Grounded

Drones are ready to change the way Americans live and work—if we'd only let them. **By Sara Sorcher**

Sky's the limit: The RMax sprays grapes in California.

A claque of 25 vineyard owners and farmers, always looking for ways to economize, had gathered on a Wednesday in November at an experimental winery owned by the University of California (Davis). There, at 11 a.m., they watched an unmanned helicopter called RMax lift off from a small grassy field. It showered 40 long rows of grapes from 2-gallon tanks mounted along each side of the fuselage, its sprayers pushing the liquid directly onto the crops. A tractor rigged to spew pesticide or fertilizer can douse the same area, just over an acre, in an hour. The drone did it in less than six minutes.

The RMax, built by Yamaha, has been a fixture in Japan since the 1990s. It sprays nearly half that country's rice crops, part of the Japanese government's solution to assist its elderly farming population and prevent pesticides from wafting into residential areas. The drones can fly much closer to the crops; the downwash from the buzzing rotor blades helps coat both the tops and bottoms of leaves, unlike more expensive piloted aircraft. American wineries, for now, rely largely on lumbering tractors, which are slowed by challenging terrain. With 1 million acres of grapes in the United States, it's a "tremendous opportunity" for the drone helicopter to change the way farmers do business, says Steve Markofski, the new business planner for Yamaha Motor Corp. USA, who attended the demonstration. And wineries are just the beginning.

Drones, a military technology best known for killing enemies, are coming home. The Federal Aviation Administration, which will begin to license them for commercial use in 2015, forecasts that 30,000 will fly American skies within the next 20 years. No, you needn't worry that a Predator will kill you with a Hellfire missile as you're eating dinner, as Sen. Rand Paul, R-Ky., warned recently. Police will use robots to help track criminals, run search-and-rescue missions, and maybe even issue parking tickets. Firefighters will plot escape routes and assess wildfires. But drones will ultimately succeed in the United States because American capitalists will do what they do best: find better ways to make a profit. The "robotics revolution" will take off, says the Brookings Institution's Peter Singer, "when you have innovation crossing with profit-seeking—people coming up with new ideas and new ways to make money off it."

Although the technology is already here, its applications are still being imagined. Drones could perch atop police or fire stations to deploy immediately when a caller dials 911. They could transport supplies for rescue missions or humanitarian relief work. They could rush important documents over congested streets. Picture a world in the not-too-distant future where unmanned planes deliver packages—and fast food arrives even faster.

All this is expected to become a $90 billion industry within the next decade and to create 100,000 high-paying American jobs along the way. The unmanned-aircraft industry today, Singer says, is like the world of desktop computers before the Internet revolutionized how we use them. Even the Internet was once a military program called Arpanet run by unwieldy and expensive hardware; now it runs through everything. Drivers of "horseless carriages" in the early 1900s had a 6-mph speed limit before motorized horsepower made the country a smaller place. The drone's future, in other words, is nearly limitless.

But there's one big problem: Most domestic drones are grounded. The FAA lists only 327 active permits, all for public entities such as law enforcement or universities. Ensuring that the national airspace—already crowded with piloted planes—will remain safe with drones is no easy task. And Americans are still ambivalent. Two-thirds worry about their privacy if police use drones with high-tech cameras, according to a Monmouth University poll last June, and lawmakers in at least 30 states have proposed legislation to either limit or ban the technology amid concerns the government will use the flying bots for spying. Unless citizens can be convinced their privacy is safe, the drone revolution will have to wait.

WATCHING, WAITING

Hawkeye UAV Americas CEO Paul Morgan is waiting for the airspace to open, hoping his 9-pound drones will make him lots of money, eventually. The former Navy helicopter pilot, who spent years managing unmanned systems for the military, is fielding requests for tasks that tax humans. Mining and construction companies want Morgan's robots, equipped with digital cameras and survey-grade lenses, to measure the volume of their inventory (gravel or sand, for instance) to determine how much they will need for projects. "It takes about four days for two guys to do an 80-to-90-acre pit," says Morgan, who is based in Maryland. "I can do that in about an hour, and my accuracy is better." Manned aircraft can do the job, but Morgan's (cheaper) drones "can do it better, with electric power and less gas." His company has invested hundreds of thousands of dollars, but for now he often donates its services, often relying on public universities to apply for the permits and invite him to teach students on-site. "I don't make any money out of it," Morgan says, "but I'm positioning my company to make money."

Meanwhile, American businesses are losing profit-making and time-saving opportunities. Many U.S. farmers would prefer to rely on MicroPilot's CropCam, which flies over huge fields and snaps pictures to determine where to spray pesticides or fertilizers. That's better than the usual method: slathering the entire field in chemicals, which wastes money and manpower and increases pollution. Crop-Cam's pictures are geo-referenced, says Pierre Pepin, vice president of sales and marketing. The idea is for tractors guided by GPS to spray either pesticides or fertilizers as they drive over the demarcated land, without any input from the operator. However, the FAA's ban on commercial drone flights makes that scenario impossible. "We couldn't sell to the United States, so we looked at other markets," says Pepin, who is based in Canada. He markets most units to emerging economies in Asia and South America.

Applying nitrogen-based fertilizer and pesticides with precision, says Patrick Egan, an unmanned-aircraft systems consultant, "makes you a better upstream neighbor, because you don't have runoff getting into the water supply." Other drone applications for agriculture or ranching—such as testing the air quality over feed lines, tracking livestock marked with ID chips, or taking the temperature of the animal from above to scope out any health issues—"blow me away," says Egan, who is based in Sacramento. "We're missing out on that."

And the business potential goes much further. Drones can carry sensors that feed facial-recognition software or use thermal-imaging technology to see through walls. "It takes 10 to 15 years for technology that's been ingrained within the military to roll out into industrial applications. It's been about that time," says David Bannon, CEO of Headwall Photonics, which sells hyper-spectral sensors, precise instruments that record a scene based on its chemical composition or spectral fingerprint—a measurement of the light or energy of materials on the ground—and not its visible appearance. (Every object reflects or absorbs light. Sensors can distinguish plant wavelengths from rock wavelengths.) Oil and gas companies want drones with these sensors—once meant for orbiting satellites—to monitor pipelines for leaks or survey whether plant life is encroaching on the route. Insurance companies could assess risk factors in housing construction. The list goes on.

For its part, Yamaha is already dreaming up new possibilities. To tend the sprawl-

"We know we can do a whole lot more."

Michael Toscano, CEO of the Association for Unmanned Vehicle Systems International

ing soy, wheat, and corn fields at the heart of American agriculture, a future version of the RMax might forgo remote control and operate autonomously, using onboard computers to follow orders from an operator and go beyond his or her line of sight. It might grow larger to carry a greater volume of pesticides or fertilizers. "If we can establish a market for RMax and prove how reliable it is—how mature the platform is, based on all the years of development abroad—and slowly [build] acceptance of how it's being used, then we can begin to look at other applications," Markofski says. "That's future thought for us."

FUTURE THOUGHT

When he was editor of *Wired* magazine, Chris Anderson realized that the bare essentials of smartphones (cameras, GPS, wireless batteries, tiny sensors, and supercomputer-quality processors) also formed key elements of an autopilot that allows an aircraft to fly GPS missions autonomously. With most of these components available at your local Radio Shack, Anderson started a website community, DIY Drones, to help people "basically … put brains in toy-grade aircraft to give them [unmanned] capability." Now CEO of 3D Robotics, a multimillion-dollar business in Berkeley, Calif., that has sold 40,000 autopilots (half outside the United States), Anderson believes, "We're in the beginning of the creation of a huge industry."

Drones have opportunities beyond agriculture, the field initially expected to employ 80 percent of the commercial machines. Yet the full range of tasks they'll ultimately perform is still an open question, Anderson says. "If you'd asked Steve Jobs what personal computers were for in 1977 … I presume he would have said, 'Well, you could program them.' That was a sufficiently good answer for engineering types to buy it on that basis. But for the average American, that was not a compelling answer. That first generation of [users] … created those applications—so-called killer apps, like video games, e-mail, word processing—that ultimately answered the question." The best way to answer it for drones, Anderson says, "is to democratize this technology. We think it is our job to make them cheap and easy and ubiquitous so that the consumers can come up with answers we never thought of."

Some entrepreneurs believe drones could meliorate some of the world's biggest problems. Matternet, a company based in Palo Alto, Calif., is developing a courier network of small electric drones, called "grasshoppers," to transport lightweight goods to help the 1 billion people who live in poor, rural areas of the world without year-round access to roads. The grasshoppers will first run from one station to another—between, say, a village and a doctor's office carrying blood sam-
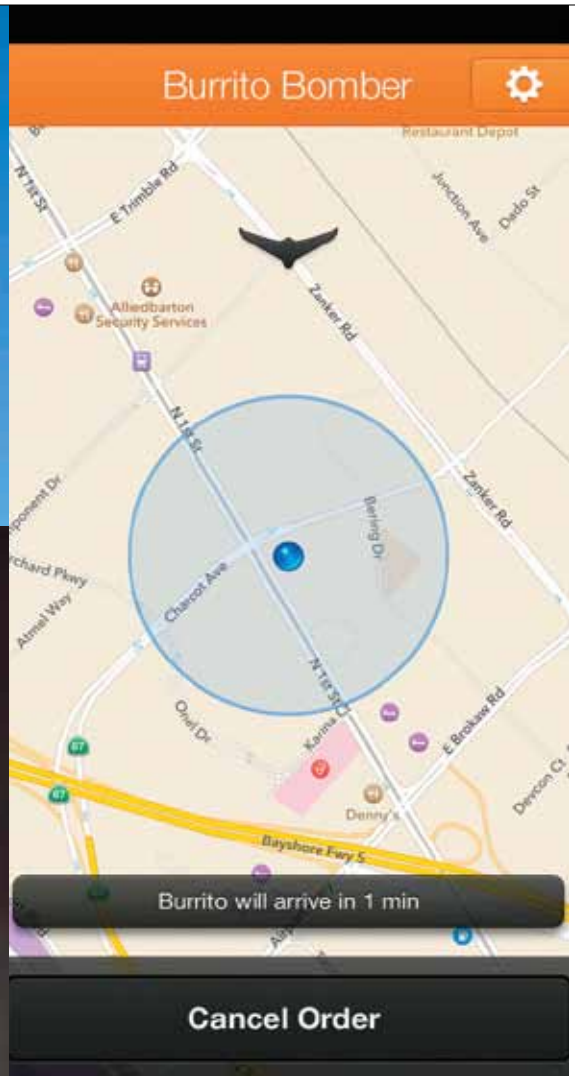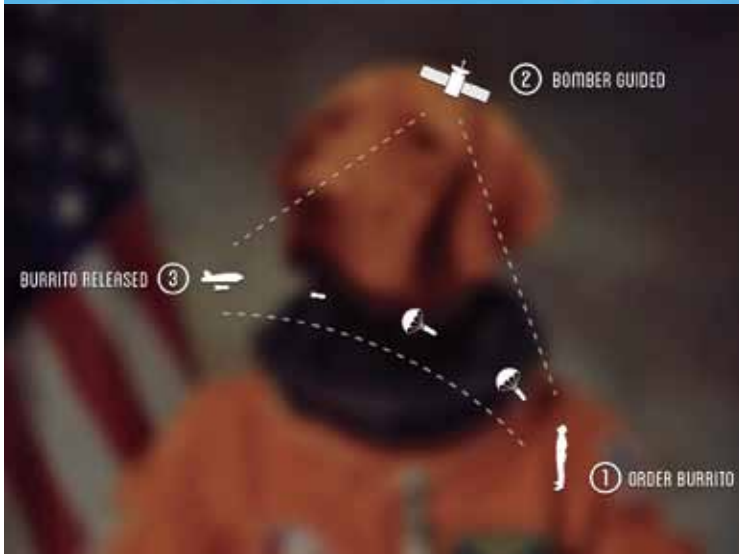
Airborne fiesta: The TacoCopter (top left); the Burrito Bomber model and app (middle left and top right), and the Yelp engineers who designed it.

ples or medicine, in seasons when the roads are impassable. The next phase brings solar-charging stations to extend the network so that grasshoppers never have to return to port to power up. Eventually, the Matternet drones could carry packages across a country or even the globe. Project leader Andreas Raptopoulos says small-scale networks will first launch in nations "where there is a huge need or appetite to leapfrog the developed world and jump onto the next paradigm of transportation."

Americans could use this system, too, says Raptopoulos, who began developing the product with other entrepreneurs at Singularity University in 2011, a 10-week summer program at the NASA Research Park in Silicon Valley. In the United States, he believes that Matternet is most likely to be deployed in emergencies at first, bringing whatever is needed—blankets, first-aid supplies, or mobile phones—to save lives. In a large-scale natural disaster, thousands of unmanned vehicles could deliver emergency supplies in a shorter time frame and at a fraction of the cost than helicopters. "Our imagination hasn't yet reached this point of understanding exactly how it will be applied."

After the airspace is integrated, "we could see more adoption—and eventually most e-commerce moved via air, rather than by road," Raptopoulos says. Online vendors are already experimenting with same-day delivery, and Matternet could offer options: "You order something and could get it within an hour at a very low cost." The idea is not as out-there as you might think: Marines are already using unmanned, remote-controlled helicopters to deliver supplies to troops at Afghan outposts in lieu of trucks that might be ambushed by militants or blown up by roadside bombs. Freight opportunities could expand in the commercial world, too. FedEx CEO Fred Smith has floated the idea of converting his delivery fleet to drones that could carry more cargo while reducing costs. At the

Wired Business Conference in 2010, Smith said the freight giant might someday fly unmanned aircraft in a formation, like a flock of birds, each wing-bot connected electronically to a piloted plane in the lead.

A group of twentysomethings is thinking this way for food delivery. Huddling in a corner of their San Francisco office for weeks, Yelp engineers used their company's 3-D printer and soldering tools to build a fixed-wing drone to deliver burritos. The group, dubbed Darwin Aerospace, wrote a smartphone app in one day: A customer can order the Mexican lunch and summon the Burrito Bomber to his location. The drone drops the burrito canister, which deploys a tiny parachute; the customer literally catches dinner. "We did this on a very limited time schedule and budget, with pretty much off-the-shelf parts," says Yoni De Beule, 26. "We're Web engineers. If we can build this in a few weeks, we figured that once the FAA relaxes regulations in 2015, then some real aerospace engineers with real funding will be able to make this happen."

They may have competition: "If it were legal to order tacos by drone today, we'd be pretty excited," says Star Simpson, 24, who helped engineer the TacoCopter, another would-be Mexican food delivery service connected to smartphones. Simpson, who studied at MIT, is busy conducting research and development on release mechanisms for her team's multi-rotor copter. She hopes other Americans start to see the potential. "People tend to exclusively focus on civil-liberties concerns rather than think of how [drones] can be helpful or fit in with their lives today," she says.

HIGH STAKES

Washington's drone lobby recognizes that the technology has an image problem. It starts with the name. "I don't use the word 'drone,' " says CEO Michael Toscano of the Association for Unmanned Vehicle Systems International. "There's a Hollywood expectation of what a drone is. Most of it is military: very fearful, hostile. These things are not that." While the group's 600 corporate members include defense giants Lockheed Martin and Raytheon, most flying robots in the United States will weigh less than 5 pounds, Toscano says.

The nonprofit association is focusing on the economic benefits in these tight fiscal times. In March, it released a study maintaining that drones would create 100,000 jobs within the decade after they are integrated into the national airspace. But securing that airspace is tough. Drones cannot yet "sense and avoid" other aircraft, something piloted planes

Inauspicious: The mobile phone and personal computer had awkward beginnings, too.

are expected to do; critics also worry about drones being hacked, and about how drones will communicate on the network. The stakes are high: Every year the advent of drones is delayed, AUVSI estimates, the United States will lose $10 billion in potential economic impact. And if future rules are too stringent, Toscano says, America's 80 percent stake in the global unmanned aircraft market could erode by about a quarter within the next decade, if other countries have less restrictive regulations.

All the uncertainty troubles drone-makers. "We can't tell venture capitalists who are interested in this area exactly when the airspace is going to open up, [when] any capital they invest is going to get a commercial payoff," says Chris Mailey, AUVSI's vice president of knowledge resources. And entrepreneurs want clarity. De Beule wonders, "Will commercial drones be allowed to be fully autonomous, or will it be similar to how Google's autonomous cars work, with a driver able to take over at any time? Will they be allowed in urban environments, or just low-population-density environments—and at what altitude?"

Regular businesses (read: companies that are not defense giants) worry they may be shut out of the drone market if the restrictions are too tight, says Egan, the unmanned-aircraft systems consultant. "If the regulations are draconian or onerous, people won't be able to fly or support a business." Insurance, licensing, and certification will present overhead costs—and it may not be worth investing if the government limits operations.

Developers are encouraged by the FAA's planned proving grounds. The agency is searching for six test sites where businesses can test drones and the FAA can work through safety issues. Roland Brockers, a research technologist at NASA's Jet Propulsion Laboratory, is designing a tiny autonomous drone with funding from the Pentagon. ("A user would point to a roof and say, 'Go there, find a place to land, and land there,' or, 'Go into the building and tell me what's happening here.' ") But every time Brockers wants to fly outdoors, he needs FAA approval, "and that's a time-consuming process." Each time he makes a modification, he needs a new permit. "Companies often have the same problem."

LIKE IT OR NOT

Drone advocates say demand will increase supply. Businesses will invest R&D funds, and robots will need operators. But some American pilots, or others in the manned flight industry, are concerned about this possibility. "It's going to create a lot of jobs, but it's also going to end a lot of jobs," Brookings's Singer points out. Robots helped revive automobile companies in Detroit, for instance, but not everyone is back to work: One in 10 autoworkers has been replaced by a robot; now other

Prescription-drug benefit: Matternet's grasshopper drone in Haiti.

industries want to "fully automate" assembly lines. Drones may exacerbate the robot take-over, because police stations will quickly figure out that instead of flying one helicopter that costs, say, $1,000 an hour to operate, they could deploy 10 drones that cost $100 each.

But the sky won't be thick with drones right away. While the FAA is working to expedite some permits for public organizations to use drones under 25 pounds, the application process remains lengthy and ad hoc. So long as the applicant can demonstrate it can operate the robots safely, without a hazard to other aircraft, people, or property, the FAA likely has no reason to deny a permit. However, this means the drones are operating, for now, under very limited conditions, because the FAA has not solved the safety obstacles that would give them freer use of airspace.

Officials will need more guidelines for mass permitting, and the agency is working to define the vehicles' limits and best practices as it drafts regulations to certify drone pilots and register aircraft. Once that regulatory structure is in place, the U.S. drone fleet can grow. The test sites will also help developers learn how to "sense and avoid" other aircraft to prevent midair collisions. The FAA's 2015 deadline is likely to be less a grand ribbon-cutting event and more the start of a long process during which the technology improves and more airspace opens to the drones.

Another obstacle to drones' rise is the lack of available wireless spectrum. So far, there are no dedicated frequencies for the flying robots to communicate with each other or with controllers on the ground, so they have to share the same bands that other devices use. That's a hurdle "but not a show-stopper," says Wells Bennett, a visiting national security law

fellow at Brookings, especially since the golden vision behind NextGen, the future air-traffic management system, is for airplanes and ground operators to use a GPS-based system to track everything airborne. Plugging drones into NextGen, Bennett says, "could solve some problems with spectrum space, because you're getting more data from satellites." The safety challenges don't end there, though. The FAA must also develop standards for what to do in the event that an operator's control breaks down while the drone is aloft—and for how much cybersecurity is needed to prevent hackers from hijacking the flying robots. "The military has a pretty closed system that is pretty spoof-proof," Bennett says, "but if you make it too expensive, maybe industry doesn't like that."

Privacy is a thorny issue, too. Civil-liberties groups are pushing for laws requiring police to get warrants before flying drones, which can hover longer than regular aircraft and potentially fly undetected. Fearful of an Orwellian dystopia, some Americans worry that Big Brother will monitor their every move. The Monmouth University poll, unsurprisingly, showed that most of us prefer the government to use drones to monitor wildfires, not give out speeding tickets. The commercial sphere presents a similar double-edged sword. A few journalism schools, for instance, are starting to teach drone-piloting to augment reporting; the cheap technology would help paparazzi follow celebrities. Fear of the eyes in the sky has also delayed the FAA's rollout; although the agency insists it is responsible for safety issues only, it bowed to pressure from civil libertarians and is now soliciting comments for a privacy policy at test-site locations.

Still, Pepperdine University professor Greg McNeal says Americans' concerns could actually present another business opportunity. "If they are smart, industry should come up with the privacy [protections] and sell it as a solution." Drones can be instructed to observe only the target of surveillance and ignore other data, McNeal says, making them better able to protect individuals' privacy than manned aircraft. Local boards—made up of citizens, civil libertarians, and police officers—could review information that law enforcement collects with drones and periodically assess privacy policy. This could prevent authorities from "selectively deleting information in a way that benefits them," McNeal says. (Some privacy advocates counter that data should not be retained except when there is reasonable suspicion they contain evidence of a crime or are needed for a specific investigation.) Another way to hold drone operators accountable: Require them to publish the robots' flight paths. It's unclear whether these policies would come from Congress, the states, or the courts, but without some sort of guidelines to reassure Americans their civil liberties will be protected, drones may stay grounded.

But surely not for long. Many in Congress see this technology's potential and are pushing the FAA to open the airspace, meaning it's only a matter of time before safety and privacy issues are resolved and drones become commonplace. History offers some lessons. According to World Bank estimates, there are 6 billion mobile-phone subscriptions worldwide today, giving access to about three-quarters of the world's population; that's up from 1 billion subscriptions in 2000. At that time, the current concept of mobile "apps"—from Facebook to sharing pictures through Instagram—was out of reach. With drones, Toscano says, "we know we can do a whole lot more," but have only a hint about how much. Getting Americans to accept the technology, he adds, "is going to be a crawl, walk, run approach."

That journey is already starting. A concerned Texan phoned C-SPAN this month after spotting what he thought, at first, was a UFO. "Turns out, it was a drone," the caller said. He drove his truck to find "the gentleman at the controls," where he learned that the Transportation Department had dispatched the vehicle to make a survey. Despite this apparently legal use of the technology, the caller described the experience as "very disconcerting." It may be that Americans may start to reap the benefits of drone labor before they see the bots in action. Yamaha's crop-spraying craft won't be a presence in the lives of most Americans, but they may soon drink wine from grapes nurtured to perfection by drones. ∎