The Right Stuff

Advanced materials and processes give drones the lift they need for food and vaccine deliveries, photography, inspections and much more

By Robert Grace

Look, up in the sky ... Is it a bird? Is it a plane? No, it's a drone delivering medications, or perhaps an order from Amazon, or even a pizza.

This is not some pie in the sky concept. It's happening already, as unmanned aerial vehicles (UAVs) grow in sophistication and surge in popularity, for use in a diverse range of innovative applications. And engineering plastics, along with composites featuring reinforcing materials such as carbon fiber, play a key role in helping to commercialize these small flying machines.

If anything, the coronavirus threat has helped to hasten this trend, as vaccines and medical supplies are badly needed and the ability to deliver the goods quickly and without human contact is desirable, for obvious reasons, during the pandemic.

Recent research by the Consumer Technology Association (CTA) of Arlington, Va., found that more than a quarter of consumers say that they see autonomous delivery technology (which includes drones) "more favorably now than before the pandemic." And more than half of consumers are saying that, "These systems are somewhat, or very favorable." So, it appears that enthusiasm is growing for this technology as the use cases become more apparent to consumers.

Further, CTA notes, there is also a strong enthusiast community. More than 20 million U.S. households now own recreational drones, which is roughly 17 percent of all U.S. households.

UPS chose Matternet's M2 drone logistics system for its 'drone airline.' Courtesy of Matternet

With appropriate clearances, commercial drones not only can fly right over dense, traffic-clogged metropolitan areas to quickly deliver goods, but can reach far-flung, sometimes remote regions, as well, such as in parts of Africa, where roads may not exist. When it comes to the logistics of parcel and package delivery, one of the biggest challenges is often the so-called "last mile," the act of getting these goods into the hands of those who need them, in an efficient and cost-effective way.

Plastics Engineering interviewed several experts in the field to gain insights into the materials and technologies being adopted by drone makers to meet the market's needs.

UPS Launches a Drone Airline

Matternet Inc. of Mountain View, Calif., a pioneer in drone delivery for medical applications, in October 2019 announced its drone delivery system is enabling the first "drone airline" approved by the U.S. Federal Aviation Administration. The certification was granted to parcel-delivery giant UPS, allowing the company to operate as a drone airline using Matternet's technology to expand on-demand drone delivery operations to hospitals around the country.

Last April, UPS reported it was teaming up with pharmacy chain CVS to deliver prescription medications using Matternet M2 drones to residents of The Villages retirement community in central Florida. The first flights were less than half a mile and were delivered to a pickup location near the community. Initially, UPS ground vehicles were used to complete the deliveries to the residents' doors.

The FAA-approved Matternet M2 drone logistics system, comprising the M2 drone and its proprietary Matternet Cloud Platform, can transport packages of up to 5 pounds over distances of up to 12.5 miles in operations beyond visual line of sight and over people. The company says its aim is to use networks of drones to deliver urgent items "on-demand at a fraction of the time, cost and ecological footprint of any other transportation method."

Ido Baruchin served from 2014 to 2020 as head of design for Matternet. Prior to that, from 2009 to 2011, he lived in London, where he earned a master's degree in vehicle design from the Royal College of Art. While there, Baruchin worked with an avant-garde designer who was experimenting with 3D printing to create jewelry, using mostly a selective laser sintering (SLS) machine to print items from nylon or various types of metals.

During his studies there, Baruchin says he also was very inspired by nature, and in particular, the structure of bird bones.

After moving to Silicon Valley, he joined Matternet in 2014, and was given a free hand to try various designs. At Matternet, Baruchin says he simply applied the same technology as he used to make jewelry, "but on a larger scale." And his previous study of biomimicry also informed the structure of his drone designs.

Since he was doing both the design and the mechanical engineering at the small startup firm, Baruchin explained in a mid-January telephone interview, he was able to develop products at a fast pace and printed a new drone roughly every month. He is now back in his native Israel and serving as a senior adviser to Matternet.

While at that time, most people thought of 3D printing as a way to produce prototypes, Baruchin said, "We didn't think of them as prototypes. We printed, painted and flew them. That was the product. With 3D printing, you can merge a lot of parts together, to save weight and assembly time."

Ido Baruchin leveraged his experience in 3D printing and interest in biomimicry to design and engineer Matternet's first drones. Courtesy of Matternet

In the space of about 12 months, he said, Matternet went from having no products to having various 3D-printed vehicles in the air. They skipped the traditional design process, with protoyping, tooling, manufacturing in China, etc., and went straight to making drones domestically. Matternet outsourced the 3D printing to a company in McMinnville, Ore., called Northwest Rapid Manufacturing LLC.

NW Rapid uses an SLS machine from EOS in Germany to 3D print the components. Baruchin said they started by making parts using powdered glass-filled nylon but needed some parts to be even stiffer. So, they began adding carbon fiber as a reinforcing agent. "When you need to build something that goes up in the air, weight is king. And these technologies allowed that."

Matternet named its first drone the M1, which was a monocoque design, meaning the frame and body were built as a single integrated structure. Each drone has two unique parts and a total of five parts. The central ring contains numerous complex channels to allow for wiring, and then four 3D-printed motor arms. One arm and the center ring were the unique parts.

Leveraging Benefits of 3D

"You could only do this in 3D printing," Baruchin said. "In the same tank [holding the powdered resin], all the parts are born—from the same womb, so to speak." This, he notes, is in contrast to injection molding, by which you mold the parts and then bring them all together to be assembled.

The average Matternet drone weighs about 22 to 24 pounds; the plastics content of each is roughly 4.5 pounds, Baruchin estimated. The battery is heavy, and accounts for at least 13 pounds.

Major firms such as Amazon and UPS foresee using drones extensively for small-package deliveries, Baruchin noted, but he still sees healthcare-related applications as making the most sense right now.

"For me, going up in the air really starts to make sense when there is a geographical barrier." Such a barrier can be traffic in urban areas, or barely navigable terrain in remote areas. Baruchin quoted his former Matternet colleague Marc Shillum as saying that a drone's value proposition increases when the reward outweighs the risk.

In the developed world, speed and predictability are key when it comes to weighing the benefits of using drones. In the developing world, the predominant factors are speed, cost and reliability.

When working in Africa, Matternet worried initially that the range capabilities of its drones may be an issue. But Baruchin said that UNICEF (United Nations International Children's Emergency Fund) told them that range was not as important as reliability. For example, on some days, motorcycle messengers in those areas couldn't deliver their goods because someone had stolen the gas from their bikes, or else the person supposed to do the delivery simply didn't show up to work.

Using drones gave healthcare facilities in these areas greater autonomy and helped to ensure that vital supplies would be there every time they were needed.

From Blood Supplies to PPE

Zipline Inc. is another drone supplier active in this field. Founded in 2014 and based in San Francisco, Zipline designs, manufactures and operates medical-product delivery drones.

On its website, Zipline says it operates from distribution centers placed at the center of each region of service. "Part medical warehouse, part drone airport, each distribution center can make hundreds of deliveries each day to any point within a 22,500+ square kilometer (8,750+ square mile) service area," the website says.

The company claims each distribution center "can move nearly 1 ton of inventory per day," using fixed-wing drones that cruise up to 60 miles per hour, carrying up to a 3.85-pound payload over a 50-mile service radius. A parachute landing system that slowly lowers the drone to the ground "can be deployed as a last resort."

The company began drone deliveries in Rwanda in 2016, initially making emergency deliveries of blood to rural clinics. In Ghana, the company began using drones in April 2019 to deliver vaccines, blood and medicines.

The COVID-19 pandemic has created new, urgent needs. First there was demand for personal protective equipment (PPE) such as medical gowns, gloves, masks, face shields, etc. Zipline claims that, within its areas of distribution, "if a health worker needs a single mask, we can cost effectively deliver it within minutes."

Last year, the FAA granted a Part 107 waiver to Winston-Salem, N.C.-based Novant Health, in partnership with Zipline, for the delivery of medical supplies and PPE to medical facilities in North Carolina. Zipline says it will be ready this spring to begin delivering COVID-19 vaccines in the countries where it currently operates—Tanzania, Rwanda, Ghana and the rural U.S.

The company plans to store vaccines in ultra-cold freezers at its distribution centers, and when a clinic needs doses, the drones can make a delivery within roughly half an hour. This is vital, given that the Pfizer vaccine has to be stored at minus 70°C, and the Moderna vaccine, while not needing quite such cold storage, still needs to be frozen until it's ready for use.

"Because we will have ultra-low-temperature freezers at our distribution centers," a Zipline spokesperson told Fast Company magazine recently, "it allows rural and remote health facilities to bypass the need for having the freezers themselves. And because we make deliveries on demand, we can send the precise amount needed at that very moment."

Delivering Cold-Chain Medicines

Volansi Inc., a leader in vertical take-off and landing (VTOL) vehicles and middle-mile drone delivery services, also has begun a commercial healthcare drone delivery pilot project in North Carolina. Last October, the Concord, Calif.-based firm partnered with pharmaceuticals giant Merck on the delivery of cold-chain medicines from Merck's Wilson, N.C., manufacturing site to Vidant Healthplex-Wilson, a Vidant Health clinic.

This first stage—which the companies claim involved the first drone delivery of temperature-controlled medicines within the U.S.—is billed as the first of three phases in a project to learn about drone technology's role and ability to improve access to healthcare.

The project uses Volansi's VOLY C10, an all-electric drone capable of carrying 10 pounds of cargo to locations from 30 to 50 miles away, depending on the weather conditions and other operational factors. The vehicle's VTOL system allows it to deliver fragile cargo with a "soft touch" automated release once the drone has landed at the delivery location. The VOLY C10 is significantly larger than Matternet's drones, measuring 6.9 feet long, with a wingspan of 9.6 feet.

In a Feb. 11 telephone interview, a company spokeswoman noted that Volansi aircraft—which she would only say are made of "a combination of composite materials"—can be

Volansi, a maker of vertical-take-off-and-landing vehicles, delivers cold-chain medicines with its drones for Merck in North Carolina. Courtesy of Volansi

configured to carry various different cargo containers. The firm's standard cargo container is a box much like a typical, everyday plastics container. "We chose this style of container so that the cost of the container isn't a constraint to our customers; they are durable and reusable, versus a one-time use cardboard container that some companies currently use."

Volansi manufactures its own vehicles in-house in California, and recently opened a second facility in Bend, Ore.

Salivating Over Flirtey

Meanwhile, Flirtey, an 8-year-old drone company based in Reno, Nev., announced last November that it was partnering with Vault Health to do drone delivery trials of the first FDA-authorized saliva test for COVID-19 in the Reno area. Under the agreement, Vault Health—a technology platform that says it aims "to help men through specialized in-home treatments for better health"—sends kits to distribution centers based on historical market demand data. When a customer places an order, a Flirtey drone will deliver the COVID-19 test kit to the customer's home on-demand.

Flirtey claims to have completed the first FAA-approved drone delivery in July 2015, when it delivered medical supplies to a health clinic in Wise, Va. In May 2018, the FAA announced 10 drone programs, including Flirtey, for its Integration Pilot Program that expands permissions to included programs that would typically need specific FAA permits due to airspace regulations.

Skyfish Climbs the Tower

Stevensville, Mont.-based drone maker Skyfish Inc. has taken aim at a different sector for drone use—cell tower inspections. John Livingstone and Orest Pilskalns launched the company in 2014, saying, "We saw a unique opportunity to leverage our software background in mapping and navigation. We focused on verticals where drones provided a distinct advantage, for example, in reaching hard-to-access points, and we focused on solving engineering problems related to surveying, scanning, 3D modeling and analyzing of critical infrastructure."

Orest Pilskalns co-founded Skyfish in 2014 with the aim of using drones to provide visual assessment and data capture of difficult-to-access assets, such as cell towers. Courtesy of Skyfish

Ultimately, Skyfish provides engineering reports, and the building blocks of those reports are models and analytics. It provides "an end-to-end solution that starts with high-quality drone data collection and outputs high-fidelity, 3D reality modeling analytics." They say they needed to develop their own hardware, because existing drones did not have the necessary accuracy or features.

The Skydio X2 drone uses Arris Composites' Additive Molding carbon fiber manufacturing technology for a key component. Courtesy of Skydio

In an email interview, Pilskalns, the chief executive officer, said Skyfish uses both carbon composites and a G-10 high-pressure, glass fiber-based laminate. "You may be surprised by the use of G-10," he noted, "but it has non-conductive properties that we found necessary."

The company does all the industrial design in-house for the mechanical and electrical engineering, and sources its composite materials from a supplier in Utah.

The Skyfish M4 drone weights about 26 pounds "all-up" (its total weight with cargo and fuel) and can fly uninterrupted for 38 minutes carrying a 5-pound payload. Pilskalns calls the Skyfish M6 drone "our monster machine," as it has a 5.5-foot wingspan. The M6 responds to robotic triggers up to five miles from the pilot. It weighs about 42 pounds all-up and flies uninterrupted for 30 minutes carrying a 10-pound payload.

Though it has had some orders from other countries, Skyfish focuses on the U.S. market, where it sells "hundreds of units" per year. Prices range from $11,000 to $40,000, depending on the configuration.

Asked his vision of the future, Pilskalns said: "I think drones will initially be focused on rural delivery—rural use-cases involve less risk (flying over fewer people) and more financial benefit (replacing trucks with small drones)."

He thinks his firm's patent-pending battery exchange system can alter the playing field. "Power is the real issue," he said. "How do you refuel battery-powered drones quickly? An automated, efficient, reliable battery exchanging system is the answer. We are working on perfecting such a system."

Eyes in the Skies

Drones are ideal for military reconnaissance and for performing asset inspection, monitoring or situational awareness tasks. This can include things such as inspecting bridges or other difficult-to-reach structures for integrity or assessing the conditions of roads, rivers or other passageways. In addition to being important for routine maintenance, this can be particularly useful for assessing damage after a natural disaster.

Even so, notes Adam Bry, founder and CEO of Skydio Inc. of Redwood City, Calif., "the scope of what's happening is so limited compared to what it could be, and ultimately, what I think it should be." Speaking in a recent interview with the CTA, as part of the association's all-virtual CES 2021 trade show, Bry (pronounced BREE) said this is because of the current requirement to have an expert on the ground, paying attention to the drone at all times while it's flying.

"Our vision at Skydio is to take it to the next level. It's a very simple concept. But, if you give the drone the ability to fly itself with onboard autonomy, AI [artificial intelligence] machine learning and start to give it the skills of an expert pilot built-in, it just opens up this entirely new world of use cases and accessibility, and that's what motivated us to start the company."

That's what Skydio has been focused on for the last several years, and those efforts, he said, are starting to bear fruit. Witness the launch in late 2020 of the $999 Skydio 2, said Bry, who co-founded Google's Wing drone delivery unit after graduating from MIT.

For one example, Bry said people would go mountain biking or hiking in a beautiful area and have a Skydio 2 drone follow them, capturing amazing cinematic footage that they couldn't get any other way. "It's kind of like having a Hollywood film crew there available in your backpack."

Arris Composite Technology

In mid-December, Skydio announced it was partnering with its Silicon Valley neighbor, Arris Composites, to use the latter's Additive Molding carbon fiber manufacturing technology to make "composite parts that are stronger than titanium with region-specific property optimization while offering the geometry and design flexibility of an injection molded part." Skydio is using the Additive Molding technology for key structural elements of its drones, starting with the airframe of the upcoming Skydio X2.

A specialized information source called sUAS News (for "small Unmanned Aerial Systems") succinctly summarizes some of this sector's key material challenges as follows: "For drone applications, parts are often expected to offer a combination of strength, thermal dissipation, electrical

grounding and shielding, or radio frequency (RF) transparency to allow for antennas to transmit and receive signals."

When strength, stiffness and thermal dissipation are required, aluminum and magnesium are common choices, as they have reasonably good strength and thermal properties for their density. But sUAS News notes, metals and carbon fiber composites block RF signals and therefore can't be used in locations near antennas. In such cases, the typical material choice is either glass-fiber composites, which offer less strength-to-weight compared to carbon fiber, but are RF transparent, or injection molded plastics, which are often less stiff and are not relied on as a core structural element.

For its new X2 model, which targets the enterprise, public sector and defense sectors, Skydio claims it has "redefined airframe design" by leveraging Arris' technology. In doing so, the partners were able to create a single, multifunctional, core structural part that replaced the previous 17-piece assembly (two carbon composite plates, one glass-fiber composite plate, four aluminum brackets, and 10 fasteners)—all while slashing part weight 25 percent. Arris says the company can optimize the carbon and glass-fiber layout based on functional requirements of individual regions of the airframe.

Skydio says that 3D printing this upper plate using Arris' composite technology lets it consolidate 17 parts into one and reduce weight 25 percent. (above) Courtesy of Skydio

Amazon got FAA clearance in August 2020 to use its Prime Air parcel delivery drones in the U.S. (below) Courtesy of Amazon

Don't Forget Amazon

Mega-retailer Amazon helped to revolutionize e-commerce. Now it may do the same for drone delivery

of packages. After first announcing its intention to adopt drone delivery in 2013, the firm on Dec. 7, 2016, showcased Amazon Prime Air service. It described this as "a future delivery system from Amazon designed to safely get packages to customers in 30 minutes or less using unmanned aerial vehicles ..."

In 2015, the FAA granted Amazon's logistics division an experimental airworthiness certificate, which allowed the company to fly drones for development and crew training. On Aug. 31, 2020, the agency cleared the regulatory skies to allow the retail giant to operate its fleet of Prime Air delivery drones. The latest Prime Air drone, unveiled in mid-2019, has a range of 15 miles and can carry packages weighing under 5 pounds. If all goes to plan, consumers can increasingly expect their packages to arrive by air.

A Pie From the Sky

Finally, about that pizza: Domino's, in conjunction with drone delivery partner Flirtey, in November 2016 became the first to deliver pizza via drone. It dropped off an order at a customer's door in Whangaparaoa, New Zealand, just north of Auckland. A team of drone experts and a pilot controlled Flirtey's DRU Drone—made of carbon fiber, aluminum and 3D-printed components—through GPS navigation to lower its cargo safely via tether.

There are likely to be many more meals delivered by drone in the coming years. But at the moment, medical applications are getting the most attention.

That said, even with a lot of drone activity in the healthcare sector, Ido Baruchin notes, "this whole market is not there yet." The challenges are not technology-related, he says. Instead, it involves "finding the right use case, and product-to-market fit." And regulatory issues remain. There are many variables, and "everything changes all the time."

The U.S. remains conservative and lags places such as Europe, Singapore and Japan when it comes to opening up its skies and promoting drone traffic. But one can expect, eventually, the time will come when unmanned aerial vehicles, combined with AI, machine learning and other advanced technology tools, will create an entirely new set of traffic patterns, well above our heads.

More information on the UAV developers and materials suppliers mentioned in this article can be found at their websites.

Matternet: www.mttr.net

Skydio: www.skydio.com

Skyfish: www.skyfish.ai

Volansi: www.volansi.com

Flirtey: www.flirtey.com

Zipline: www.flyzipline.com

Arris Composites: www.arriscomposites.com

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