BETTER PHOTOS: HOW TO USE LENS FILTERS P18

www.Drone360mag.com ▪ March/April 2017

drone360™

5 QUESTIONS WITH INSITU'S GREER CARPER

START RACING

WITH THE **BLADE CONSPIRACY 220**

PLUS

- A POCKET-SIZED DRONE
- ENTRY-LEVEL CONTROLLER
- AND MORE! P22

THE QUEST TO FIND **THE BEST BATTERY** P62

DON'T SHOOT!

THE TENSION BETWEEN GUN OWNERS AND DRONE PILOTS P48

ALSO INSIDE

DRONES **HELP SAVE** PRICELESS ARTIFACTS P54

INSIDE BNSF RAILWAY'S DRONE PROGRAM P36

UNFAIR ADVANTAGE? DRONES ON THE HUNT P42

From the publishers of *Discover* and *Astronomy*
Vol. 2 ▪ Issue 2

WE BUILD IT. YOU RACE IT.

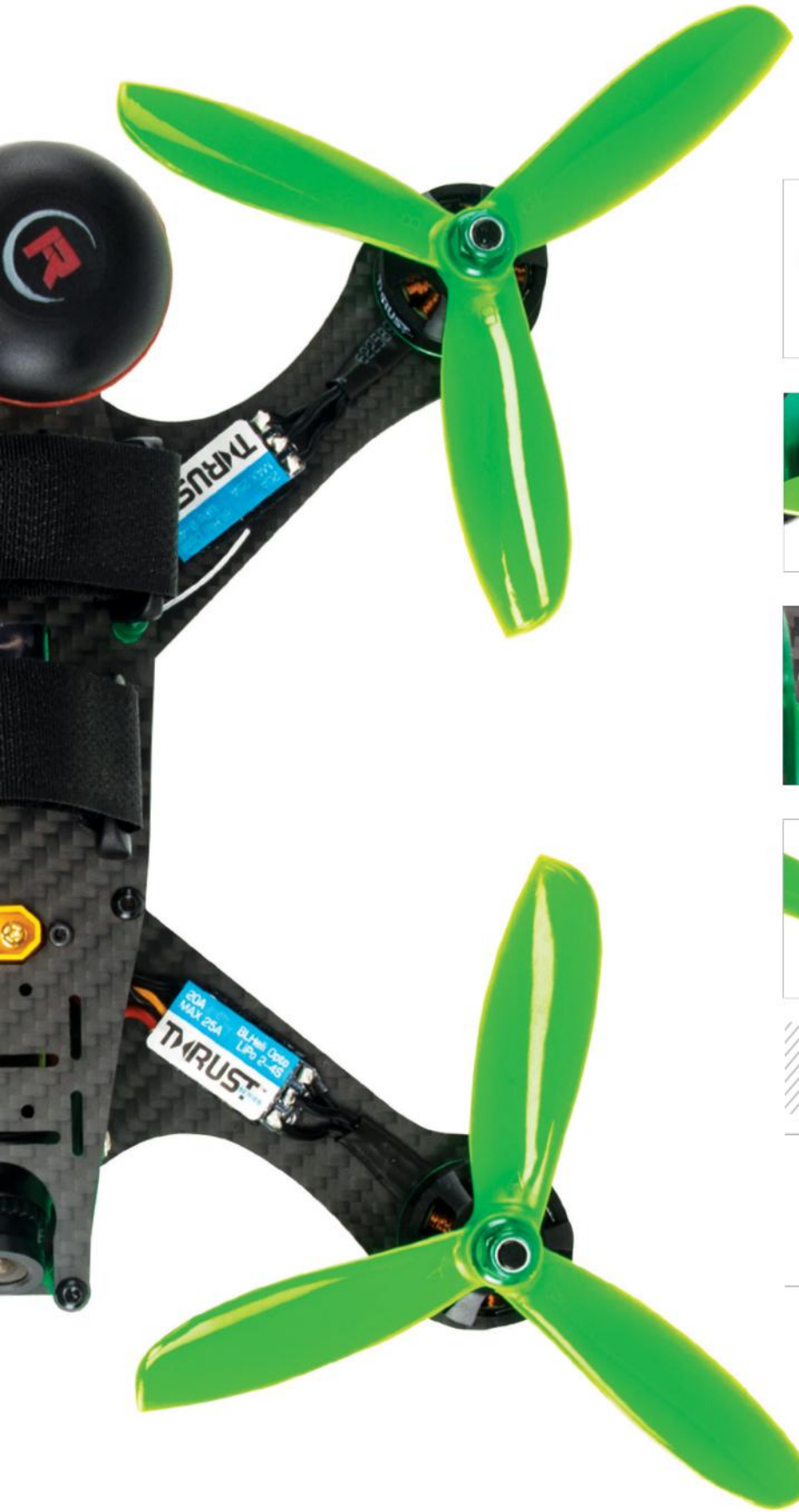
BLADE® CONSPIRACY™ 220 QUADCOPTER

FLIGHT READY ON DAY ONE

Racing FPV is a roller coaster thrill ride where you have control. Combining high speed with high performance, this is heart-pounding action at your fingertips and right in front of your eyes. With the Blade® Conspiracy™ 220 FPV Racer, everything needed is race-ready right out of the box. Fully-built and tuned, it rivals custom-build quadcopters. Powered by the Spektrum™ FC32 Rev 6 flight controller, you have the capability of fine-tuning each flight with Cleanflight software. The onboard 650TVL FPV camera and 200mW video transmitter (BLH02000EU - 25mW video transmitter EU) provide a clean and powerful video signal to compatible Fat Shark headsets. Additionally, the Thrust™ performance ESCs add a highly responsive feel and precision control when pushing the limits and racing for the finish line.

Find out more at
BladeHelis.com/Aircraft

facebook.com/bladehelis



FLIGHT CONTROLLER

Out of the box you get a professionally tuned FC32 (Naze32 equivalent) flight controller equipped with serial LEDs and a Beeper. Plus, adjustments are easy with Cleanflight.

MOTOR/ESC

Pre-flashed with BLHeli and ready to rip! These Thrust™ performance ESCs are more than enough for hardcore racing or freestyle of any intensity.

CAMERA

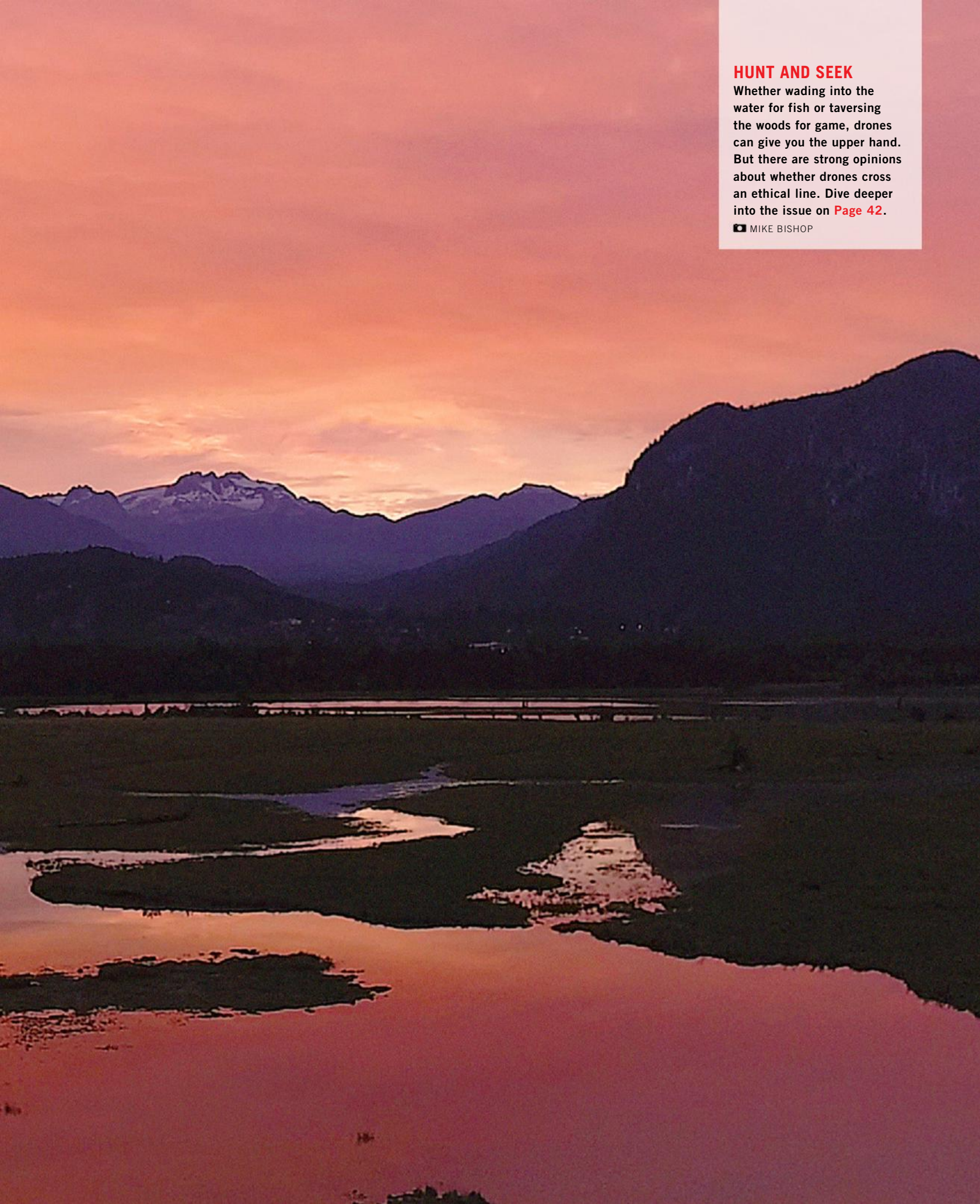
The gold standard in racing, the Spektrum™ 650 TVL CCD camera provides a clear view and is fully adjustable for any condition, day or night.

4MM TRUE CARBON FRAME

The true 4mm carbon fiber unibody frame makes for one heck of a strong chassis. It's designed to hold and protect all electronics even in the nastiest crash.

SAFE® AS3X® DSM X® BNF®
Blind-N-Fly® Ready to fly, redefined.

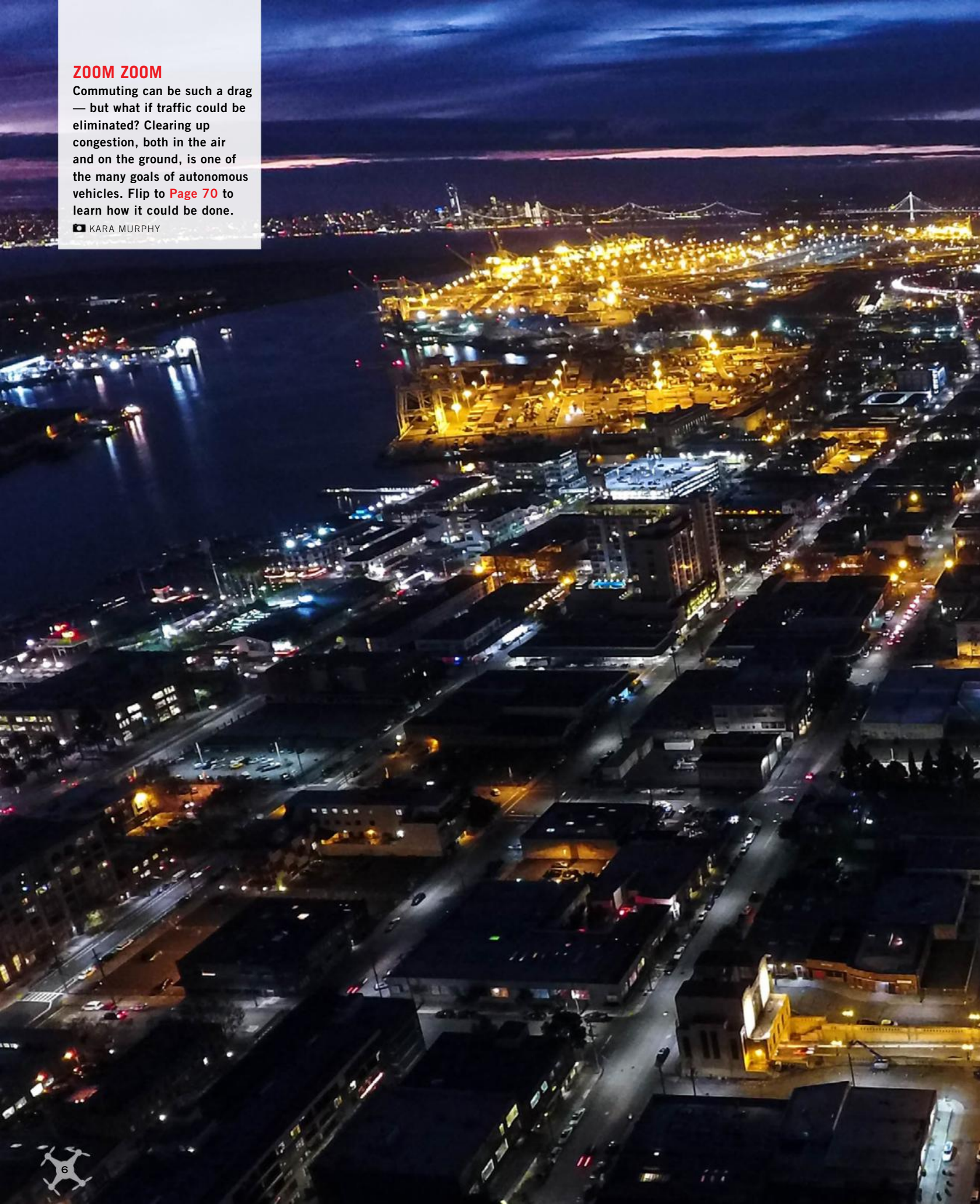
BLADE®



HUNT AND SEEK

Whether wading into the water for fish or taversing the woods for game, drones can give you the upper hand. But there are strong opinions about whether drones cross an ethical line. Dive deeper into the issue on Page 42.

MIKE BISHOP



ZOOM ZOOM

Commuting can be such a drag — but what if traffic could be eliminated? Clearing up congestion, both in the air and on the ground, is one of the many goals of autonomous vehicles. Flip to Page 70 to learn how it could be done.

KARA MURPHY

AERIAL ARCHAEOLOGIST

Behold! The Pyramid of the Sun! Not only are drones capturing stunning images like this, but they're also helping archaeologists unearth and preserve history. Find out more on Page 54.

VSI AERIAL, TRVLR

March/April 2017
Vol. 2 ▪ Issue 2

ON THE COVER
No need for tinfoil hats or Illuminati theories — the Blade Conspiracy 220 is for real.
HORIZON HOBBY

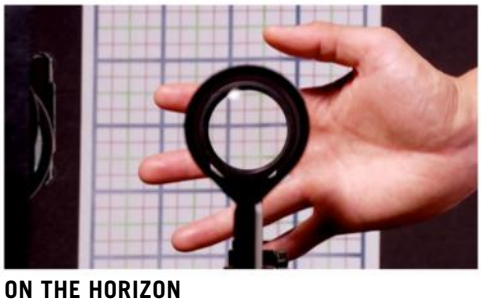
26 ZEROTECH DOBBY

DEPARTMENTS

Drone360mag.com

FEATURES

BEGINNING A NEW ERA
HAYLEY ENOCH



ON THE HORIZON
ERIC BETZ

THE MOST DANGEROUS GAME
LEAH FROATS

IN THE CROSSHAIRS

Ever been scared someone will shoot at your drone while out flying? The danger is real. Hobbyists and pros alike have to be aware of the risk, but also have to be drone ambassadors. Read our take on Page 48.

WILLIAM ZUBACK

THE FUTURE OF THE PAST

KATHLEEN FERRARO

INSIDE CHINA'S SILICON VALLEY

PATRICK SHERMAN

MINDS OF THEIR OWN

MATT WINDSOR

editor's welcome

UNANSWERED QUESTIONS

If you've paid any attention to the consumer side of the drone industry recently, you have probably witnessed some tectonic shifts. Perhaps the most public shakeup was the tooth-shattering reversal of fortune 3D Robotics suffered last year, resulting in 150 layoffs and expending nearly $100 million in venture capital with very little to show for it.

Parrot missed its fourth-quarter sales estimates by 15%, and announced in January that it would let go of one-third of its drone division — nearly 300 jobs.

Frankly, it's hard to compete in the consumer market when the biggest drone manufacturer, DJI, can slash model prices multiple times per year, while also introducing new hardware that comes in cheaper than similarly capable aircraft from competing brands.

This has led some to lament (or rejoice) that we've reached "peak drone" and that the popularity of consumer copters is on the wane. It's difficult to argue that the last two years have seen sales of drones rise with a ferocity that couldn't be sustained for an extended period of time. However, it's also worth noting that a lot of those sales figures were buoyed by cheap, expendable toy drones.

Perhaps we have surpassed peak drone and consumer sales will slow substantially. But I think that's an unanswered question. For those of us who are close to the drone industry, watching and living it, it's easy to think that drones have become mainstream, because we see them all the time. We can see the vast possibilities the technology holds.

The truth is that drones are anything but top of mind for the general public. Questions surround what drones are, what they look like, who uses them, and what they're capable of. They worry about a world of fewer choices.

We talk to people unfamiliar with the industry all the time — after all, it's part of our mission to inform and educate. And you'd be surprised how many conversations revolve around racing or something that someone saw on a hit morning show, but that's the extent of the knowledge.

"Oh yeah, didn't someone shoot one of those down with a shotgun?" was a question I recently fielded. "You shouldn't do that, right?" No, you shouldn't. It's dangerous and a federal crime.

And commercial drone use has just gotten started — none of us knows where it can lead. Of course, we are still in the early days of the new White House administration, and its disposition toward commercial drone operators is still very much up in the air.

For all we don't know, we do stand at an inflection point, and the developments in our drone tech today will help shape the world of this century and the next.

Timothy E. Kidwell
Editor

drone360

Editor
Timothy E. Kidwell
tkidwell@drone360mag.com

Chief Designer
Drew Halverson
dhalverson@drone360mag.com

Associate Editor — Website
Lauren Sigfusson
lsigfusson@drone360mag.com

Art Director
Thomas G. Danneman

Senior Graphic Designer
Scott Krall

Assistant Editor
Leah Froats
lfroats@drone360mag.com

Lead Illustrator
Rick Johnson

Editor-at-Large
Eric Cheng

Illustrators
Kellie Jaeger, **Roen Kelly**

Contributing Editors
Elisa R. Neckar, Carl Engelking

Photographer
William Zuback

Editorial Director
Diane M. Bacha

Production Coordinator
Cindy Barder

ADVERTISING

Ad Sales Representative
Dina Johnston
262-796-8776 x523
djohnston@kalmbach.com

TO SELL DRONE360 IN YOUR STORE:

Phone: 800-558-1544
262-796-8776 ext. 818
(Outside the U.S. and CAN)
E-mail: tss@kalmbach.com
www.Retailers.Kalmbach.com

CUSTOMER SALES AND SERVICE

800-533-6644
813-910-3616
(Outside the U.S. and CAN)

Customer Service
Drone360@customersvc.com

Digital
Drone360.Digital@customersvc.com

Back Issues
Drone360.SingleCopy@customersvc.com

KALMBACH PUBLISHING CO.

Senior V.P., Sales & Marketing
Daniel R. Lance

Vice President, Content
Stephen C. George

Vice President, Consumer Marketing
Nicole McGuire

Corporate Advertising Director
Scott Bong

Corporate Art Director
Maureen M. Schimmel

Director of Innovation
Jeanne Wieland

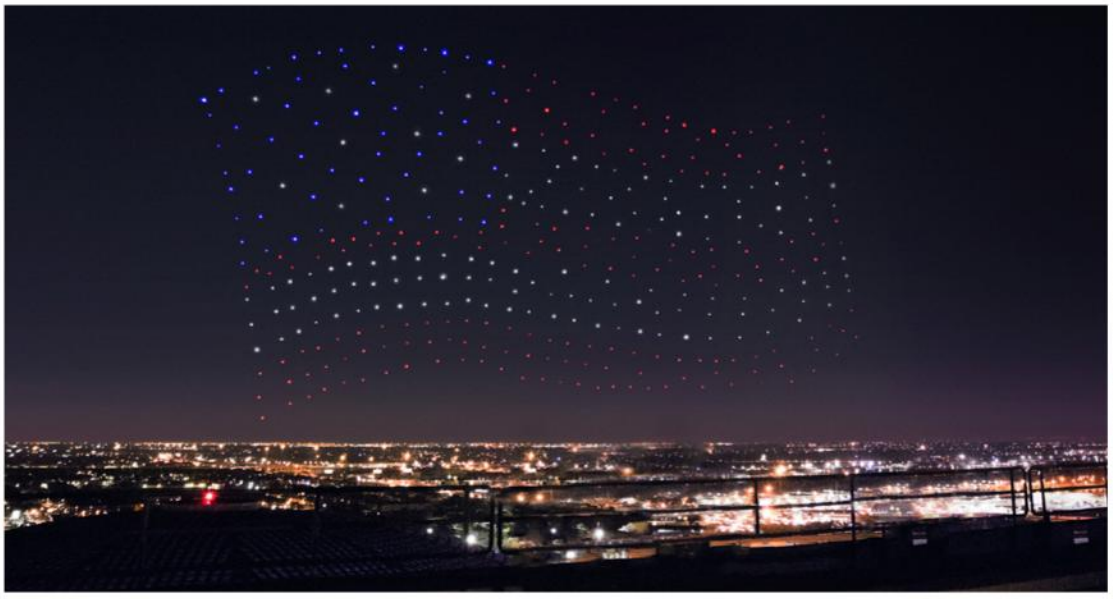
Art & Production Manager
Michael Soliday

Circulation Manager
Kathy Steele

Editorial phone: (262) 796-8776; advertising: (888) 558-1544; customer service & sales: (800) 533-6644; outside the U.S. and Canada: (813) 910-3616. Subscription rate: Single copy: $7.99. Subscription rates: U.S.: 1 year (6 issues) $24.99; 2 years (12 issues) $45.99; 3 years (18 issues) $64.99. Canadian and all other international subscriptions: Add $10.00 postage per year. Payable in U.S. funds, drawn on a U.S. bank. Canadian price includes GST, BN 12271 3209 RT. Not responsible for unsolicited materials.

KALMBACH PUBLISHING CO.

INTEL'S SHOOTING STAR DRONES LIGHT UP THE SUPER BOWL



What could possibly be more patriotic than 300 red, white, and blue Intel Shooting Stars as the U.S. flag?

DURING THE SUPER BOWL 51 halftime performance, pop superstar Lady Gaga sang "This Land Is Your Land" in front of a fleet of 300 Intel Shooting Star drones — considering the television audience of an estimated 111 million people, the performance marks the most mainstream, widespread public drone demonstration to date.

Intel's lightweight quadcopters briefly sparkled, swirled, and swarmed, eventually forming a somewhat pixelated semblance of Old Glory waving over NRG Stadium in Houston, TX. The drones were shown again after the full halftime performance, creating an aerial Pepsi logo and then rearranging themselves to form the Intel logo.

As news of the drone performance leaked the weekend of the big game, industry insiders speculated as to how the stunt would be executed — the FAA had announced a 34.5-mile radius of drone restrictions around the stadium. It was unclear if this included the impending drone swarm.

It turns out that the drone performance was only shown to TV audiences and was prerecorded earlier that week due to concerns about weather necessitating the closing of the stadium's dome, obstructing views of the drone light show.

We were rooting for you, Lily. We were all rooting for you.

LILY ROBOTICS CLOSES DOORS

In yet another major crowdfunding failure, the wildly popular drone startup Lily Robotics shut down operations in January. Despite $34 million worth of preorders from over 60,000 customers, the company was unable to produce a viable consumer product.

Many within the drone industry were skeptical of the Lily's promised capabilities — a commonality shared with other failed crowdfunded drones. The Lily was advertised as a throw-and-fly, waterproof, portable, auto-follow drone with 1080p HD video and 12MP stills.

Some of these features were displayed in Lily's promotional video, for which the now-defunct company is currently under added scrutiny.

The San Francisco district attorney sued Lily Robotics, alleging the company had intentionally misdirected customers about the drone's capabilities.

As of this writing, Lily has promised full refunds to its customers within 60 days of the company's Jan. 12 closing.

AIRPORT ENLISTS 3DR FOR EXPANSION PROJECT

On Jan. 10, design and engineering firm Atkins, 3DR, and Autodesk flew a Site Scan 3DR drone in Class B airspace over a parking structure for the Hartsfield-Jackson Atlanta International Airport (ATL) — the first such operation under new Part 107 rules.

The city of Atlanta commissioned Atkins to assist in expansions to the airport. In order to plan adequately for the construction of a new parking lot, Atkins brought in Autodesk and 3DR to create digital models of the area.

"At Atkins, we were particularly interested in leveraging 3DR's technology, because it allowed us to collect a great amount of accurate project data quickly, with no disruption to airport users," said Chris Harman, Atkins senior project engineer, in a 3DR web post.

The drone's flight team was required to communicate with the ATL control tower at all times and needed to maintain three visual observers throughout the duration of the flights. The team completed seven flights, capturing a total of over 700 images and covering over 40 acres of land.

According to a web post by Kevin Sartori, senior product marketing manager at 3DR, "Safety is always everyone's number one priority, but following right behind safety, the experience of passengers must be at the forefront of everyone's minds."

How many visual observers does it take to fly a 3DR quadcopter in Class B airspace? Well... three, apparently. Good to know.

CLOCKWISE FROM LEFT: INTEL, YOUTUBE/LILY, 3DR

FAA QUIETLY REVOKES CLOSED-SET EXEMPTIONS

On Nov. 14, 2016, the FAA posted a notice to the Public Register of a new amendment to current Section 333 exemptions for closed-set operations.

Under the previously established Section 333 framework, closed-set exemptions allowed for operations over people — this newly issued amendment revokes that allowance.

The FAA opted to not notify the individual operators and institutions that held this particular type of exemption of the changes, leaving many operators in the dark as to whether or not they are operating legally.

Operations over people are now, and indefinitey, held only by a very small handful of entities.

© ALEXANDER KOLOMIETZ / DREAMSTIME

Shutting down the sets

The notice opens with an explanation of why individual operators and companies holding Section 333 exemptions for closed-set operations were not personally notified of the change.

"The Federal Aviation Administration (FAA) has determined that good cause exists for not publishing a summary of the petition in the Federal Register because this amendment to the exemption would not set a precedent, and any delay in acting on this petition would be detrimental to the petitioner," the FAA said in the amendment.

UAS semantics

The primary 10-page document explains operations and restrictions in much the same way as standard Section 333 exemptions. The phrasing that signals the rule change is tucked into a footnote: "For the purposes of this exemption,

previously-issued exemptions for 'closed-set filming and television production' are considered 'aerial data collection' under this definition."

This change of wording is key. In the Section 333 era, closed-set operations were the only way for operators to legally fly drones over people.

Now, redefined simply as aerial data collection — a much more general exemption category — the ability to fly over consenting people not directly involved in the operation of the UAV has been revoked.

According to the FAA's publicly accessible Section 333 exemption database, 590 closed-set authorizations have been granted. NBC Universal, CNN, the University of Miami, Wild Rabbit Productions, and NFL Films are among the companies, institutions, and individuals affected by the change.

Coming in for the landing?

There is little reason to expect that the entities affected by the change will be receiving permissions to fly over people under the new Part 107 framework any time soon. CNN currently holds the only Part 107 waiver for "operations over human beings" — and even this waiver was a result of safety standards set forth through a Section 333 exemption.

Taking the closed-set Section 333 amendment into account, CNN's waiver makes it one of very few companies, organizations, or individuals that may legally fly drones over people under any circumstance. A small handful of companies that received one-year renewals on their Section 333 exemptions are also unaffected by the rule change.

Let me put you on hold

This amendment marks a significant step back in the FAA's progress toward a rule for widespread drone operations over people. The FAA announced its intent to release a Notice of Proposed Rulemaking before the end of 2016, but failed to meet that deadline.

In a speech at CES this year, FAA Administrator Michael Huerta was expected to give an update on the NPRM for flights over people. Instead, Huerta cited safety and security concerns related specifically to the operation of drones over people.

"We will be looking to our industry partners to develop more ingenious ways to ensure drones can fly over people without sacrificing safety or security," he said.

As of this writing, there is no word from the FAA on whether the NPRM is on indefinite hold, or when the drone community can expect its release.

Moving forward

Drone360 reached out to the FAA with questions on various aspects of the Section 333 amendment notice, including whether the NPRM was delayed and whether this notice sets a precedent for future rule changes made by the FAA, but the administration declined to comment on either topic.

As of this writing, President Trump's regulatory restrictions on government agencies also inhibit the FAA's ability to put out new rulemaking measures for drone operation.

The Commercial Drone Alliance, a non-profit group dedicated to supporting commercial drone end users, urges operators affected by this amendment to contact the FAA directly to ask for a restoration of their operational permissions.

5 questions with

INSITU PRODUCT MANAGER GREER CARPER

1 HOW DID YOU GET INVOLVED IN THE WORLD OF UNMANNED VEHICLES?

I wish I could tell you that I flew R/C aircraft from a young age and I've been tinkering with them ever since, but that's not the case. I've spent most of my career in the defense sector, and my first involvement with unmanned vehicles was with the U.S. Army's Future Combat System — a large modernization program that included both unmanned aircraft and unmanned ground vehicles.

Over the years, I've worked on military and commercial unmanned systems from ones that fly in the air to those that float on the sea. It's the incredible rate of technology change for unmanned systems that keeps it exciting.

2 IF YOU COULD IMPROVE ONE BIT OF UAS TECH WITH A SNAP OF YOUR FINGERS, WHAT WOULD IT BE?

I'd love to see low-cost video encoders that offer low enough latency to be viable in FPV drone racing. Analog is still king for the pilots but leaves much to be desired as a spectator.

3 PUT YOUR FUTURIST'S CAP ON AND THINK 10 YEARS DOWN THE ROAD: WHAT DOES OUR AUGMENTED AND MIXED-REALITY WORLD LOOK LIKE?

In 10 years, I think we'll find augmented reality will simply be a part of our lives in subtle ways. There's a great example of this in the book *Ghost Fleet* by P.W. Singer and August Cole. In it, the use of mixed reality minimizes the likelihood of *faux pas* in social interaction by combining facial recognition with social media searches.

I think it's safe to say we've all been there — we forget someone's name or struggle to remember where they're from, and then we discretely pull our smartphones and attempt to ascertain the desired information.

It's these innocuous situations where we'll see the most impact, although a part of me hopes I'm completely wrong and we get something similar to the Metaverse out of Neal Stephenson's *Snow Crash* novel.

IN 10 YEARS, I THINK WE'LL FIND AUGMENTED REALITY WILL SIMPLY BE A PART OF OUR LIVES IN SUBTLE WAYS.

4 YOU'RE A SUPER-FAN OF ONLINE GAMING. WHAT'S YOUR FAVORITE GAME AND WHY?

I love playing the *Battlefield* games by EA DICE, most recently *Battlefield 1*, a World War I first-person shooter. *Battlefield* games are known for their sandbox environment where players choose their roles, from a soldier on the ground to a pilot in the air. *Battlefield 1* is particularly compelling in that it takes place in a world undergoing rapid technological change. It was literally the biplane era back then, and I love playing as a gunner shooting down rival aircraft in intense dogfights.

5 BEST MOMENT INVOLVING A DRONE?

Definitely my best moment was giving my dad a drone and watching him fly it around for the first time. As a teenager, my dad got his pilot's license before his driver's license. However, as an adult, he lost interest in flying aircraft. I felt I was rekindling something in him that was previously only a distant memory — and that was pretty awesome. 360

Then and now: Greer Carper thanks the Cyberathlete Professional League organizers for putting on a great event at the Summer 2007 Championships in Dallas, TX. (Left) As Inexa Control product manager, Greer (in plaid) develops technology to improve drone control. (Right)

GREER CARPER (1), INSITU; OPPOSITE: JEREMY PHILLIPS/INSITU

GREER CARPER

INSITU
PRODUCT MANAGER FOR INEXA CONTROL

Greer has worked for Boeing and its various subsidiaries for more than 10 years, guiding research and development projects for unmanned and autonomous platforms. At Insitu, he determines product strategy and develops new products for the Inexa Control ground station software. He lives in northwestern Oregon.

Babcock State Park's Glade Creek Grist Mill (it's fully operational!) is one of the most photographed locations in West Virginia. Walter put a PolarPro ND64 filter on his DJI Phantom 4, allowing him to drop the shutter speed and get that silky texture with the whitewater.

Demystifying lens filters

Adding this bit of glass to your drone kit can take your aerial photos and videos from "meh" to magnificent

Story and photos by Walter Scriptunas II

One of the best accessories you can purchase for your drone is a quality set of lens filters. Lens filters can help protect your camera lens from debris while you're flying, but just as importantly, a properly used filter can turn an average photo into a spectacular, eye-popping image with no editing required. They can add more flexibility when recording video, too.

Filter basics

A neutral-density (ND) filter is the most common type of filter for aerial platforms. Typically colorless or gray, ND filters reduce the amount of light entering the camera. The majority of drone cameras currently on the market only come equipped with the option of changing ISO (the camera sensor's sensitivity to light) and shutter speed. This means that in order to avoid overexposure on bright days with your standard drone camera, you must increase its shutter speed. Since ND filters restrict the amount of light entering the camera, you can still shoot on low shutter speeds on sunny days.

You can also create motion blur with an ND filter. Let's say you're photographing whitewater rapids or a waterfall. You can attach the ND filter to your camera and set the shutter speed to a slower setting than you normally would for daylight conditions. The filter lets the shutter stay open longer without overexposing the image, and the water takes on a more artistic, ghostly appearance. While it is possible to capture longer exposures without an ND at dusk or dawn, when ambient light levels are at their lowest, a filter will give you more opportunities to create images in brighter light.

Similarly, using an ND filter while shooting video can help you achieve smoother recordings. We've all been out shooting during the day and when we look at the footage, it's all jumpy and jittery, especially in the turns. Again, applying an ND filter limits the amount of light entering the camera, reducing the visibility of moving objects and the depth of field.

Another popular filter option is a circular polarizer (CP): CP filters can darken skies and reduce glare from polarized light reflecting off non-metallic surfaces like water or trees. Without getting too deep into the science of it all, a you orient the filter so that its polarization will negate the light from direction it is reflected. When oriented correctly, the CP lens will filter out polarized light — rendering skies darker, emphasizing clouds, deepening color tones, and sharpening landscape details.

Something else you might run across while shopping are UV and haze filters. Don't be duped into thinking that these will help improve your photo or video clarity. In reality, they're glorified lens protectors, and if you're using a DJI Phantom, you already have one installed on the drone's camera at the factory. Use your money to buy ND filters instead.

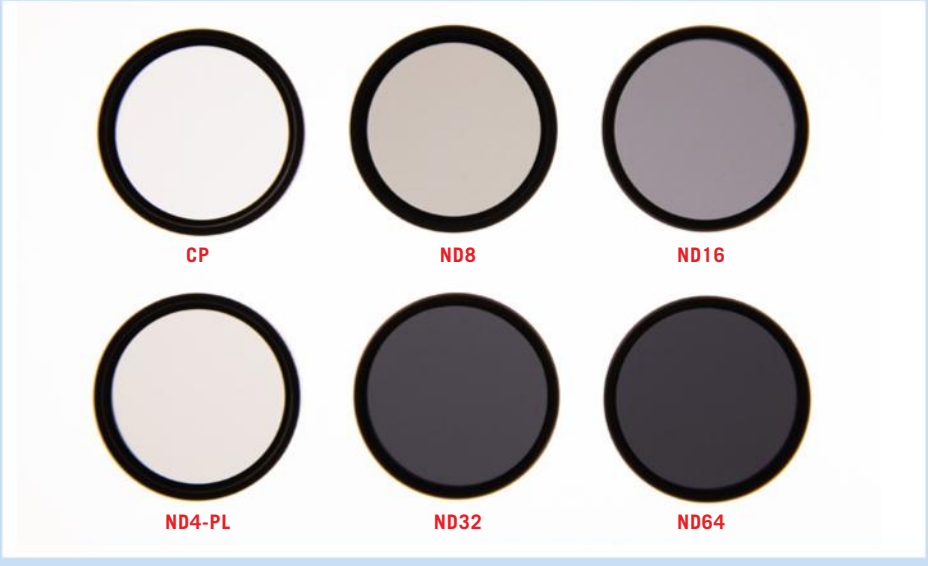
Purchasing filters

Despite the handful of companies that manufacture lens filters for drone cameras, I think PolarPro and Snake River Prototyping (SRP) are the best. Both companies make high-quality glass filters, and you cannot go wrong with either brand. While DJI's Phantom drones may be the most popular currently on the market, PolarPro and SRP both have an extensive line of filters that fit GoPro HERO cameras and the DJI Inspire 1.

PolarPro offers eight ND filters ranging from 2 to 6 stops, which reduces the amount of light your camera lens gathers, allowing you to lower your shutter speed. Each filter allows you to cover a variety of lighting conditions, from cloudy to midday sun. In addition to regular ND filters, SRP makes graduated ND filters, which means the intensity of the filter increases across the lens' diameter. These filters are great when one part

Flying high above the New River near Hawk's Nest, WV, Walter captured this early morning photo using only a circular polarizer. Just look at those deep color tones!

A polarizing filter can be used to darken a bright sky, as shown here. Walter was able to bring out the cloud details in the sky overlooking the Greenbrier River near Cass, WV.



Here you see a range of PolarPro filters and their comparative tints from a circular polarizer in the upper left to an ND64 in the lower right.

How to use ND Filters

CHOOSING WHICH ND FILTER TO USE can be extremely challenging, especially if you've never used filters before. Filter choice hinges upon the time of day and lighting conditions. For instance, when filming at dusk or dawn, a lighter ND4 filter is best. When flying at high noon in strong sunlight, the darker ND32 will work better. For even brighter conditions, such as flying over a snow-covered landscape during the middle of the day, you'll use an ND64. The reason for the darker filters is to trick the digital camera, which automatically speeds up its shutter speed in brighter conditions, into thinking it's darker out than it is. That slows down the shutter speed and you get a more cinematic look.

Pro tip: Your shutter speed should be approximately double your frame rate. For instance, if you are shooting at 4K/24, you will want your shutter speed to near 1/60.

of the image is brightly lit, like sunrises and sunsets. You can position the filter to darken the sky, bringing out details, without muting the ground colors.

In my estimation, I think the SRP filters' glass is of slightly higher quality. However, I prefer how PolarPro's filters screw on like a typical DSLR lens filter, rather than pressing into place.

A poor-quality filter can ruin an image. Before buying a new lens filter, make sure the filter is glass and its coating is even and undamaged. The frame should be heavy enough to withstand a lot of handling — if it's flimsy plastic, you probably don't want that filter. Also, make sure that the filter connects to the camera lens. Finally, regardless of the filter you purchase, you'll notice a little bit of a color shift — either warmer (red) or cooler (blue). The better the filter, the less noticeable the shift will be. Reading reviews can help steer your search. When it comes to money, you've already spent a considerable amount on your aerial photo and video platform. Don't skimp on the accessories that will improve your work.

Maintenance and storage

Take care of your filters. Each one is made of fragile, high-quality glass, so you need to be cautious to not scratch them

Watch a video filmed with the Phantom 4 Pro online at Drone360mag.com/Phantom4Pro.

during handling and storage. PolarPro offers cases designed specifically for its filters. You can also find sturdy pouches at photo supply shops. Keep a clean microfiber cloth and lens cleaning solution on hand; you never know when you'll hit a bug or accidentally leave a fingerprint on the filter. Do not use your shirt, a paper towel, or any other cloth that might be lying nearby to clean your filter, or, for that matter, your camera lens. You will scratch it, and then you'll be sorry.

Gazing into my crystal ball

As integrated drone cameras become more advanced, the use of filters may decline. The DJI Phantom 4 Pro boasts a vastly improved camera. Not only does it feature a 1-inch sensor, but it also includes aperture control — a first on a consumer drone. With aperture control, you will no longer need an ND filter to limit the light entering your camera. Instead, you will simply close the lens aperture. I expect this to become more commonplace as UAV photography evolves. 360

What does Walter use?

I MAINTAIN A VARIETY of ND filters, polarizers, and graduated filters from both PolarPro and Snake River Prototyping (SRP). Overall, my most-used filter is the PolarPro circular polarizer, followed by the SRP graduated neutral density.

Pro tip: Planning to buy filters? Be sure to really think about which filters you want — consider the conditions under which you take most of your drone photos, what you spend the most time fixing in editing, and what you want to achieve. Do your research, and most importantly, happy flying!

BLADE CONSPIRACY 220

Have you had your eye on the world of drone racing? Want to experience the thrills of aerobatic flight without the hassle of building and tuning something yourself? Then the Blade Conspiracy 220 offered by Horizon Hobby might be the machine you've been looking for!

Out of the box, you're looking at the basic Conspiracy 220 quad, complete with motors and receiver, an FPV camera, a set of tri-blade props, a decal sheet, and a user manual. To get in the air, you'll need a 6-channel Spektrum DSMX transmitter, 3S or 4S LiPo battery and charger, and FPV goggles — why fly FPV if you aren't gonna go for the full experience?

BEFORE FLYING

First, you'll need to refer to the manual to set up your Spektrum transmitter to fly the Conspiracy. Navigating all of the menus can be a bit of a pain if you haven't set up a transmitter before, or if you have but don't do it very often. The best advice is to go slow, and keep a pencil handy to check off the adjustments you've made. Once you've finished, go back and double check your work. And if there's something that just doesn't seem right to you, check again. A mistake during this step could cut your first flight short. Consider yourself warned!

Binding is usually the easiest part of setup, but procedures differ between models of Spektrum transmitters. Refer to your controller's user manual to make sure you're following the correct method.

Don't worry about getting into PID (proportional-integral-derivative) math to modify your flight specs. The Conspiracy 220 is already pro-tuned, so your flights will be buttery smooth right from the beginning.

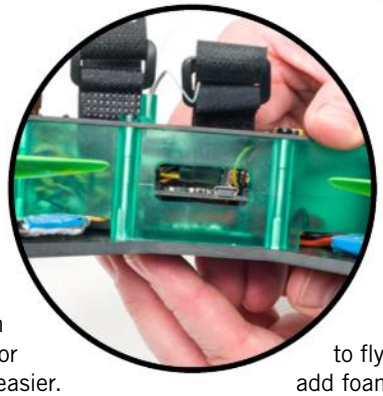
With a 4mm carbon-fiber frame and meaty arms, the Conspiracy 220 feels beefy compared to the 3mm airframes commonly used for drone racing. Built to take more abuse than other machines I've flown, it features a durable, rigid body that keeps the internal electronics safe during crashes.

Onboard is a 650TVL CCD camera featuring a 2.8mm lens, great for racing and shooting tight gaps. You can adjust the camera tilt up to 45 degrees to get just the right angle for your flying style. I normally prefer a 2.1mm lens, which provides a wider viewing angle and allows me to see more of the world while flying.

That being said, 2.8mm seems to have become the out-of-the-box standard, and I love it for hitting gaps — its low

20

by Horizon Hobby



SYSTEM SPECS

BLADE CONSPIRACY 220

Available: Horizon Hobby (horizonhobby.com)

Rotor type: Quadcopter

Diagonal: 220mm

Weight: 1.2 pounds

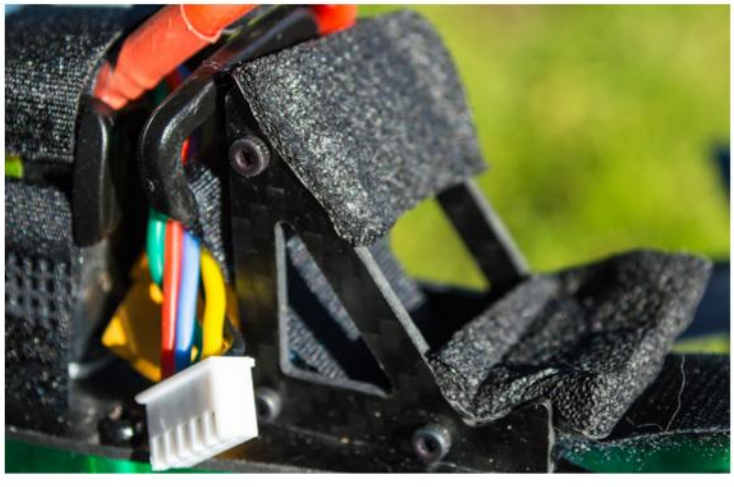
Flight time: 4+ minutes

Price: $349.99

visual distortion makes aiming for narrow spaces easier.

The Conspiracy 220 also comes with a tilted camera mount for recording HD footage of your flights via a GoPro or similarly shaped action camera. You'll need to partially dismantle the racer to add the mount, but it's easy to put together and only takes a few minutes of work.

If you're going to fly with a GoPro, add foam to the camera seat. It will absorb some of the aircraft vibration and give you better-looking footage. (I do this with all of my machines, not just the Conspiracy 220.)



If you intend to use a GoPro or other camera to film your flights, add foam to the camera seat. It'll absorb vibration and improve your video.

INTO THE BLUE

No joking, this bird is quick. Coming equipped with Thrust 2205-2350Kv motors paired with Thrust 20A ESCs puts speeds of up to 60 mph at your fingertips. And when something this small gets moving that fast, it's intense. If you're new to drones, you'll want to ease into it. If you're an experienced pilot, the Conspiracy 220 is a blast!

This machine flies great out of the box without any tweaking to the flight controller settings. I also flew it with a number of different props — including quad-blade — beyond the dual- and tri-blades included with the drone. It flew wonderfully with every style, although my favorites for the Conspiracy 220 are APC 5x4.5 quad-blades.

I tested the Conspiracy 220 with 4S 1300mAh 30C and 1550mAh 95C Tattu R-Line batteries, and both worked great. The larger 1550mAh battery provides better balance when flying with my GoPro Hero5, but it also adds weight, slowing down the quad. The manual recommends using a 4S 1300mah 30C battery, but I think the Conspiracy 220 benefits from a higher C rating, especially if using aggressive three- and four-blade props or when you want to take it out racing and pin the throttle.

In the air, the Conspiracy 220 handles just about everything I've thrown at it and just asks for more. Remember, it's not an ultra-light, record-breaking, speed machine. It's meant to fly well, and take the crashes as they come. And, not surprisingly, the times I've crashed have only required me to replace the props. Good on you, Blade!

FINAL THOUGHTS

Once you get a few flights under your belt, I recommend

I really like APC 5x4.5 four-blade props. They allow me to fly aggressively, with plently of lift, while still allowing me to pull super-tight aerobatics.

downloading the Cleanflight app from the Google Chrome Web Store. With it, you can connect to the Conspiracy 220's FC32 flight controller and adjust its configuration. But before you go monkeying with anything that can throw things way out of whack, I suggest enabling Air Mode (appropriately found under "Modes"). Air Mode increases the quad's stability in some situations and makes for a more pleasant flying experience. You may also want to upgrade the FC32's firmware, since it's most likely running an older version of Cleanflight.

The Conspiracy 220 is easy to work on, which may not seem important, but it is. Eventually, you'll have a bad crash and need to replace broken parts — probably motors and ESCs. You don't want a quad you dread repairing. And you won't with the 220. Motors and ESCs are accessible without dismantling the aircraft, and that alone makes it much easier to work with compared to other ready-to-fly quads on the market. And because it's hobby grade, when the time is right, you'll be able to swap out the components and upgrade.

My only quibble: The sample unit I received had two motors with bad bearings. I can hear the problem mid-flight, but it doesn't seem to affect flight performance. Realistically, you'll end up crashing and ruining the bearings on any machine. What matters is how the motors hold up to abuse — and, so far, these handle it extremely well.

If you're looking to get into drone racing without the hassle and time spent putting a machine together, the Conspiracy 220 is an easy buy. It's a great all-around setup to learn and grow your skills as a pilot, and, as a seasoned pilot, it's a delight to fly. ***— Zoe Stumbaugh***

HIGHLIGHTS

- **True hobby-grade quad**
- **Easy entry into racing**
- **Speeds up to 60 mph!**
- **Comparable performance to more expensive kits**

TOP: ZOE STUMBAUGH; BOTTOM OPPOSITE: ZOE STUMBAUGH

ZEROTECH DOBBY

Packaging is a big deal to me, and I love the utility of Dobby's Apple-esque box. It doubles as its case and there's a spot for each item — though I admit, this frustrates me when I'm in a rush or less particular about where things go. What's in the box: aircraft, battery, charger, adapter, USB cable, micro-USB, and the ever-important manuals.

When folded, Dobby fits in the palm of my hand — which, for comparison, is the size of a child's hand. The drone comes with four sets of pre-mounted, 3-inch foldable propellers.

HIGHLIGHTS

- Highly foldable, portable, and durable
- 1080p video and 4K photos
- Ample supply of Dobby the House Elf puns
- Palm take-off and landing

DO.FUN APP

House elves aren't supposed to have fun, but ZeroTech thinks differently. Inside the app you can view content from other Dobby pilots, submit malfunction reports and feedback, control Dobby, and more. To fly Dobby, you must download and use its app, because it does not come with a traditional transmitter.

The main interface of the controller shows the Wi-Fi status, current flight altitude and distance, battery life, and gives the options to take photo and video. Photo and video can either be saved via the app to a smartphone (content is available when not connected to the drone, hooray!) or transferred to a computer using the micro-USB.

There are four flying modes: Motion Sense, Swiping, Free Sticks, and Safe Sticks. I tried all of the modes, but I mainly chose to fly using Motion Sense and Free Sticks.

Now to the goods: the advanced features. Inside the app are icons that activate facial recognition, target tracking, orbit mode, palm take-off and landing, auto take-off and landing, gesture control, voice control, and burst shot photo.

BEFORE YOU FLY

Dobby must be connected to its Wi-Fi; you can find the information on the underbelly of the drone. Unfortunately, Dobby needs to be manually connected to the Wi-Fi each time it's powered on.

Tapping the middle icon that's shaped like a folded Dobby brings up the controller interface. Once that's open, the drone needs to be calibrated, which must be done anytime you're flying in a new area, both inside and out. Otherwise, the drone will drift and be hard to control. Don't say I didn't warn you.

INTO THE BLUE

When Dobby first took off indoors, my initial takeaway was that this drone, like many others, is loud. Eventually, I got over the loud buzzing (sort of) and started ordering Dobby to move.

This drone is responsive, though it can take some getting used to the fact that when in Motion Sense mode, sharp movements on your end are

FULLY RETRACTABLE PROPS

mimicked on Dobby's end. But don't worry, Dobby never became a free elf — the drone recovers and hovers like a champ.

The first time I flew this drone outside was when I was home in Washington state for the holidays. The weather wasn't great while I was there, but Dobby was determined to fly.

In the manual, it says, "Don't fly Dobby in bad weather conditions, such as high wind, rain, snow, etc." Well, it was winter when I conducted this review, so some days I flew when it was 30 degrees and there were 13 mph winds (below the advertised max wind resistance of 17 mph, and admittedly below the 32 degree advised operating temperature — oops). And honestly, Dobby performed extremely well.

I was impressed by most of the features, which you activate by simply tapping icons. Dobby mimicked my movements like a charm when flying in Motion Sense Mode. Palm takeoff and landing is awesome. Dobby has optic flow and ultrasonic sensors, which allow it to accurately sense when a hand is underneath it.

When flying indoors, I got an alert that read "Optic flow sensors low. Landing now." The the online guide showed many reasons why this can happen. In this instance, it was likely due to the floor. Apparently, the optic flow system has problems working above surfaces without clear textures, so I put a textured, firm pillow on the ground and took off. It worked. My advice: don't be afraid to troubleshoot.

Typical dronie waves! Dobby flew (on a plane) and traveled home to Alger, WA, with me for the holidays. The drone's high-resolution camera captured the perfect photos and video of the winter wonderland.

In Orbit Mode, there are two options: orbit under GPS positioning or under target tracking. Both functions work well, but it takes a while for Dobby to measure the distance between itself and the chosen orbit point. Once the orbit starts, it flies a full circle and automatically stops and hovers where it began.

Want to have Dobby follow someone? Target Tracking Mode allows you to track an object or person by drawing a box around your target, though if it's windy or cold, it can be difficult to lock down a target. A few times the drone focused on the ground rather than my set target. Bad Dobby! I emailed ZeroTech. Customer service replied, "Make sure you wear a different color top" — otherwise Dobby's computer vision can mistake its surroundings for targets.

Excited to use voice command? I was too, but it didn't work. ZeroTech customer service says that speech recognition doesn't always "work smoothly in English." Honestly, neither does Amazon's Alexa. Too bad.

This little drone churns out some high-quality photo and video. The camera captures 1080p video and photos with a resolution of 4208 x 3120. In Orbit, Target Tracking, and several other modes, it records video automatically.

Aside from the camera lens facing directly forward, the camera pitch angle can be *manually* adjusted to sit at five different degrees: up 22.5 and down -22.5, -45, -67.5, and -90. There are lines that delineate each angle so you know to what degree you're setting the camera. Some features, like the Target Tracking, require specific pitch angles — remember to adjust it before flying to save on battery!

The drone comes standard with one battery, which lasted about six minutes (below the advertised nine minutes) for me. You can always get more on Amazon.com.

Dobby works hard and is tough. If something gets in its way, it bites. Dobby ran into a brick wall — marked up the bricks. It collided with a glass frame — left gouges in the glass. It ran into my boyfriend's hand (he had the best of intentions) — resulted in blood. (Dobby and BF were fine.)

If you plan to fly Dobby indoors, I suggest buying prop guards. Both props and guards are available on Amazon.

FINAL THOUGHTS

Overall, I like Dobby: It's portable, fun, and full of cool features. Flight time was meh, but Dobby is great for people looking to capture a quick high-quality shot. ***— Lauren Sigfusson***

DREW HALVERSON (2), LAUREN SIGFUSSON (TOP RIGHT)

SYSTEM SPECS

ZEROTECH DOBBY

Available: ZeroTech (zerotech.com)

Diagonal: 7.8 inches

Weight: 7 ounces

Flight time: About 6 minutes

App name: Do.Fun

Price: $399.99

When Dromida calls a drone XL, it isn't kidding! Measuring 370mm on the diagonal (nearly 15 inches), it has a footprint comparable to a DJI Phantom 4. Add the blade guards, and you're talking about some serious real estate. Plus, its unsettling design resembling something akin to an oversized mechanical insect hunting for its next meal makes it seem even larger than it is. I make a point about this because you don't often see drones this size outside of the photo-video consumer market, especially with the growing focus on racing.

As you would expect from a ready-to-fly (RTF) package, the XL comes fully assembled (minus prop guards), with a Wi-Fi enabled Tactic DroneView 1080p HD camera payload underneath. It also includes a 2.4GHz transmitter shaped like a console-game controller, which seems to now be the industry standard.

Spare props, screwdriver and 12 screws, four AAA batteries for the controller, a 4GB micro-SD memory card (installed in the camera), a 7.4V 2200mAh LiPo battery, and an AC balance charger round out the contents.

BEFORE YOU FLY

As much as I like to get out and just fly, the weather outside just wasn't cooperating, so I decided to make my initial XL flights indoors. As I said, it's big, and not that I don't have confi-

HIGHLIGHTS

- Sturdy, cool-looking plastic fuselage
- Spare propellers
- 3.7V 1S 750mAh LiPo battery and USB charger
- Three flight modes

dence in my piloting skills, but I also know how quickly things can go wrong. If you're going to fly indoors, or if you're new to quadcopters, attach the prop guards. There's no shame in it and don't let anyone tell you otherwise.

Each guard consists of two pieces that you affix with three screws. The locator pegs are a bit of a tight fit, but with a little patience, they fit quite nicely.

The instructions say that it takes about two hours to charge the LiPo battery with the supplied charger. In my experience, it takes about 90 minutes. By no means fast, but a little quicker than what they say. If you really want to speed up those charge times, I recommend you pick up a balancing charger like a DuraTrax Onyx 235. And I'm a big proponent of getting a second or even a third battery. No one likes to fly for 10 minutes and then have to wait two hours before being able to get back in the air.

I'm not a fan of the XL's battery bay. The latch that holds the LiPo in place is extremely stiff, which means the battery is held secure, but it's a massive pain to get in and out. The latch is just a flange of flexing plastic, so with repeated use it might loosen a bit, but right now, it's no fun.

If you aren't calibrating your quad before taking on its first flight, start. Yeah, it may not need it, but it might. Avoid possible trouble and just do it. Calibrating the XL really quite easy: Make sure all the control trim adjustments are centered, place the copter on a level surface, link it to the controller, and arm the controller. Press and hold the right stick in the lower right corner; then move the left stick to its lower right. When the LEDs on the quad start to flash, let the sticks go. The LEDs will stop flashing, and you're good to go. It takes less than a minute and can greatly improve your flight experience.

DRONEVIEW

If you want to fly right away, you can do it without doing anything more. However, if you want to take advantage of the live feed from the quad's camera, download the DroneView app. While the quick-start guide says that it can be used from Apple or Android devices, I couldn't download it onto our iPad Mini, but it loaded just fine on my iPhone; it works best with generation 6 and later. On earlier versions, the video freezes.

If you're on an Android phone, it will automatically connect to the XL when you launch DroneView. For an iPhone, go into the Wi-Fi setting and select the DroneView network. It may take a minute for the phone to recognize it and show it as an option. Be patient.

You can take photos and shoot video with the DroneView app. There is also a file gallery in which you can view the images and footage you've taken. You can also export those files to your phones camera roll. Another option is to export files directly from the micro-SD card, which is a good idea for videos. There are some minor adjustments you can make to DroneView settings, like brightness and contrast, or switch between 720p at 60fps (smoother video) and 1080p at 30fps (larger field of view).

INTO THE BLUE

Getting the Dromida XL flying poses no problem at all. Turn on the transmitter and the drone, and arm the controller by moving the throttle to full and then to low throttle. When the transmitter beeps, you know it's ready to go. At the push of a button, you start the motors, and with the push of another button, the XL automatically takes off and hovers about 4 feet off the ground. Alternatively, you can use the throttle to take off.

I didn't dig flying the XL. The controls seemed to lag in low-rate mode, and only got minimally more sensitive in high rate. There were a couple of times when it seemed that no matter what I told it to do via the controls, it was interested in pursuing its own agenda. While exciting, I don't live for those anxious moments while flying.

One of the XL's selling points is that it can flip and roll, which is unusual in a drone this size. Let me warn you now, don't try to do this stunt indoors. You will crash. Hard. Luckily, I had the foresight to head out to give this a try (as the user guide also tells you — reading is your friend).

Get at least 30 feet in the air before you flip or roll. You'll need the altitude because the XL loses a lot in the process. To flip or roll, simply push in the throttle (left) stick and then determine the direction with the pitch/roll (right) stick. Then the XL flips. Not the prettiest aerobatics, it's still pretty cool to watch this size drone flip over.

FINAL THOUGHTS

Rather than spend $2,000 on a consumer quad that you can't use to the fullest because of your inexperience, the more economical choice would be to get something affordable that does some of the things you can do with the more expensive model. That's where the XL fits in.

In my quest for a thorough test, I bounced the XL off the ground after some aggressive flipping and blindly careened down a hall at the office. I can attest, it can take some punishment. I mean, don't drive your car over it, but don't sweat the newbie mistakes. ***— Tim Kidwell***

SYSTEM SPECS

DROMIDA XL FPV

- Available: Dromida (dromida.com)
- Rotor type: Quadcopter
- Camera: Tactic DroneView Wi-Fi HD FPV
- Diagonal: 14.6 inches
- Weight: 1.15 pounds
- Flight time: 10 minutes
- Price: $249.99

BLADE NANO QX2 by Horizon Hobby

You all know that I was a fan of the original Blade Nano QX. It was a great little quad for learning to fly. The design was solid enough (with minor modifications) to spawn the Nano QX 3D, and now the QX2 FPV.

It only makes sense that the Blade would take the agility of the QX 3D, add an integrated 25mW 5.8GHz micro camera up front, and make an entry-level FPV quad. As you'd expect in a bind-n-fly (BNF) package, the QX2 includes a 3.7V 500mAh LiPo battery and USB charger, spare props, and a user manual.

BEFORE FLYING

Because the QX2 FPV is a BNF quad, you'll want to make sure that you have a compatible Spektrum DSMX controller — the DXe (see Page 32) works wonderfully — and go through the setup process. Compared to other quads I've flown, the QX2 setup is a breeze.

Charging the included battery takes about an hour. I hear the complaints all the time: It takes so long to charge the battery, and I don't get very much time in the air. All I can say is get used to it. In this hobby, flight times come at a premium. Add the additional weight and power draw of an FPV camera, and you start to reduce flight times even more. The best thing you can do is pick up a couple of extra batteries and have them charged and ready to go.

HIGHLIGHTS

- Easy-to-use FPV micro camera
- Spare propellers
- Compatible with Spektrum DSMX transmitters
- Two flight modes

USE GOGGLES LIKE THESE FAT SHARK FOCAL V2

Of course, the whole point of FPV is to feel like you're sitting inside the drone while piloting it. If you have yet to invest in goggles, that's OK. While you don't need goggles to enjoy the QX2, you will eventually want them. A pair of inexpensive Fat Shark Dominator V3 goggles runs about $350. (Nowhere and at no time did I say this was going to be a cheap hobby.)

The QX2 has two flight modes: Stability and Agility. In Stability Mode, the LED inside the copter shines blue. Bank angle will be limited and when you release the sticks, the QX2 will level out. In Agility Mode, the LED turns red (you know, to help keep you calm), and the bumper pads come off. There aren't any limits to banking and you have to level the quad on your own. Rates and expo are your friends here.

Basically, if you haven't flown a quad before, or this is your first foray into FPV, then stick with Stability Mode. If you want to pull flips and rolls, Agility is where it's at, but the only person who can decide what you're ready for is you. And if you're gonna go all aerobatic, then make sure you're outside or a big, open indoor space. You'll need the room.

INTO THE BLUE

There's no arming the Nano QX2 FPV; as soon as the transmitter and drone are linked, the throttle is active. So don't bump your throttle as you're pulling on your goggles.

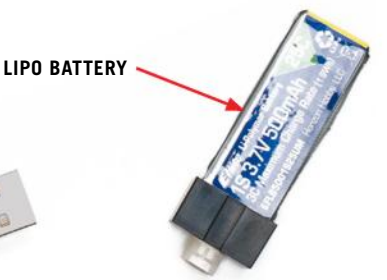
The QX2 benefits from agile controls. It's very responsive, even in Stability Mode, and it can be surprising how quickly you can move from one end of a room to the other. You can adjust the tilt of the camera to suit your preference and flying style, but there isn't a huge range. If you cruise around at top speed, tilt the camera up. If you're a slow to moderate flier, having the camera positioned dead front should be fine.

I experienced intermittent static via the FPV feed. It was nothing more than I would normally expect, and definitely nothing that affected my ability to fly or diminished my enjoyment.

The blade guards may look fragile, but they're stronger than they appear and can take moderate bumps and scrapes. The only difficulty I ran into with them is the fine ends of the feet getting stuck in the tightly knit carpet at the office. It's not a big deal, but if you're flying off that sort of surface, just be aware of the possibility.

FINAL THOUGHTS

There are a lot of FPV quads out there screaming that they're just right for you to start FPV racing. While the Nano QX2 FPV isn't a racing drone — not in any serious capacity — it is definitely an entry-level quad you can learn to fly FPV on. As your skills improve, you can head outside and start playing with Agility Mode and learn how to pull flips and rolls like a pro. ***— Tim Kidwell***



SYSTEM SPECS

BLADE NANO QX2 FPV BNF

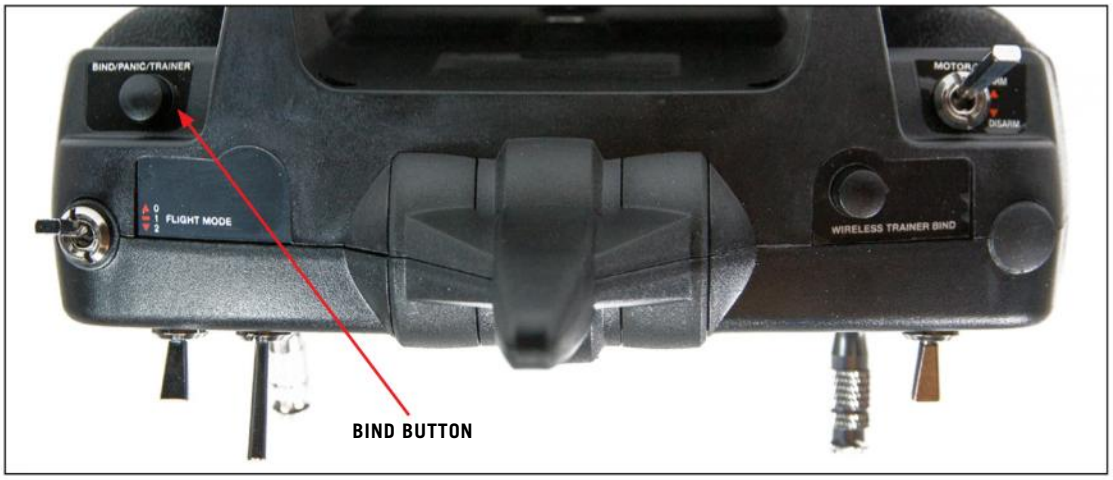
- Available: Horizon Hobby (horizonhobby.com)
- Rotor type: Quadcopter
- Camera: Tactic DroneView Wi-Fi HD FPV
- Diagonal: 7.2 inches
- Weight: 1.8 ounces
- Flight time: 6 to 8 minutes
- Price: $159.99

OPPOSITE: DREW HALVERSON (TOP)

SPEKTRUM DXe

by Horizon Hobby

OPPOSITE: DREW HALVERSON (3)



One of the more daunting decisions new remote pilots face is what controller to buy. It's easy to be overwhelmed by the sheer number of brands and models — and that's not even broaching the number of rates, channels, frequencies, and other options that might be offered.

With the new Spektrum DXe transmitter, you can bury the worry over buying your first controller somewhere in your backyard. At its most basic, the DXe operates like a 6-channel transmitter and will allow you to fly a range of bind-n-fly (BNF) multirotor helis — and airplanes, too, if you're into that.

For most of your entry-level drones, that's all you're going to need. Our DXe came with a compatible AR610 receiver and four AA batteries. Just pop them in and you're ready to go.

THE BASICS

In case you don't know, when I say six channels, I mean there are six ways to communicate with your aircraft. The first four are the basic controls: throttle, yaw, pitch, and roll, all controlled via the transmitter's two control sticks. The last two channels are dedicated to a three-position flap switch and a two-position auxiliary function switch that can be assigned tasks depending upon your aircraft.

In the U.S., the DXe comes set up in Mode 2, meaning the left stick controls throttle and yaw; the right stick controls pitch and roll. It's the most common setup for a controller, and if you've picked up any ready-to-fly aircraft, you're probably already familiar with how this feels.

On the transmitter's upper left corner is a bind/panic button. Obviously, as the name implies, you'll use this button when binding the transmitter to an aircraft. With BNF vehicles, this is pretty simple: Plug in the aircraft battery, hold the bind button down, and turn on the transmitter. Once the receiver in your drone shines solid, you can let go of the button. The DXe is bound and ready for action.

A dual rate switch allows you to easily toggle from low to high rates. When properly set, you can achieve more aggressive maneuvers with the high rates without having to land and make adjustments to your aircraft. And when you're done showing off, you can switch back to low rates and cruise around before coming in for an easy landing.

SOME ADVANCED FEATURES

One of the cool features of the DXe is that it can be programmed via your smartphone or PC. Just download the Spektrum DXe Progammer app. If you use a PC, you'll need a special USB programming cable (No. SPMA3065). If you're going to use your Android or iOS device, your best choice is the Bluetooth module (No. SPMBT1000).

Inside, you'll find a space to save different models, modify flight modes, and change between aircraft types. On more advanced controllers, you can access these options directly on the transmitter, making for a quicker transition, say, from one quadcopter to another. However, if you're starting out, or upgrading from one of the controllers included in an RTF package to something more substantial, this shouldn't be a problem for you.

And take your time exploring the options. There's nothing saying that you have to use these features, but they are there when you're ready for them.

SYSTEM SPECS

SPEKTRUM DXe WITH RECEIVER

Available: Horizon Hobby (horizonhobby.com)

Channels: 6 to 9 (depending upon configuration)

Modulation: DSMX

Band: 2.4GHz

Programming: Airplane (can be used for quadcopters)

Price: $89.99

FINAL THOUGHTS

The Spektrum DXe (also available in a transmitter-only package for $59.99) is an excellent entry-level transmitter. The advanced features allow you plenty of customization and model memory options. It's inexpensive, which can be a factor when just getting started in a hobby. And by the time you're ready to move up to a more advanced radio, like a DX6e or DX8, you'll know exactly what you're looking for and exactly what you need.

— Tim Kidwell

HIGHLIGHTS

Super beginner-friendly

PC or mobile apps for model memory and more

Wallet-friendly

ASCEND

Conference & Expo powered by Drone360

Premier Sponsor: UpSonder

Contributing Sponsor: FLIR

ATTENDEE REGISTRATION IS NOW OPEN!

The Essential Event for the Commerical Drone Industry

Make connections with industry experts, **get practical, hands-on advice** from businesses using drones every day, and **return home with actionable processes** you can put to work right away.

July 19-21, 2017

Oregon Convention Center | Portland, Oregon

Flying is just the beginning.

Register now at ascend-event.com

P30229

Photo courtesy of Travel Portland

WHO SHOULD ATTEND?

Hands-on workshops, panel discussions, and individual sessions will be offered in these areas:

- **CONSTRUCTION**
- **INSPECTIONS**
- **PHOTO/VIDEO**
- **PRECISION AGRICULTURE**
- **SEARCH AND RESCUE**
- **SURVEYING & MAPPING**
- **UTILITIES**
- **AND MORE!**

FEATURED SPEAKERS

JONATHAN EVANS
Skyward
CEO

COLIN SNOW
Skylogic Research
CEO and Founder

ANDREW DENNISON
Uplift Data Partners
COO

BRENDAN STEWART
AeroVista Innovations
President

SALLY FRENCH
TheDroneGirl.com
MarketWatch

DAVID LANG
OpenROV
President

CASEY ADAMS
Kansas City Drone Co.
CEO

SHARON ROSSMARK
AeroVista Innovations
COO
WomenandDrones.com

Beginning an Era

BNSF Railway uses drones for inspections

By Hayley Enoch

The HQ-40 mixed fixed-wing and quadcopter can take off and land vertically and is capable of flight lasting up to two hours.

BNSF Railway has become a leader not only in railroads but also in UAS because then-CEO Matt Rose watched an aerial video taken by a drone in 2014.

Todd Graetz, BNSF director of technology services and UAS, says Rose quickly grasped that unmanned aircraft had potential to make maintenance-of-way work safer and more efficient — all from an amateur video overlooking a train. Rose charged Graetz's group with putting together a drone demonstration program soon after.

Even three years ago, using drones to assist in maintenance work, or any commercial activity, was something the FAA was unequipped to handle. BNSF's program provided an opportunity to partner with the government for a cooperative research agreement. That led the railroad to become one of a number of companies involved in the budding Pathfinder program, along with the likes of CNN and PrecisionHawk.

To make BNSF's program a reality, Graetz and fellow railroaders had to determine which drones were appropriate for railroad work. Under his direction, BNSF amassed a fleet of 20 multirotor copters from DJI, AirRobot, and SenseFly, a subsidiary of Parrot Group. These aircraft, ranging from about 2 to 6 feet in diameter, typically hover as low as 50 feet over the tracks. BNSF also bought three larger, mixed fixed-wing and quadcopter HQ-40s from Latitude Engineering. These larger aircraft use electric motors for vertical takeoffs and landings and an internal combustion engine for forward flight, cruising at altitudes up to 400 feet for tens or hundreds of miles.

BNSF modified all of the drones in its fleet with aftermarket digital cameras and sensors. Finding the correct camera for the railroad's needs took collaboration with suppliers and a lot of in-house tinkering. Graetz says BNSF's program required a greater image resolution than anything that was available at the time — even better than military operations. The resolution required for effective inspections has to be high, showing details as small as one-quarter of an inch. With testing, Graetz's team met that goal and was also able to snap two photographs per second.

Learning to fly

BNSF software engineers developed programs that could "learn" what an ideal railroad track should look like. Then, they began tweaking the algorithms to identify flaws, such as rotted ties,

Above: A BNSF Railway-operated DJI Inspire 1 hovers alongside a trestle in Montana. BNSF officials say quads are best for inspecting structures. Right: An overhead image from a BNSF-operated drone. Hundreds of miles of track can be inspected by a fixed-wing aircraft.

ALL PHOTOS: BNSF RAILWAY

out-of-gauge rails, and missing rail fasteners. Almost from the outset, the UAS program yielded faster and more precise results than manual inspections.

"Instead of sending track managers out in a truck to look for problems, we can hand them a report that tells them exactly where and what to look for," Graetz says.

Aerial inspections have also been helpful for identifying tracks and other structures that have shifted out of proper clearance, and for taking inventory of equipment stored in sorting yards.

BNSF found quads were best suited for inspection of bridges and other structures where the drone would be in close proximity. The pilots generally work on the ground and are rarely more than a mile away.

Pilots of the fixed-wing aircraft, by contrast, may work from ground stations up to 150 miles away, well beyond visual line-of-sight. Fixed-wing UAS are better suited for inspecting long stretches of track because of hours-long gas-powered flight, and because they can fly high enough to photograph both sets of tracks along double-tracked stretches at once.

Lots and lots of data

Drones generate a ton of data. Transferring that information can be problematic. Luckily, BNSF was building the backbone of its positive train control system (PTC) while it was also testing its UAS program. The PTC helps avoid train collisions, and its network happened to work well for transferring drone data, too.

Graetz says BNSF plans to add multispectral sensors to its drone fleet to detect structural problems invisible to the human eye. For example, radar could potentially reveal shifting bridge supports, and thermal imaging may reveal stress spots on the rails. The hope is to collect enough data to not just detect current problems, but to eventually predict and repair them before they happen. 360

This story originally appeared in the April 2017 issue of Trains *magazine.*

ON THE HORIZON

Nanostructured synthetic materials will change the way we drive, see, and fly

By Eric Betz

Metamaterials already appear in radar and satellite antennas. They'll soon make vehicles with autonomous features, like the Tesla Model S, safer.
FLICKR/NORSK ELBILFORENING

Self-driving cars. Atomic vision. Invisibility cloaks. So many scientific advances promise a science fiction future that they simply cannot deliver. But one new field of research seems to have cracked the code on all three of those sci-fi technologies, and it's also allowing commercial drone pilots to implement detect-and-avoid technology this year.

This miracle science is called metamaterials. Designed to have properties that are not found in nature, metamaterials — from the Greek *meta*, for "beyond" — are remarkable in their simplicity. Scientists create microscopic patchwork substances with structures that resemble interlacing checkerboards, corkscrews, and spheres. And by creating those structures with gaps smaller than the wavelengths of light the metamaterials manipulate, scientists can impart on them seemingly impossible properties.

Light's Holy Grail

John Pendry of Imperial College London was the first to recognize the possibilities of these materials more than two decades ago. He was hired by a British defense contractor to examine a carbon fiber exterior siding used on navy ships that concealed the vessels from radar detection. At the time, no one really understood why it was working.

Engineers suspected something about the carbon itself was making the ship invisible to radar. But Pendry soon realized the underlying structure was responsible. The fibers were spaced just enough to absorb incoming light at radar frequencies.

"Here was a material which was still carbon, but when you put the structure in a different form, it completely alters the properties," Pendry says. He used the idea to cook up a way to make magnets without magnetism — a first — thanks to a clever winding of a copper ring. Then, in collaboration with a group of scientists at Duke University, Pendry and his team started tinkering with some truly bizarre physics.

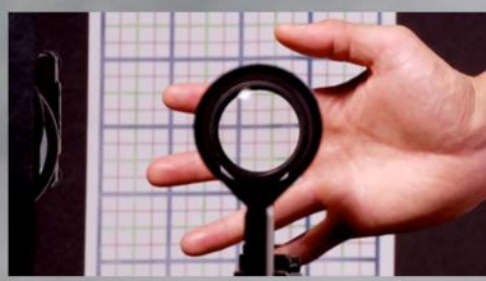
Russian scientist Victor Veselago had done the math decades before and came to the conclusion it was theoretically possible to produce negative refraction, where light would pass entirely through an object without reflecting back. But Veselago never found a naturally occurring material capable of negative refraction. Pendry's trick was to have humans make the material themselves.

"What we brought to the party was [that] we used metamaterials for some very interesting properties, like negative refraction," Pendry says.

Once they'd unlocked these negative refraction properties, it opened up the possibility of creating technologies we'd only dreamed of in sci-fi stories like cloaking devices, machines that can image objects smaller than wavelengths of light, and the ability to steer or gather light and its energy. Some 26,000 scientific papers have now cited Pendry's early metamaterials study.

Bending beams

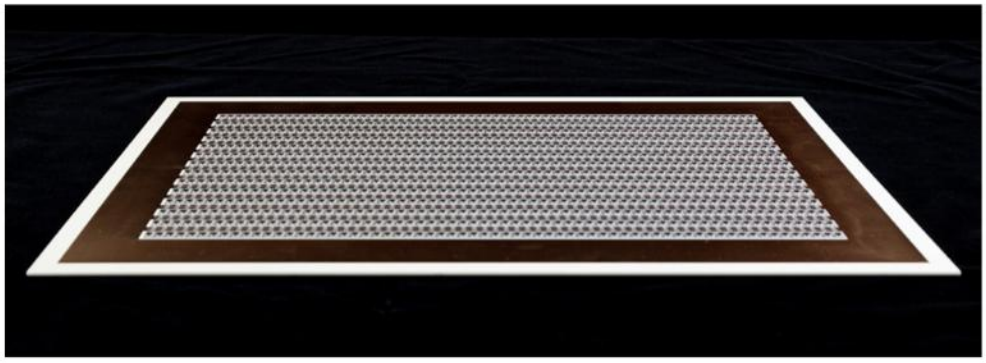
Every element has an index of refraction that describes how light bends and speeds as it travels through. For example, water's refractive index is about 1.3, meaning that light travels 1.3 times faster through a vacuum — where there's nothing to bounce off — than it does through water. And for as long as



Metamaterials can bend light waves to create optical illusions. Look, ma!
YOUTUBE/UNIVERSITY OF ROCHESTER

The compact autonomous Google car carries a full suite of sensors to help navigate safely — metamaterials will help keep this cute little vehicle, and its human cargo, where it needs to be.

FLICKR/SMOOTHGROOVER22



The simplicity of Echodyne's Metamaterial Electronically Scanning Array (MESA) makes it "thinner, lighter, and lower-cost" than other electronically scanning radar technologies.

ECHODYNE

humans have searched, no one's ever found a natural element with a negative refractive index. That's what metamaterials allow.

The light human eyes can see travels via waves that span just a few hundred nanometers (for comparison, a human hair is about 75,000 nanometers). So scientists wanting to manipulate visual light have to make magnificently tiny metamaterial structures.

But radar wavelengths are much bigger. "At radar wavelengths, the metamaterials need only be as small as centimeters across," Pendry says. The wavelength of radar makes it the low-hanging fruit of metamaterials, so it's the easiest place to start turning theories into real-world technologies.

While there's a lot of excitement about these possibilities in the scientific community, most applications of metamaterials haven't made it out of the lab. But radar-based metamaterial technologies are starting to roll out into the field. Researchers can now, with relative ease, build structures that replace the functions of atoms and molecules.

Metamaterials to market

One group leading that charge is Intellectual Ventures, a Bellevue, WA, company focused on creating and buying ideas and inventions.

More than a decade ago, Nathan Myhrvold — a theoretical physicist, former chief technology officer of Microsoft, and founder of Intellectual Ventures — became intrigued by early metamaterials research. While some still considered metamaterials rather crazy, he started hiring scientists in the nascent field and put them to work.

By 2011, Intellectual Ventures had launched a metamaterials startup called Kymeta, which hopes to soon sell small satellite antennas that can connect vehicles to high-speed internet.

Metamaterials company Kymeta designs small, lightweight satellite antennas like this one, the mTenna, to help maintain high quality communications while in the air, at sea, or on the road.

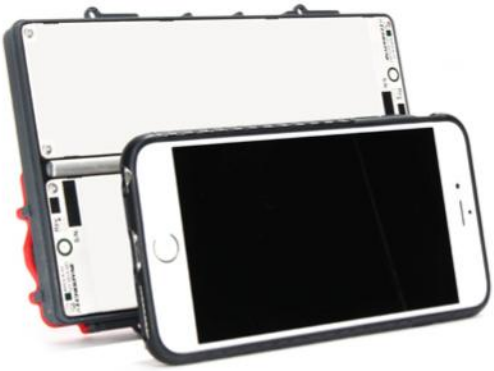
KYMETA

Toyota has already tested the technology in its cars in an effort to achieve real-time communication with vehicles all over the planet. And Kymeta thinks its metamaterials-based tech could make satellite communications as widespread as wireless is now — and it could ease the data burden as cars become increasingly high-tech.

The Department of Transportation expects a more connected future, too. Last December, the agency moved to push auto manufacturers to build vehicles that can talk to each other as well as other smart devices, like traffic lights.

Echodyne, the latest Intellectual Ventures project, was founded in 2014 with $15 million in seed money from a list of investors that includes Bill Gates. "Echodyne's innovative use of metamaterials holds great promise for a wide range of new radar applications," Gates said in an announcement of the launch.

And, all hype aside, Echodyne looks to be one of the first to market with a product using metamaterials: MESA, or Metamaterials Electronically Scanning Array. MESA is about the size of an iPad



Is that a tiny Echodyne radar in your pocket, or are you just happy to see me?

ECHODYNE

mini and, unlike conventional radar, has no moving parts.

"It's super fast and can point from one direction to another direction in under 100 nanoseconds," says CEO and cofounder Eben Frankenberg.

Echodyne's aim is to corner the autonomous navigation market. The company has already been testing a developer kit that's proven itself in drones, cars, and even boats through contracts with the military and at least one aspiring self-driving car maker.

Detect-and-avoid

MESA went to market in early 2017. And because it can point so quickly, the radar allows drones to sense obstacles in time to avoid them — a hurdle that's kept many drone operators from moving to beyond visual line-of-sight (BVLOS) navigation.

Eventually, Echodyne engineers expect MESA will be capable of tracking many objects at once and updating positions while still scanning for other hazards. That will be crucial to its widespread use in both manned and unmanned vehicles.

"Some people like to talk about detect-and-avoid as keeping your DJI drone from crashing into the side of your house," Frankenberg says. "That is not what we're talking about."

Instead, he sees MESA helping workers who inspect railroads, pipelines, bridges, power lines, and oil fields. Those are all applications where drone operators might want to fly their UAVs beyond their line-of-sight. It's also a potential game changer for other applications like surveillance and package delivery.

Frankenberg points out that if a small aircraft flies toward your drone at 150 mph and your radar can only pick out obstacles a few hundred feet away, you might sense the plane, but you won't be able to avoid it.

"You're going to hit the thing before you can do anything," he says.

That fear has kept the FAA from opening up U.S. airspace to BVLOS drone flights. Instead, MESA could spot a Cessna flying nearly 2 miles away with a much larger field of view. But the FAA is unlikely to get fully comfortable with the idea of BVLOS until sense-and-avoid technologies mature further.

On the radar

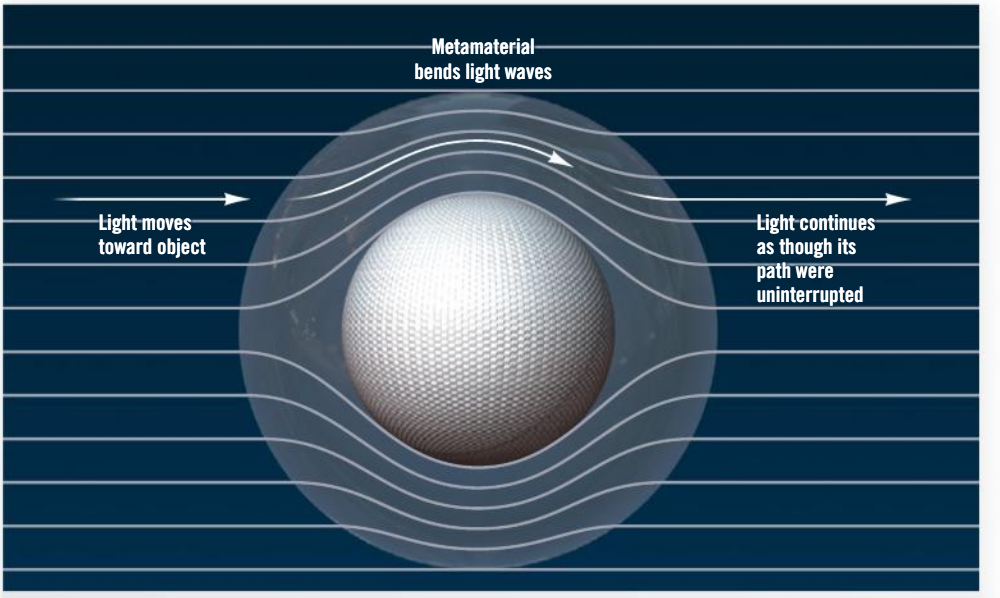
That same reality is a big problem for self-driving cars, which currently suffer from significant blind spots. In summer of 2016, a Tesla driving on autopilot failed to spot a semi truck in a neighboring lane and ended up beneath it. That's because the sensors currently in use across the industry only spot hazards horizontally, not vertically.

According to Frankenberg, even the best current radar scanners in use on cars can only spot obstacles just a few hundred feet away and have a limited field of view, requiring multiple sensors in various locations to see everything.

Echodyne has also reached out to companies building the old-school style radar that has long been used in naval ships. The constantly spinning, mechanical dishes haven't changed much over the decades, and Frankenberg doesn't expect the manufacturers will be quick to adopt the newer technology. The more likely military application is in Predator drones, which currently have extremely expensive radar systems.

For now, MESA's latest iteration is selling for around $10,000, but Echodyne hopes to get the cost under $1,000 if they can achieve greater scale. And if they can get there, radar arrays made of metamaterials could soon take vehicles to our doors, delivering packages and pushing drones to their next technological step.

"[The study of] metamaterials is still a fairly academic field for a lot of people," Frankenberg explains. "Not many [metamaterial technologies] are being commercialized yet, and I'm not exactly sure why." 360



HIDING THE LIGHT

HARRY POTTER MANAGED PLENTY OF MISCHIEF using little more than youthful overconfidence and his invisibility cloak — a garment that projects only what's behind him. And while that level of sophistication has yet to reach our muggle realm, scientists are now harnessing the magical physics of metamaterials to pass light around objects, rendering them invisible.

At labs around the world, researchers are already employing an array of approaches — from lens systems that pass light around an object to sheets that can manipulate how light waves absorb and scatter. Most of these devices are bulky and don't make you invisible enough to sneak past Snape. But the U.S. Department of Defense (DoD) is already intrigued by the idea of deploying the technology.

In 2015, Boubacar Kante, an assistant professor at the University of California, San Diego, created a cloaking material that's not as thick as previous versions, which often had to be bigger than the object they were hiding. These thin Teflon sheets are embedded with cylindrical ceramic particles, and by changing their height, the scientists can control how light reflects off the cloak. Kante's research was published in the journal *Progress in Electromagnetics Research*, and, according to a report from the Army Times, the team also submitted a proposal to the DoD.

But that's not all this tech is good for. "It's not just cloaking," adds the Imperial College London's John Pendry, who first schemed up using metamaterials to make invisibility cloaks. "It's the ability to steer light away or gather it."

Scientists are now trying to use metamaterials to build solar collectors that harness the sun's energy more effectively than conventional solar panels.

THE MOST DANGER

Are drones the next step in the advancement of hunting and fishing technology?

By Leah Froats

OUS GAME

An aerial (or underwater) vantage point certianly helps in scoping out areas where fish, fowl, or game may be hiding — but some assert that drones violate fair chase ethics.

THOMAS DANNEMAN

eaves and twigs rustle quietly underfoot as you edge, inch by inch, around the forest's felled detritus, target in sight. You silently raise your weapon, lining up for the perfect shot. Loosening your muscles and taking in breath, you ready your aim — but the deer is suddenly spooked. You then hear an unnatural, high-pitched whine quickly approaching and turn to spot a small quadcopter hovering behind you. By now, the deer is gone.

This is just one of many unpleasant scenes that hunters envision when thinking about how drones will affect the world of hunting and fishing. For traditionalists, UAVs are nothing more than a technological irritant disrupting the integrity of the sport. But is it possible that drones have a place in the world of hunting and fishing — and what might that place be?

FAIR AND SQUARE

The primary nexus at which hunters can unite is the shared ethical concept of fair chase. The idea is self-explanatory: The animal you're hunting has to stand a chance in evading you. Proponents of fair chase explain that this is what sets those who hunt apart from those who kill.

Former President Theodore Roosevelt pioneered the idea of fair chase — yes, like the story where he refused to shoot the bear tethered to a tree. (Google it.)

The Boone and Crockett Club, a conservation organization founded in 1887 by Theodore Roosevelt and George Bird Grinnell, defines fair chase as "the ethical, sportsmanlike, and lawful pursuit and taking of any free-ranging wild, native North American big game animal in a manner that does not give the hunter an improper advantage over such animals."

Clayton Liebherr, a lifelong hunter and Wisconsin resident who also works with drones professionally, is a strong advocate for the ethic of fair chase. Liebherr acknowledges that the exact definition of fair chase could be subjective, but for him, drones for the hunt crosses a definitive line.

"To me, this is a cut-and-dried answer. Yes, I feel that the use of drones to aid the hunter in any way is absurd, and definitely violates the concept of fair chase," he says. "The U.S. government uses drones to target insurgency. But we are not at war with deer."

THE HIGH-TECH HUNT

Hunting is, of course, no longer the spears-and-rocks endeavor pursued by our ancient ancestors. Technology has advanced, and those developments have trickled into the world of hunting in some pretty dramatic ways. Advanced trail cameras, scent control sprays, mobile GPS, digital game calls, wind detectors, and ever-evolving weapons are just a sampling of what is available to contemporary, tech-savvy hunters.

Hunting and fishing technology has come a long way from the days of rocks and sticks. But at what point does this tech provide an unfair advantage to the hunter?

THOMAS DANNEMAN

Fishing gear has come a long way, too: Braided fishing line, sonar bobbers, underwater cameras, and computerized fishing poles all help to reel in a keeper. Oh, and of course, there are drones.

When it comes to their application, there are a few ways that drones can, hypothetically, be used in hunting: scouting to determine location, flushing out or herding, or, in the most extreme case, shooting from an aerial vantage.

For fishing, drones can be used to scout for locations of fish using cameras or sonar. But the most popular application is using UAVs to carry out fishing lines and lures to catch bigger fish — especially when surf fishing from shore.

To anyone who has actually flown a drone, it is likely clear that UAVs are not the platform most conducive to the stealth and quiet usually associated with hunting. And flying over water is more than enough to make even an experienced pilot wary.

Despite these shortcomings, a quick search on YouTube will yield dozens of drone-hunting videos. These posts show that not only are people confident that a drone is a good tool for hunting and fishing, but that they're also emboldened enough to post footage on the internet.

But is this really something that we should be thinking about? Are there really people out there using drones to get the upper hand on their prey?

LAW OF THE LAND (AND SEA, AND AIR)

These questions may only be relevant if you happen to be in a place where such activity is legal — which has become increasingly rare in the past few years.

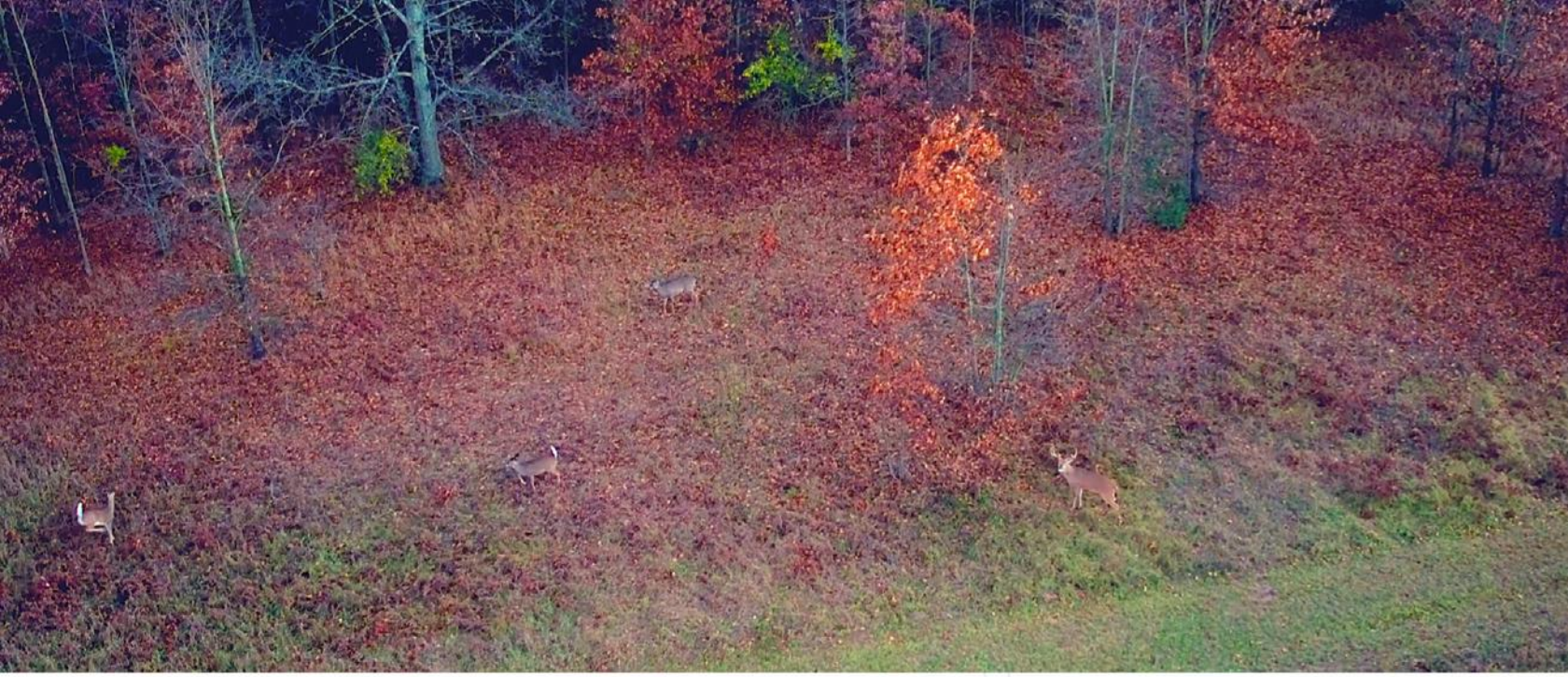
In the U.S., nearly all 50 states have regulations in place to prohibit the use of aircraft or other motorized vehicles to hunt, scout, or take game. But the phrasing of these rules varies — some say that an aircraft can't be used in any way, others say an animal can't be hunted from a vehicle. Some regulations apply to waterfowl, or "game animals," or "protected species," or mammals, or wildlife altogether.

There are other variants to the rules: Pennsylvania's rules don't prohibit vehicles or aircraft, but they do ban hunting with any "electronic contrivance or device." So it can become a little unclear exactly where drones fall under the rules.

However, a handful of states have added specific and concrete reference to drones or unmanned vehicles within their rules. In 2014, Colorado became the first state to explicitly ban the use of drones for hunting — more states followed suit. Arizona, Wisconsin, Minnesota, and others reference drones or UAVs by name in their updated hunting legislation.

Bob Thompson, lead investigator for the Colorado Parks and Wildlife Service, explains that no one incident inspired Colorado to make the first move toward outlawing drones for hunting. Instead, it came back to the importance of maintaining fair chase.

"THE U.S. GOVERNMENT USES DRONES TO TARGET



Not everyone endorses drones for hunting. Aerial photographer George Sharick prefers to use his drone for wildlife shots, and PETA used their UAV to monitor hunters' actions.
GEORGE SHARICK (ABOVE), PETA (RIGHT)

And in response to New Hampshire's decision to ban the use of smart rifles, live-action game cameras, and drones for hunting, the state's Humane Society Director, Lindsay Hamrick, issued a statement, saying, "The Fish and Game Commission took a huge step in the right direction .... These advanced technologies completely erode the essential principle of fair chase, and stack the deck against wildlife at an unacceptable level."

There are some other interesting rules: States like Kentucky and Oklahoma have rules in place that allow hunters with disabilities to use motor vehicles to hunt, under specific conditions. Whether drones may be included under that designation is unclear. In Texas, Oregon, and Tennessee, standing regulations on hunting with aircraft or vehicles can vary depending on if the hunting is happening on private property.

Another strange legislative twist: Multiple states now ban the use of drones to harass hunters or interfere with legal hunting operations.

These regulations likely come in response to a 2013 campaign by the People for the Ethical Treatment of Animals (PETA) to use "Air Angels" drones to capture "footage of hunters engaging in cruel and/or illegal activities," according to PETA's blog on the subject. PETA originally offered the Air Angels UAVs for sale through its online catalog, but the drones are no longer available.

ENFORCEMENT WOES

While the legislative efforts of these states are all well and good, the question that follows is one that has plagued the drone industry as a whole — who will enforce these rules, and how?

Fish and game wardens are usually the ones tasked with upholding hunting and fishing regulations. A hunter could try to put up a drone to scout or flush game without anyone noticing, but Liebherr isn't too worried about the illegal use of drones on the hunt.

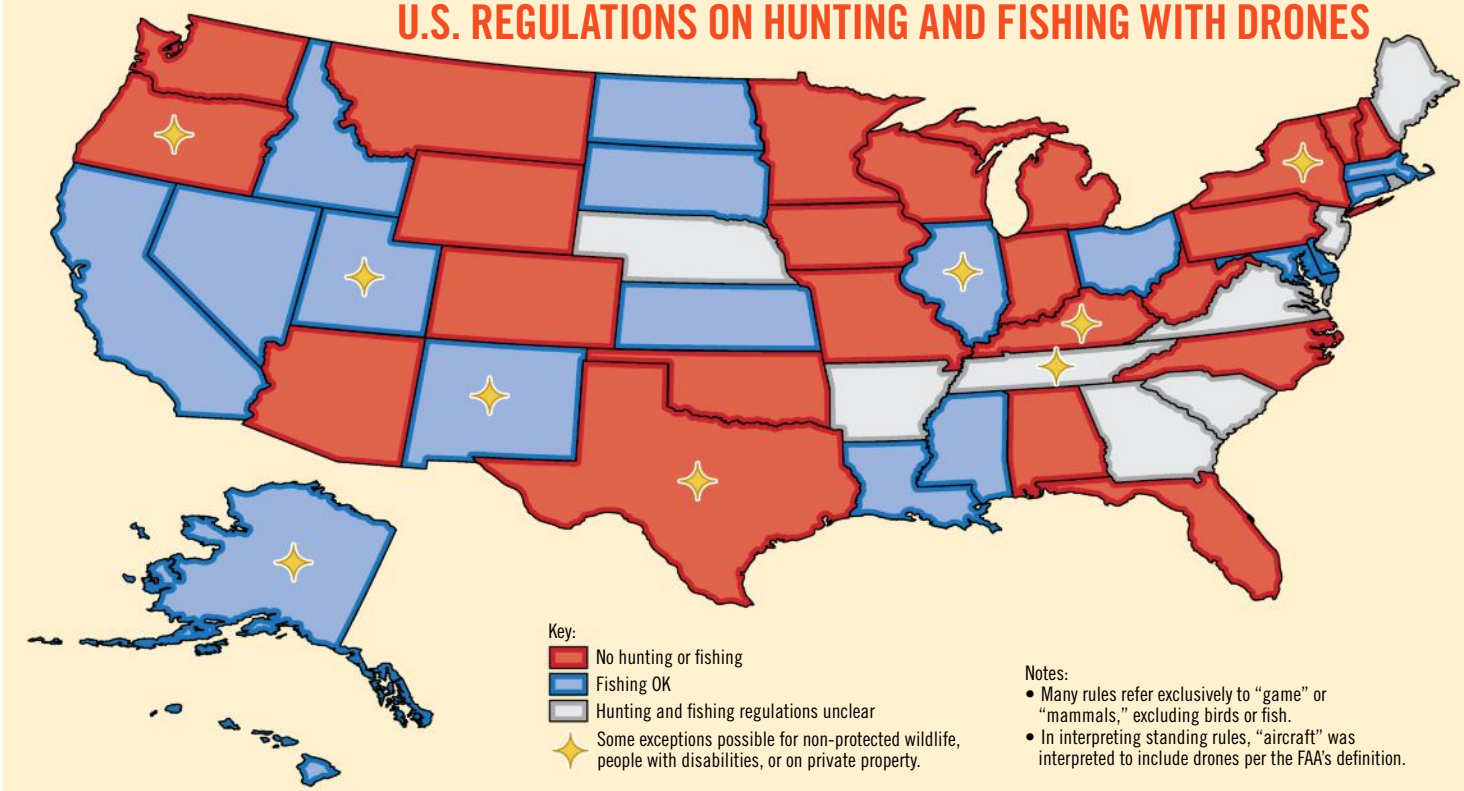
While he does acknowledge that laws can be broken in the relative isolation provided by the practice of hunting, drones tend to be both visible and noisy — if it doesn't attract the game warden's attention, another hunter will likely take notice and pass along that information.

And as those of us in the drone community know, people with guns who don't take too kindly to drones are often inclined to take matters into their own hands (Page 48).

Even if you're just putting up your drone to film the hunt or take some scenic photos while you're hot on the trail of big game, it could be hard to prove whether or not you were using the drone to aid

INSURGENCY. BUT WE ARE NOT AT WAR WITH DEER."

U.S. REGULATIONS ON HUNTING AND FISHING WITH DRONES



ILLUSTRATION/RICK JOHNSON

The Swellpro Splash UAV is just one of many attempts to create the perfect fishing drone. The company claims the Splash is both waterproof and wind resistant. Willing to test that?

SWELLPRO

the hunt. There's currently minimal precedent for how these issues would be handled by a game warden or other law enforcement officials.

"If the drone were equipped with thermal sensors, then I would guess that it's being used as a real-time scouting/flushing aid, giving the hunter an unfair advantage," says Liebherr.

And Thompson clarifies that, at least in Colorado, harassment of wildlife comes with its own punishment, even if you're not using the UAV for hunting — a criminal statutory misdemeanor charge.

So if you're using your drone in a manner that "in any way endangers, worries, impedes, annoys, pursues, disturbs, molests, rallies, concentrates, harries, chases, drives, herds, or torments wildlife," you're still in violation of the law, according to Thompson.

If you're at all unclear on the rules, the best thing to do is to call your state's fish and game commission to determine exactly what is or is not allowed. To quote Montana's hunting education course, "If you hunt, you must know the laws and respect them. Ignorance is not a defense!"

SOMETHING'S FISHY

What may come as a surprise is how few states prohibit the use of drones for fishing. This is possibly due to the very recent surge in the popularity of drones for this application. Based on current phrasing in state regulations, as many as half of U.S. states appear to lack concrete regulation barring the use of UAVs to fish.

And while the "drones for fishing" thing is just recently starting to take off, using a mechanism to carry out fishing lines isn't a new idea.

In New Zealand, a style of fishing known as "kontiki" has used vessels — evolving from small, makeshift craft carried by wind to modern autonomous seafaring drones — to carry lines to where the fish are for decades.

Aerial drones have all the benefits of these seafaring kontiki, but also allow the fishers to scout from the skies for the best location to drop their line.

There are numerous brands that market aquatic or aerial drones specifically for the purpose of fishing: AguaDrone, Seahorse Electric Kontikis, and Swellpro all sell drones optimized with special

"THESE ADVANCED TECHNOLOGIES COMPLETELY

features or attachments for fishing. Others offer drone-fishing accessories, like the Australian company Gannet, which designs accessories for DJI's Phantom line of drones.

That being said, any multirotor rigged with a line-dropping mechanism can serve as a useful tool for shore fishing. Just ask Jaiden Maclean, the drone pilot responsible for the flight in perhaps the most viral drone-fishing video on YouTube. Simply entitled "Drone Fishing for Tuna," the April 28, 2016, video has more than 2.7 million views.

ALIEN INVASION

Responsible hunting and fishing practices help to keep populations of certain animals in check when their numbers grow to unsustainable levels. But sometimes a species can end up where it doesn't belong, resulting in populations so high they threaten entire ecosystems — a situation where drones may come in handy.

A perfect example of such a destructive invasive species is the lionfish. Native to the Indo-Pacific, lionfish are ravaging prey species and reefs in the west Atlantic, Caribbean Sea, and Mediterranean Sea. How lionfish ended up so far from the Indo-Pacific is unclear, but their impact on their non-native environment is undeniable.

The lionfish has no natural predators in its new surroundings, so their numbers grow extremely quickly — populations have reached over 1,000 per acre in the most extreme cases. These huge numbers of lionfish result in over-predation of the lionfish's prey species, damaging entire reef ecosystems.

The group Robots in Service of the Environment (RISE) is aiming to use drones to help mitigate the damage done by these invasive fish. RISE's website explains that no traditional trapping or fishing methods have been effective in controlling the invasive lionfish population — there are just too many for these efforts to make a dent. Hence the creation of a remotely operated vehicle (ROV) designed to cull the lionfish without harming other species.

The PowerRay ROV was designed specifically for the hobby of drone fishing — it even has an electronic light "lure," much like the anglerfish.
POWERVISION

PowerVision, creator of everyone's favorite ovoid aircraft, recently released the PowerRay. This underwater ROV can release a Fishfinder sensor orb to locate nearby prey.
POWERVISION

If RISE succeeds in controlling the populations of lionfish, similar techniques could be employed by drones in other contexts to help control the populations of other invasive species — if it's within the law, of course.

IS THE SAFETY ON?

For now, drones are still fairly new on the scene for hunters and fishers — many states have yet to form concrete rules on whether these technologies are allowed. It's possible that, with some effort and collaboration from the hunting and drone communities, UAS could become more accepted for these applications.

And with innovative and beneficial concepts like those from RISE, the future landscape of drones for hunting and fishing could become even more complicated. Whether by sea or air, UAVs could find their rightful place in the arsenals of hunters and the tackle boxes of fishers — only time will tell.

"I'm more of a traditionalist when it comes to hunting," explains Liebherr, "[but] I could see the up-and-coming generations of hunters possibly warming up to the idea." 360

Lionfish are just as menacing as they appear. Their venomous fins are dangerous to humans, making them the perfect prey for drones.
OREGON STATE UNIVERSITY

ERODE THE ESSENTIAL PRINCIPLE OF FAIR CHASE."

In the CROSSHAIRS

Shooting down drones puts lives at risk

By Faine Greenwood

"I took off and started taking pictures, and then I heard a gunshot."

It's the first line of a drone-pilot horror story, and it happened to Abbe Lyle. A photographer and drone operator in California, Lyle decided to pull off the road and take some panorama shots of the always-lovely Napa Valley. Lyle hadn't noticed any signs that the property was under private ownership, and she assumed the gunshot came from a hunter farther up the valley.

"I heard a second gunshot and thought, 'Oh my god, this is for me!'" she says.

Lyle scanned the area, but couldn't see the shooter. Whoever it was hadn't hit her DJI Phantom 2 Vision+ quadcopter, so she desperately began to maneuver it in for a safe landing. That was when the shooter emerged, shotgun in hand, and he looked angry. He sounded angry, too.

"This is a crime scene! Don't move!" he shouted over and over, according to Lyle. She didn't know if "don't move" applied to her thumbs on the sticks as she piloted her drone down, but swallowed her apprehension and kept working. The man, the owner of the property adjacent to where Lyle was flying, called the police even as she apologized for accidentally flying over his land. Soon, a police officer pulled up on a motorcycle.

Now, with the police on the scene, the man's demeanor softened. He offered that

Focusing on the mist in the distance and the rolling landscape, this was the photograph an unsuspecting Lyle took just before gunshots were fired at her quadcopter and safety became her number one concern. ABBE LYLE

Focusing on the mist in the distance and the rolling landscape, this was the photograph an unsuspecting Lyle took just before gunshots were fired at her quadcopter and safety became her number one concern. ABBE LYLE

he suffered from PTSD and had served three tours in Afghanistan. He said the hum of the drone's motors and propellers had upset him — that it sounded like the drone was flying in upon his family.

"I reassured him, and, in the end, I made a panorama of his property and sent it to him," Lyle says. She still has the shotgun shell the property owner gave her as a memento of their encounter.

Lyle isn't the only drone pilot who's been shot at or who has had a drone shot down. Irate bystanders have been threatening to shoot drones down ever since consumer models started to get popular, claiming they reserved the right to meet robotic trespassers with gunfire.

As a hobby drone pilot, this kind of talk makes me nervous: I'm worried my own drone flights might be met with gunfire, putting me and my friends and colleagues at risk. And I'm especially worried future drone shootings will end less happily than Abbe Lyle's did.

How often does this happen?

As more drone-shooting stories hit the headlines, I decided to look into the incidents that have happened to date, with the goal of helping drone pilots better understand how often this happens and what they ought to do if they find themselves the target of aggression. I also started thinking about why drone shootings are becoming more common, and why many people seem to find gunning down a drone acceptable.

What's more, is there anything we, as a community, can do to better protect ourselves?

While I had a gut feeling that drone shootings were becoming more common, I wanted evidence. I performed an admittedly unscientific analysis of news stories

in the U.S. and Canada in which a civilian shot down another civilian's drone, excluding incidents that involved police or government action. Ultimately, I found 13 different instances in 10 U.S. states and two Canadian provinces that occurred between January 2012 and the end of October 2016. I counted eight drone shooting incidents reported in the media between January 2016 and October 2016, while I could find only two such incidents for 2015 — which may be an indicator that more drones are getting shot down. (I could not find a news report of a civilian drone being shot down by another civilian prior to 2012).

Why more drone shootings?

There's one simple explanation for the increase in drone shootings: There are more drones in the sky than even just a year ago. More drones translates into a greater chance that they'll come into contact with disgruntled, armed property owners. But while this increase in drone ownership is indisputably a big factor in the increase in the number of shootings, I suspect it's not the whole story. Sensational media coverage of drone shootings, legitimate concern over threats to privacy, and a lack of public understanding of the exact capabilities of small consumer drones are also to blame.

While media coverage of drones is hyped-up less than it was a few years ago, recent drone shootings have attracted serious attention — and lots of commiseration with the shooters. This public sympathy most strongly swelled around William Merideth, the Kentuckian who shot down a drone in July 2015, sparking a legal battle with the drone owner — and thousands of arguments across social media.

I rolled into a few of these arguments myself, and I found myself shocked by how many people who professed to abhor violence offered full-throated support to Merideth and his tactics. Many saw him as a man who'd struck back against both tiresome Silicon Valley techies and government overreach. To them, the shooting represented something very different from firing a gun at a human trespasser: Merideth had defended himself against a robotic interloper and, in the process, stood up for property owners' rights. Merideth and supporters quickly capitalized on his heroic status, selling T-shirts and launching a meme-heavy "Drone Slayer" Facebook page that can proudly claim more than 1,200 followers.

Merideth was charged with first-degree criminal mischief and first-degree wanton endangerment. The presiding judge, Rebecca Ward, threw out the case, deeming the drone's low altitude posed an invasion of Merideth's privacy.

"He had a right to shoot the drone," Judge Ward said, dismissing the charges.

In all the cases I looked at where a drone has been shot down, the shooters (at least those who spoke to reporters) use invasion of privacy as a common justification for letting lead fly.

The violent response to drone overflights may also stem from widespread misconception concerning what consumer quads can actually do. It's hard to blame people: The word drone can mean a lot of things given the wide range of UAVs that fall under the term's umbrella. Meanwhile, TV and movie portrayals of small drones — think *Agents of S.H.I.E.L.D.*— show sophisticated spy devices capable of silently hovering wherever they're sent for hours at a time, responding with dog-like intelligence to voice commands, and stealthily creeping into homes. Stories of terrorists deploying consumer drones to rain destruction and death from on high will not prove helpful either as we move forward.

Nevertheless, those of us who fly (and crash) consumer drones know they aren't capable of persistent, silent surveillance, operating many miles away from their pilot, effectively tracking and attacking a target, or performing complex autonomous tasks. Sadly, these limitations don't make for attention-grabbing online articles or quick-hit news segments. The result is a media representation of drones that is not entirely accurate — which leads to public misinformation, distrust, and fear.

Talking to drone skeptics

It sucks for everyone in the drone community to see people approvingly share memes and bluster about shooting down drones. Can we convince them to put away their shotguns?

When I discuss shooting drones, I try to appeal to both heart and head, addressing the very real safety issues to innocent people and the legal liabilities one might face for shooting down an aircraft.

Safety: Shooting down a quadcopter does more than destroy the aircraft; it endangers people and property on the ground. Anytime a gun is discharged, there is a chance of injury — every year, people get hurt or die after being hit by stray bullets and celebratory gunfire. This is why it's unlawful to discharge a firearm in most populated areas in the U.S.

Simply using smaller ammunition (like birdshot) doesn't increase safety, despite what aspiring drone slayers may think. While hunters often wear eye protection, drone pilots typically don't. What's more, they usually turn their gaze skyward, putting them at higher risk of eye injuries from shot and falling debris.

Making matters worse, most drone pilots don't fly alone. Many will take along a companion or two to help them haul gear and act as spotters to reduce the risk of interfering with other fliers, flying over people, or getting too close to obstacles. Sometimes they bring children with them when they fly. Some drone pilots are children themselves.

While gun owners may know not to shoot in the direction of people, many

William Merideth holds the shotgun he used to shoot a drone out of the sky above his backyard in Louisville, KY, in July 2015. All criminal charges were dismissed.

THE WASHINGTON POST/GETTY IMAGES

You could hurt more than a drone

284
stray-bullet shooting events

317
people injured

81%
of victims unaware of events leading to shooting and injury

65
deaths, most the same day or at the scene

March 2008-February 2009
Source: UC Davis Health

BEGINNING THE CONSUMER DRONE MAKEOVER

Let's face it, drones have a shady reputation among the general populace. This is in large part, but not entirely, because the word, *drone*, is so closely associated with military aircraft. But it is the word we're stuck with, so stuffing that particular genie back in the bottle is wishful thinking. It also doesn't help that quads and hexacopters tend to look menacing, like predatory insects. However, there are some things — centered around the technology, education, and our own attitudes — that both the industry and remote pilots can do to help the public at large feel less nervous about our flying robots. The drone community needs a public-relations makeover so potential shooters will be less likely to assume the worst when they see a multirotor copter or its pilot.

TECH

Property owners inclined to pull the trigger before asking questions might welcome technology that tags every drone with a unique ID that can be read from the ground. NASA is working on Unmanned Aerial System Traffic Management for civilian drones that might enable this capability without imposing restrictive weight requirements.

"If every drone had a signature, there'd be a way for ambulance drones or humanitarian drones to be identified. Maybe people on the ground could have scanners like Flight Aware telling them this is a humanitarian drone," says Loretta Alkalay, a drone attorney and former FAA regional counsel.

Beyond sophisticated scanning tech, drone professionals and state and national authorities may also create special markings for drones performing particular beneficial tasks to make them easier to identify.

Think about it: We mark ambulances, fire trucks, and police cars with special lights and reflective decals. We could do something similar for UAVs used during search-and-rescue missions or ecological research. Specific markings and particular light patterns could reassure property owners that the drone's mission doesn't involve hovering over their hot tub.

Another option might be an open service that allows property owners to geo-fence their land and make it inaccessible to flights by consumer drones not specifically used by law enforcement or other authorities.

EDUCATION

You can't imagine how effective the act of asking permission to fly over a person's land can be. In my experience, asking permission leads to a conversation, and, almost like magic, can turn drone skeptics into drone owners. I've lost count of how many people ask where they can buy a quad after they've seen me fly mine. Asking permission costs us nothing and the payoff can be huge. What's more, you have the peace of mind knowing that no landowner is going to come out of the woods with a gun leveled at you or your drone.

While we protect ourselves by talking to everyone we can about drones, we should also be introspective and ensure we take the privacy and safety concerns of property owners seriously.

Avoid condescension or getting frustrated with people who don't understand the technology — patient explanations go a long way toward fostering good feelings toward drones and you and me, their operators.

Also, make yourself as plainly visible as possible while out flying. Doing so makes clear that you aren't trying to hide. It also makes you approachable.

So many people have come up to me while I'm flying in public parks just to watch me, which always leads to conversations and my last point.

DON'T BE A JERK

While drone pilots absolutely should argue against the normalization of shooting at drones, that won't be enough to stop public hostility focused on our flying machines. The unpleasant reality is that we lack leverage: We're the people pushing a new technology.

Sure, it's tempting to meet belligerent "I'll shoot your drone!" threats in kind, but that approach will likely escalate an already tense situation. If we don't want property owners to be jerks to us, we must first try not to be jerks ourselves.

Alkalay says the Golden Rule of droning is, "Drone unto others as you would want them to drone unto you."

Start by avoiding flights over private property without permission, if you can help it. A number of the drone shooting cases I researched involved a drone pilot (often accidentally) flying over private property without first asking permission. Just because you can legally fly over someone's property without warning them in advance doesn't mean that you should. Journalists can make arguments about overflights, but that's another discussion.

As a hobbyist, you have practically no reason to avoid making a good-faith effort to ask a property owner for permission to fly; making the effort matters even more if you're doing commercial work.

"If you're doing a job, you have an even greater obligation not to trespass," says Alkalay. "It's about being a good neighbor or being a good businessperson."

Flights over private property can be seen as intensely personal invasions. Each angry homeowner who tells their friends about the creepy drone that hovered over their hot tub does damage to the entire drone community's reputation. Further, it does nothing to help deter people from taking direct action, possibly with a firearm.

"I don't want to give drones more of a bad name or a bad rap than they already have," says Abbe Lyle. "If I can turn this story around and make it a feel-good story, it benefits us. It's not an 'us' and 'them' situation, and unfortunately, that's what it becomes."

A drone community that develops a reputation for good behavior and respectful requests is more likely to be viewed favorably by local voters and policy makers. If we are to realize the amazing potential of drone technology, we need to pair self-protection and advocacy with education and understanding.

On a larger level, if we want frightened or angry property owners to extend basic politeness and human decency to us (by not shooting without warning), that means we should set the example by doing the same and asking before we fly.

I'm hopeful that we can reduce the number of drone shootings, fending off a potential future in which we're forced to don bulletproof vests and safety goggles to go out and fly our drones.

"DRONE UNTO OTHERS AS YOU WOULD WANT THEM TO DRONE UNTO YOU."

don't know how close the average small-UAV pilot is to the aircraft. They may assume small drones have long-distance operating ranges, like sophisticated military UAVs deployed overseas. And it's unlikely that the average citizen knows that drone operators have to keep their aircraft within visual line-of-sight.

A property owner bent on shooting down a drone is often unaware most pilots are within a few hundred feet of their drones. Rather than shooting at the drone, they'd be better served trying to locate the pilot before opening fire on an object that may not be far from a person.

The National Shooting Sports Foundation, a firearms industry advocacy group, agrees with my safety assessment: "Although we respect the rights of property owners who may not want drones operating over their property, we can never recommend shooting at drones," said a foundation spokesperson in an email.

And what of a damaged drone? Depending upon flight conditions and the pilot's experience, multirotors can be challenging to maneuver even when fully functioning and intact. If it doesn't tumble out of the sky after being shot, the operator could have a tough time landing without crashing, damaging property, or perhaps hurting themselves, the shooter, or other bystanders. To think anyone would be safe under such conditions is a complete misunderstanding of the factors in play.

This is also a matter of civility. It's safe to assume the vast majority of drone pilots don't actually mean to trespass. It makes more sense to at least attempt finding other solutions to unwanted drone intrusion before breaking out a shotgun.

Legality: While the legal status of drones remains a complex topic, one thing's clear: The FAA considers drones to be aircraft. Because federal statutes state it's a felony to destroy or to damage aircraft, the same goes for drones.

Despite the FAA's assertion that shooting a drone constitutes a felony, the FAA has yet to bring charges against someone for shooting down a drone — a failing that has drawn considerable criticism from UAS-industry advocates who'd like to see harsher punishments for drone shooters. To date, criminal charges against drone shooters tend to be of a less serious nature, focused mostly on the value of the drone and discharging a gun in populated areas.

While property owners may assume any drone flight over private property is trespassing, the legal reality remains hazy. States and local governments scramble to create laws about drone flight over private property, but the FAA has reiterated that it has exclusive authority over navigable airspace. There is still no clearly defined altitude where public airspace ends and private airspace begins, and the June 2016 Small UAS Rule (Part 107) does not address drone flights over private property.

The continued legal uncertainty means that spooked homeowners should think twice before pulling the trigger. They should weigh the privacy risk the drone presents against the safety risk of opening fire. That risk assessment looks very different for someone living in the woods of Idaho's panhandle than it does for the resident in downtown Boise.

"The thing you do can only be proportional and reasonable," notes Michael Froomkin, a robotics law expert at the University of Miami. "Shooting into the air is generally pretty dangerous. Unless you're in the middle of nowhere, the risks are much bigger than the benefits."

Ryan Calo, law professor at the University of Washington, is even more explicit. "In my view, the only justification for the use of a shotgun for shooting a drone is if you are physically in peril," he says. "But there's almost no scenario in which shooting [the drone] doesn't cause your risk to go up instead of down."

In short, when confronted with an unwanted drone flying over their property, owners should call the police as their first resort, not their last.

The impression that drones are devices built to peep into backyards and through open windows simply isn't true. Frankly, noisy quadcopters just aren't that useful for spying.
SERGE MOURARET/GETTY

So you've been shot at

What do you do if you're flying a quad and someone shoots at it (or you)?

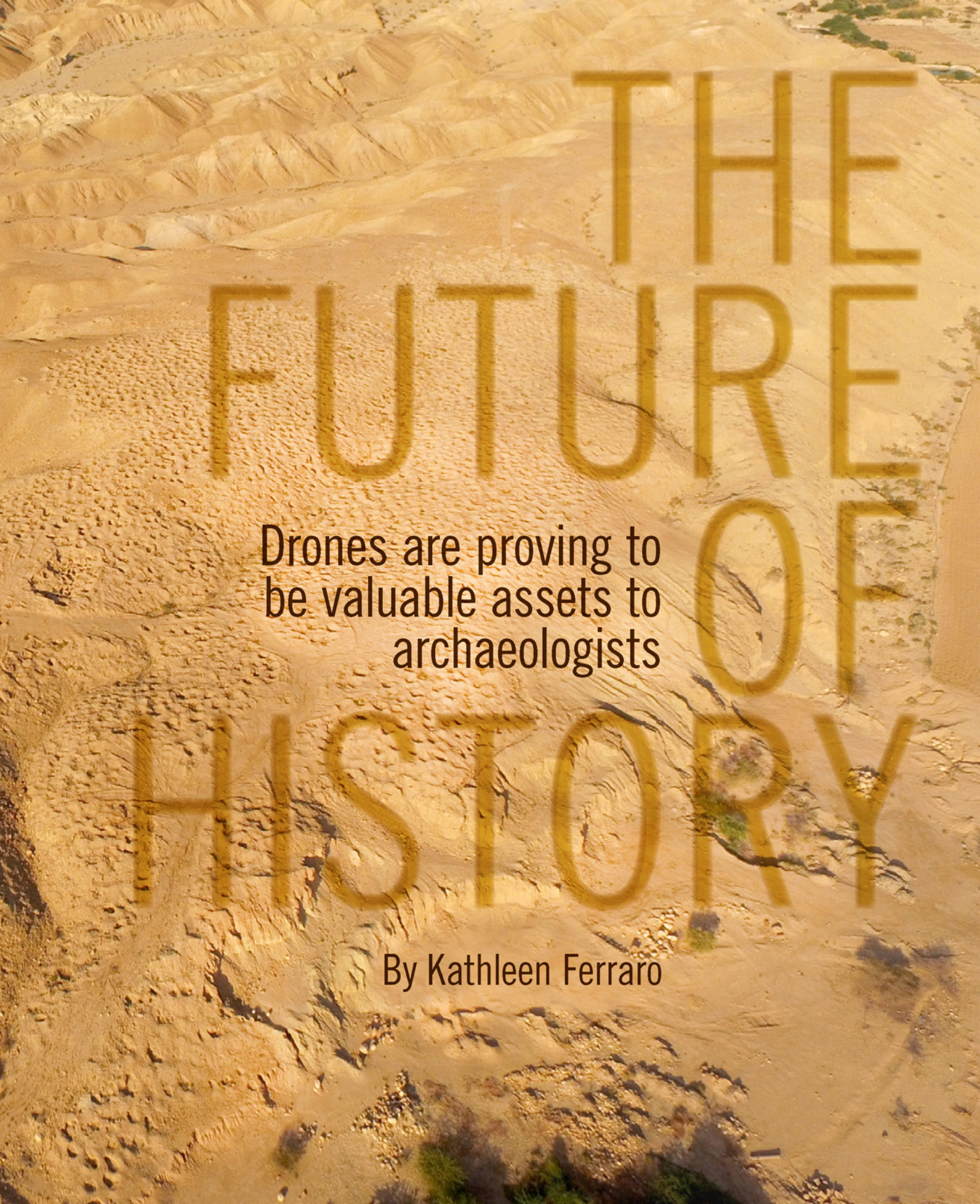
First, try to stay calm. "The moral of the story, for me, was keeping calm and not arguing with him [the landowner], even though he was really pissing me off something rotten," Lyle says.

Jeffrey Antonelli, an attorney specializing in UAS law, emphasizes that you should understand the immediacy of your danger, take cover, and call the police. "Someone out here is willing to fire a firearm — don't get shot!" he says. Once the police are on the scene, report the incident to the FAA. You might consider taking the shooter to court.

Attorney Jonathan Rupprecht says if a drone shooter has a criminal case filed against them, the drone owner could work with the prosecution to secure restitution for any losses as part of a plea deal. "Multiple drone operators filing small-claim cases around the U.S. have been successful in obtaining the value of the drone from the shooter," he says.

Drone insurance may also be a smart protective measure — Verifly and AIG both offer drone coverage — leaving the hassle for recouping damages the insurance company. However, before buying a policy, check to see if it covers shooting incidents. After all, that's the point. 360

Holy moly, that's a lot of holes! A team of archaeologists is using drone technology to find looters of graves — that's right, each pit is a tomb that's been dug up — at a 5,000-year-old burial site in Fifa, Jordan. AUSTIN "CHAD" HILL



THE FUTURE OF HISTORY

Drones are proving to be valuable assets to archaeologists

By Kathleen Ferraro

Ancient artifacts and broken ceramics littered the moon-like landscape. Dozens of holes peppered the arid terrain, unearthing tombs five millennia old, their contents uprooted and scattered in the dust. The last thing you'd expect to see in the sky above such a scene is a neon R/C airplane with a GoPro strapped to its front.

But for Morag Kersel, archaeologist and professor at DePaul University, piloting drones above the burial site at Fifa in southern Jordan is just another day at the office.

Kersel and her team — which includes Austin "Chad" Hill, a post-doctoral researcher at Dartmouth College, and Yorke Rowan, senior research associate at University of Chicago's Oriental Institute — have spent the last four years on the Dead Sea Plain monitoring the burial site, tracking man-made changes in Fifa's landscape with drone footage.

Her team's research focuses chiefly on documenting the activity of artifact looters who scavenge tombs for ceramic pots and then sell the antiquities on the black market. Kersel's research using drones has become an experiment in the effectiveness of aerial robots as an archaeological tool, helping to usher in the future of studying the past.

Since the beginning of the project, drone imagery has helped the team identify a startling 61 new holes looters have dug into graves, says Kersel. Given that the dead in Fifa's tombs are buried with between six and 30 objects, the monetary value of the illegal dealing of burial artifacts could amount to over $200,000.

SUPERIOR ALTERNATIVE

Aerial imagery provides a much-needed bird's-eye view to scout, survey, monitor, and map a particular area to supplement on-the-ground research. While the use of drones in place of other aircraft is a recent development, archaeologists have been capturing overhead images of field sites for nearly a century — some of the more adventurous actually hovered in hot air balloons to get their photos.

"The U.S. military, the Royal Air Force, and many other Western military organizations were taking photographs from planes," says Emily Hammer, an archaeologist at the University of Chicago. "Those images, going back to the '40s, sometimes even to the '20s or the 1910s, those have been used in archaeology for a long time."

But today, with photographs from the '20s outdated and the high costs of traditional aerial imaging methods, drones are at the forefront of aerial imaging techniques.

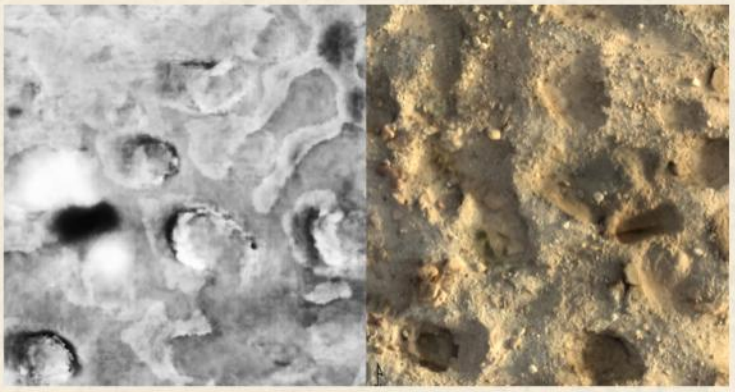
After failing to find a commercial aerial photographer — services which range from a manned aircraft carrying a photographer to a third party specializing in drone or satellite aerial surveying — at a reasonable price, the idea to use drones at Fifa developed naturally. Hill, a longtime R/C enthusiast and drone builder, suggested using drones as an alternative to purchasing costly commercial images.

They may not look like much, but these ceramic pots unearthed from the Fifa burial site are exactly what looters are after. Pots like these can go for $30-$150 each on the black market. MORAG KERSEL

Whether gathered by manned aircraft or professional drone companies, commercial images can run upwards of $500 per site for a limited number of photos. And this doesn't usually include travel costs. Many entry-level off-the shelf drones with cameras have a one-time $1,000-range price tag, according to the 2016 Society for American Archaeology (SAA) Archaeological Record publication. Given the constant need for new images to keep up with changes in the landscape over time and multi-site coverage, these seemingly one-time commercial costs pile up quickly compared to the cost for a drone.

Hill began with a basic off-the-shelf Skywalker R/C aircraft, mounting cameras to the fixed-wing airframe to collect simple images. He piloted the drone manually, flying it back and forth across Fifa, hoping to visually line up the flight pattern to collect corresponding images. Between mastering his piloting skills, eyeballing the drone's altitude, and

Researcher Austin "Chad" Hill prepares to launch a Skywalker 1680 FPV drone with an attached GoPro Hero camera and a Canon S100 digital camera at the site of Fifa, Jordan. The drone was also running an APM 2.6 flight control computer. MORAG KERSEL



Comparing two digital elevation models helps determine whether or not new looting holes have appeared at Fifa. Left of image: The black shape means a negative change occurred (new hole), while the white means positive change occurred (new dirt pile). AUSTIN "CHAD" HILL

Archaeologists Morag Kersel and Austin "Chad" Hill take a dronie — proof you can both work and play when dealing with history — while surveying Fifa with their DJI Phantom 3. AUSTIN "CHAD" HILL

dealing with undesirable weather, this was no easy feat.

Eventually, Hill moved from using various iterations of do-it-yourself fixed-wing drones to a donated DJI Phantom 3. The Phantom 3 can fly autonomously and cover a defined area at a preset altitude to collect images more efficiently — fortunately so — than its manually controlled counterparts.

Most recently, an autonomous fixed-wing drone (also a Skywalker aircraft) was added to the Fifa fleet. This drone can fly farther and longer per battery, allowing Hill to cover more of the site from relatively similar altitudes in a single flight and resulting in more consistent, higher-quality images.

MAPPING MADE EASY

Drones also make it possible to collect data with relatively low effort, says Hill.

To operate most of the project's multirotors and autonomous fixed-wing drones, Hill relies on open-source hardware packages like Pixhawk or ArduPilot Mega. These systems are capable of autonomous stabilization, waypoint-based navigation, and transmitting real-time measurements and data collected in flight to computers on the ground, making a drone a veritable fourth member of the Fifa research team.

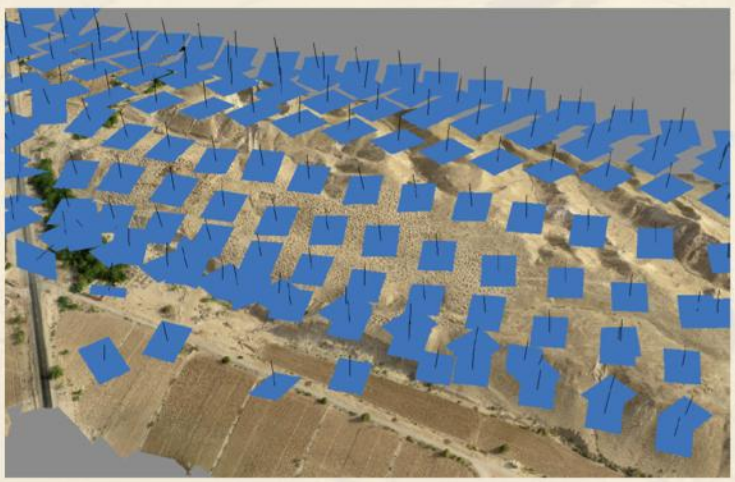
With systems like these, Hill need only input the GPS coordinates of the site and the desired altitude that a drone should fly above a designated area. After that, the drone takes off, flies the preprogrammed flight pattern, and lands on its own.

According to archaeologist Mark Altaweel of University College London's Institute of Archaeology, these hardware packages still keep the cost lower than expensive commercial photography or satellite images — remember a commercial image of a strip of land can cost up to $500. In contrast, autopilot hardware packages like the aforementioned Pixhawk run about $150 per drone, and include flight control computer, GPS sensor, barometer, magnetometer, and gyroscopes to make the craft fully functional to fly on its own.

During a typical flight, Hill directs a drone to cover about 0.4 square miles of the burial site at an altitude of roughly

Over 200 drone photos captured in 2016 were overlaid to create this orthographic map of the Fifa site in Jordan. AUSTIN "CHAD" HILL

This DIY drone uses a Tarot quadcopter frame and was flown for the 2014 season at Fifa, Jordan. Fun, and somewhat disturbing, fact: It's sitting on dirt that was dug up from a grave. AUSTIN "CHAD" HILL



To create a 3D model, PhotoScan calculates a drone's ground control points. Each blue square — they're not sticky notes — represents the location of the drone when snapping images. AUSTIN "CHAD" HILL

500 feet. This altitude allows an image resolution of about half an inch per pixel on the ground. Hill almost exclusively uses a Canon S100 camera that's strapped to his DIY aircrafts, although he sometimes relies on the Phantom 3's standard onboard camera to collect the more oblique, illustrative images of Fifa.

"The primary goal of a flight is to get sets of overlapping images that are sufficient for doing 3D modeling. We are also collecting ground control point data, so we get millimeter-accuracy ground control points that appear in the photographs," Hill explains. "As long as you get a set of images that overlap by like 60%, then you can combine them in the photogrammetry package to get a complete map of the site."

In other words, a drone will sweep back and forth across a designated area to collect overlapping photos that, when lined up, create a detailed spatial map.

To create said maps, Hill uses digital image processing software packages like PhotoScan Pro and Bundler to combine drone footage with photogrammetry — the use of photos to measure distance between objects. In order to ensure accuracy of each flight mission, he processes the images from each drone flight the same day at low quality.

But the real magic happens after the field season.

Once back in the U.S., Hill works from his desktop computer to finalize map editing with high-quality image resolution and full geo-referencing. Thorough geo-referencing — finding and manually placing the ground control points from the drone flights — is arduous, so final processing can take a couple of days. But these comprehensive 3D models of the site are worth the grind.

Before software like PhotoScan, Hill would use terrestrial survey equipment to take hundreds or thousands of individual photos, which were then converted to schematic maps using geographic information system software. To cross check the maps and visualize the site from above, a droneless Hill attempted every low-cost and low-quality option: climbing poles, ladders, anything conveniently located. Now image processing software has vastly improved the amount of spatial data recorded and the ability to visualize the landscape overall.

Once maps are completed, the team analyzes them relative to one another in order to detect new looting holes at the site: If Image A from research season one doesn't have a hole at a certain coordinate, but

Image A from research season two does, then the team reasonably concludes that looters have penetrated a new tomb.

"In addition to visual inspection, we're also doing change detection using the digital elevation models to detect strong positive or negative changes: positive change from pile of dirt, negative change where new hole itself is," Hill says. "We can frequently identify new pits that are difficult to pick out by eye because we have this high resolution 3D data."

Furthermore, Kersel's team has the luxury of walking to places of interest based on what they see in the drone footage — otherwise known as ground truthing. Drone images provide a broader look at Fifa, revealing patterns and landforms that the crew might have missed while walking. It also works the other way around: The team can confirm things they noticed on the ground by referencing maps.

MORE THAN JUST DATA

But drones are just an added tool to Kersel's arsenal. She also supplements her drone work with ethnographic research — immersive, on-the-ground, human-centered investigation — to understand how modern-day looters, dealers, buyers, and locals interact with Fifa. By conducting extensive interviews with these individuals, she gathers qualitative insights that elucidate the landscape changes she observes on drone images.

Furthermore, Kersel notes that drone use at the burial site encouraged local, governmental, and scientific interest in her work.

"People have been really interested, from all walks of life," she says. "Not only the [Jordan] Department of Antiquities and other archaeologists, but local folks who can come up and see the drones and talk to us."

Similarly, the insights afforded by drone footage

YOU BETTER BELIZE IT: A SEARCH FOR ANCIENT MAYAN STRUCTURES

WHAT WERE YOU DOING IN 2008? Maybe that's not a memorable year for you, but it is for archaeologist Mark Willis: That's when he began using drones in his research.

"Having the capability to fly a drone on demand helps document excavations and may help identify archaeological features that are not visible from the ground," Willis says.

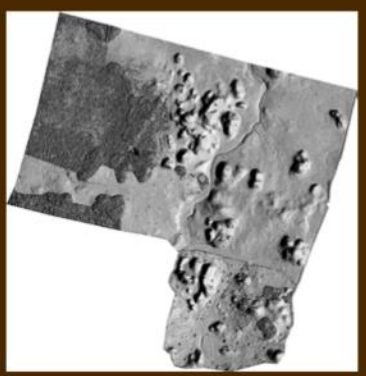
His first drone was a MikroKopter, which required assembly by hand, an expertise in soldering, and a basic understanding of electronics to get up and running. But things in the drone world have dramatically changed since then: Willis and his team now use much more advanced drones, like the those from the DJI Phantom series and fixed-wing Skywalker UAVs.

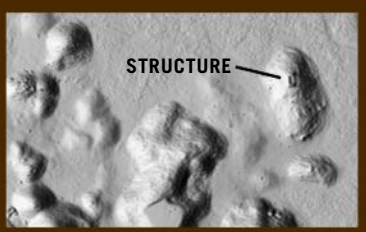
With drones in tow, Willis and his research team traveled to Belize in 2016 hoping to discover ancient Mayan structures, according to a research publication by Willis. They flew two fixed-wing Skywalker drones equipped with Pixhawk autopilot, a mounted Samsung NX2000 camera, and a near-infrared digital camera.

The photos to the right were all taken by drone at the Wamil Study Area (WSA) in Gallon Jug, Belize — home to many archaeological sites. Mostly a clear and open pasture area, the top image was generated from hundreds of images (that means an exhausting amount of drone flights) and shows the WSA.

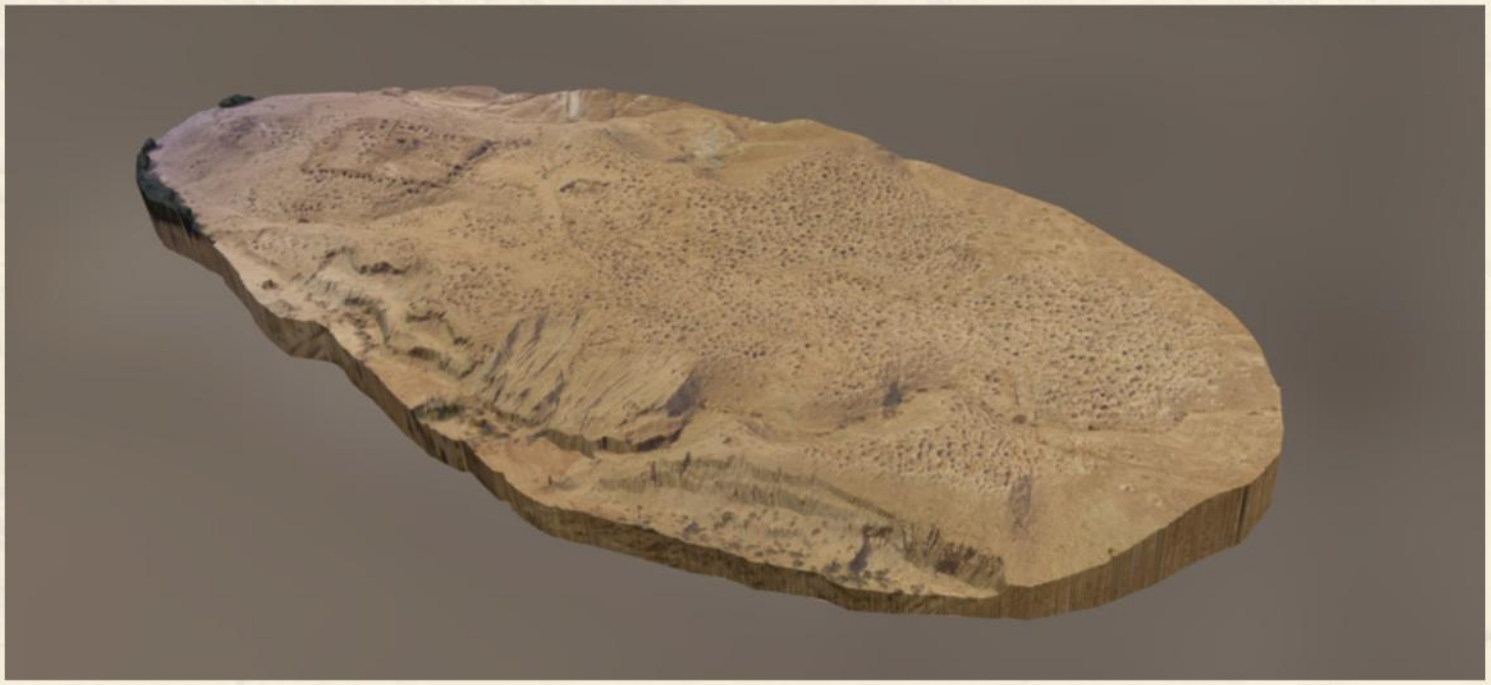
The middle image is a digital terrain model (DTM) of WSA, while the third image is a close-up of the DTM. These models are created using photogrammetry data gathered from a drone and, as demonstrated in the lower photo, show an incredible amount of landscape detail compared to a regular drone image.

Unfortunately, UAVs don't always provide shocking discoveries. While his team discovered prehistoric structures and other archaeological features, Willis believes they could have been easily seen from the ground. Even though he didn't unearth anything solely because of drone tech this time around, he will still continue using drones in future archaeological adventures. — *Lauren Sigfusson*





Mark Willis operates a drone from the DJI Phantom series as a graduate student from Texas Tech views a live FPV video stream of a research site in Belize. Willis and his research team hoped using drone technology would help them discover ancient Mayan structures that would be hard to see from the ground — that wasn't the case. But hey, at least they had fun flying! MARK WILLIS (4)



This oblique view of the Fifa site is a screenshot of an interactive 3D view that was created from numerous drone images. Archaeologists actually 3D-printed a version of this in order to provide a tangible way of interacting with the 3D data. Austin "Chad" Hill

help build bridges between the archaeologists and local authorities. The looting patterns revealed by drone imagery, in tandem with Kersel's ethnographic research, revealed that locals view looting as a potentially legitimate use of the Fifa landscape, according to Kersel.

She shared her insights with Jordan's Department of Antiquities and the Petra National Trust (an organization dedicated to preserving Petra, a UNESCO World Heritage Site) to develop outreach programs that educate locals to preserve national heritage sites destroyed by looters in the artifact trade.

And other archaeologists echo the benefits of drone usage that Kersel's team has enjoyed. Nadine Moeller, an archaeologist at the University of Chicago who uses aerial surveys in her work, agreed that aerial imaging information, from drones to satellites, allows archaeologists to work alongside local authorities.

"Ideally, you want to work with the local authorities and the local people. It's a lot about creating awareness, education, supporting local efforts, because you can't just waltz in there and come up with standards," Moeller says.

BRIGHT FUTURE

Kersel, Hill, and Rowan found that drones transformed their ability to obtain images, create maps, and monitor Fifa in an efficient, detailed, and cost-effective manner.

"These are amazing tools, and I think it's fair to call [drones] something of a revolution," says Rowan.

As with any emerging technology, drones have certain unavoidable shortcomings in archaeological research. The legality of operating drones varies from site to site and country to country, says Hill.

In order to fly their drones in Jordan, according to Kersel, the Fifa team submits a proposal to work with drones three to four months in advance of their field season. After that, they must also get security clearance and approval from Jordan's Department of Antiquities. This is often a lengthy and unpredictable process that, thankfully, has thus far yielded positive responses for Kersel and her research team.

While local and national limitations on when and where researchers can fly their UAVs may restrict drones' utility on a project-to-project basis, Kersel and her team see a promising future for drones in the field of archaeology.

Archaeologists around the world are using drones for projects ranging from mapping Arizonian rock formations to generating digital terrain models that could detect ancient Mayan structures (see Page 59) and everything in between, according to the SAA Archaeological Record.

And alongside this ever-expanding list of research applications, archaeologists are introducing new uses for existing drone tech itself.

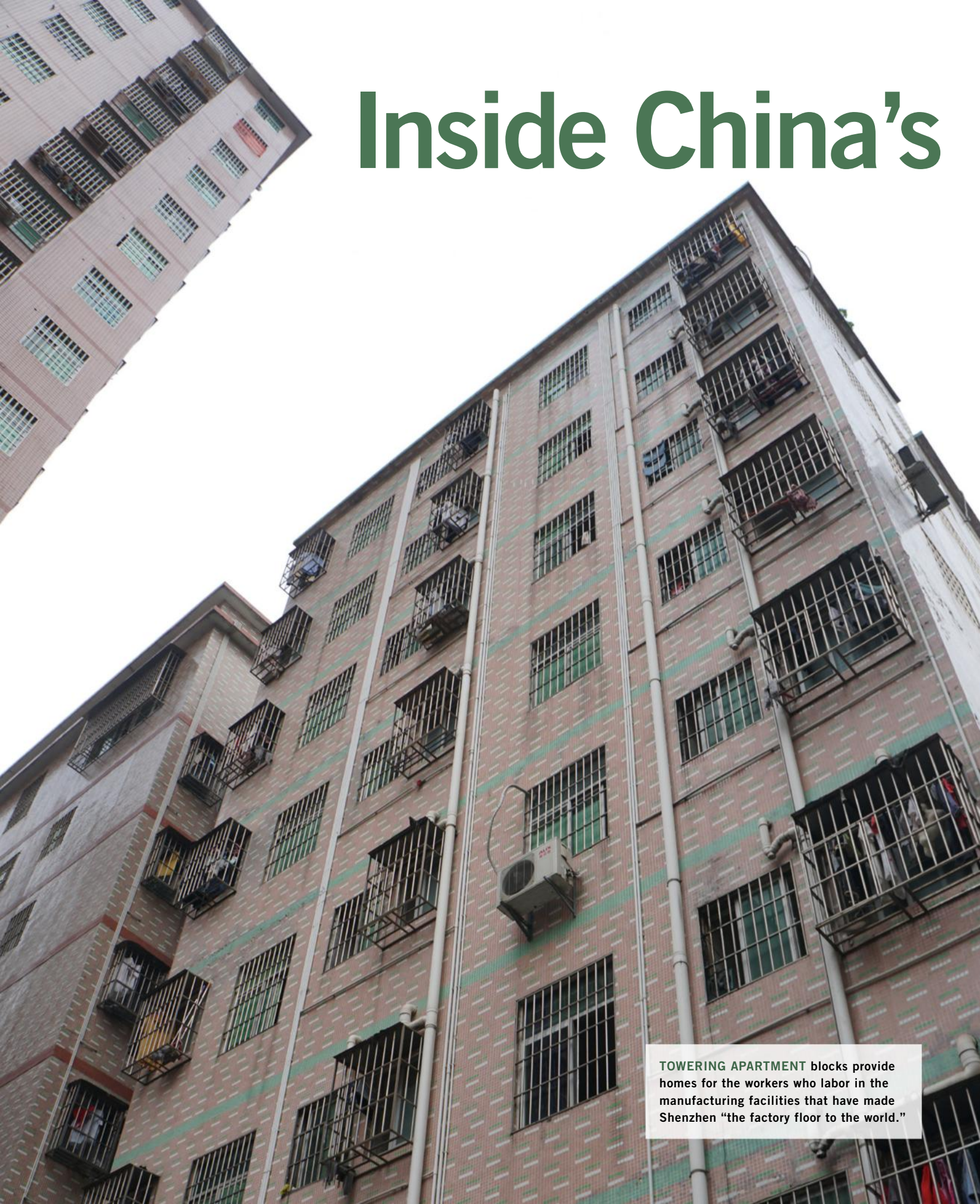
For instance, Hill says drones equipped with thermal cameras can help detect buried archaeological sites and features. This is mainly because buried features, like old building foundations, tend to absorb and release heat at differing rates than surrounding soil. Drone footage can then help identify likely sites based on thermal differences in a given image.

But for now, the team looks forward to continuing its drone work for the fifth and final field research season at Fifa. Beyond that, the possibilities for drones in their future endeavors seem limitless.

"The novelty of this project is it's not just drones, it's not just archaeology, it's not just cultural anthropology: It's all of those things together," Kersel says. "We can always learn from this looted landscape: There are things left to be learned from Fifa and the locals who interact with it, and drones help reveal that information here and at other places." 360

"THESE ARE AMAZING TOOLS, AND I THINK IT'S FAIR TO CALL [DRONES] SOMETHING OF A REVOLUTION."

Inside China's



TOWERING APARTMENT blocks provide homes for the workers who labor in the manufacturing facilities that have made Shenzhen "the factory floor to the world."

深圳 Silicon Valley

The back alleys and towering factories of Shenzhen have long been an incubator for cutting-technology. Now, the city may be leading us to better, longer lasting batteries that could change the way we measure drone flight times from minutes to hours

Story and photos by Patrick Sherman

Drones have a serious problem with flight time, and I spent 14 hours inside a cramped aluminum tube to see if I could find a solution. After testing a bunch of drones at the Roswell Flight Test Crew over the past several years, I came to the inexorable conclusion that battery-powered platforms max out at about 20 minutes. Tinkering with different airframe materials, motor designs, and propeller sizes might help a little bit, but, as an industry, we're only going to achieve serious improvements through a more fundamental change.

Thus, the aluminum tube I mentioned earlier: an Airbus A330, which would carry me very nearly halfway around the globe from my home in Portland, OR, to Shenzhen, China. Known as the Silicon Valley of Hardware, Shenzhen went from a sleepy fishing village of 20,000 people to a sprawling megalopolis of more than 20 million in just two decades. It is home to literally hundreds of drone companies, including the most recognized drone brand in the world: DJI.

However, my ultimate destination was not the headquarters of that global titan, a glittering tower of glass and steel rising high above the tree-lined streets. Instead, I visited one of the scrappy upstarts dwelling in its shadow: MicroMultiCopter Aero Technology (MMC). MMC makes large, weatherproof drones for use in industrial and public safety applications. Almost unknown in the U.S., its products are widely used across China and other countries in Southeast Asia, which account for nearly 50% of the world's population.

Of course, I'd seen plenty of industrial birds before this trip, but MMC had created something unique. The drone company is developing an onboard hydrogen fuel cell that's powerful enough to keep a multirotor aloft not for 20 minutes, or for an hour — but for *three hours*, and perhaps a good deal longer as the technology continues to mature.

Maxed out

Before I folded my 6-foot-5-inch frame into a coach airline seat for long enough to watch the entire *Lord of the Rings* trilogy — and then peruse an additional two hours' worth of DVD extras — I wanted to make sure that the full potential of lithium-polymer (LiPo) batteries had indeed been exhausted. So, I put the question to David Ainsworth, the CTO of OXIS Energy: Have we already achieved maximum flight time based on current battery technology?

Based in the UK, OXIS was founded in 2004 at the Culham Science Centre in Oxfordshire, where lithium-ion battery technology was developed and prototyped. The company's specialty is battery chemistry: the artful science of combining different elements to create new types of cells with improved storage capacity.

Ainsworth sounded like a scientist as he patiently explained to me the potential for further gains in LiPo battery technology.

"The lithium-polymer battery is a class within lithium-ion battery technology and is based on the same active materials for the cathode and then anode," he says. "For any given

BEWILDERED BY BATTERIES: After talking to David Ainsworth, I went straight to Wikipedia to find out what I could about batteries. It turns out, for something so simple in looks, how a battery works is anything but. Here's what you need to know:

- A battery is a device that turns chemical energy into electrical energy.
- Each cell within a battery is divided into two pools of chemicals, one consisting of negatively charged ions, and the other with positively charged ions.
- The ions are attracted to each other. The flow of particles from the anode (the negative side of the battery) to the cathode (positive side) creates the electrical current that you can use to power your quadcopter.

TO PROVIDE A LEVEL SURFACE for the final assembly of its aircraft and components, MMC uses an enormous slab of marble, which does not respond to changes in temperature and humidity.

cathode and anode, there is a 'theoretical capacity' and, thanks to 25 years of development, they are approaching their practical limits."

For those of us who aren't scientists, he means there is only so much energy you can store inside a LiPo battery given the specific materials involved. Try to go beyond those limitations and bad things can happen, as Samsung so ably demonstrated last September with the flameout of the Note 7 smartphone.

"The large-scale lithium-ion cell manufacturers, such as Samsung, LG, Panasonic, and Sony have not made any significant progress on energy density over the last five years," Ainsworth says.

Satisfied that we aren't going to be squeezing more juice out of our LiPos anytime soon — except at the risk of transforming our drones into spinning incinerators — I applied for my Chinese entry visa, packed my bags, and walked down the jetway to the waiting A330.

Stranger in a strange land

The photos you see of Shenzhen in the media depict a thoroughly modern city, with towering office buildings and lush, green parks. Having seen it with my own eyes, I can report that those images accurately reflect the city — but not the *whole* city. During its development, the government mandated that the factories be relocated to what is referred to as the "suburban area."

In the mind of a typical American, the word suburban conjures up images of single-family homes, white picket fences, and carefully tended lawns. In China, not so much.

The so-called suburbs of Shenzhen are more urban than most of the urban areas of Portland. The predominant features are towering factory buildings and high-rise apartments. At street level, the buildings along the main thoroughfares host small shops selling street food, cell phones, clothing, groceries, and household supplies — along with internet gaming parlors and driving schools.

Carts selling live fish and crabs, fresh cuts of meat and whole, plucked birds, crowd the alleyways hard up against men playing dominoes and smoking cigarettes. The roads are navigated by a mix of pedestrians, bicyclists, motorcycles, cars, and heavy trucks, all of which vaguely adhere to traffic laws that resemble the U.S.'s, at least on paper.

The whole scene was at once hardscrabble and vibrant. Exploring the neighborhood around my hotel, I halfway expected Rick Deckard (*Blade Runner*, hello) to push past me in desperate pursuit of a wayward replicant.

Made in China

For most of my life, the words "Made in China" have carried the connotation of cheap manufactured goods, often designed to imitate products made in the U.S., Europe, or Japan. However, even before my trip to Shenzhen, the drone industry had forever transformed my perception of China and its goods.

It was February 2012 — 35 drone years ago, assuming that each terrestrial year delivers seven years worth of growth and progress in the drone industry — and at the Roswell Flight Test Crew, we were struggling to cobble together reliable aircraft for our early missions alongside firefighters and hot air balloonists. The state-of-the-art flight management system in those days made use of

accelerometers and gyroscopes scavenged from Nintendo Wii controllers.

What made the "MultiWii" so special was that drone operators could return the aircraft to a level orientation all on its own when the radio's right stick was centered: a primitive form of what we now call Attitude Mode. That was an enormous leap forward from the previous generation of controllers, which, like today's racing quads in Rate Mode, required constant input from the pilot to maintain straight and level flight.

Searching for a better solution, we stumbled across an online video demonstrating a new flight controller with a peculiar name — NAZA — made by a Chinese company called Da-Jiang Innovations.

Of course, Da-Jiang Innovations is known today as DJI and the NAZA became the bedrock upon which the company built its category-defining personal drone: the Phantom. However, all of that was still a few years away when I plunked down a couple of hundred bucks for a mysterious plastic box.

When the NAZA arrived direct from China, we installed it on our home-built flagship hexacopter — RQCX-3 Raven — and it worked magnificently. We started referring to the NAZA as the "Make-It-Fly" box, because you seemed to be able to mount it on any multirotor and it flew perfectly.

Blogging about this wondrous discovery, I was bothered by the name. I kept asking myself: "What is a NAZA, anyway?" I started digging around on DJI's website and found that the names of many of its products — such as its first multirotor kit, the Flame Wheel — were drawn from Chinese mythology.

That's when it hit me: If you create something, you get to name it. And many times culture serves as a reference point for understanding it.

Having grown up reading about the Mercury, Gemini, and Apollo astronauts, along with the XB-70 Valkyrie, the F-16 Fighting Falcon, SR-71 Blackbird, the P-3 Orion, the

SHENZHEN'S downtown core, away from the hardscrabble suburban area, is a modern city, complete with interactive water features that allow playful residents to escape the heat and humidity.

LEFT An MMC worker completes a motor nacelle for one of the company's drones. It's constructed of carbon fiber to provide strength while limiting weight.
RIGHT The recreational district in downtown Shenzhen features attractions familiar almost anywhere: restaurants, shops, and a contemporary art museum.

AV-8B Harrier and many, many others, it came as quite a shock to me that anything that flies could take its name from source other than European mythology or the birds of North America.

In that moment, I realized that the Chinese weren't just participating in the drone revolution — they were leading it — and it was foolish or delusional to think otherwise.

Enter the dragon

Arriving for the first time at the MMC factory, that revelation was very much in the forefront of my mind. I fully expected to see cutting-edge systems and innovative, new products. But to get the most out of my visit, I needed to understand what my hosts said.

Unfortunately, I arrived in China with precisely two Chinese words at my command: *ni hao*, which means hello, and *xiè xiè*, which means thank you. I left China having added one more word to my vocabulary: *shì de*, which means yes.

There was considerable variation in English-speaking fluency between the individuals I met — ranging from fair to non-existent — but the employees at MMC tackled this problem with a pragmatic tenacity that seems to be a hallmark of Shenzhen's ethos. While they might not have every resource that would be ideal for the project at hand, such as perfect command of spoken English, they never stop trying. They come back at a problem again and again and again until they see it accomplished.

The MMC factory itself embodied this same spirit. I cannot imagine how a U.S. Occupational Safety and Health Administration inspector would react during a tour of the facility: I haven't seen so many trip hazards since the last time I was aboard a Navy vessel. As best I could tell, there wasn't an elevator anywhere in the four-story structure. To conserve electricity, lighting and air conditioning were powered up only as needed, and they appeared to be absent altogether from communal spaces, such as hallways.

It was spartan by U.S. standards, possibly more than the law would allow in some cases. And like nearly every other building I visited in the suburban area, it evinced a gritty practicality: Its appearance mattered far less than its function.

That said, it was tidy and well organized. The employees wore uniforms bearing the MMC logo and the walls were covered with hand-painted murals encouraging them to work hard and be an effective member of the team. These, I determined, were the equivalent of those motivational posters found in break rooms across America, with mountain climbers standing triumphantly on snow-capped peaks, highlighting virtues like achievement, greatness, and perseverance — albeit with a decidedly sterner tone.

One thing that had no equivalent in any U.S. business that I've ever visited was the tea table that each manager maintains in his office. About the same size as a coffee table, they were typically surrounded by couches and chairs, and managers use them to entertain visitors, like me, or to hold team meetings.

These tables incorporate a built-in water reservoir, two electric burners, and a basin. The manager brews tea and serves it with a unique style to guests in tiny cups. I discovered that tea tables weren't unique to MMC, but typical of the culture of Guandong Province, where Shenzhen is located. The company's chief designer Shiqian Deng, respectfully referred to as Mr. Deng by other employees, impressed me the most with his tea service. Obviously refined over

IN ADDITION to hydrogen fuel cells, MMC makes lightweight aircraft that operate using conventional LiPo batteries — and the company claims it can achieve flight times approaching one hour.

many years of practice, he nimbly washed the rims of his cups with the first batch of tea using only chopsticks to avoid scalding his hands. With that accomplished, he made a second pot for drinking with tea leaves from his home province.

Drones at work

Adjacent to its factory, MMC maintains a walled courtyard where it performs quality assurance tests on all of its drones before they are shipped out to customers. That was where I had the opportunity to see its interchangeable payloads in action. In just a few seconds, without the use of any tools, an electro-optical camera with a 30x zoom lens can be swapped for an intelligent drop mechanism, a searchlight, or even a loudspeaker.

In all, MMC makes more than 200 different payload modules, enabling its drones to do jobs that I had never considered before my visit. In the U.S., inspecting power lines is an application receiving a lot of attention. Right now, in Indonesia, MMC drones are being used for stringing power lines. These are serious machines doing serious work, and U.S. companies looking to build out their drone fleets would be well-advised to take a close look at what they can do.

Of course, any application that can be accomplished in 20-minute increments is an application that would be more efficiently and easily accomplished in three-hour increments — which is what led me to a secure laboratory inside the factory where the company is developing its hydrogen fuel cell technology.

My hosts requested that I leave my camera on the other side of the security door, so I can only describe what I saw for you: a box (about the size that could house a pair of ankle boots) with four cooling fans on one side, and what looked to me like an air filter on the other side. This was connected by a hose to a lightweight pressure cylinder, like the ones firefighters wear as part of their breathing apparatus, which contained the hydrogen gas. The device was controlled by a fairly intricate looking circuit board, and the only exhaust produced was tiny droplets of water.

It was astounding: The fuel cell drove a dummy load set up on the work bench, and if its readout was accurate, the system was entirely capable of powering a large multirotor — large enough to lift the fuel cell itself, the pressure cylinder, and quite a substantial payload, while sustaining it in the sky for hours.

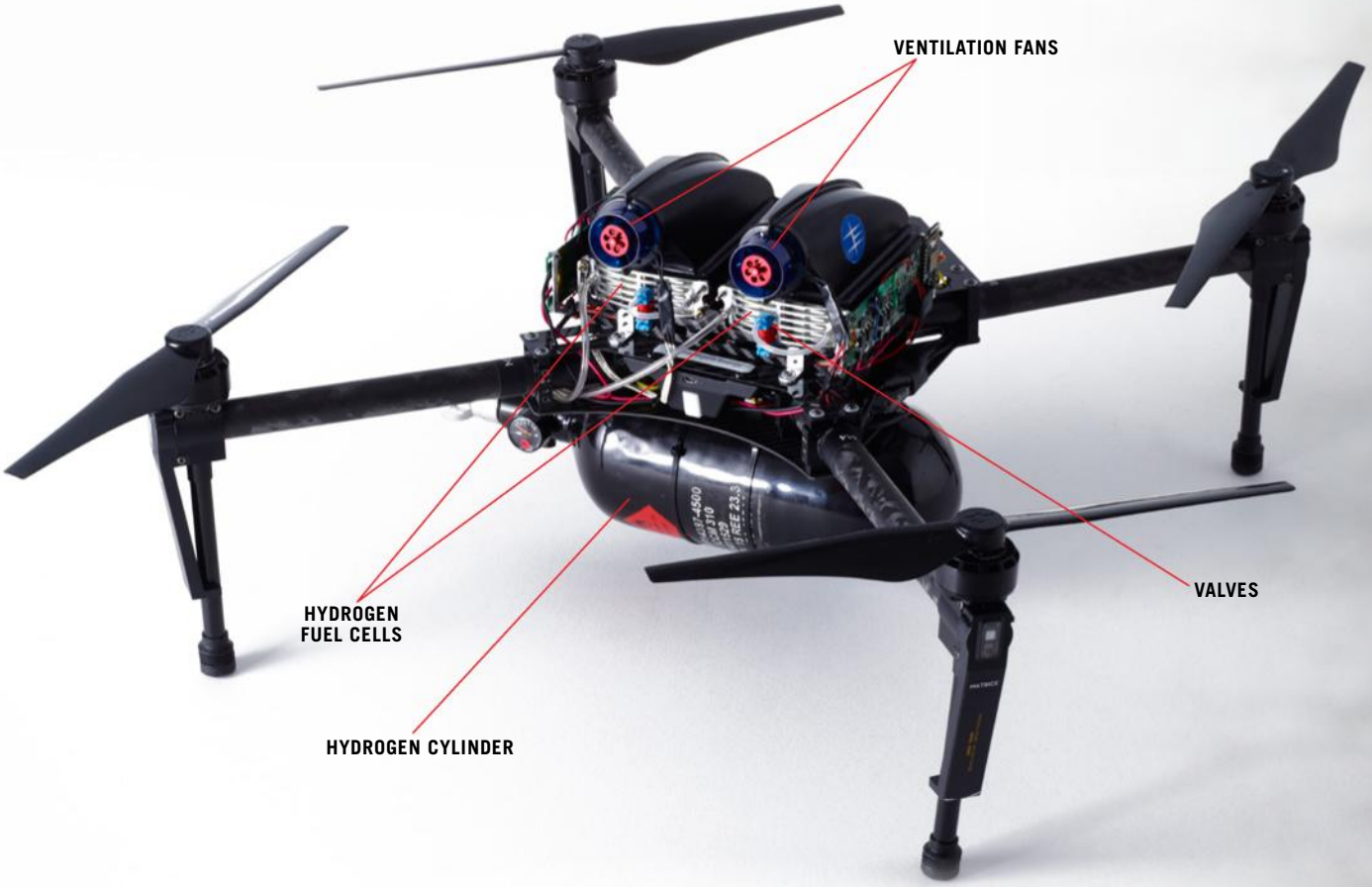
Of course, as a journalist, I was trained to be skeptical. I immediately reflected on Carl Sagan's wise words of caution: "Extraordinary claims require extraordinary evidence."

Hydrogen explosion

To verify the credibility of what I had seen, I contacted Julian Hughes, the senior vice president for North America at Intelligent Energy. The U.K.-based company has offices in Japan, India, China, Singapore, the U.S., and France. Intelligent Energy specializes in the development of hydrogen fuel cells for a range of applications, including automobiles. Hughes began by confirming that yes, indeed, a hydrogen fuel cell can power a drone — as his own company had recently demonstrated.

FUN FACT: Benjamin Franklin — U.S. founding father, politician, and scientist — is credited with first using the term "battery" in 1749 to describe a device for storing electrical energy.


休闲零食
群福便利店
休闲便利店



"A fuel cell can be more than twice as efficient as an internal combustion engine," he explained in an email. "A conventional engine burns fuel to create heat and in turn converts heat into mechanical energy and finally electricity. In contrast, a fuel cell produces electricity, water, and heat directly from hydrogen and oxygen."

Hughes went on: "Fuel cells are like batteries in that they are electrochemical devices, but unlike batteries, they do not need recharging and will continue to operate as long as they are provided with fuel in the form of hydrogen, and an oxidant — oxygen, taken from the air."

Of course, hydrogen gas and aviation have a decidedly mixed history. NASA has been using fuel cells on its spacecraft since the 1960s. On the other hand, there was the unfortunate incident involving a certain German airship trying to dock at Lakehurst Naval Air Station in New Jersey, in 1937. So, I asked Hughes if drones could safely carry hydrogen fuel.

"Hydrogen is no more or less dangerous than other flammable fuels, including petrol and natural gas," he said. "In fact, some of hydrogen's properties actually provide safety benefits compared to petrol or other fuels. For example: It dissipates very quickly and is much less likely to explode in open air because of its high buoyancy and diffusivity. This contrasts sharply with much heavier gasses such as natural gas and gasoline vapor."

Hughes pointed out that hydrogen, with more than 50 million tons produced annually, has an excellent safety record. However, he warned that hydrogen and all flammable fuels must be handled responsibly.

"Like petrol and natural gas, hydrogen can behave dangerously under specific conditions," Hughes said. "Hydrogen can be handled safely when appropriate guidelines are observed and the user has an understanding of its behavior."

Beyond any doubt, MMC had offered me a glimpse of the future. In spite of the potential of this technology to rewrite the industry's most fundamental assumptions regarding multirotor drone performance, especially in heavy-duty commercial applications, I'm not sure it was the hydrogen fuel cell that impressed me most during this journey. Rather, it was the people that I met, and the appreciation I gained for the culture in this crucial part of the world: a city summoned up out of the jungle that has in just two decades achieved profound global influence.

The people who live and work here are intrepid and endlessly striving, relentlessly practical, eager to learn, and excited to make new friends. They are optimistic without being starry-eyed and proud without being conceited. In the end, it is that bright and engaging culture that may be their most important contribution to our industry and world, rather than any particular piece of hardware. 360

ABOVE I couldn't get a photo of the MMC hydrogen fuel cell, but Intelligent Energy shared an image of one of its prototype designs fitted to a DJI Matrice 100. LEFT The alleyways of Shenzhen's suburban area evoke the dystopian sci-fi classic *Blade Runner* far more than the sunny suburbs of *Modern Family*.

On a rainbow-colored racetrack in England, miniature cars zip and bumble along. Some take slow tumbles; others flip themselves against the track's walls. A few manage to hesitantly navigate curves and maneuver around the other cars. To most spectators, this would seem like quite a poor show of racing skills.

But these cars are not under the remote control of a human racer. Instead, they are driven by the coding skills of their "drivers" through small onboard Raspberry Pi computers. A successfully crowdfunded Kickstarter campaign launched this autonomous race series, known as Formula Pi, which has attracted entries from around the world.

However, this isn't the only instance of real-world autonomy. Out on the plains of central Canada, wheat farmer Matt Reimer built a self-driving tractor using parts he bought online and programming skills he acquired in an online course from MIT. The autonomous John Deere can drive alongside Reimer's lumbering combine harvester, cruising over to collect wheat at the touch of a button.

And it certainly seems as though aerial drones have also entered the age of autonomy. On Dec. 7, 2016, Amazon.com completed the first drone delivery for its much-publicized Prime Air initiative. Amazon noted that the flight was fully autonomous, with no human pilot. Two weeks later, Flirtey, which has notched several drone-delivery firsts, announced that it had completed 77 autonomous drone deliveries for 7-Eleven in Nevada.

In addition, the industry-leading DJI Phantom 4 has forward-facing stereo cameras and ultrasonic sensors that can detect obstacles up to 45 feet away to stop the machine. If its battery reaches a critical level, the Phantom 4 will automatically return home, avoiding any obstructions it meets on the way.

DJI's mission planning app, much like the open-source software available for the 3DR Solo and many other consumer UAVs, even gives pilots the option of autonomous flight. Draw a series of waypoints on a Google Maps-style interface, and the drone will navigate between them on its own.

Safe and sound?

"You could fly your drone autonomously right now," explains Allison Ferguson, Ph.D., director of airspace safety research at UAV-based aerial data company PrecisionHawk. "But it's not legal to do that because it's not safe."

Why isn't autonomous flight safe? Just check YouTube, where there's plenty of evidence that collision-avoidance features like those on the Phantom 4 are far less

Minds of

their own

Where autonomous drones are today – and where they're going next

By Matt Windsor

than foolproof. Then there are all the unknowns: How often do autonomous drones fail? In what situations? And how can they be integrated into the national airspace? PrecisionHawk is developing new technologies to help address these questions, as are many other UAS companies and academic researchers.

The FAA, through its Pathfinder Initiative, and NASA, through its UAS Traffic Management (UTM) program, are performing tests as a step toward new autonomous flight regulations. NASA is scheduled to hand off UTM testing to the FAA in 2019. In addition to the Pathfinder and NASA initiatives, other important projects are being conducted at the seven designated UAS test sites in the U.S., the ASSURE UAS Center of Excellence, and by private-sector organizations.

"The FAA will continue to assess its requirements for UAS regulatory development and will utilize the best practices available to successfully accomplish safe integration," said the FAA in a statement.

The FAA's rules for autonomous UAS flight are spelled out in Advisory Circular 107-2, which states that the remote pilot in charge must have the ability to change the drone's route and command the aircraft to land. Whether they are flown by hobbyists or commercial users, UAVs must remain in the visual line-of-sight of the pilot, and no pilot can operate more than one drone at a time, unless they have received an FAA waiver.

While the autonomous features of consumer-grade drones might not yet be infallible, experts believe they are crucial to unlocking the economic and societal benefits of drones.

"If you are a professional UAV service provider, you make more money the more you can get done," Ferguson says. "And the more automated you are, chances are the more you can get done."

Charlton Evans, senior manager for commercial aviation at Insitu, says, "Ultimately, you will see the economics drive it all." Insitu is one of the largest and most experienced companies in the

Disney and Intel created an autonomous aerial light show, featuring Intel's lightweight, caged-propeller Shooting Star drones. Don't try this move without caged props.

INTEL

Intel's RealSense technology was originally designed for computers, but has helped bring about autonomous operations like sense-and-avoid and advanced fleet formations.
INTEL

autonomous drone industry. "In every aspect of what we're doing, automation is the key to success," Evans says.

Automation also makes flights safer and more predictable, which means more individuals and companies may give drones a try. "Most commercial users aren't model aircraft enthusiasts," Ferguson explains. "They just want a tool that can do what they need it to do."

Autonomy to the fullest

Regulations aside, how close are we to a fully autonomous drone? A 2015 paper in the journal *Nature* by robotics researchers Dario Floreano and Robert Wood explored the technical challenges in achieving fully autonomous vehicles.

The first is sensory-motor autonomy: the ability to execute complex human commands, such as moving to specific GPS coordinates. Many inexpensive consumer drones can already do this today.

Next comes reactive autonomy: avoiding obstacles, taking off and landing without human control, and coordinating with moving objects such as other drones. Some of the more advanced prosumer-level drones are developing in this area.

The final step is cognitive autonomy: This includes resolving conflicting information, planning for events such as battery charging, and machine learning.

In the *Nature* article, Floreano and Wood predict that reactive autonomy will be widely available in small commercial drones for long-range operations in the next five to 10 years. They also write that they "expect rapid progress in cognitive autonomy, which will continue to be driven by the development of artificial intelligence for smartphones capable of identifying human users," such as Google's Project Soli miniature-radar.

Face recognition and gesture-based interaction will be available on "hobby and toy drones within the next five years," say Floreano and Wood. The feature is already available in selfie drones like the Hover Camera Passport. But "mapping and path planning for autonomous flight in partially unknown and changing environments will represent a challenge for small drones for at least the next 10 years," they conclude.

In the meantime, drone owners will benefit from incremental advancements. The progress around self-driving cars is a good analogy, says Anil Nanduri, vice president of the New Technology group at Intel, which has made a major investment in drones.

"We all get excited about the prospect of a car that is completely autonomous,

but along the way you get a lot of safety capabilities that enhance today's driving" — things like intelligent cruise control and self-parking, Nanduri says. "These are all in the realm of 'driver assist.' We [at Intel] are working on the same concept: pilot assist."

Leader of the pack

As a recorded choir joyously sings "O Christmas Tree," 300 drones, illuminated by onboard LEDs, form a stylized spruce tree hundreds of feet above the Walt Disney World Resort. The performance was part of the first major drone light show in the U.S., Starbright Holidays, which ran twice a night at Disney World from last November to January.

"When you are operating a whole fleet of drones, you have to think about how to charge them, how to navigate them, how to program them, and ensure they don't collide," says Nanduri.

Those lessons can then be applied to other problems, such as finding lost hikers or reconnaissance after disasters.

"You need to know where to focus resources, and you may not be able to get a helicopter in," Nanduri says. "It would be much easier to fly a fleet of autonomous vehicles in, to gather information with no human risk."

Clever programming can keep a flock of drones from crashing into each other — but keeping drones away from other obstacles provides an additional level of challenge. That's why sense-and-avoid technology is the hottest area in autonomous drone tech right now.

Originally, Intel developed the RealSense vision system to allow hands-free interaction with computers. The system combines an HD camera, infrared camera, and infrared laser projector to recognize a person's movements and gestures.

On a RealSense-equipped drone, such as the Yuneec Typhoon H or Intel's own Aero, these sensors build a three-dimensional picture of the surrounding environment. The drone can then use that information to route itself around obstacles and return to a preprogrammed flight path.

Much like the human eye, however, these technologies have a difficult time in the dark and in inclement weather conditions. So new sensors, such as miniaturized radar or lidar systems, will need to be added, Nanduri explains. "You can fly at 20 miles per hour today, but you want to have it work at 50 miles per hour," he says.

Using Fleetlights, a demonstration project from British insurance company Direct Line, people traveling or working at night can summon a group of drones, equipped with high-powered spotlights, to light the way at the touch of a button in a smartphone app. FLEETLIGHTS

Getting to know autonomy

Here's some next-generation hardware and software that's advancing the self-flying envelope:

- **RTK (real-time kinematics) GPS:** An advanced form of satellite-based navigation that offers centimeter precision, compared with a precision of around 23 to 39 feet using standard GPS. Drone-capable systems are now available for as little as a few hundred dollars.
- **ADS-B (automatic dependent surveillance – broadcast):** These transponders are becoming standard in manned aircraft, but have been large and power-hungry. Miniaturized versions, such as the Ping from uAvionix, could offer enhanced position-tracking data for unmanned aircraft, and help operators detect other aircraft, both manned and unmanned.
- **Lidar/radar:** Both systems are used for rangefinding and obstacle detection in self-driving cars. Smaller, cheaper versions could be used in conjunction with camera-based vision systems for sense-and-avoid capabilities in UAVs and UGVs. In summer 2016, Echodyne demonstrated a radar system a little larger than a smartphone — check it out on page 40. A Scottish firm called Mapix has developed a lidar system called the UAV LidarPod.
- **Mission-planning software:** Preset routes and mission types are allowing operators to design and execute precise, repeatable missions. This software can also maximize battery life by plotting the most efficient routes to gather data.
- **Traffic management:** NASA is studying UAS traffic management systems, including PrecisionHawk's LATAS, as part of its UTM program. Safely incorporating UAS into the National Airspace System could pave the way for legal autonomous flight.

Open-source, open skies

Intel's new Aero drone, launched last December, is equipped with both RealSense and a powerful Aero Compute Board processor. The machine is aimed at drone application developers and hobbyists, Nanduri says, giving them a common hardware platform with which to innovate — much like the Raspberry Pi platform used in Formula Pi races.

Open-source innovations have been a key driver of drone autonomy — largely due to the popularity of ArduPilot, a system which consists of both hardware (a processor and sensors) and software that can control virtually any remotely operated vehicle. In 2009, ArduPilot emerged as an open-source project from the DIY Drones online community. Autopilots for UAVs at the time cost five to six figures, but ArduPilot made the capability of autonomy accessible, according to Craig Elder, technical community manager for ArduPilot.

"The next big change is the use of RTK [real-time kinematics] GPS," Elder says. Standard satellite navigation chips offer around 23 to 39 feet (7 to 12 meters) of precision, he explains. "But with RTK, you can get centimeter precision."

The ScanEagle N202SE is recovered after a successful flight supporting track inspection for BNSF Railway in New Mexico.
INSITU

RTK will help autonomous drones better negotiate obstacles and maintain precise flight paths. It could also usher in the age of other autonomous consumer robotics, like the self-driving lawnmower. "We have created a really low-cost RTK solution, and soon everyone will have one," Elder says.

ArduPilot is widely used by researchers to push new boundaries. In 2015, an MIT team using ArduPilot demonstrated a fixed-wing UAV that can autonomously fly through obstacles at 30 mph. And students from the Naval Postgraduate School launched a record-setting swarm of 50 fixed-wing, ArduPilot-powered UAVs controlled by a single operator.

But these innovations aren't exclusively confined to elite research labs. Reimer, the Manitoba farmer, says his autonomous tractor project was inspired by posts on DIY Drones. "I didn't know there was anything out there in the hobby world that could do this until I stumbled across ArduRover" — the ground vehicle version of ArduPilot — Reimer says.

His first step was to create a proof-of-concept model using an R/C car. Then, once he understood how all the components worked, he evolved a full-scale solution. At first, mechanically controlled servos handled the throttle and steering, but now a computer runs the whole show with an Arduino processor at its heart and line upon line of Python code for the brains. Reimer tells it what to do via a touchscreen interface. "I just keep making improvements over time," he says — and all his code is shared online.

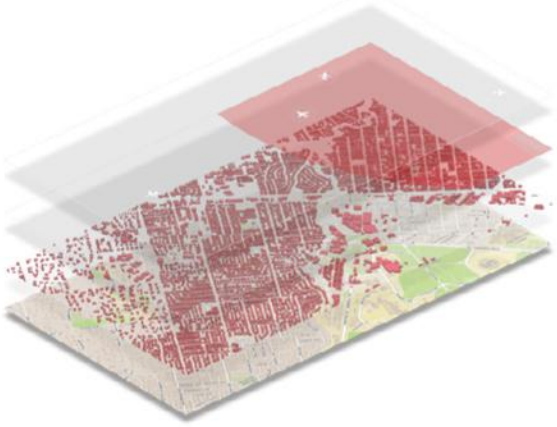
Inspector gadget

In October 2015, an Insitu ScanEagle cruised over central New Mexico, soaring along 140 miles of track belonging to BNSF Railway as part of the FAA's Pathfinder program. The week-long series of flights revealed washouts and bridge damage in what was the first commercial beyond visual line-of-sight (BVLOS) operation in the contiguous 48 states.

Companies like BNSF, with thousands of miles of track to inspect, are a natural fit for fleets of highly automated drones. "The amount of information they want is massive, and they want it quickly and accurately," says Evans, who led the Pathfinder collaboration with BNSF.

For that project, Evans notes that the flights were in a remote area. "To take it further, we are going to need detect-and-avoid capabilities," which is a current focus of work for the ScanEagle, he says.

Meanwhile, advanced mission planning software, such as Insitu's INEXA Control, is bringing new aspects of autonomous function to UAS operators. Mission-planning software allows operators to design and save routes, so they can ensure the best coverage of a given area



With PrecisionHawk's LATAS system, UAV operators can track manned and unmanned aircraft, as well as ground obstacles and restricted airspace, in a single view. PRECISIONHAWK

during each flight and can repeat that route whenever desired. Operators can even simulate the entire flight in the mission planner to rehearse each operation and get an idea of potential problems. Features under development for INEXA Control include a search plugin programmed with standard search patterns that can be configured based on target size and available vehicle sensors. An RF Link Analysis tool will be able to identify areas on a map where signals are anticipated to be weak, and suggest the best place to situate a ground station.

"Automating the collection process allows the user to create a mission that is highly tailorable and repeatable," says Greer Carper, product manager for INEXA Control. "If I want to inspect something every week, and compare it over time, that is of the utmost importance." (Get to know Carper on Page 16).

Putting it all together

On a testing ground in the Piedmont region of North Carolina, PrecisionHawk is collecting invaluable data about extended visual line-of-sight (EVLOS) flying. During these tests, an operator concentrates on looking out for hazards while maintaining control of the UAV through a ground station.

In January, PrecisionHawk began the third phase of its Pathfinder testing, using its Low Altitude Traffic and Airspace Safety (LATAS) traffic management system. While sense-and-avoid technologies aim to avoid collisions, "traffic management is how you keep from needing to avoid collisions," Ferguson says. LATAS consists of a small black box equipped with an LTE cellular modem that's mounted to the UAV — plus accompanying software for the drone's pilot, which displays several layers of operational data on a single screen.

The system shows operators the position of their own UAV, plus any other LATAS-equipped drones in the area. It flags ground-based obstacles, such as hills and buildings, on a color-coded relief map, along with any restricted airspace. LATAS also displays a live map of the position and direction of manned aircraft in the area — this data is pulled from the ADS-B (automatic dependent surveillance – broadcast) beacons that these aircraft carry, which constantly transmit identification, position, altitude, and velocity.

For now, LATAS simply relays information to the pilot. But it could be connected directly to a UAV's autopilot system and programmed to take evasive action if it detects obstacles or an impending collision, Ferguson says. As ADS-B beacons become smaller and cheaper, they could be added to UAVs for redundancy and safety, she adds.

"Traffic management is all about flow, which is what makes drones scalable," Ferguson says. "If you manage traffic correctly, you can avoid collisions."

New technologies will be able to address the regulatory and technical challenges of autonomous flight, says Intel's Nanduri. But, he believes that first we need to prove that autonomous flight can be done safely in the real world.

"The science fiction movies have shown us what can be," Nanduri says. "It's up to us to make that a reality." 360

Pilots need not apply

Applications for self-flying, self-driving, and self-cruising vehicles include:

- Delivering goods
- Search-and-rescue in confined or hazardous environments, both indoors and outdoors
- Long-range inspections, such as railroads or pipelines, as well as routine inspections that require precise, repeatable routes
- Transporting medical supplies to disaster areas
- Providing mobile communications coverage to rescuers in disaster situations
- Improved safety for hobby drones
- Maneuverable lighting for road construction and other industries working at night
- Boat inspections and marine surveying with autonomous underwater vehicles
- Robotic lawnmowers, snow plows, or leaf blowers

On a single interface, the LATAS application program provides drone pilots with layers of data, including a live map, obstacles, and the position of their drone and others' using the LATAS app. PRECISIONHAWK

Ambitious, inspired, driven

Emblematic of the emerging drone industry, Lyela Mutisya looks to use UAS to change coffee farming in Kenya and beyond

By Leah Froats

GRANDIOSE DREAMS OF FLYING CARS and drone deliveries dominate much of the vision of drones' long-term potential. But while tech giants in Silicon Valley patent drone dirigibles, young aviators are finding quieter, but no less hopeful, ways that unmanned systems can change the way we live — like saving coffee.

Farm (to drone) to cup

Thousands of half-caf lattes and dry cappuccinos seemingly appear from thin air at coffee shops across the U.S. each morning, so one may assume that high-quality coffee is an abundant resource.

It's easy to forget that coffee is a crop — a delicate and difficult one to grow — and that there are, according to the human rights NGO Global Exchange, "approximately 25 million farmers and coffee workers in over 50 countries involved in producing coffee around the world."

Lyela Mutisya's father is one of those 25 million coffee workers. Born in Kenya, Mutisya moved to the U.S. in 2001. She currently lives in Chicago and attends college, but in 2014, Mutisya traveled back to Kenya for the first time.

"That's when I found out my dad had a coffee farm, and I was just really fascinated," she says.

This was the first spark of her passion for coffee — not just as a drink, but as a way of life. She talked to her father about his experience working on his farm, asking if he made good money through the growth, harvest, and sale of his coffee. The answer was no.

"He makes about $0.20 a pound for his coffee. That's close to nothing, especially because the coffee gets sold anywhere from $2 to $5 a pound, depending on the quality," she says. "And that really broke my heart."

But she wasn't sure how she could help improve his situation. It wasn't until she returned to the U.S. for her courses at Lewis University that Mutisya realized that drones were the missing piece — she could use them for precision agriculture on her father's farm.

Precision agriculture is a method of farming which uses various methods of data collection to produce crops more effectively. Drones are perfect for this

Lyela Mutisya proudly holds her 3DR Solo drone and MicaSense RedEdge sensor — both the result of a recently acquired internship.
MERVYN JOHN

Mutisya's trip to her father's Kenyan coffee farm inspired her passion for the coffee industry — but her courses at Lewis University are what drove her to use drones to improve coffee farming conditions.

application: They are relatively inexpensive, easy to fly, and provide actionable data to farmers.

Getting off the ground

At 25, Mutisya is already pushing hard to bring her vision of a drone future to life. This year, she'll be graduating from Lewis with a bachelor's degree in aviation administration, minoring in unmanned aircraft systems.

"I had no intention of doing anything in the drone industry," says Mutisya. "But in fall of 2014, I took an introduction to unmanned aerial systems class, and that's when I was able to learn the different applications for drones. That's when the light bulb just turned on."

Mutisya's other studies ranged from aviation regulations to meteorology, crew resource management to visual aircraft recognition. While she believes the courses helped her develop her interest in the field and her foundational knowledge, she doesn't know if they're necessary for those who are looking to get into drones.

Mutisya explains that the more valuable knowledge came from industry events and networking. While attending a panel discussion at Drone World Expo, Mutisya introduced herself to Robert Blair, vice president of agriculture at Measure. Blair took an interest in Mutisya's vision, helping her understand the use of drones in precision agriculture and encouraging her efforts.

"So far, everyone [in the drone industry] has actually pushed me to not give up on my dream — to keep my dream alive and keep pushing," Mutisya says.

For now, that means graduating and getting her degree. She's also hitting the books for her Part 107 exam, which she hopes to take (and pass) this spring. She also explains she was recently offered an internship from an aerial sensing company, which sent her a 3DR Solo and sensors for her to practice flying with.

Creating a buzz

But Mutisya doesn't only work within the drone industry. She has also worked closely with various major coffee organizations and associations both in the U.S. and Kenya to help build connections and further her knowledge.

In August 2015, Mutisya started her own coffee importing company called Kahawa Yetu, Swahili for "our coffee." Through Kahawa Yetu, Mutisya helps her father import and sell his coffee in the U.S. — and gains a working knowledge of the complex coffee importing, cupping, and roasting world.

When Mutisya speaks of coffee now, she's well versed in the challenges that coffee farmers face: destructive pests, expensive fertilizers, and various diseases. These are all detriments to the production of high-quality coffee — and challenges that drones can help with. She explains that Kenya's coffee production was highest in the late 1980s, but the country's coffee production has sharply declined since.

She has attended events organized by the Specialty Coffee Association of America, one of the most respected coffee entities in the country. She says that even when discussing her goals with those in the coffee industry, she receives support.

Her short-term goal is to help farmers understand drone technology and how it can help them improve their quality, yield, and profits — bringing together the two distinct niche industries of coffee and drones. But in order to accomplish this, she first needs to acquire the necessary permissions from a third distinct group: the Kenyan government.

"I met with the minister of agriculture last year in August," Mutisya says, "and I proposed to him these ideas using drones for precision agriculture in the coffee sector. He was very intrigued."

Despite the minister's desire to aid Mutisya in moving forward with her work, there was little that he alone could do to help. Kenya doesn't have a formal commercial drone framework like Part 107 in place, and with the country's hesitance to accept the technology, Mutisya has more diplomatic work ahead of her to gain the needed permissions.

"With the help of my father, hopefully that's something I can achieve before the end of next year [2018]," she says.

Setting waypoints

But Mutisya has goals far beyond gaining permissions. In 10 years, she intends to have her own research and consulting company, enabling farmers and companies in countries across Africa to use drones commercially.

"A lot of people my age in Kenya graduate from college and don't get jobs," she says. She hopes that drones will help create new employment opportunities for her peers once the technology becomes more widely understood and accepted within the country.

She knows that there will be more challenges, but she remains undaunted. "It's both exciting and scary at the same time," she says. "But my passion is what keeps me going." 360

FROM LEFT TO RIGHT: SHIRLEEN LEMBI MULWA (2), LYELA MUTISYA

ANNOUNCING

2017 Women TO WATCH IN UAS

THE NOMINATION PROCESS IS OPEN *NOW!*

THE EMERGING UAS INDUSTRY IS FULL OF INSPIRING WOMEN SHAPING ITS FUTURE.

Our global search for women impacting the drone industry through achievements in technology, business, agriculture, governmental relations, advocacy, research, journalism, education and more is underway. Tell us who you are watching in 2017 – and give them the recognition of this important Award.

Learn more and submit your nominations at **WOMENANDDRONES.COM.**

Finalists will be honored at the **ASCEND CONFERENCE & EXPO**, July 19-21, 2017 in Portland, OR.

ASCEND Conference & Expo powered by Drone360

drone360

Women AND DRONES

Cool. Curious. Bizarre.

By Leah Froats

COZY ON UP

When the weather outside is frightful, staying by that delightful fire can be awfully tempting — especially since drones and chilly temps don't mix well.

Danielle Baskin, a multi-talented self-described "parallel entrepreneur" who has started various businesses such as custom avocado printing (yeah, we don't really know what that means either), has a solution to the problem of cold drones. And it's pretty straightforward: sweaters.

Yep, sweaters for your drone. And it's just as cute as it sounds. Since these Drone Sweaters are custom-made, they can fit any drone from your Yuneec Typhoon H all the way down to a DJI Mavic. Not sure about those nano-quads, but hey, it wouldn't hurt to ask.

We know you've wanted to coordinate that chartreuse argyle with your drone when you're out flying — now, you can. But Baskin's site makes it clear: "Drones cannot, or should not, wear pants — only sweaters and jackets." Got it.

SEEKING A DRONE FOR THE END OF THE WORLD

For drone hobbyists who aren't the best at repairs, it can be scary to fly quickly or near obstacles — which is a bummer, because those are some of the most thrilling ways to fly. What are we supposed to do, fly slowly in open areas? Of course not.

While a lot of companies are developing more "durable" drones that come with easily replaced parts, a new company called Aerodyne RC really took things to the next level. Meet the Nimbus drone, which looks like it could survive pretty much anything you could throw at it (or fly it into).

The Nimbus has the mother of all advertising videos — clips of the drone being run over by a car, flown into a wall, and landing in puddles have gone viral on Facebook. Its website also touts speeds of up to 100 mph. Since we all want to crash our drone and have it too, it seems like Nimbus is filling a big hole in the market.

The Nimbus racing drone is still in the production stage on Indiegogo — so take these claims with a grain of salt. This drone could very easily go the way of the dearly departed Lily (RIP) — only time will tell.

DON'T BE A DUMMY

We all know that drones can do some really wonderful stuff — they're technological marvels that have revitalized aviation for a whole new generation. But it's hard to not feel at least a twinge of fear in your stomach when a drone is flying just a little too close for comfort.

It's probably a near-universal response — you see those whirring propellers, and all you can imagine is the gruesome horror that would unfold as they embedded themselves in your tender flesh.

And this is why researchers at Virginia Tech are intentionally flying drones into faces. Well, into the faces of a sensor-laden human dummy, that is. Not human faces. That wouldn't be very responsible research.

The university's renowned injury biomechanics group is flying drones in the face of safety in order to determine and evaluate the precise risk that small UAS pose to unprotected individuals on the ground. This information will help regulatory bodies like the FAA establish guidelines that maintain safety while advancing the application of drones.

Through these tests, Virginia Tech is helping move drones into the future — very important, serious work. But there's also something oddly cathartic about watching a drone boldly fly straight into the face of a humanoid test dummy.

Just check out that photo up there. Doesn't that satisfy your most morbid curiosities?

Although, let's be honest — maybe we're all just thankful that we're not the ones getting hit.

CLOCKWISE FROM LEFT: MAX PIXEL, DREW HALVERSON, YOUTUBE/AERODYNE RC, YOUTUBE/ VIRGINIA TECH, YOUTUBE/AERODYNE RC (2)

POWER FORWARD

APRIL 16–19 2018

DENVER COLORADO

POWER LINES, THE NEXT AIR ADVENTURE.

Join over 700 exhibiting power and energy related companies as Denver plays host to the Transmission & Distribution industry's most powerful and experiential conference and exposition. It's no surprise the Drone business is on the rise and in this industry it's no exception. This is your opportunity to gain access to over 12,000 electrical and energy professionals and decision-makers. Don't miss this unparalleled chance to grow your network, connect globally and discover new opportunities to power your Drone business up and forward.

BOOTHS ARE GOING QUICKLY.
SIGN UP TO BECOME AN EXHIBITOR
TODAY AT POWERFORWARDDENVER.ORG

IEEE PES T&D CONFERENCE & EXPOSITION

IEEE PES Power & Energy Society® IEEE Xcel Energy® Host Utility

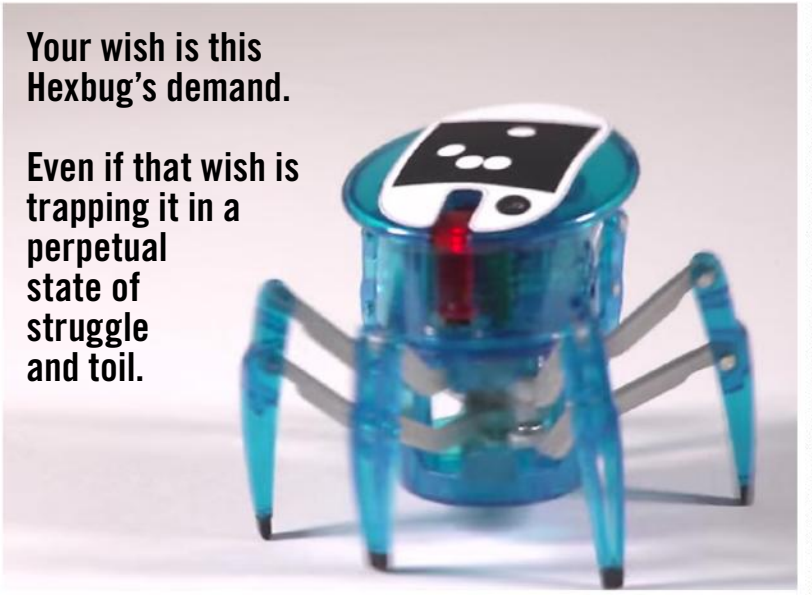
FOLLOW US TO LEARN MORE

MAKE GRAFFITI GREAT AGAIN

In the days and weeks following the inauguration of the new U.S. president, tensions ran high. A lot of very strong opinions were expressed in a variety of ways. One graffiti artist decided to respond to the appointment of President Trump the only way he knew how: drone graffiti.

KATSU, who has used drones for graffiti before, updated his "Icarus One" modified DJI drone into the new "Icarus Two," capable of translating computer text into spray-painted messages.

The artist contacted *Motherboard* to announce his new drone and clarify his feelings for the new administration. KATSU also released a video of the Icarus Two in action, with a certain political message attached. *Drone360* is apolitical, so we won't reiterate what KATSU's exact message was. But a certain line of hotels may want to invest in counter-drone technology, just in case the Icarus Two decides to take things to the streets.



THE BOT OF SISYPHUS

Have you ever wanted to control the Fates, fiendishly toying with the whims of beings smaller than yourself?

Then boy oh boy, do we have the drone for you. A new system from bots_alive allows a modification to Hexbug bots, enabling autonomous navigation of mazes and obstacles to reach a set location.

The standard set includes five "vision blocks" — four red, one blue. The codes on the blocks are scanned in real time by a smartphone app, which communicates the blocks' location to the Hexbug. The drone then determines multiple paths to reach the blue target block while avoiding the red obstacle blocks.

This is where your cruelest, most sadistic tendencies can run wild. Want to trap your Hexbug in an eternal prison, placing the target tantalizingly beyond its reach? Or perhaps make your Hexbug toil ceaselessly, traversing uphill over and over, only to again place it at the bottom as an allegory for the futility of human (and robotic) existence?

Or you can, like, just make it walk through a maze. That's fine too.

DORITO DELIVERY DRONE DREAMS

Drones played a surprisingly large role in this year's Super Bowl. A drone was caught flying over the Falcons pre-game practice, Lady Gaga serenaded viewers amidst hundreds of glowing Intel quadcopters — and a certain online retailer reminded the public that drone delivery is just around the corner.

Amazon.com had an advertisement spot late in the game as the New England Patriots were making their shocking comeback against the Atlanta Falcons. As millions of viewers were glued to their screens, they were greeted with an image of a notoriously over-hyped Amazon delivery drone.

As a man watching television on a couch sloppily licks his fingers and scrounges in a bowl of Doritos, the woman next to him scowls in disgust and orders a new bag of the snack chips through her Amazon Alexa home assistant via the company's Prime Air service. In an instant, a drone appears in the living room window — not very believable.

To be fair, the ad did feature a tiny disclaimer: "Prime Air is not available in some states (or any really). Yet." Nice move, Amazon.

A DRONE IN SHEEP'S CLOTHING

Watching nature shows like *Planet Earth* or *The Blue Planet* is always an extraordinary experience — seeing our world in new, unexpected ways helps us relate to our planet and its many animal inhabitants. And now, the BBC has a new idea for how to use drones to reveal the emotional similarities between humans and animals.

Its new five-part miniseries, *Spy in the Wild*, is centered on bio-mimicking, camera-laden bots that infiltrate animal communities to better understand their behavior — without a human cameraman standing by.

Some of the spies are simply animatronic robots, incapable of movement. But the machines designed to get up close and personal with polar bears are remotely operated — under the guise of a floating icebergs and moving snowcaps. Unfortunately, the polar bears were not too convinced by these disguises.

In a clip released by the BBC, three different camera-laden drones are shown being examined by the

bears. Two end up completely decimated by the bears' investigative efforts. Luckily, the drones still managed to get some adorable and educational footage.

You know what they say — curiosity killed the drone. (They say that, right?)

CLOCKWISE FROM LEFT: FLICKR/ELVERT BARNES, YOUTUBE/BOTS_ALIVE, WIKIMEDIA COMMONS/ SCOTT EHARDT, PBS

Drone360 (ISSN 2470-4687) is published bi-monthly by Kalmbach Publishing Co., 21027 Crossroads Circle, P.O. Box 1612, Waukesha, Wisconsin, 53187-1612.
Application to Mail at Periodical Postage Prices is pending at Waukesha, Wisconsin, and additional mailing offices. Postmaster: Send address changes to Drone360, PO Box 62320, Tampa, FL 33662-2320.

FALCON

Edition

"Charting New Horizons"

NEW PHANTOM 4 PRO MODEL

- 20X BETTER SIGNAL
- DUAL WIFI BOOSTERS
- CUSTOM COOLING
- PATENT PENDING

ORDER NOW $200 OFF Use Coupon: **DRONE360200**

WWW.DRONE-WORLD.COM/FALCON

DRONE WORLD™ | 1(888) 901-3108

INSTANT ACCESS TO:
DRONE WORLD SQUAD

THE CHARGE MASTERS

X4 AC PRO

Four Channel Multicharger

- 200 Watts Total AC Charge Power
- 300 Watts Total DC Charge Power
- Built-in Bluetooth for Smartphone App Operation

X2 AC PLUS

Twin Channel Multicharger

- 100 Watts Total AC Charge Power
- 300 Watts Total DC Charge Power
- Optional WiFi Module for Wireless Control

LiPo	LiHV	LiFe	LiIon	NiMH	NiCd	PB
1-6 cell	1-6 cell	1-6 cell	1-6 cell	1-15 cell	1-15 cell	2-20V

SMARTPHONE APPS AVAILABLE

X4 AC PRO

Available on the App Store

ANDROID APP ON Google play

X2 AC PLUS

OPTIONAL WiFi CAPABILITIES

- Compatible with Both Chargers.
- View, Change & Customize your Charger Options via Smartphone

EXPERIENCE THE FUTURE OF CHARGING!

Hitec's latest AC/DC Multichargers, the X4 AC Pro and X2 AC Plus, bring ultra-performance and reliability to your workbench and to the field. Both are capable of operating on AC household current or a DC power source and feature AC Power Distribution capabilities for the ultimate in charging flexibility. With a wide range of battery charging options and 10 programmable profiles per channel, these powerhouses make charging different types of batteries a breeze. Combine all the features with our PC software and Smartphone Apps and you'll know why we call them the Charge Masters.

Master your world of futuristic battery charging, master it with Hitec!

Hitec RCD USA, Inc. | 12115 Paine St. Poway, CA 92064 | 858.748.6948 | www.hitecrcd.com |