. I laid the glass flat on a storage bin without its top, and placed the bin on top of a bench to bring the tabletop up to workable waist height. For the light underneath, I used a 23-watt compact fluorescent bulb screwed into a light adapter and plugged it into a power strip, all inside the bin.

This improvised light table worked like a charm. I taped the poster together in no time, it came out looking great, and my wife was happy — which is what really counts, isn't it?

Hiram Cook is a CNC programmer from Allentown, Penn., who enjoys solving problems with low-tech solutions.

Illustration by Damien Scogin

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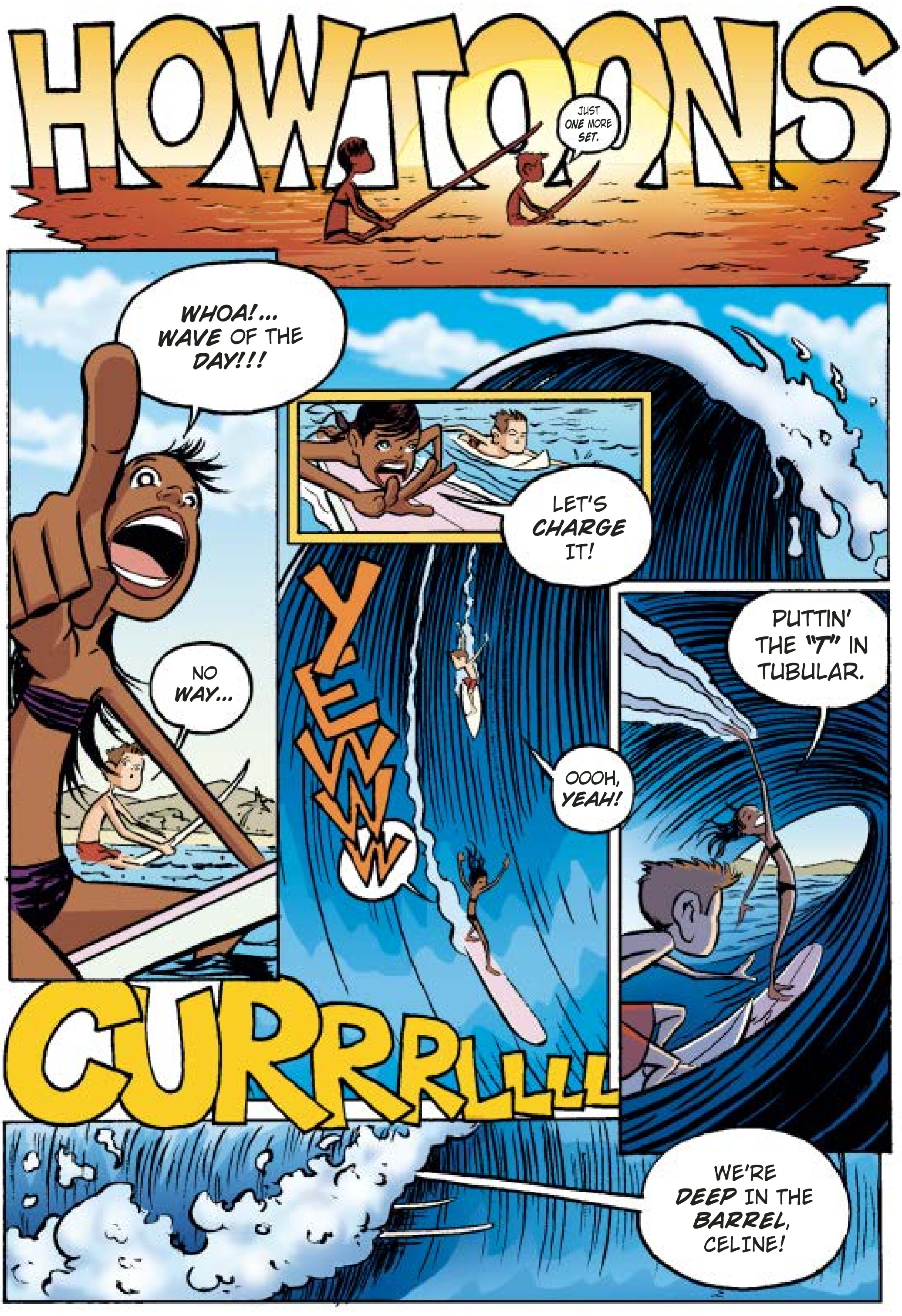
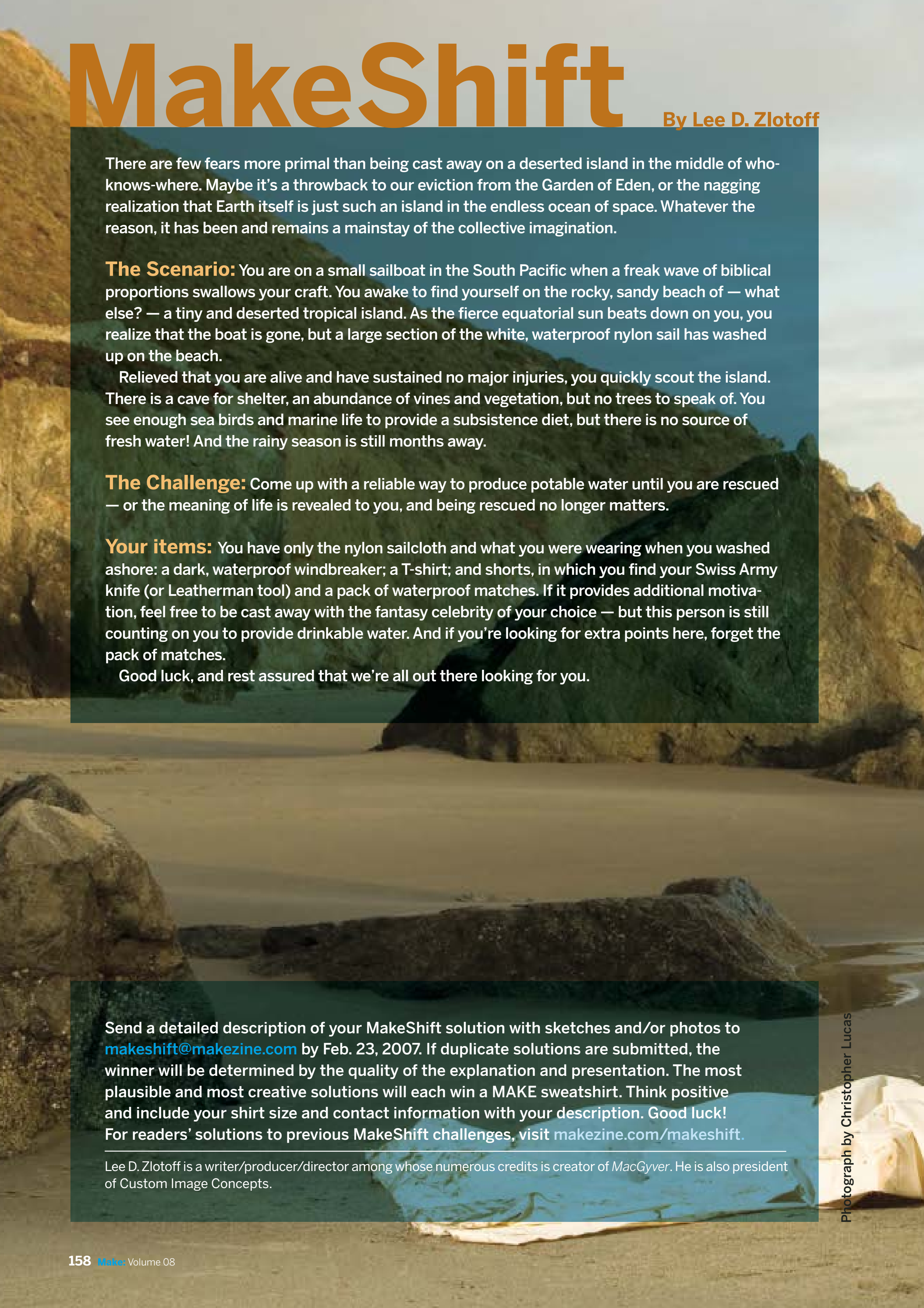



NOW LET'S CARVE IT UP.
WOOOOOOH
STICK THAT STALEFISH TUCK!
HANG LOOSE CELINE, ROLA BOLA!
KILLER SESSION, CELINE.
YEAH DUDE.
Build Your Own... ROLA BOLA!
PVC PIPE SHOULD BE A COMFORTABLE HEIGHT AND WIDER THAN THE DECK!
MAKE SURE YOUR DECK IS 30-36 INCHES LONG...
...AND WIDER THAN YOUR FOOTSIES.
ATTACH A STOPPER FOR SAFETY!
USE MANY SCREWS FOR STRENGTH!
END FOR NOW!



MakeShift

By Lee D. Zlotoff

There are few fears more primal than being cast away on a deserted island in the middle of who-knows-where. Maybe it's a throwback to our eviction from the Garden of Eden, or the nagging realization that Earth itself is just such an island in the endless ocean of space. Whatever the reason, it has been and remains a mainstay of the collective imagination.

The Scenario: You are on a small sailboat in the South Pacific when a freak wave of biblical proportions swallows your craft. You awake to find yourself on the rocky, sandy beach of — what else? — a tiny and deserted tropical island. As the fierce equatorial sun beats down on you, you realize that the boat is gone, but a large section of the white, waterproof nylon sail has washed up on the beach.

Relieved that you are alive and have sustained no major injuries, you quickly scout the island. There is a cave for shelter, an abundance of vines and vegetation, but no trees to speak of. You see enough sea birds and marine life to provide a subsistence diet, but there is no source of fresh water! And the rainy season is still months away.

The Challenge: Come up with a reliable way to produce potable water until you are rescued — or the meaning of life is revealed to you, and being rescued no longer matters.

Your items: You have only the nylon sailcloth and what you were wearing when you washed ashore: a dark, waterproof windbreaker; a T-shirt; and shorts, in which you find your Swiss Army knife (or Leatherman tool) and a pack of waterproof matches. If it provides additional motivation, feel free to be cast away with the fantasy celebrity of your choice — but this person is still counting on you to provide drinkable water. And if you're looking for extra points here, forget the pack of matches.

Good luck, and rest assured that we're all out there looking for you.

Send a detailed description of your MakeShift solution with sketches and/or photos to makeshift@makezine.com by Feb. 23, 2007. If duplicate solutions are submitted, the winner will be determined by the quality of the explanation and presentation. The most plausible and most creative solutions will each win a MAKE sweatshirt. Think positive and include your shirt size and contact information with your description. Good luck! For readers' solutions to previous MakeShift challenges, visit makezine.com/makeshift.

Lee D. Zlotoff is a writer/producer/director among whose numerous credits is creator of *MacGyver*. He is also president of Custom Image Concepts.

Photograph by Christopher Lucas

PRIMER

Molds can be made of rubber, steel, clay, brass, wood, plastic, lead, and even sand, and people use them to cast objects ranging from 40-foot bronze Buddhas to microscopic cell structures. This article focuses on casting small objects in rubber, which is a reliable technique that's employed throughout the film and special effects industries, as well as the jewelry industry.


Photograph courtesy of Adam Savage

Moldmaking

How the pros replicate objects.

By Adam Savage

In principle, moldmaking is a simple process, but with every object you want to replicate comes a new series of pitfalls, innovations, and solutions.

This article explains how to make a two-part, underpoured block mold, which is a versatile and beginner-friendly type that's great for small, detailed objects such as jewelry, game pieces, masks, picture frames, and figurines. I learned this technique by apprenticing under some of the great moldmaking masters in the special effects industry, and this article reveals their unpublished tricks. I hope they don't get mad.

We'll make our mold out of silicone rubber, an excellent casting material, but it costs about $100 per gallon. This process uses as little of it as necessary, and it's important to follow all of these instructions, because a mistake can be costly. Then we'll cast our duplicates in opaque urethane resin (clear resin requires a more difficult process).

Why a Two-part, Underpoured Mold?

Two-part molds can handle more shapes than one-piece molds, which work only for simple, completely convex objects. And underpoured molds minimize problems with bubbles in the resin.

Underpouring means that you pour the resin into a main intake vent (or *sprue*) that curves around to fill the mold up from below, rather than simply pouring into the top (Figure A, opposite). Meanwhile, smaller vents on top allow the displaced air to escape. As you pour, resin splashing down forms bubbles which can stay in the main cavity and ruin the surface of the casting. These bubbles also tend to collect in fine-detail areas, where they are the most difficult to deal with.

The advantage of under-pouring is that it generates fewer bubbles, and lets them rise up into the vents where they won't cause trouble. Top-pour molds are sometimes acceptable, but pouring from underneath is generally worth the extra silicone required.

Design the Mold

The first step in designing a mold is to visualize your object upside-down and inside-out. Imagine it as a cavity being filled with resin, imagine the path that resin will take, and what happens to it along the way. Where will bubbles form? Where should the main vent go? How should the object be positioned? (Probably upside down, so most cleanup takes place on the underside.) What will be the hardest part to clean up? Where do I need to put vents? Should the piece be cast as one part, or broken into several parts?

Thinking through these questions makes everything easier later, when you clean up the casting. This means cutting off and sanding any excess resin from the vents and seam, and filling in any bubbles. A good casting has few bubbles and is easy to clean up, and this starts with good mold design. It's always easier to sand away material than to fill voids.

As an example, we'll cast an angel figurine (Figure B). I decided to remove her arms and cast them separately because they looked like trouble; they extend far from her body, and the hands have delicate detail. Broad, thin parts are also difficult to cast, so I removed the wings and replaced them with new ones I made separately on a vacuform machine, which is excellent at producing flat forms.

1. Set up your object on a piece of foamcore and build up the *pouring gate* and *vents*. After removing the angel's arms and wings with a Dremel tool, I set up the body upside down; the bottoms of her feet are flat, so they made an ideal point to pour into. I sprayed the body with primer in order to see the surface better where I had made the cuts (Figure C).

Form the pouring gate using a plastic hemisphere, and make the sprue and main outlet vent using armature wire. Use cyanoacrylate (CA) glue with an accelerator to piece everything together. To make clean-up easier, the contact between main chamber and vent should be as small as possible; I sanded the wire to a point where it touched the angel's head. I then used .06" square styrene strips to add smaller vents from the folds of her skirt and sleeves, which seemed bubble-prone.

2. Use a Sharpie to mark along the *parting line*, the line along which you'll cut the mold open (Figure D). It should extend across the base itself and all the way around the model, following any corners that exist, or along high points and open spaces to define a seam. *Flash* (excess material) from mold separation can form along this seam, so you should place it where the flash will be easy to sand and fill.

3. Build the mold box around the object using one large piece of foamcore (Figure E). Score and fold the foamcore without cutting through it, roughly following the object's shape. Keep at least ¾" between the model and the outside of the mold. Thinner, and the silicone can deform under the poured resin later; thicker, and you're wasting silicone and the part will be harder to cut out.

* Taking Care

***Many mold materials are time-sensitive, so after each step, you lay out all the things you'll need next.**

***Molds are too often destroyed by impatience; not spending an extra 2 minutes mixing the silicone (for example) can throw away several days' work.**

***Some materials, such as the thickening fillers, are also toxic, so wear eye protection, gloves, and a smock or apron, and work in a well-ventilated area.**

***Finally, no matter how careful you are, be prepared to mess up until you have more experience.**

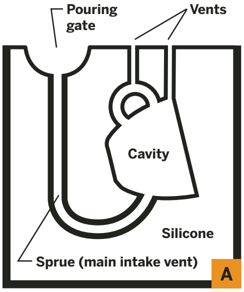
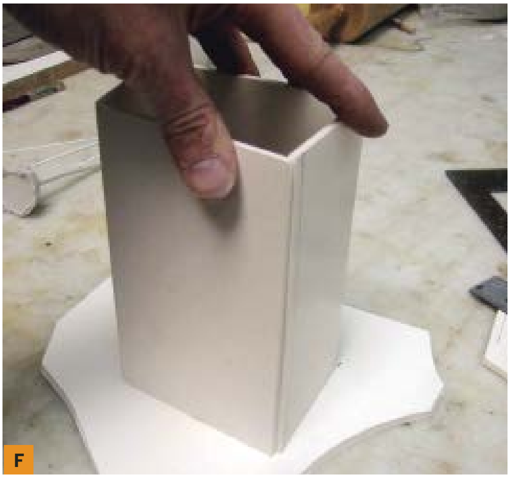


Fig. A: Cross section of underpoured mold.
Fig. B: The object we're going to cast, an angel figurine.
Fig. C: The angel being set up for molding. The sprue runs to her feet, which are a conveniently flat surface.
Fig. D: Marking the parting line, along which the mold will be cut later. Fig. E: Building the mold box using a single piece of foamcore. Fig. F: The mold box, ready for sealing with hot glue.



Photography by Adam Savage

4. Use a hot glue gun to secure the box to the base, and to glue the (single) seam of the box (Figure F). Carefully examine your entire glue seam to make sure it will hold the liquid silicone, which will leak out of the smallest of holes.

Pour the Silicone

1. Figure out how much silicone you need by calculating the volume of your box. I do all my moldmaking in grams instead of ounces, since it's so much easier to multiply and divide by 10. Remember, *volume = length × width × height*. Measure in centimeters, and you'll get a volume like 755 cubic centimeters. Silicone is close to the specific gravity of water, so thanks to the convenience of metric, this is the same number as the weight in grams of silicone you'll need. If you measure in inches, multiply your cubic inches volume by 17 to get the rough equivalent in cubic centimeters or grams.

2. Measure the silicone and activator. Almost all silicones use a ratio of 10:1 silicone to activator. You can also add an accelerator, in the amount of 2-10% of the total weight, but the resulting silicone won't be as durable and will tear more easily. Curing times will be 24 hours with no accelerator, 4 hours with 2% accelerator, and 1 hour with 10% accelerator.

3. Mix the silicone, activator, and accelerator, if used (Figure G, opposite). The activator is blue to give you a visual cue when you're done mixing. If you see any streaks, you're not nearly done. Make sure you're using a mixing stick that's strong enough, and scrape the sides and bottom, where it's hardest to get a good mix. I usually mix by pushing the mixing stick down the sides of the bucket, and dragging it across the bottom, turning the bucket as I go, for as many as 6-10 full revolutions. Silicone is thick, so it helps to have someone else hold the bucket.

Beginners often make the mistake of not mixing enough; a good rule is to mix until you think you're done, then mix for another 3 minutes (Figure H). There's nothing worse than wasting a mold because of inadequate mixing.

Here's What You'll Need

This is a lot of stuff, but it's all essential; the price of a missed step is often catastrophe. Also, you can use these tools and supplies to make many more molds.

Silicone RTV (room temperature vulcanizing) rubber and activator Silicone is soft (low durometer), durable, and accurate for detail. Many varieties and colors are available, which will all work for our purposes, and I've found moldmaking suppliers to be helpful about which products are best suited to different projects.

Urethane resin or other casting material

Talcum powder or cornstarch

Wax and shellac (optional) It is necessary to seal the pores and keep the silicone from sticking if your object is unglazed terra cotta, wood, or other highly porous material.

Styrene strip or equivalent Most hobby stores carry Evergreen or Plastruct brands.

Hobby knife with a curved blade and regular #11 blades

Matte knife Or snap-blade knife

12" or 18" straightedge

Armature wire 3⁄16" or 1⁄4" At any art store

Plastic hemisphere(s), at least 3⁄4" diameter From plastics supplier or art store

Cyanoacrylate (CA) glue Such as Zap a Gap or Krazy Glue

CA glue accelerator (or baking soda) This makes the CA glue "kick" almost immediately; regular baking soda works well for this, and with no smell!

Paint mixing sticks

Tongue depressors or popsicle sticks

Mixing cups

1-gallon paper paint bucket

Hot glue gun and glue sticks

3⁄16" or 1⁄4" foamcore

Rubber bands

Small cloth sack

Permanent marker Such as a Sharpie

Scale Digital is best, but a triple beam balance will do

Dremel tool with fine cutting wheel

Orbital palm sander Or large massage vibrator

Needlenose pliers

Rubber or nitrile gloves From drugstore or medical supply

Safety glasses or goggles

Respirator Silicone is relatively benign, but a respirator is a good idea

Wet paper towel Or water-based clay

And for those more serious:

Pressure pot

Evacuator/vacuum chamber

Air compressor

4. Now the silicone is ready to pour into the box. Don't just pour it willy-nilly; this is a surefire way to trap bubbles in parts of your mold. Instead, pour in one location, away from your part, and let the silicone slowly fill up the mold around it (Figure I). Pour as thin a stream as you can, about as thin as a pencil lead. This starts to remove some of the tiny, invisible bubbles formed during mixing. Use the stir stick to scrape every last bit of silicone out of the bucket.

Should you discover silicone leaking from a small hole in the box, stop it with a wet paper towel or, better, a small piece of water-based clay. The water helps the silicone coagulate. Trying to patch the hole with hot glue might just make it wider.

5. In a professional shop, bubbles are removed by putting the bucket into an evacuator (vacuum chamber), a piece of equipment which can cost $1,200. On a budget, you can *degas* your mold by agitating it with an orbital palm sander. Just hold the sander against the table, right next to the mold, for about 5 minutes. A layer of bubbles should rise to the surface.

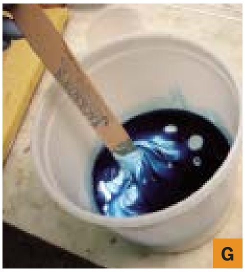
6. Wait until the mold "kicks," 24 hours for most RTV silicones without an accelerator.

Cut the Mold

1. Remove the box and silicone from the mold base by inserting your X-Acto knife blade at an angle from just above the hot-glue seam around the bottom (Figure J, next page). This frees the mold, but keeps almost all of the box intact. We like this box. It will keep our mold aligned and accurate.

2. Give the box a yank to separate it from the base. There will be some stickage of silicone and you will tear loose the glued-down pouring gate, but nothing major. After you free the base, cut an *alignment key* into the edge of the box and the newly exposed top

Fig. G: The silicone before mixing. Fig H: The silicone after mixing. If you see any white streaks, you're not nearly done. Fig I: Pouring the silicone. You should pour thinner than this, unless you have an evacuator to put the mold into immediately afterwards (like I did).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H

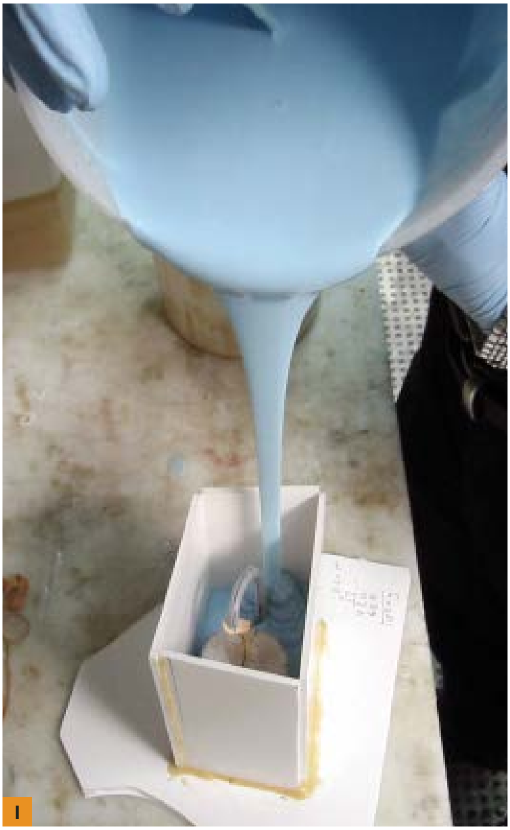
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Fig. J: The mold, ready to be cut out. Fig. K: Cutting the box seam. Fig. L: The mold, released. Fig. M: The jeweler's cut. Fig. N: Prying the halves apart. Fig. O: The angel revealed (with vents, etc. removed). Fig. P: Dusting the mold with release agent (cornstarch or talcum powder).

of the mold. This is a marker notch that lets you exactly replicate how the mold fits into the box. Lining up this key prevents deformed castings when the box isn't precisely symmetrical (which it isn't).

3. Cut open the seam by inserting the blade perpendicular to the butt joint of the foamcore and slicing downward (Figure K). Try not to damage the box, because as I said, it will support the silicone later, during casting. Release the mold (Figure L).

4. Now that our mold is released, it's high time we released the object inside. This involves what may be the toughest skill in the moldmaker's arsenal: the dreaded *jeweler's cut*. You're going to cut the part out by cutting the silicone block in half, but you also want the 2 halves to line back up just the way they started, or "key together" in moldmaker's terms. The jeweler's cut creates bumps and ridges that force the halves to key together (Figure M).

On the silicone block, find the line of ink that transferred from the section of parting line that you drew on the base. Using a curved X-Acto blade, start cutting at this line from the inside out, never deeper than 3/16" (3-4mm), following the line drawn on the object out to the edge of the block.

As your hand drags the knife through the silicone, twist the curved blade side to side with the tips of your fingers. This twisting action creates the hills and valleys that define the jeweler's cut. After you cut your first twisty line, pry that slice as wide as you can with your fingers (or use mold spreaders, a tool that's like reverse pliers), and make another twisty cut at the bottom of the gully you just created. This is where the curved blade comes in handy: a straight blade, encountering a bump from a previous cut, will cut right through it, whereas the curved blade moves around it!

Some pointers: Make your hills and valleys deep, but no wider than 3/16". Areas where the model comes closest to the edge of the block have the most danger of leakage, so you want at least 2 complete passes of hills and valleys between the model and the block's edge.

Stagger your cuts. Don't cut your hills all in a line, because this will let the mold halves slide along one axis relative to each other. If your mold can move, I guarantee you it will. Also, if you're slicing through the hills from a previous pass, you're not spreading your mold apart enough. Always cut from the inside out, and go slowly!

This takes practice; I won't lie to you. It takes a time to get a feel for it, and spreading the silicone is hard work. But careful attention here can make the difference between a casting that comes out ready to paint, and one that needs a day of sanding and filling.

5. Keep cutting and cutting until you can separate the halves and remove the object (Figures M, N, and O).

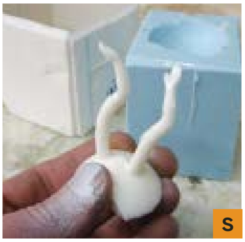


Fig. Q: Pouring the resin. Fig. R: The main casting unpacked from the mold. Fig. S: The arms removed from their mold. Fig. T: The finished casting, cleaned up, glued together, and painted with primer.

Cast It!

1. Remove the original part, sprue, vents, and pouring gate, and dust the inside of each mold half lightly with cornstarch or talcum powder. I put my powder into a small cloth sack, secured with a rubber band, to spread it evenly without clumping (Figure P). Silicone rubber gets a slippery tack to it, as the silicone gradually sweats out. This means that silicone molds generally need no *mold release*, because the silicone itself prevents sticking. But a light dusting still helps the two halves align together perfectly, and also acts as a sponge to the resin, drawing it into the fine details of your mold and inhibiting small bubbles which can gather at the high points.

2. Put the mold halves back together, box them in their original box, and secure it all with rubber bands, pouring side up.

3. Mix the 2 components of the resin, following package instructions. I used a common, fast-setting urethane resin called Insta-Cast, from Douglas and Sturgess, which has a pot life of only 60-90 seconds. This means that you have to mix it fast! In general, I mix by counting 30 strokes with the mixing stick, taking care to scrape the sides and bottom as I go.

4. Pour the resin into the mold (Figure Q). The hemispherical pouring gate provides a spill-proof cup for the resin (imagine trying to pour accurately into a tiny hole). When you see the resin come up the vents, you're done. I usually keep an old simple mold at my pouring bench, so that when I have extra resin in a cup from a pour, I can dump it somewhere useful. If resin doesn't come up the vent, the vent may be blocked, or the main sprue needs to be thicker. If that's what you suspect, let the resin set, and use a knife to widen the vents or the sprue on the open mold afterwards. I often add vents where I find unexpected bubbles in my molds. Moldmaking is all about improvisation, and as long as you prepare well, there are many problems you can solve even after casting.

5. Wait for the resin to set, and unpack the casting. To remove the extra resin from inside the vents, break them off with needlenose pliers, then sand the surfaces smooth. On my angel, I was right about the vents in the dress and the shoulders, as she needed no clean-up at all (Figure R). For her arms I just made an overpoured mold (Figure S) and shoved a Q-tip down the hole after pouring the resin to free up bubbles. Then I glued the arms on, installed new wings, and painted it all with primer (Figure T).

Another tip: After pulling the parts out of the molds, I weigh them and write the number of grams on the foamcore mother mold. This lets you know exactly how much resin it takes, so you can mix only what you'll need.

Adam Savage is, above all else, a collector of skills. He makes a lot of stuff you might know about, and a bunch of stuff you don't. He lives in San Francisco with his wife and twin sons.

Create your own computer games, discover some magnetic attractions, and become a paper airplane champion.

TOOLBOX

Stop Buying Hideous Board Games

Prices vary ebay.com

Compared to 30 years ago, today's board games are pieces of junk. Last year I bought three games I remember loving as a kid: Life, Kerplunk, and Trouble. I wanted my 8-year-old daughter to experience the fun I had playing them. But when I opened the boxes, I was disgusted with the shoddiness of the materials. The straws in Kerplunk were made of astonishingly flimsy plastic, making it difficult to push them though the holes. The pieces on the Life gameboard constantly fell off, forcing us to stop playing every so often to reattach components. And the cylindrical game pieces in Trouble bounced out of the holes every time you pressed the Pop-O-Matic die tumbler.

I couldn't believe how lousy these formerly terrific games had become. I went to eBay to look at pictures of the old versions and discovered that you could buy the original games there, often at lower prices than the new, junky versions. A 1967 model of Kerplunk, with stiff sticks and a cylinder that doesn't fall apart every time you touch it, can be yours for under $10. A vintage 1965 edition of Trouble, with pieces that stay put, is just $5. And a 1960 edition of The Game of Life, featuring Art Linkletter's hearty endorsement and board pieces that don't fall out, is $15.

The other bonus you get from buying old board games is the cheerful, well-designed package and gameboard graphics. The modern versions are so ugly that they depress me. From now on, eBay is the only place I'll ever buy a popular board game.

—Mark Frauenfelder

Photograph by Tracey Jipson

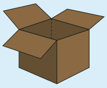
Battling Tops

$20–$30 ebay.com

Battling Tops was my favorite game in the 1960s, and its gladiator-like action is still popular today, inspiring other wind-up top games like Beyblades. It can be appreciated by little kids (as long as someone helps wind their tops) and adults alike. The secrets of winning are well guarded (they might include variations in winding or in wrist action, but I'll never tell). The original 1968 Ideal version remains my favorite among the several versions produced since then; its rink is larger and the graphics on the labels are classic. It can be found used on eBay for $20-30 (or more for rare-colored rinks that are collectors' items). A new version called Original Battling Tops by Mattel is available in stores, but it has a smaller rink that pales in comparison to the original. Whatever version you find, the name of the game is still last top standing!

—Barton Blum

Box-a-holic



Cardboard boxes, Free

The first thing that comes to my mind when I think of my favorite toys is a big cardboard box, like a refrigerator or washing machine box. Let's face it. Boxes are the coolest toy on the planet. You can do anything with a box. Need a ride to Mars? All aboard the cardboard-box rocket ship. Looking for a good robot to play with? Stuff one of your lil' friends in a cardboard-box robot suit. Playing house? Box. Love to paint murals? Box.

As attention span stretchers, boxes are the only disposable fun I've ever seen, and they easily outline a roly-poly trapped in a jar. Bugs could have topped the list of favorites, had torturing them not been deemed cruel and unusual by the insect world.

But I can't write about a box now, can I? That would be simply ridiculous because, in the real world, toys are not really considered toys until they are purchased at a retail store. Boxes, as we all know, are usually free. But that's where makers come in. Cherish your boxes. Give them respect. Think inside the box for once.

—Kristina Reed

Easy as Pie

PyGame, Free pygame.org

If you've ever pondered the idea of creating a computer game but thought that the learning curve was just a little too steep, consider giving PyGame a shot. While you may not make the most cutting-edge game the world has ever seen, PyGame does have several important advantages: it's written in Python (a very easy language to pick up); doesn't cost anything; gives you an easy entry point into the paradigm of game development; and makes tasks such as rendering graphics, playing sounds, and interfacing to the mouse and keyboard as easy as ... py.

At the end of the day, these advantages make a tremendous difference in your productivity, and they allow you to spend more time having fun. Think about it: not sinking hours into figuring out where to start, and then getting bogged down with an unimaginative task, means you get to spend more time on interesting activities that will make your game more enjoyable to play. You can download PyGame and try out some of its excellent tutorials. It's an easy install and it only takes a couple of hours to create one of the example games. Why not get started?

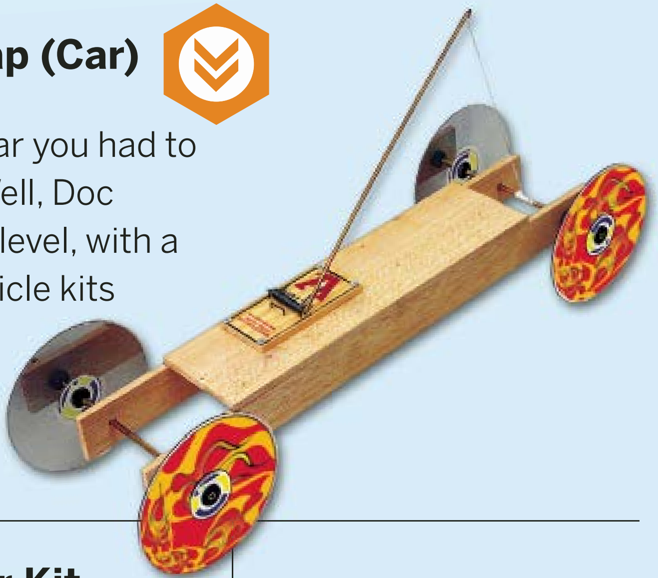
—Matthew Russell

Editor Phillip Torrone talks about kits that caught his eye on makezine.com/blog.

Build a Better Mousetrap (Car)

$8–$20 docfizzix.com

Remember that mousetrap car you had to build back in grade school? Well, Doc Fizzix has taken it to the next level, with a website full of mousetrap vehicle kits (even balloon-powered ones) and a book of tips and advice for the fledgling maker.



Embedded Linux Starter Kit

$399 emacinc.com/trainers/linux_starter_kit.htm

Adding to the list of interesting kits, EMAC has an embedded Linux starter kit. A lot of equipment uses embedded computers these days, from soda machines to incubators. This kit will get you familiar with embedded Linux systems.

Change Your Point of View

$37.50 makezine.com/go/pov

Check out these incredible LED bicycle wheel animations using the SpokePOV kit. Mario scoring points, a running mouse, rock 'em sock 'em bots, Pac-Man eating a ghost, and Duck Hunt!

Too Hot to Be Cool

$50 makezine.com/go/logger

If you need to log temperatures, this looks like a pretty interesting kit that uses iButtons. The logger automatically wakes up and measures temperature at user-programmable intervals from 1 to 255 minutes; programmable high and low temperature alarm-trip points are available. Find out which part of your backyard is the warmest, or make sure your fridge is keeping an even temperature.

Top Chopper

$22 makezine.com/go/heli

Build a working helicopter out of wire, balsa, and rubber bands. The kit also "teaches basic helicopter theory." Clearly, a lesson for life.

Homemade Electronics Lab for Kids

Free makezine.com/go/kids

OK, here's a great how-to on making a fun experimenter's board for your little one. It's never too early to learn about electricity!

I Want My MP3

$72–$115 teuthis.com/html/kits.html

Here are a couple open source MP3 player kits; PCB/schematics and source code are all available. You get a pre-programmed PIC, but it's reprogrammable. There's also free email support if you need it. A MAKE-branded kit is on its way! (Check the MAKE store: makezine.com.)

Tube Time

Crystal Radio Kit for the Modern Era

XS404 Big Brother Crystal Radio Kit

$35 midnightscience.com

In this modern world of radio communications and surface-mount component design, it's easy to dismiss radio kits as a remnant of the past. However, nothing could be further from the truth. This Xtal Set Society kit is designed to bridge the gap between the basic crystal receivers of yesteryear and the solid-state component receivers typically used today.

Offering molded coils — as well as the option to wind your own — the kit features an antenna tuner, a variable capacitance diode for station tuning, and a transistor amplifier for the included earpiece. Unlike the simple crystal receivers (and their accompanying frustrations) we all grew up with, the XS404's tuner aids in suppressing nearby signals while the transistor serves to boost weaker ones.

The kit, based on a 1N34 crystal diode, also includes the obligatory printed circuit board, Fahnestock clips for attaching the earpiece and antenna, two varactor diodes, two panel-mount 10K variable resistors, other miscellaneous resistors and capacitors, two black pointer knobs, and a front panel. A 9-volt battery is required.

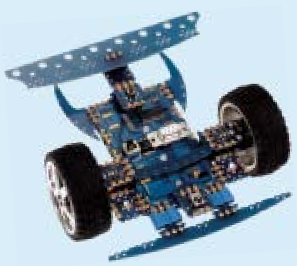
Thanks to the efforts of the family-owned and -operated Xtal Set Society, kit enthusiasts can once again put solder to the pad and enjoy a great (not to mention functional and educational) radio build.

—Joseph Pasquini

The Viper Is Coming

$140 makezine.com/go/viper

William Cox wrote a great review about the Viper kit from Microbric. Looks pretty good; you get a lot of components for the price (he even goes so far as to call it a "steal") and his only complaints are minor. Plus, it's called the Viper.



TOOLBOX FAVORITE THINGS

Chosen by the designers at Wild Planet

RadioShack 10-Watt Handheld Powerhorn
Wild Planet's product design department uses the Handheld Powerhorn to summon a meeting's latecomers. While this tactic may sound a little harsh to outsiders, it's all done in the name of good, clean fun!

Hi-Tec-C Pilot Pen with 0.4 Tip These Japanese pens are highly sought after in many design departments, and guarded intensely at Wild Planet headquarters. Some of our finest designers claim "it writes and draws so well that it is therapeutic!" The highly pigmented, insoluble gel ink dries fast, doesn't smudge and has a super-fine point for drawing and writing precision. The pens are normally available only in stationery stores in Asian countries, but they've been known to pop up occasionally on websites like eBay.

Wild Planet's Spy Video Car We hate to toot our own horn, but the spy video car is a must for keeping office time interesting. A video camera attached to a remote-controlled car allows you to drive into top-secret territory without being detected. You can also see in the dark: infrared light illuminates real-time video transmitted to your headset's private eyepiece. Where was this technology when we were kids?

TiVo HD Series Three At $800, this technology doesn't come cheap, but it's truly awesome. The new TiVo records in HD, so not only can you watch your favorite shows at your leisure, but you'll see them at the same quality as if you were watching the program live, with movie-quality sound. TiVo keeps our designers in touch with pop culture, even when they're working late nights at the office.

Sharper Image Sound Soother 20 The design department is all about keeping a soothing, Zen frame of mind, even when hectic deadlines are looming. The high-quality speaker masks the office din and makes cube life a little less stressful as you listen to all-digital recordings of peaceful sounds like the rainforest, the ocean, a heartbeat, or chirping crickets.

Dimension BST 3D Printer This printer builds functional 3D models from the bottom up — one layer at a time. The use of ABS plastic ensures that the prototype models are durable, which, as you might guess, is pretty important. Affectionately named Hal 9000 by Wild Planet's design and engineering teams, the Dimension BST produces high-quality 3D forms in a fraction of the time it would take using conventional processes.

Founded in San Francisco in 1993, Wild Planet creates kid-cool products that garner parent approval. Wild Planet playthings focus on fun and imagination, and are available worldwide. Through Toy Opinion Panels and Kid Inventor Challenge contests, Wild Planet encourages children to invent, and then turns their ideas into real toys. wildplanet.com

Flex Your Plexus

Superplexus toy

$15 ebay.com
www.superplexus.com
en.wikipedia.org/wiki/superplexus

The Superplexus is a clear plastic handheld sphere the size of a head of cabbage. Inside, there's a crazy path — a series of ramps, tubes, chutes, and grooves — through which you must deliver a small steel ball by tilting the sphere. The goal is to get the ball to the end without having it fall off the path.

Along the route, you must pass 100 numbered points, each of which represents an obstacle to navigate. Every time I pick this up, I get immersed inside Superplexus' twisty 3D maze. I become the little steel ball. Despite having had this puzzle for over a year, I've never made it all the way to the end, but I'm not discouraged, because I've never gotten the feeling it's impossible to solve.

The Wikipedia article on Superplexus has a couple of cool concept sketches and prototype photographs, as well as inventor Mike McGinnis' notes on its design and history (he made the first prototype while he was in junior high school). You can learn even more about McGinnis' terrific puzzle at the Superplexus website. I'm astonished that it's no longer in production.

—Mark Frauenfelder

If You Can't Open It ...

OpenX clamshell box opener

$5 myopenx.com

You can hurt yourself opening clams and oysters, even if you have the right tool. I once jabbed the point of an opener in my palm trying to make oysters in the half-shell. You can also get hurt trying to rip open clamshell packages, the sealed plastic packaging that encases electronics such as batteries, flash memory, and game accessories.

Also known as blister-packs, these clamshells are frustratingly difficult to open, whether you use scissors or your teeth, and you wonder if the manufacturer ever intended you to open it. Another special feature of this packaging is that you can't reclose it. Not knowing this is part of the difficulty in opening them; I try to open them in a way that allows me to put the two sides back together when I should just shred the plastic.

OpenX is a special tool with two different blades designed to slice into and separate the two pieces of plastic so you can get to what you want inside. There's no disputing that OpenX works better than scissors or a kitchen knife, but the fact that I need a tool bothers me, even if it costs under $5. Then again, I wouldn't try to pry open an oyster without something other than my teeth.

P.S. David Pescovitz pointed out on Boing Boing the irony that OpenX arrives in a clamshell package.

—Dale Dougherty

Straws and Connectors

$15 constructiontoys.com/store/straws.php

Cheap toys that thoroughly entertain kids for longer than 30 seconds are rare. I find it impossible to keep children interested in pretty much anything for more than a couple of minutes, and that includes playtime. But Straws and Connectors are the exception to the rule.

Cheap, easy, and fun (no, not me), Straws and Connectors are awesome when you're stuck with twenty 5-year-olds on a rainy San Francisco day, praying for a break in the weather so you can boot their little hyper-hypo behinds out the door for five minutes of peace and quiet. They love this game.

It's also a team builder. There are lots of games the kids love to fight over, like Legos and puzzles. Kids have a tendency to get territorial over things, and it's completely normal. I have a great deal of respect and appreciation for any toy that encourages kids to work toward a collective goal, like building the tallest building in the world or the longest train on the tracks. It's heartwarming to see them work so hard to help each other find the right pieces. That's too cool for school. So cool that grown-ups love them, too. They're actually perfect for helping to think in 3D.

And if you want to go even cheaper, you can make your own set with a $1.99 package of drinking straws and some of those lil' mini potatoes ... or big, fat grapes. Your pick.

—Kristina Reed

By Michelle Hlubinka

MAGNETS

Playful, mysterious, surprising, they provide a creative force for many makers. A few magnetic playthings stand out in their field.

Shogun

boardgamegeek.com/game/2043

This game operates on a similar principle to Touché — except this time it's a variation on checkers rather than tic-tac-toe. As you advance, the number of spaces the piece can move on your next turn changes dynamically as a number between 1 and 4 swings into alignment over a hidden magnet.

Uber Orbs

uberorbs.com

These highly stylized super-duper magnets look like a pair of pets from another planet. An accompanying training manual includes special tricks you can have your orbs perform, such as leaps and wiggles and curious chirps.

One important caveat for households full of geeky gadgetry: orbs must not be allowed to sneak near any digital device. We store ours on a low bookshelf among our Clarke and Dahl paperbacks.

Touché

boardgamegeek.com/game/2763

In this suspenseful variation of tic-tac-toe, magnets flip some markers' loyalties from white to black, or black to white. I found this at a yard sale in Jamaica Plain, Mass., en route to a housewarming party. Soon after arrival, I had a roomful of twenty-somethings oohing and aahing as I and my opponent took turns gingerly placing our pieces on the grid, never knowing which polarity would lay beneath our chosen square.

Polarity

boardgamegeek.com/game/380

In this unique game, players float magnetic discs off other nearby discs' fields. It intrigues. It frustrates. Half an hour into the game the sudden jumps — as nearby pieces snapped together — still startled us.

Busy Bugs Music Box

schylling.com

Wind it up, and two cheerful, wobbly ladybugs spin around the top, guided by magnets just beneath the surface, creating a delightfully erratic dance step. And you can even pluck one off, and its partner continues its joyful reverie, and nobody gets hurt. (This is great for the longevity of the toy, as a mechanically attached bug would be easier to destroy!)

Magnetic Play Theatre

makezine.com/go/theatre

This Czech mini-stage is the commercial, prince-and-princess version of a clever DIY project I first saw in an elementary school in St. Paul, Minn. In the homespun original, Mrs. T waved unseen magnet-wands below her stage to guide the kid-made magnet-mice around a small wooden set (made of a fruit crate).

Michelle Hlubinka is education and public programs manager at Zeum, an arts and tech museum for children, and owns more than 200 board games.

As Good As It Gets

The Great International Paper Airplane Book **by Jerry Mander**

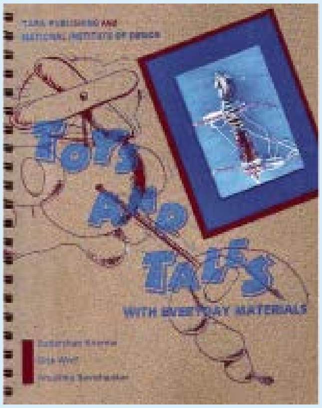
$3.29 and up, Simon and Schuster

When I was a kid, I'd bother my father all the time to steal office supplies. I knew that, in the momentous bureaucracy of his university, there were sheets of colored paper perfect for paper airplanes.

I must have folded thousands of them. If only I had known then of the existence of *The Great International Paper Airplane Book*, I could have stood on the shoulders of giants, jumped off, and flown farther.

Everyone from schoolboys to professional aerospace engineers participated in *Scientific American's* "First International Paper Airplane Competition" in 1966, and the variety and beauty of the final products is astounding. I'd bet that this book did more for innovation in aviation than any before or after it. This is the book for any maker's coffee table, a table hopefully covered in a pile of tax, insurance, and modern bureaucracy forms that are looking for a more important purpose. Take to the wing.

—Saul Griffith



How-to Tales

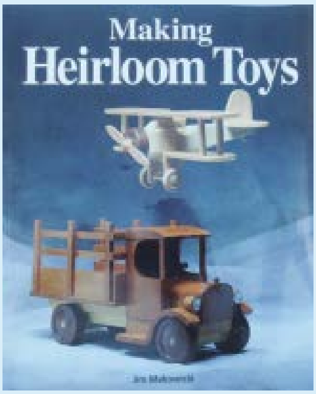
Toys and Tales with Everyday Materials **by Sudarshan Khanna, Gita Wolf, and Anushka Ravishankar**

$20, Hushion House, Tara Publishing

Written by professors at India's Toy Centre for Research, this book is inspired by folk and vernacular toys in India. Each project has a simple how-to for younger kids, a technical explanation for teens, and a short essay on the politics and sociology of play for adults.

Covered in brown paper with pasted-in project photos, it has a fun, homemade feel. Whether it's a section on practical joking or a snazzy spin toy used to show how wings work, it's a great book for getting kids interested in playing with materials and building things, and a wonderful resource for anyone interested in learning how to connect the things kids do with the workings of the world.

—Arwen O'Reilly



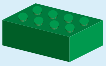
Not Disposable

Making Heirloom Toys **by Jim Makowicki**

$14, Taunton

Are there kids in your life who deserve better than those expensive, battery-powered, disposable plastic toys you find at the mall? *Making Heirloom Toys* is a serious woodworker's guide that seems like it was written by grandfathers for grandfathers (or grandmothers). This book presumes you already own and regularly use a lathe, router, and drill press. (If you don't, try *Riding Machines for Kids*, by Edward Baldwin, instead.) These are beautiful, small, indoor-rug toys with a focus on high-quality wood, construction, and durability, and tips on making age-appropriate design modifications. There's a refreshing emphasis on longevity and reuse. So go on: build any of these toys for a child you know, and prevent cheap toys from becoming landfill.

—Christy Canida


I have liked Legos ever since I was 4; before that, I was into regular wooden building blocks. It was like the next step for me. One reason I like Legos so much is that they let your imagination run wild. I cannot tell you how many countless hours my friends and I have spent building our own super-cool Lego armies and then fighting with them. Or maybe we build our own high-tech racing vehicles and then race them. We might even build our own spaceships and race, or fight, in space. We build sport fields and play Lego baseball, or have downhill snowboard competitions. Sometimes we play poker and bet with our Lego vehicles. I've liked Legos for a long time, and I hope they keep making them in cool sets like *Star Wars* and Harry Potter.

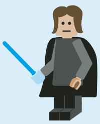
—Kindy Connally Stewart, age 11


I like Risk because, in the game, you can own different countries. It's fun to own places like Africa or China. It's been around for a long time so lots of people know how to play, so you can play with your grandfather. It gets you all worked up because it's about world domination.

—Emmett Mountjoy, age 11


I had teddy bears since I was zero. I really like them because they are cute and they are very soft. Me and my friends dress them up, and we play with them. We make up stories, and I imagine that I am in a forest and there are a lot of animals. I can use my other stuffed animals to pretend they are forest animals, too! I love them when I sleep with them, and I love them in the morning when I play. They help me with my feelings. I hug them when I am sad. I play with them when I am happy, and I squeeze them when I am asleep. Teddy bears are my best friend for always.

—Kiera Collins, age 6

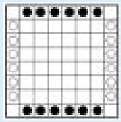

I love playing chess with our *Star Wars* chess set. It's a very exciting game with all my favorite characters. It is from *A New Hope* so it has R2D2, C3PO, Princess Leia, and more. Chess is one of my favorite games.

—Cassidy Mountjoy, age 8


Pac-Man is cool. I like it because you can eat up points and you have to get away from a light pink ball that will eat you up. I like to play it on the TV. There are little ghosts, and if you eat them, they give you points, but if they hit you from behind, you just lost a life. The Pac-Man figure looks like the circle from the book *The Missing Piece.* And that's why it's my favorite game.

—Oona Albertson, age 9

Lines of Action



Free wikipedia.org/wiki/lines_of_action

Try something new the next time someone questions your board-game skills by introducing Lines of Action (LOA), an abstract strategy game that two people can play with an ordinary checkers set. Apart from using the same board and pieces and being really easy to learn, LOA is nothing like checkers.

A game of LOA starts by setting up the board and picking your color. The object is to connect all of your pieces together sooner than your opponent, and there are only a few rules to remember: 1) you can move your piece in any straight line on the board, but only as many spots as there are pieces in that particular "line of action," 2) you can jump your own pieces but not those of your opponent, 3) if you land on an opponent's piece after a move, your opponent loses that piece and it gets removed from the board, and 4) you can't land on your own pieces.

You can read more about LOA on Wikipedia, but the best way to learn is by playing. Dig that old checkers set out of the closet and go challenge someone to a game!

—Matthew Russell

Barton Blum is VP of American Soil and Stone, and lives with his family and his seven sets of Battling Tops.

Christy Canida is a distracted biologist who builds things in Oakland, Calif.

Andrea Dunlap is a photographer and filmmaker for seedlingproject.org.

Ross Orr keeps the analog alive in Ann Arbor, Mich.

Joseph Pasquini is an avid amateur radio operator as well as a shortwave and scanner listener.

Kristina Reed is a kindergarten teacher in San Francisco by day, and a crazy Yelp reviewer by night.

Have you used something worth keeping in your toolbox? Let us know at toolbox@makezine.com.

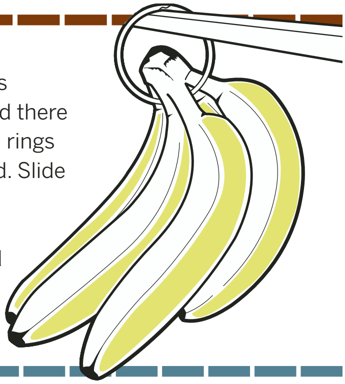
RENEW, REPURPOSE, ↻

FROM MAKER TO MAKER

Who doesn't appreciate a really good tip now and then? Especially the kind, as one reader put it, "that changes your life." Whether it's something as easy as getting permanent marker off your whiteboard or as clever as repurposing bathroom hardware to help ripen bananas, we all rely on our friends and neighbors to tip us off to what's new and good. *—Arwen O'Reilly*

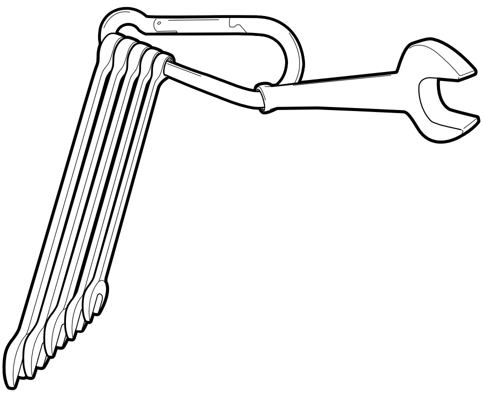
Banana Hacking

When Sarah and Daniel Drucker moved into their new apartment, chaos reigned. "After our first grocery trip, the kitchen counter was a mess and there was nowhere to put the produce. But there was a box of shower curtain rings on the bathroom floor. We used a hinged, circular ring that snaps closed. Slide the open ring between the stems at the top of a bunch of bananas, and close it around any accessible bar or hook where it can swing freely, so the bananas will ripen evenly. If the ring is closed all the way you should be able to yank a banana off the bunch without undoing anything."



Tools in a Jumble?

Corwin Hardham of Squid Labs suggests: "Try using a big carabiner as a cool means to store your box-end wrenches. The beener keeps all the sizes in order (or more precisely, you can keep them in order on the beener), and the whole mess clips to your belt for easy transport ... and for making more jingling noises than your high school janitor."



Have a tip for MAKE readers? Send to tips@makezine.com.

Lock It Up

Wendy Boswell, over at the Lifehacker blog, has a great tip for remembering your lock combinations: "Just add your birthday or other important date (the month, day, and last two digits of the year) to the lock combination numbers and write it in permanent marker on the back of the lock. No one else will have a clue what the numbers mean, and if you forget, all you have to do is subtract."
makezine.com/go/lockit

The Sharpie Incident

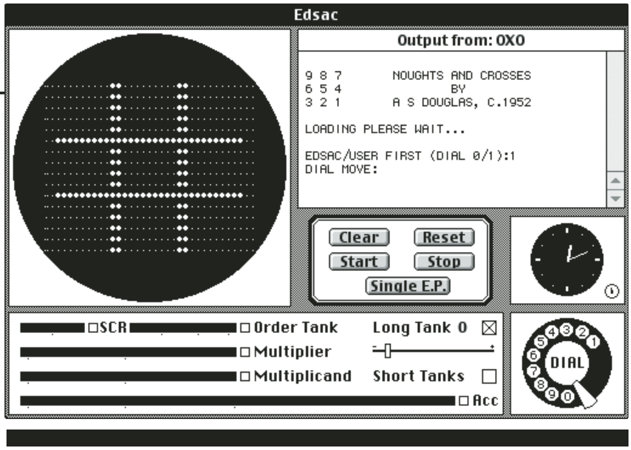
Now in my opinion, Sanford, the makers of Sharpie and Expo dry erase markers, haven't done enough to differentiate their products. It's all too easy when you're caught in the fire of a new idea to pick up that permanent marker and scrawl all over your whiteboard, only to find out afterward that no amount of scrubbing with the "eraser" will get it off. But wait, there is a solution! And it's easier than you think! Just write over the permanent marker with the dry erase marker, and your scrawl will disappear like magic. I first discovered this by accident, but there's a great post on wikiHow.com about it, too.
makezine.com/go/sanford

Illustrations by Tim Lillis

Gaming on the EDSAC and PDP-1

By Tom Owad

From the earliest computers came the first computer games.



The Edsac Simulator lets you recreate what may be the first computer game: *OXO*, a tic-tac-toe game written by a Cambridge University grad student.

Electronic Delay Storage Automatic Calculator (EDSAC).

DEC Programmed Data Processor-1. There's something in the names of these pioneering computers that suggests they may not be the greatest gaming platforms. Nonetheless, in between searching for prime numbers and analyzing elliptic curves, A.S. Douglas found time to write what may have been the first computer game. *OXO* was a tic-tac-toe game Douglas wrote as a demonstration for his doctoral thesis in 1952. The board was displayed on a 35×16 pixel CRT and allowed players to match wits with one of the earliest digital computers. Today, if you don't have the EDSAC in your garage, you can download Edsac Simulator (www.dcs.warwick.ac.uk/~edsac), which includes *OXO*.

The next well-known digital computer game came in 1962, when MIT's Stephen "Slug" Russell wrote *Spacewar* for the PDP-1. *Spacewar* was a two-player game in which the objective was to shoot the opposing spaceship and avoid being captured by the gravitational pull of a nearby star. User input was via switches on the front panel. Missiles and fuel were limited. A hyperspace mechanism allowed players to jump out of the paths of incoming missiles, but on the third hyperspace jump, your ship exploded.

Spacewar quickly became very popular and was eventually ported to countless mini and microcomputers. While the only remaining operational PDP-1 is at the Computer History Museum, it's still possible to capture the feel of the original by running on a similar 1970s minicomputer. Fred White has done just that with his Digital Computer Controls (DCC) D-116 and an old oscilloscope, which he exhibited at the Vintage Computer Festival East in 2004 in Burlington, Mass.

Oscilloscopes were commonly used as minicomputer displays, using a digital-to-analog converter card. White didn't have one, so he built his own using a Burr-Brown DAC7624. The board connects to the oscilloscope using three wires: X, Y, and intensity. *Spacewar* loads the X and Y registers with the desired position of the spot and then pulses the intensity line to make it light up. This can be performed a few tens of thousand times per second — enough to display several hundred pixels without flicker. If you'd like to read more about White's D-116 projects, visit d116.com.

In 1977, Cinematronics released an arcade version of *Spacewar*, faithful to the original. The hardware for Cinematronics' arcade system is emulated in the Multiple Arcade Machine Emulator (MAME), and with the proper ROM it's possible to play this early version of *Spacewar*. MAME is capable of creating a very authentic game-playing experience, and many enthusiasts have built custom controllers and arcade cabinets to house their MAME PCs. Original *Spacewar* arcade machines may be impossible to find, but with some craftsmanship and MAME, it's possible to create a reproduction with all the tenor of the original.

+ More information on Cinematronics' version of *Spacewar* can be found at mameworld.net/maws/romset/spacewar.

Source code to the original 1963 version of *Spacewar* can be found at applefritter.com/spacewar.

See photos of Fred White's D-116 at d116.com.

Tom Owad (owad@applefritter.com) is a Macintosh consultant in York, Pa., and the editor of applefritter.com. He is the author of *Apple I Replica Creation* (Syngress, 2005).

AHA! Puzzle This

By Michael H. Pryor

MAKE's favorite puzzles. (When you're ready to check your answers, visit makezine.com/08/aha.)

Gold Chain

A man has a gold chain with seven links. He needs the service of a laborer for seven days at a fee of one gold link per day. However, each day of work needs to be paid for separately. In other words, the worker must be paid each day after working, and if the laborer is ever overpaid he will quit with the extra money. Also, he will never allow himself to be owed a link. The laborer will keep the links he is paid in his pocket until the end of the week.

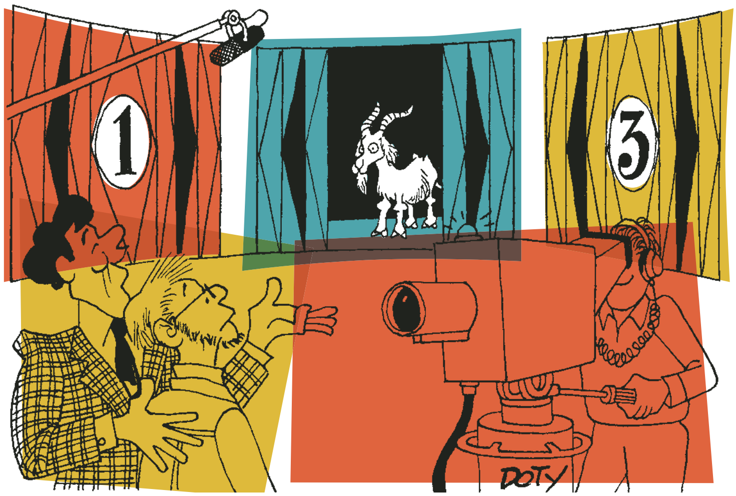
What is the fewest number of cuts the man can make to the chain to allow the laborer to be paid?

Monty Hall Problem

Monty Hall, host of the game show *Let's Make a Deal*, presents you with three doors. One door has a million dollars behind it. The other two have goats behind them. You do not know ahead of time what is behind any of the doors, but Monty Hall does.

Monty asks you to choose a door. You pick one of the doors and announce it to him. Monty then counters by showing you one of the doors with a goat behind it and asks you if you would like to keep the door you chose, or switch to the other unknown door.

Should you switch your choice, and if so, why? What is the probability of finding the million dollars if you don't switch? What is the probability if you do?



Chicken Nuggets

You can go to a fast food restaurant to buy chicken nuggets in 6-packs, 9-packs, or 20-packs. Is there such a number *N*, so that for all numbers bigger than or equal to *N*, you can buy that exact number of chicken nuggets using 6, 9, and 20 packs?

Illustrations by Roy Doty

Michael Pryor is the co-founder and president of Fog Creek Software. He runs a technical interview site at techinterview.org.

BLAST FROM THE PAST

Selections from the 1948 Union Hardware and Supply Catalog By Mister Jalopy

Old catalog provides glimpse of how modern civilization was built without laser levels or pneumatic nail guns.

THE POST-WORLD WAR II ECONOMIC BOOM

in Los Angeles required tools and materials to meet the latent demand for everything from housing to airplanes. Union Hardware sold it all. The 1948 Union Hardware and Metal Supply Catalog is a wonderfully illustrated peek into how things were done yesterday. Though some of the tools seem quaint, like a butter churn, there are some great ideas that are still applicable today.

Vaughan Vanadium Ripping Hammer

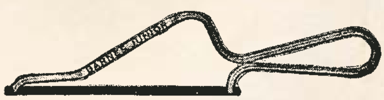
Certainly an elegant-looking hammer with the octagonal neck and white hickory handle, but what is vanadium? Thanks to Wikipedia, we learn the element vanadium (V, atomic number 23) is added to steel to create a rust-resistant alloy. And what about the wax hole? When hammering a nail into hardwood, the wood will sometimes split instead of yielding to the nail. Not surprisingly, there is an elegant old-world trick to avoid this problem: lubricate the nail with beeswax. Clever! As soon as I saw this picture, I immediately drilled a hole in a hammer handle to create a handy wax reservoir.

Hammer with beeswax reservoir, 1948..$3.00
Today's dollars..$23.51

VANADIUM, HICKORY HANDLE HAMMERS ARE AVAILABLE TODAY.

Barnes Junior Mini-Hacksaw

Instead of trying to unscrew a ridiculously corroded galvanized pipe elbow, professional plumbers will often gently cut the offending pipe off with a close quarter saw. With patience and attention, you can remove the old component without damaging the threads on the underlying pipe. I can't tell you how many pipes I have broken off in the wall before my hometown's best plumber gave me the killer tip. (Thanks, John!) I should have asked years ago. The trick is the very thin, very hard, and very sharp blade that makes a regular hacksaw look quite crude in comparison.



Mini-hacksaw, 1948..$0.41
Today's dollars..$3.21

AVAILABLE: $10.15 LENOX CLOSE QUARTER SAW FROM *amazon.com*

Mal-ette

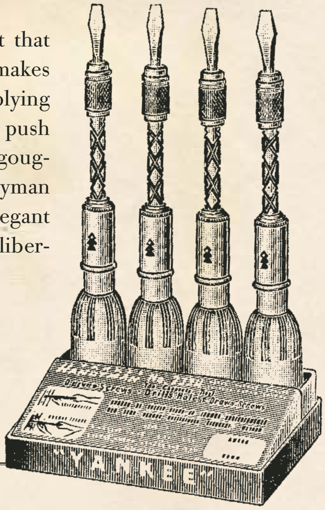
Besides the knockout graphics, this is a great idea! Rubber mallets take a heck of a beating as they are usually hammering something harder than the rubber head. Long before the handle wears out, the rubber face on a typical mallet is gnarled like a deformed walnut. It doesn't appear that the Mal-ette is currently manufactured, but I would buy one the day it becomes available!

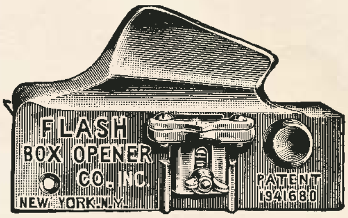
Rubber head for hammer
1948................................$.80
Today's dollars:.................... $6.27
Not currently being manufactured.

Yankee Handyman

As I own the Yankee Handyman, I can report that the ratcheting screwdriver is a concept that makes sense in theory alone. In my experience, applying adequate turning pressure is always enough to push the driver right out of the screw, resulting in gouging your work. However, when you fit the Handyman with the included drill bits, it is a remarkably elegant solution to drill perfect holes with the slow, deliberate precision that a hand-powered tool allows.

Push drill/ratcheting screwdriver
1948..$3.85
Today's dollars...............................$30.17
Not currently being manufactured; last manufactured by Stanley.





Flash Box Opener

Sure, there are box cutters available for pennies, nickels, and dimes, but they don't have an adjustable depth guide to keep from damaging the box contents. How often have you seen boxes of Cocoa Pebbles that have been cut with a blade? Smart!

Adjustable cardboard carton opener, 1948.......................................$2.01
Today's dollars...$15.75
AVAILABLE: $18.75 FROM *postagetape.com*

Note: "Today's dollars" prices (2004) were calculated based on CPI, using the handy and free NASA cost-estimating website at www1.jsc.nasa.gov/bu2/inflateCPI.html.

Paper Water Bomber

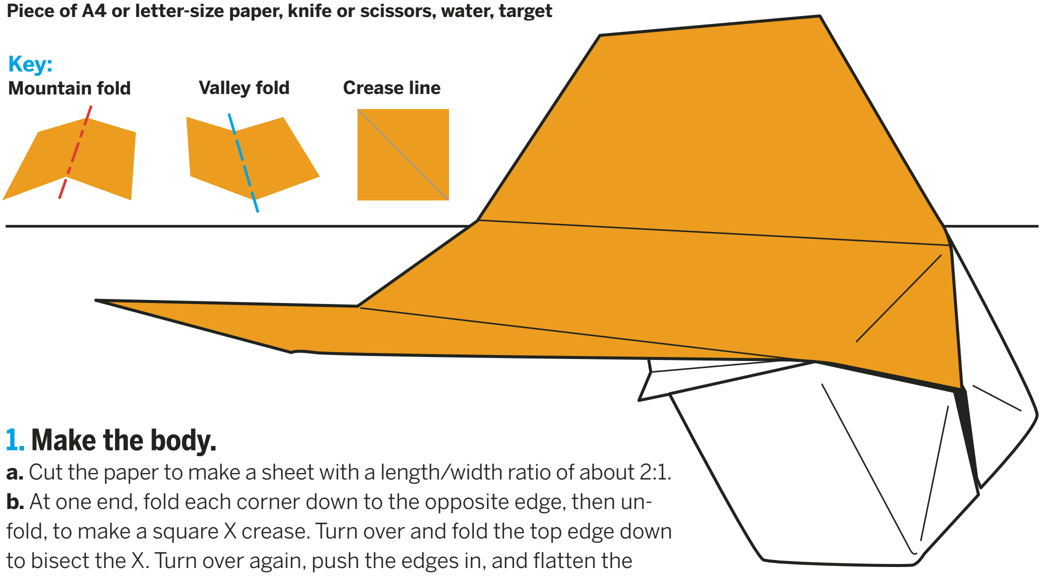
By Ewan Spence

Winged origami missile with front-load tank delivers wet payload.

You will need:
Piece of A4 or letter-size paper, knife or scissors, water, target

Key:

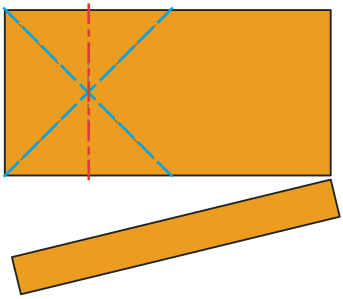
Mountain fold **Valley fold** **Crease line**



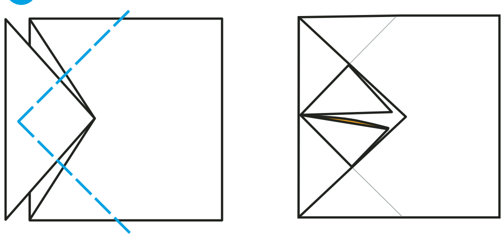
1. Make the body.

a. Cut the paper to make a sheet with a length/width ratio of about 2:1.
b. At one end, fold each corner down to the opposite edge, then unfold, to make a square X crease. Turn over and fold the top edge down to bisect the X. Turn over again, push the edges in, and flatten the paper so there's a point at the top.
c. Turn over, and fold the triangle down along its bottom edge. Fold each entire top corner down along the centerline and unfold just the back corners. Leave the front corners folded down.
d. Invert the crease you just made on the back corners, so they lie underneath and inside, making the top pointy again.

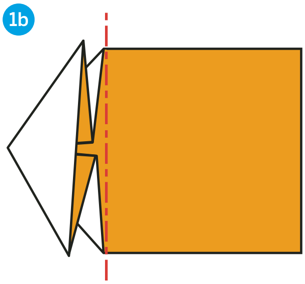
1a



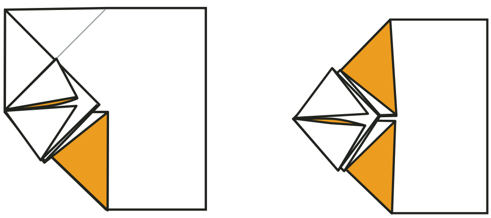
1c



1b



1d

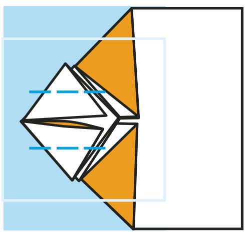


Illustrations by Gerry Arrington

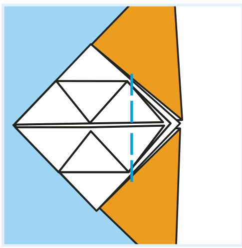
2. Fold the cargo bay.

a. Fold the side of each flap in front to touch the centerline.
b. Fold the bottom point of each flap up to touch the same point.
c. The tricky part: Fold the bottom points up again diagonally, and tuck them inside the pockets you made in the previous step (see 2d).
d. Fold each side corner of the diamond back to touch the centerline behind. Fold the top and bottom corners in front to touch the centerline. Unfold all four folds.
e. Crease the wings to line up with the edges of the cargo section.
f. Blow into the nose of your plane while gently pulling up to inflate the cargo section into a cube.

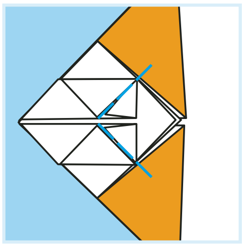
2a



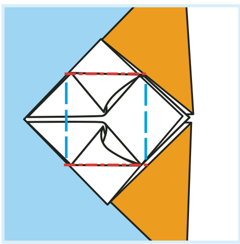
2b



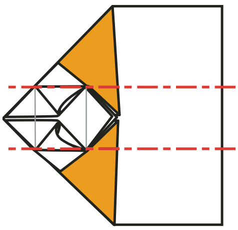
2c



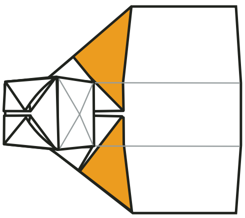
2d



2e



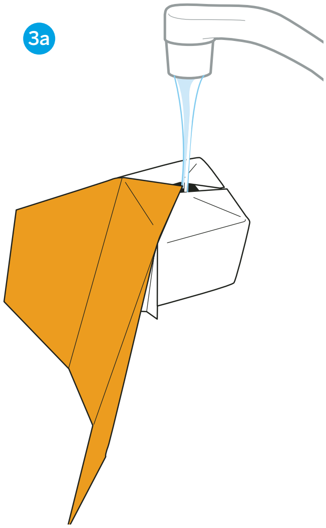
2f



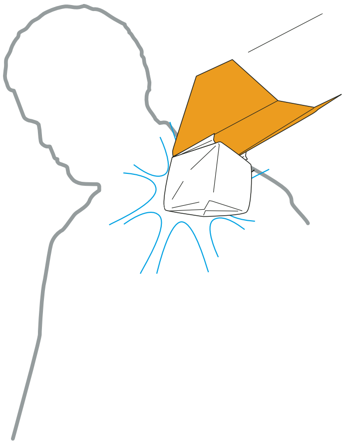
3. Bombs away!

a. Fill the cargo section with water, pouring carefully into the hole in front.
b. (Optional) Wait until no one is looking.
c. Chuck the bomb at your target or victim of choice.

3a



3c



Ewan Spence (ewanspence.com) is a podcaster, blogger, reporter, new media junkie ... generally a hoopy frood who's fun to be with.

READER INPUT

Where makers tell their tales and offer praise, brickbats, and swell ideas.

I'm sure a thousand people have already mentioned this, but in MAKE 07, on page 17, the penny-powered LED, there's a comment about older pennies working better, and it says you don't know why. I don't know the year offhand, but at some point the rising price of copper caused the mint to switch pennies to a copper-coated zinc core, instead of pure copper. Cut one in half, or more fun, hit one with a propane torch. By the way, unbelievably great magazine. Keep it up!

—Dave Schaum

I've been playing fangirl for MAKE. [My friend] and I met a 15-year-old at the dog park recently who is really into making potato guns (and his mom is very supportive, bless her, but he's going to try out marshmallows next because he's afraid of hurting someone). I suggested he check out the MAKE website for more fun projects. The next time I ran into him at the park, he told me that the MAKE site is "the coolest website I've ever seen." I had an extra copy of a MAKE quarterly in my car, so I gave it to him and he immediately started devouring it. It made me feel really good and I hope it does you, too!

—Becky Carella

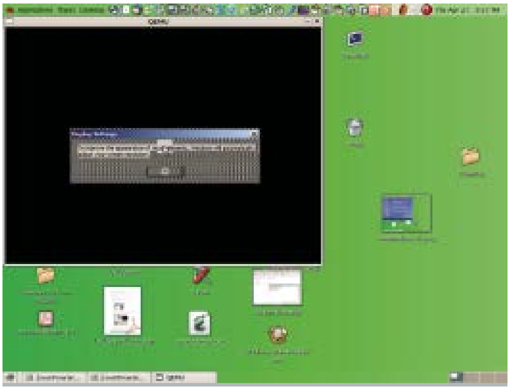
MAKE has reawakened my creativity. After seeing a blurb on a blog somewhere, I picked up my first copy and remembered just how much fun I had as a kid tearing things apart to see how they work. Since then, I've built several projects — including the spider gun and the cigar box guitar — and I've launched into several other things as well. MAKE gets the thanks for that, too.

—Andrew Setters

Just read the "Life Hacks" in Volume 07. Don't forget, XP [extreme programming] espouses pair programming. In my case I am lucky to have a great wife who sits with me and makes sure the unit tests pass....

—James Warfield

I just subscribed to your magazine and I wanted you to know it was because of your podcast that I did so. Although I'm relatively new to podcasting



This is in regard to pages 124–125 of Volume 06.
DUAL BOOTING? (sigh) ... There's a better way.
Emulators will run a guest OS without the need for repartitioning and re-installing anything. A good commercial emulator is VMware (vmware.com).
Us geeks, however, like a more free and open source solution, which is why I use QEMU (fabrice.bellard.free.fr/qemu).
It is my opinion that QEMU is superior to VMware, which could just be my open source bias, but I have used both and QEMU was better. I have included some screen shots of XP running on my Linux box thanks to QEMU.

—Rev. Martin S. Murphy

I really love what your team is doing. Thanks for the mind candy.

—Howard Horkey

So having seen MAKE before and finally deciding to pick up an issue, I was pleasantly surprised to see that it's published by O'Reilly. I have been a fan of your computer books for a while now, and thus, my expectations were high. In almost every way, as I read through the issue, those expectations have been met. I have, however, one complaint.

There are one or more websites listed for each project. I plan to visit them all at a later time. But nowhere can I find a card where all of the sites are listed for me. I will now have to go back to each article and write down the sites that I want to remember for later. Is it critical? No. Will it prevent me from reading the magazine again, and probably subscribing? Not in the least. Will it prevent me from trying anything? Absolutely not. Will it bug me a little bit? Yeah. Providing the directory (in a tear-out card would be even better) would make it easier to go online after reading a few articles instead of having to jump to the computer after each article to note the website.

This magazine is everything that I expect from an O'Reilly product. It's extremely well-written (even if I do find myself a bit over my head sometimes, but as a perpetual beginner, I have gotten used to that with your materials, as I find them written to appeal to users of all levels) and enjoyable. It is a perfect way to sit down and spend a few quiet hours, planning ways to spend some not-so-quiet ones later in the week. I look forward to future issues.

—Justin Meyer

Editor's Note:* We thought Justin's idea was a good one, and would be even better if it was online and the links were already live. So now, every URL mentioned in each issue of MAKE is available on one page. For this volume, go to makezine.com/08 and click "View a list of all links referenced in this volume" near the top of the page. *Thanks, Justin!

I really enjoy MAKE but I do have a gripe.

You publish electronic projects without including schematics. Why? Do you think your readers are "dumb" and wouldn't understand? I don't think that is the case. In the latest issue [Volume 06], on page 155 you almost get it right. Almost. Why the pictorial of the LED?

On page 81, "Build Your BeamBots," you have some great macro photography pictures. If they had been annotated with part names and had an included schematic, it would have been *much* better. In my mind I can see little markings on the pictures like "U1," "U2," "R1," and "C4" in nice contrasting colors. On page 85, you could have used a real technical drawing of a TO-92. Take a look at: fairchildsemi.com/ds/2N/2N3904.pdf. It is right on the first page. I hope (expect?) that any transistor manufacturer would let you use their drawings if you asked to.

Please keep up the good work. I will continue to subscribe (even if you don't take my suggestions <sigh>). Even go monthly (insert an <evil grin> here, because I think I have a grasp of how much work *that* would be).

—Louis Taber

Editor's Note:* Louis is right. Schematics are important and we're starting to include more of them in the issues, and online if we're tight on space. Be sure to check the corresponding webpage to all projects and DIY articles for extra information, possible corrections, and more illustrations. *Thanks, Louis!

MAKE AMENDS

On page 17 of Volume 07, the "Penny-Powered LED" article implied there was zinc on the outside of the dimes, when in fact there isn't any zinc on the exterior surface of any U.S. coins — it's all nickel. Zinc is too soft and reactive, but there is still enough potential between the nickel and the copper to make a battery. It would, however, work better with zinc.

In Volume 07, the "Home Molecular Genetics" article contained a few errors:

• The batteries shown in the "Gel Box" illustration on page 66 should be shown connected in series, not in parallel. The text does explain setting the batteries up in series and should be followed.

• On page 67, in the "Prepare the DNA" section, the amount of running buffer should read "75 µl (3 droplets)."

• In the "Stain the Gel" section (page 67), the dilution ratio for 2.3% Methylene Blue should be 115:1.

• In the diagram on page 69, mineral oil only surrounds the reaction tube; the PCR reaction mix inside the tube is a water-based solution. See scq.ubc.ca/MAKE for a full discussion of the project.

In the "Tips, Tricks, and Traps" section on page 74 of the "Hack Your Plants" article in Volume 07, the fifth bulleted item should express degrees in Fahrenheit, not Celsius. The sentence should read: "Keep your scions cool. 'Dormant scion wood — stems from pear, apple, peach, cherry, and other trees — is best stored between 30 and 38 degrees [Fahrenheit].'"

In Volume 07, page 92, the direction of rotation of the pulleys is incorrect in the "Two-Can Stirling Engine" article. A corrected PDF of the page is available for download at makezine.com/images/07/p92new.pdf.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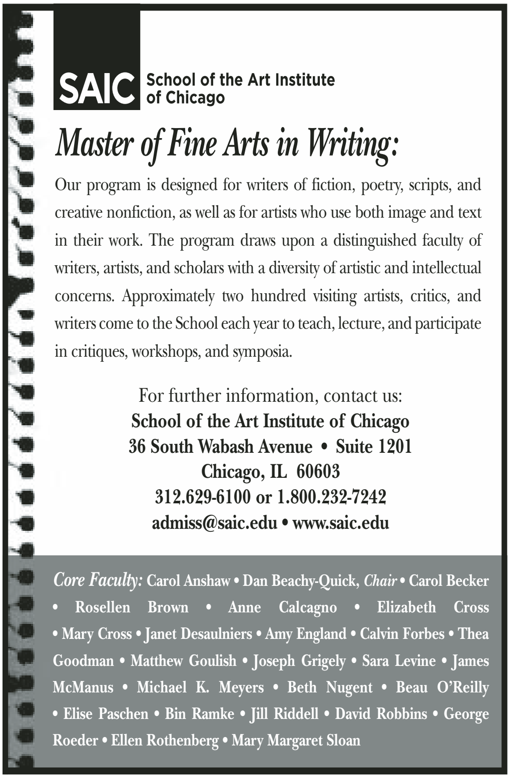
1-866-61-FIXIT iFixit.com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Making It

How I went from cubicle slave to full-time maker.

By Mikey Sklar

THIS ARTICLE SHOULD PROBABLY BE called "Making It Out of IT." I spent the last ten years as a Unix admin in IT, and now I'm out. I climbed the ridiculous corporate ladder to the highest technical position that I could reach. I rode my bike to Wall Street each morning and back home to Williamsburg, Brooklyn, each evening. This commute provided a fleeting feeling of freedom that would end once I arrived at my cubicle. I did collect a large paycheck, but it came with strings attached, of course.

I crammed my evenings with the things that I wished I had the time to do during the day. As my interest in IT wavered, a love of electronics emerged and occupied my nights. I wanted to make circuit boards, program microcontrollers, and design gadgets of questionable usefulness all the time. I was no longer interested in writing high-level-language Perl scripts that monitored things I cared little about. I wanted to work in the physical world, and the IT gig was clearly not the way.

Unsure where the road away from IT led, I quit and made my first unemployed decision. My new goal: connect microcontrollers with some force from nature. I chose fire. Looking around my apartment, I realized that it was time to expand. Sure, I could make wearables and mess with RFID implants in my apartment, but imagine what

Photography by Wendy Tremayne

I could do with real space and low rent!

Just two weeks after leaving my IT job, I left New York City and its high cost of living for a piece of the New Mexico desert. Here I planned to work with metal, fire, and electronics. I became a full-time maker living in a town full of artists in the desert. For the trade, my rent in New York ($3,220 per month) secured me a great house ($78,120 including closing costs), space to work, and freedom to make, build, or invent whatever came to mind, full time (12–14 hours of "work" per day) — with money to spare.

In the six short weeks after the move, my girlfriend and I designed and built *The High-Lighter* — a fire trampoline that demonstrates how to misuse common backyard items: a trampoline and a BBQ propane tank. A custom circuit board, an ultrasonic distance sensor, a solenoid valve, and many long nights of programming brought the trampoline to life. *The High-Lighter* shoots fireballs vertically based on how hard a person jumps on it.

I built in an RFID reader that responds to a tag I had implanted in my hand months before departing New York. The RFID reader adds an additional level of safety to the device (and gave me another excuse to use my implant) — if I'm not present, nothing works.

The High-Lighter's first performance was at the 2006 Maker Faire's fire show. It shared the stage with fire artists Lucy Hosking's *Satan's Calliope* and Therm's *Darwin*. Since then, I've revamped *The High-Lighter*: the flame ball is nearly three times its original size. Our next stop was Burning Man.

My future plans include building a workshop where I can teach people how to work with fire interactively via microcontrollers. But because New Mexico has been on high fire alert since I moved here in March, I've had to look at options that offer work that is more than seasonal.

Building environmentally clean buildings, growing food, and generating power are also calling to me. The desert environment is ideal for working with adobe, straw bales, rammed earth, papercrete, and used shipping containers. My LED work is likely to develop into indoor food-growing environments that offer year-round growing with minimal power draw. And all with no strings attached.

Mikey Sklar is an inventor in Truth or Consequences, N.M., who creates uncommercializable electronics with open source tools.

My fire trampoline, *The High-Lighter,* was part of the Truth or Consequences Fiesta, an annual parade and celebration that commemorates the town adopting the name of the popular 1950s game show.

RETROSPECTIVE

Barricelli's Universe

By George Dyson

And the evening and the morning were the fifth day...

At 10:38 p.m. on March 3, 1953, Italian-Norwegian mathematical biologist Nils Aall Barricelli (1912-1993) inoculated a 5K digital universe with random numbers generated by playing cards drawn from a shuffled deck. A viral geneticist with a background in physics, Barricelli was granted access to the computer at the Institute for Advanced Study (*see Make, Volume 06, page 190*) to investigate the role of symbiosis in the origin of life.

"A series of numerical experiments are being made with the aim of verifying the possibility of an evolution similar to that of living organisms taking place in an artificially created universe," he announced in the Electronic Computer Project's monthly progress report for March 1953.

These experiments were hosted by mathematician John von Neumann, who, after the success of the Manhattan Project at Los Alamos, decided that building a digital computer was next. "I am thinking about something much more important than bombs," he explained in 1946. "I am thinking about computers." He was also thinking about self-reproducing automata and the origins of life.

The Institute's computer was used for meteorological and other scientific problems during the day and ran bomb calculations for "the AEC boys" at night. Barricelli took whatever time was left. He often operated alone, without engineers in attendance. Though his log entries recorded the usual problems ("Something is wrong with the building air conditioner. One of the compressors seems to be stuck and the smell of burning V-belts is in the air."), he had an unusually high success rate, despite the running battle between coding and engineering. ("Code error! Machine not guilty!" and "Dr. Barricelli claims machine is wrong. Code is right.") Often he was still at work when the engineers showed up at dawn. "Machine worked beautifully. Off!" is his last entry in the early morning of May 31, 1953.

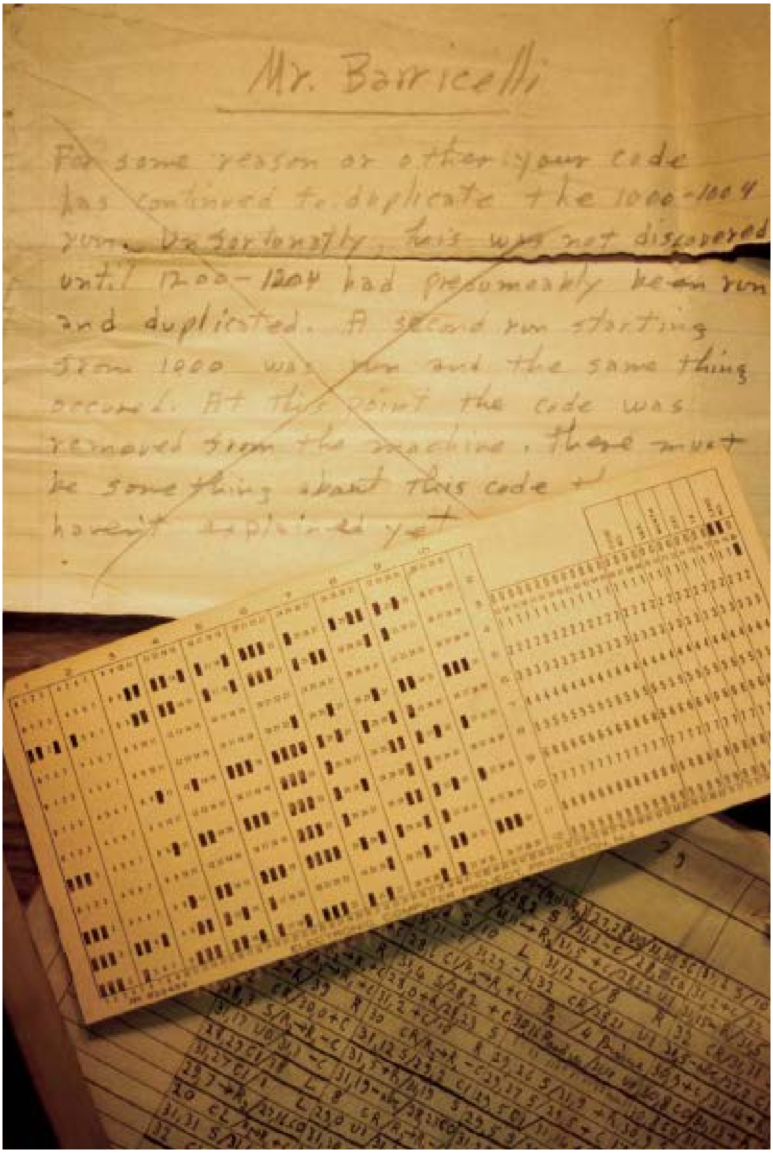
Barricelli's universe was designed to appear unbounded to any of its inhabitants. "The universe was cyclic with 512 generations ... and the code was written so that various mutation norms could be employed in selected regions of the universe," he explained. "Only 5 out of each 100 generations were recorded during reconnaissance. Interesting phenomena were then reinvestigated in more detail." These included symbiosis, incorporation of parasitic genes into their hosts, and fruitful crossing of gene sequences, which suggested sex.

"But," he reported in August 1953, "in no case has the evolution ... led to higher and higher organisms. Something is missing if one wants to explain the formation of organs and faculties as complex as those of living organisms. No matter how many mutations we make, the numbers will always remain numbers. They will never become living organisms!"

Two essential characteristics of real biology were missing: environmental diversity and the interplay between genotype and phenotype that allows Darwinian evolution to advance. "In 1954, new experiments were carried out," he reported, "by interchanging the contents of major sectors between three universes. The organisms survived and adapted themselves to different environmental conditions. One of the universes had particularly unfavorable living conditions, and no organism had been able to survive in that universe previously during the experiment." To make the leap from genotype to phenotype, he concluded, "we must give the genes some material they may organize and may eventually use, preferably of a kind which has importance for their existence."

"The distinction between an evolution experiment performed by numbers in a computer or by nucleotides in a chemical laboratory is a rather subtle one."

Barricelli spent much of the remainder of his life circulating among computer facilities in the United States and Europe, seeking the CPU cycles his numerical "symbio-organisms" needed to grow. "The distinction between an evolution experiment performed by numbers in a computer or by nucleotides in a chemical laboratory is a rather subtle one," he noted in 1962. He began to develop the functional equivalent of a phenotype by interpreting moves in



DIGITAL PALEONTOLOGY: Engineer's note, output card, and input code from a numerical evolution experiment run on the Institute for Advanced Study computer, ca. 1954. The note to Barricelli reads: "For some reason or other your code has continued to duplicate the 1000-1004 run. Unfortunately, this was not discovered until 1200-1204 had presumably been run and duplicated. A second run starting from 1000 was run and the same thing occurred. At this point the code was removed from the machine. There must be something about this code that you haven't explained yet."

Photography by George Dyson, courtesy of the Institute for Advanced Study

various board games, including chess, via a limited alphabet of machine instructions to which the gene sequences were mapped. The process mimicked the way that nucleotide sequences code an alphabet of amino acids to translate proteins from DNA.

"Perhaps the closest analogy to the protein molecule in our numeric symbio-organisms would be a subroutine, which is part of the symbio-organism's game strategy program, and whose instructions, stored in the machine memory, are specified by the numbers of which the symbio-organism is composed," he explained.

Barricelli's insights into viral genetics informed his understanding of computers, which in turn informed his understanding of the origins of the genetic code. "The first language and the first technology on Earth was not created by humans," he wrote in 1986. "It was created by primordial RNA molecules — almost 4 billion years ago. Is there any possibility that an evolution process with the potentiality of leading to comparable results could be started in the memory of a computing machine?" He titled his final paper, published in 1987, "Suggestions for the starting of numeric evolution processes intended to evolve symbio-organisms capable of developing a language and technology of their own."

RETROSPECTIVE

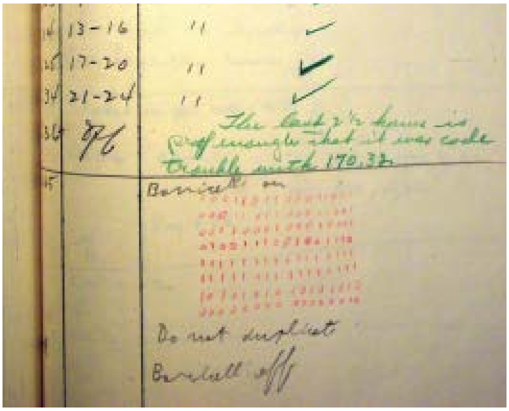
"Are they the beginning of, or some sort of, foreign life forms? Are they only models?" he asked. "They are not models, not any more than living organisms are models. Unless some other severe limitation is imposed by the conditions of the experiment or the type of universe in which the organism exists (computer, planet, or test tube), there is no a priori reason for assuming that other classes of symbio-organisms could not reach the same complexity and efficiency characteristic of living organisms on this planet." Barricelli knew this would take some time. "A question that might embarrass the optimists," he warned in 1954, "is the following: If it's that easy to create living organisms, why don't you create a few yourself?"

In November 2000, while excavating in the basement of the Institute for Advanced Study, I turned up a cardboard box abandoned since the shutdown of the computer project in 1958. The smell of burning V-belts still permeated a layer of black, greasy dust that had settled in the box. At the bottom was a carton full of IBM data-processing cards, accompanied by a note written on a half-sheet of disintegrated lined paper that identified them as "Barricelli's Drum Code." (A 2,048-word high-speed magnetic drum was added to the computer in 1954.) The box also contained three sheets of ledger paper filled with the original coding for the universe that was preserved, in a state of suspended animation, on the cards.

"Mr. Barricelli," the note read, "there must be something about this code that you haven't explained yet."

The note writer, an engineer, was right. Barricelli's numerical organisms had roamed an embryonic universe of $^1/_{200}$ of a megabyte, running at 16 kilocycles for an hour or two at a time. Fifty years later, we have only their fossilized imprint, confined to a box. What if they were brought back to life? What if they had continued to evolve? What if they had escaped?

At the same time as Barricelli's first announcement that "we have created a class of numbers which are able to reproduce and to undergo hereditary changes," a similar class of numbers — the order codes — had already taken root and seized control in the von Neumann universe. Order codes constituted a fundamental replicative alphabet that diversified with the proliferation of different metabolic hosts. In time, successful and error-free sequences of order codes formed into subroutines — the elementary units common to all programs — just as a common repertoire of nucleotides forms into strings of DNA.



MACHINE LOG, 22 NOVEMBER 1954. Barricelli's annotation "Do[es] not duplicate" indicates that the computer failed to duplicate and suggests hardware trouble. The note in green pencil reads: "The last $2\frac{1}{2}$ hours [without hardware trouble] is proof enough that it was code trouble with 170.32."

These were numbers that did things: they manipulated other numbers, represented text, modeled nuclear weapons, and made fortunes for IBM. They organized themselves into an expanding hierarchy of languages, which influenced the computational atmosphere as pervasively as the oxygen released by early microbes influenced the subsequent course of life. They formed collective structures such as operating systems, which now amount to millions of lines of code. They accounted for money, and so became money; they represented music, and so became music. They learned how to divide into packets, traverse the network, correct any errors suffered along the way, and reassemble themselves at the other end.

These numbers have infiltrated every facet of our existence and have now begun to form complex metazoan structures that are distributed across the internet. The search engines that allow us to collectively scour computers are allowing computers to complete their collective search of us. The barriers between their universe and ours are breaking down completely as digital computers begin to read and write directly to DNA.

Barricelli's universe is no longer confined to a box.

See more images at makezine.com/08/dyson

George Dyson, a kayak designer and historian of technology, is the author of *Baidarka*, *Project Orion*, and *Darwin Among the Machines*.

MAKER'S CALENDAR

Our favorite events from around the world
Compiled by William Gurstelle

2006 was a banner year for makers who love to join like-minded tinkerers to show off their projects and get ideas for new undertakings. Millions of people attend technology-centric events ranging from kinetic sculpture races to air shows to robotics conventions.

The Maker's Calendar editors maintain a database of hundreds of technology events, ranging from small and intimate specialist gatherings to gigantic affairs that exceed a half million people. And the database grows each month.

So how to decide which events to attend? Here MAKE's staff gives you their picks of unique and entertaining Maker Events for 2007. Some are extremely popular, so plan ahead.

Kinetic Sculpture Race

Cabin Fever Expo

Jan. 20–21, York, Penn.

An expo of men, metal, and machines. Exhibits include home shop machine tools, miniature engines, handmade vehicles, and similar creations. A model-maker's dream come true. cabinfeverexpo.com

Maker Faire

May 19–20, San Mateo, Calif. Other locales and dates TBA

At Maker Faire, 20,000 makers come together for a weekend of tech-centric projects, eye-opening demonstrations, and DIY fun. It's a celebration of the maker ethos encompassing exhibits, seminars, and hands-on opportunities galore. makezine.com

ITP Show

May and December, New York City

The Interactive Telecommunications Program Show is a 2-day exhibition of interactive and unusual sights, sounds, and objects from the student artists of ITP. itp.nyu.edu/show

Kinetic Sculpture Race

May 26–28, Arcata to Ferndale, Calif.

25,000 happy people converge on two small Northern California towns to watch builder-racers maneuver their elaborate human-powered kinetic sculptures across 33 miles of land, sand, muds, & suds. kineticsculpturerace.org

DEF-CON

Summer, Las Vegas

DEF-CON runs for several days and includes many computer- and hacking-related speakers as well as social events and contests. defcon.org

Experimental Aircraft Fly-In

July 11–15, Arlington, Wash.

The fly-in is a celebration of aviation technology featuring commercial exhibitors, forums, workshops, aircraft demos, and flypasts. nweaa.org

Speed Week

Aug. 11–17, Bonneville Salt Flats near Wendover, Utah

There's acceleration and horsepower galore when speed junkies bring everything from blown fuel streamliners to vintage Corvettes to the desert. scta-bni.org

The World Championship Punkin Chunkin'

November, Millsboro, Del.

Hundreds of punkin chunkers bring forth giant hurling and shooting machines to see who can fire a pumpkin the farthest. punkinchunkin.com

Important: All times, dates, locations, and events are subject to change. Verify all information before making plans to attend.

Know an event that should be included? Send it to: events@makezine.com. *Sorry, it is not possible to list all submitted events in the magazine, but they will be listed online.*

If you attend one of these events, please tell us about it at forums.makezine.com.

January 2007

Manitou Springs Fruitcake Toss

Jan. 6, Manitou Springs, CO

Hurling enthusiasts take note. A fruitcake toss is held at Manitou Springs Memorial Park near Colorado Springs, Colo., each January. Participants use mechanical devices such as catapults and oversized slingshots to rid the town of unwanted fruitcakes. manitousprings.org

Light in Winter

Jan. 26–28, Ithaca, N.Y.

Ithaca hosts a midwinter festival of science and art. This year's performers and presentations include NPR's Bruce Adolphe, *The New York Times'* Andrew Revkin, String Theory, Wine and the Mind, Birds That Roar, and more. lightinwinter.com

February 2007

Western WinterBlast

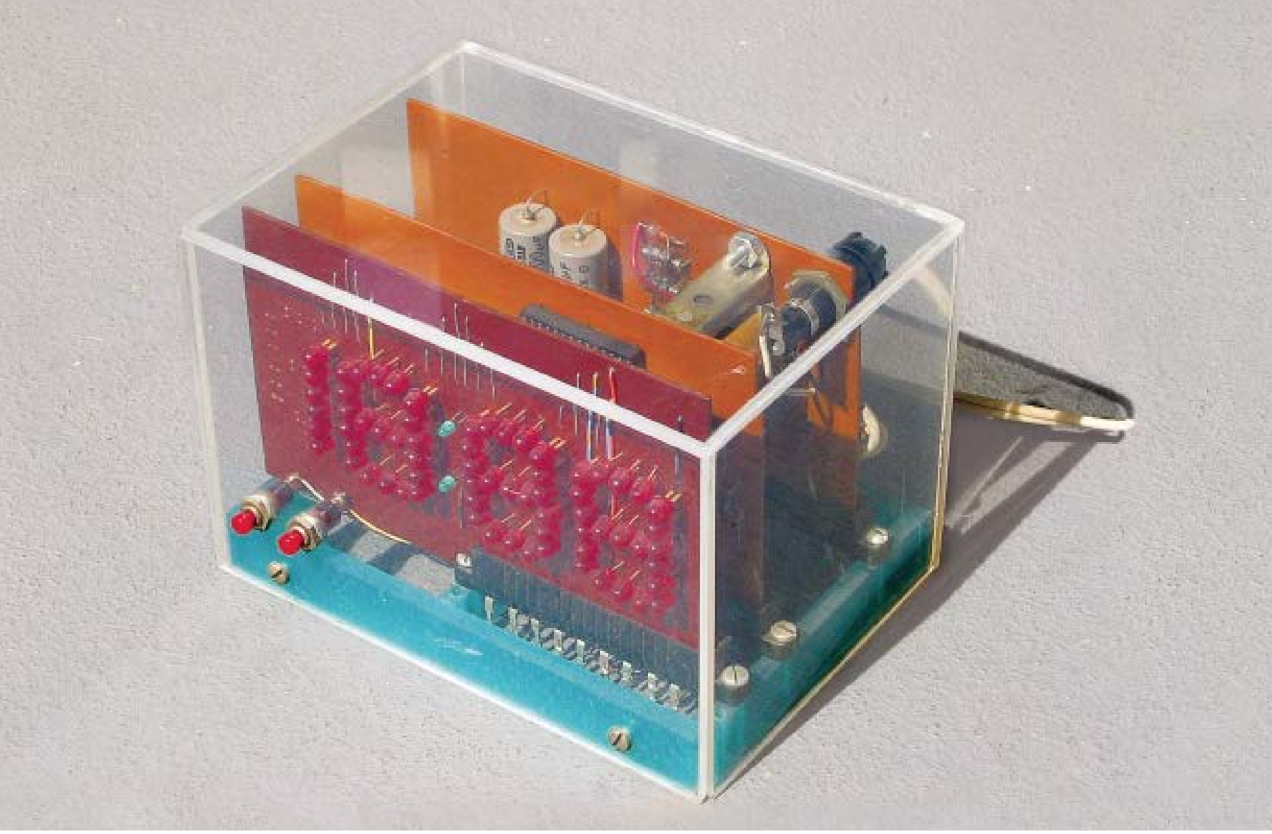
Feb. 16–19, Lake Havasu City, Ariz.

The Western Pyrotechnic Association's annual event is the premier pyrotechnic event of the winter. westernpyro.org

Engineers Week

Feb. 18–24, Nationwide

Engineers reach out and touch their communities with numerous events to increase awareness and appreciation of the engineering profession. eweek.org



HOMEBREW

My LED Heirloom Clock

By Blake Hannaford

In the summer of 1975, I had just completed a rigorous course in digital logic design and decided to build an LED clock to last the rest of my life. To start, I partitioned the design into three printed circuit boards: display, clock logic, and power supply. I bought copper-plated boards and ferric chloride at RadioShack, signed each card with my name and the date, and etched out the boards in the backyard of my parents' house. I bought discrete red LEDs from a surplus dealer; two green LEDs made the blinking colon between hours and minutes. The shop manager at Chicago's Institute of Design helped me cut out the plexiglass pieces for the case on a table saw. The clock's design mirrors Mies van der Rohe's famous Crown Hall, the building in which it took shape. I ordered the MM5313 clock chip (the closest analogy today to the power of that chip would be building your own 60GB video iPod) and power supply parts and was off to the races.

Since then, the clock's little green colon has blinked almost a billion times. The fuse I installed for safety has never blown; the capacitors in the power supply still seem to be fine. Nothing inside its plexiglass walls ever changes. Every three to five years, some of the segments begin to dim, so I remove the display board and clean the copper pads with just a pencil eraser.

Sometimes all that is required to keep the clock running smoothly is to pick it up a couple of inches and drop it. We all have our favorite old pieces of retro electronics, but how many have been powered up and working almost continuously for 31 years?

I recently came into possession of my family's heirloom grandfather clock. The owners of the clock have signed their names inside the front door in pencil, starting with John Gates, who built the clock in the early 1800s. I don't know anything about him, but presumably he bought the mechanism and built the clock with hand tools out in his barn — a process not really all that different from my own. I doubt that my clock will serve as long as the grandfather clock has, but the lesson is clear: when doing your next project, put your heart into it. Design it to last. Build it well. You will be glad you did.

Blake Hannaford directs the Biorobotics Lab at the University of Washington, Seattle.

Photograph by Blake Hannaford

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