WHITE PAPER

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Exploring the Transformative Effects of Drone Technology

Use Cases and Benefits

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Abstract

Recent advancements in drone technology have ushered in a new era of operational efficiency and environmental sustainability, presenting significant benefits to communities and organizations worldwide. This whitepaper delves into the multifaceted advantages of drone operations, ranging from economic development and job creation to substantial reductions in energy consumption and enhanced disaster response capabilities (Figure 1). We examine the potential of drones to reduce greenhouse gas emissions, increase the efficiency of emergency management and public safety operations, support safe infrastructure inspection, and assist in disaster recovery. Finally, we discuss various strategies to foster community support for drones, highlighting the importance of creating spaces for personal and recreational drone use, supporting formal and informal learning programs, and establishing effective communication channels to inform and engage community members.

Figure 1: Examples of drone operations in communities

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Drone Use Cases and Benefits

Drones or Uncrewed Aircraft Systems (UAS) have made numerous advancements since their conception in the 20th century. However, modern drone technology notably emerged in the early 21st century, signifying a pivotal transition in the development of drones for both military and civilian applications. Since then, drones have become increasingly prevalent and diverse in their applications, ranging from surveillance to commercial photography, agriculture, and recreational use.

While the integration of drones has proven easier for private businesses conducting operations on private property (e.g., warehouse and inspection applications), the integration of drones in public spaces has proven more challenging. However, integrating drones into community settings presents a unique opportunity for enhancing the recreational, educational, and operational aspects of local environments. Recent studies have demonstrated several benefits to both the organizations that would use them and the communities in which they would be used. These benefits span from opportunities for job creation and economic development through the reduction in energy consumption related to transportation services all the way to providing quicker and safer disaster response. In this whitepaper, we highlight these benefits and mention relevant leading research.

Economic Development

Investing in drone infrastructure, operations, and training creates skilled job opportunities, such as high-paying and accessible jobs in aviation, operations, maintenance, engineering, and finance. Drone Industry Insights[1] searched drone-related jobs from April to May 2022 and found 1,004 open drone jobs in 94 companies using LinkedIn, Indeed, StepStone, and company websites, among other sources. Figure 2 shows the different categories of drone-related job offerings and compares these two months in 2022 to the same months in 2018. As one can see, drone companies offer various positions, and the USA is leading the market in drone-related job demand. As per Precedence Research, the global drone services market size accounted for USD 8.09 billion in 2022, and it is expanding by around USD 87.02 billion by 2032 with a registered compound annual growth rate (CAGR) of 26.81% from 2023 to 2032[2]. Specifically, the drone logistics and

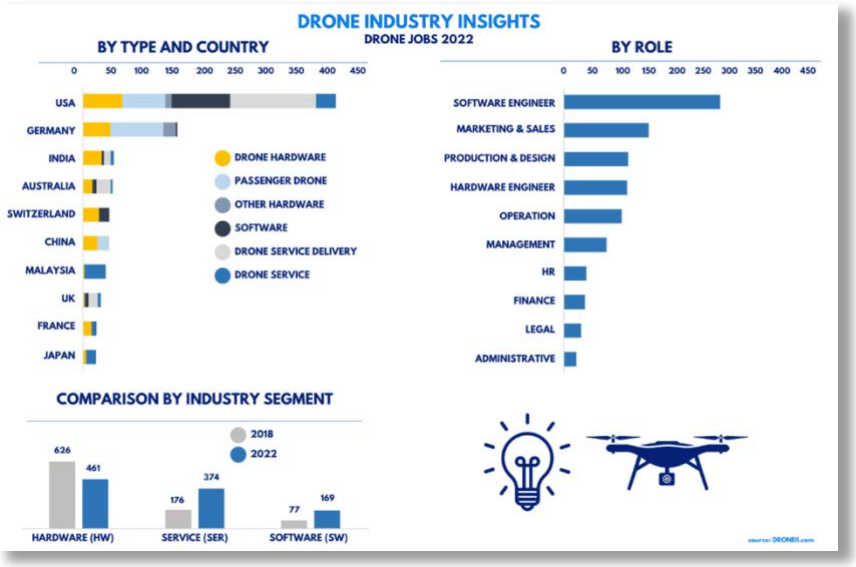

Figure 2: UAS related jobs worldwide (created by: Drone Industry Insights)[1]

1. Lotfi, Z. 2022, *Where the Drone Jobs Are*, Drone Industry Insights, <https://droneii.com/where-the-drone-jobs-are>
2. Precedence Research 2023, *Drone Services Market Size is Expanding Around USD 87.02 Bn by 2032*, Global Newswire by Notified, <https://www.globenewswire.com/news-release/2023/01/19/2591769/0/en/drone-services-market-size-is-expanding-around-usd-87-02-bn-by-2032.html>

transportation market size is expected to hit $59.52 billion by 2030, with a CAGR of 21.2% from 2021 to 2030[3]. Communities can take advantage of this projected growth by creating environments in which drone businesses can operate.

Energy Reduction

Urban transportation, mobility, and cargo delivery systems are critical components of human life and society, impacting the economy, the habitability of localities, and community equity. However, the mass use of these conventional modes of transportation and the reliance on internal combustion engines emitting high amounts of greenhouse gas (GHG) emissions is antiquated and unsustainable to the wellness of our communities and the environment. For example, first and last-mile household deliveries create approximately 158.4 g of CO_2 per km per order when delivered by light commercial vehicles, cars, and motorbikes. This value is substantially higher than the widely accepted emission target of 0.147g of CO_2 per km per delivery[4]. The use of innovative, fully electric, last- and middle-mile delivery transportation solutions utilizing drones has the potential to alter the landscape of delivery and services and reduce CO_2 and other GHG emissions.

However, this task is complex, and drone integration will serve as one component in a landscape of environmentally friendly measures. Achieving significant improvements in the energy productivity of freight transportation is challenging, especially in the overwhelmingly petroleum-powered transport sector, where medium and heavy trucks in the United States comprise 24% of transportation energy use. This sector is responsible for 37% of transportation-related GHG emissions, while light-duty vehicles comprise 57% of transportation GHG emissions and 64% of transportation energy use.[5]

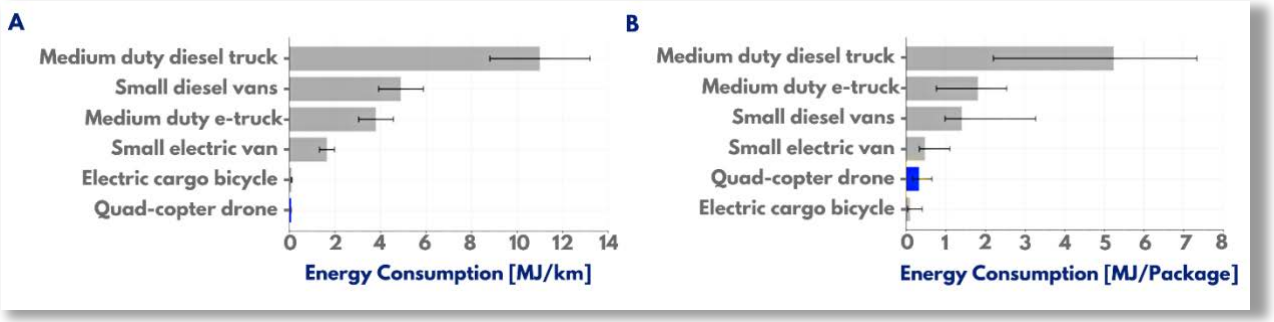

Figure 3: Energy consumption comparison between drones and other transportation solutions. A: per distance, B: per package. (Created by Rodrigues et al.)[5]

A recent research study compared the environmental impact of various last-mile delivery methods and found that CO_2 emissions per parcel were 84% lower for drones than diesel trucks and consumed up to 94% less energy per parcel than trucks[5]. See the energy consumption and CO_2 emission comparison in Figure3 and Figure 4.

3. Precedence Research 2023, Drone Logistics and Transportation Market Size, Report By 2032, Precedence Research, <https://www.precedenceresearch.com/drone-logistics-and-transportation-market>
4. European Parliament, Council of the European Union 2019, Document 32019R0631: Regulation (EU) 2019/631 of the European Parliament and of the Council of 17 April 2019 setting CO2 emission performance standards for new passenger cars and for new light commercial vehicles, and repealing Regulations (EC) No 443/2009 and (EU) No 510/2011, EUR-Lex, <https://www.legislation.gov.uk/eur/2019/631/contents>
5. Rodrigues, T. A., et al. 2022, *Drone flight data reveal energy and greenhouse gas emissions savings for very small package delivery*, Patterns 3, August 12, 2022, <https://doi.org/10.1016/j.patter.2022.100569>

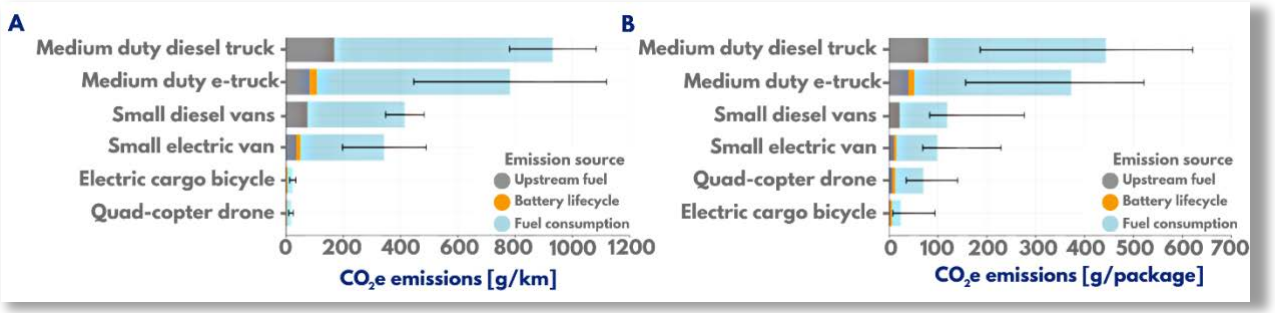

Figure 4: CO_2 emission comparison between drones and other transportation solutions. A: per distance, B: per package. (Created by Rodrigues et al.)[5]

Two drone delivery pilots conducted by Airspace Link and various partners in Michigan have projected a substantial reduction in CO_2 emissions when transitioning from package delivery by ground transportation to utilizing drones.

The first pilot study, conducted in Michigan in June 2021 in the suburbs of Royal Oak and Birmingham in Southeast Michigan, compared delivery by drones to delivery by a standard SUV and demonstrated that CO_2 emission per the investigated route an MG VELOS 100 drone in the pilot scenario is only 31% of the CO_2 emission of a standard SUV conducting the same route. Even if we assume two drones are required to cover the same route as a car, we achieve a reduction of almost 38% in CO_2 emissions[6].

The second Michigan pilot study took place in November 2023 and compared the CO_2 emission per route of two different drones (WA4-100 "Horsefly" and DDC-Sparrow) to four vehicles: 2022 Toyota Corolla 2.0 L, 2023 Ford Transit Connect Van FWD, 2023 Ford E Transit, and Tesla Model 3. Both drones showed similar CO_2 emission reductions, ranging from CO_2 emission at a rate of 9% of the 2023 Ford Transit Connect Van FWD to CO_2 emission at a rate of 19% of the Tesla Model 3[7].

The GHG emission of the electric drone is dependent and directly proportional to the GHG emission rate of power manufacturing in the area. Different areas in Michigan have varying power manufacturing GHG emission rates, which contributes to the difference in CO_2 emission savings in our calculations. Both pilot projects model a significantly lower CO_2 emission per mile for drones, which aligns with the theoretical modeling above by Rodrigues et al., showing the low energy consumption of drones compared with other transportation solutions.

Disaster Response

Disasters are sudden events causing great damage and loss of life; effective risk management offers an opportunity to control hazards and, in turn, prevent many disasters. In the case where mitigation attempts are not successful effective disaster response is crucial. Response efforts are categorized into three stages: (a) pre-disaster planning and preparedness, (b) disaster response and management, and (c) post-disaster recovery[8]. There are many ways that drones can be utilized for responding to both natural and artificial

6. Airspace Link 2022, *Final Report: Airspace Link Drone Delivery Services for Healthcare Systems,* ArcGIS Story Maps, <https://storymaps.arcgis.com/stories/78a1f76daf484f01a50253af625872c2>
7. Workhorse Aero 2024, Publication in process
8. IFRC. (2020). About disaster management. International Federation of Red Cross and Red Crescent Societies (IFRC), <https://www.ifrc.org/en/what-we-do/disaster-management/about-disaster-management>

disasters. From blizzards and earthquakes to train derailments and building collapses, drones are rapidly becoming a key asset to first responders and a much-needed tool in emergency response plans.

Drones can be deployed much quicker and, in some cases, with more accuracy than traditional crewed aircraft, which gives first responders the most critical asset they need: time. They can also access areas that are inaccessible by other aircraft or human responders. Drones can be used for detailed reconnaissance of the disaster area before sending out relief workers, resulting in increased safety for all involved. They can quickly cover a large search area by leveraging visual, thermal, and other sensors, which is much more efficient than traditional ground search and rescue teams. Below are links to some articles that show real-world use cases where drones play a crucial role in disaster response.

- North Dakota Blizzard Response using drones
- Hurricane Ian Response
- Using Drones in Response to Train Derailments
- Using Drones in Response to Landslide Hazards
- Using Drones to Assist with Earthquake Crisis Management

These examples demonstrate that drones are rapidly becoming an indispensable tool for emergency management plans needed for communities to handle most forms of disaster response.

Safety & Security

Public safety operations lead the way in drone integration into community service, improving public safety through technology that increases response time, efficiency, and intelligence. In a survey of 860 police departments conducted in late 2018, 47% of respondents were using drones in some manner, and an additional 34 percent were interested in obtaining them for use in the future[9]. As predicted, the use of drones for public safety has increased, and the trend continues to be significant[10]. This growth is driven by awareness of the capabilities and benefits of drones as assets for operations ranging from SWAT deployments to searching for critical missing persons (someone at an elevated risk of danger based on age or circumstance) instances in which short response time is imperative. Drones can also provide real-time intelligence to officers in the field, enabling them to quickly develop a plan to de-escalate situations before the officer arrives on the scene. In addition, fire departments are using drones to determine how chemicals and hazardous materials are spreading in fires without endangering any member of their team.

To capitalize on modern and expanding technologies, communities are establishing *Real Time Crime Centers* (RTCC) to centralize, manage, and coordinate efforts. Combining an RTCC with a *Drone as a First Responder* program enables a community to gather the information officers need to respond to calls. By combining the drone with other cameras around the jurisdiction, officers can track suspects and adjust their responses to calls as information is updated in real time. Here are a couple of examples of Drones as First Responders programs implemented in Georgia and California:

- Brookhaven, GA. Drone as a First Responder Program

9. Police Executive Research Form 2020, Drones: A Report on the Use of Drones by Public Safety Agencies- and a Wake-Up Call about the Threat of Malicious Drone Attacks. Office of Community Oriented Policing Services, Department of Justice, <https://portal.cops.usdoj.gov/resourcecenter/RIC/Publications/cops-w0894-pub.pdf>
10. Police 1 Staff, 2023, *Report: Global public safety drones market set to reach $3.7 billion by 2032* , <https://www.police1.com/report-global-public-safety-drones-market-set-to-reach-3-7-billion-by-2032>

- Chula Vista, CA. Police Department Drone as a First Responder and Drone Program

Inspections

Safety use cases extend into other areas as well. Drones are used for inspection applications across various industries for three primary reasons: safety, speed, and advanced data collection. Inspection operations include *infrastructure inspections* (of bridges, dams, pipelines, powerlines, and other critical infrastructure), building inspections (for both exterior and interior maintenance, structural integrity, and compliance), *roof inspections* (for damage, leaks, or wear and tear), *agricultural inspections* (for crop monitoring of disease, infestation, and nutrient deficiencies), *environmental inspections* (for monitoring environmental conditions, detecting pollution or hazards, and collecting data), *industrial inspections* (of equipment in manufacturing plants, refineries, and factories), and finally *inspection of confined spaces* (e.g., tunnels, ducts, and storage tanks).

Safety: Many of the applications described require workers to access areas that are hazardous due to heights, confined spaces, hazardous materials, electrical systems, radiation, or other physical hazards. Drones give workers the ability to access these dangerous and difficult-to-reach areas safely.

Speed: The speed of infrastructure inspection can also be significantly improved. Conventional inspections of infrastructure can necessitate extensive planning and scheduling, often spanning weeks or months. These inspections might also require operational shutdowns and the leasing of costly equipment and can result in significant operational delays. In addition, the impact on the general community is also decreased as drone use in transportation infrastructure inspections (e.g., bridge inspections, etc.) reduces lane closures[Error! Bookmark not defined.].

Advanced data collection: Finally, drones facilitate advanced inspection data collection. Advanced technologies allow drones to capture Lidar, thermal imaging, and high-resolution photos and videos that can easily be analyzed for anomalies and shared across organizations for greater collaboration and awareness.

The deployment of drones operated by a certified remote pilot and the appropriate drone technology mitigates many industry risks and expedites the completion of tasks according to operation specific requirements. Overall, drones offer a cost-effective, efficient, and safe solution for inspections across a wide range of industries, helping organizations improve asset management, maintain regulatory compliance, and enhance safety protocols.

Medical Deliveries

Drone technology can potentially make a lasting impact within the medical ecosystem, with decreased costs for healthcare systems and patient care services, reduced wait times for lab results, and greater access to treatment options. Package delivery using drones for medical applications is being tested across many use cases, including transporting lab specimens and samples, organs, test kits, medications, vaccines, and more. These benefits are actively being quantified, and the concept of operations is tested and proven. Airspace Link participated in various test flights and showcases of drone-enabled medical deliveries.

The first test flights for medical delivery were completed In March 2019 by WakeMed Health & Hospitals, United Parcel Service (UPS), and Matternet, a drone company.[11] They piloted lab specimens over 1/3 of a mile from WakeMed's medical park to their main building.

Then, the next major step was taken in January 2021, when the COVID-19 Humanitarian UAS Response Partnership (CHURP)[12], consisting of Airspace Link, DroneUp, NUAIR, Emergent 121 Consulting, and Akin Gump, LLP, completed two test cases. The group completed the first flight to operate with an FAA Section 107.39 Operation Over People Waiver[13]. This waiver allowed flights over the public and moving vehicles to deliver COVID-19 test kits four blocks away from The State University of New York's (SUNY) Upstate University Hospital's helipad and the Central New York (CNY) Biotech Accelerator[14].

Also in early 2021, the first 35-mile autonomous, multi-modal organ transport demo was completed by Airspace Link, VyrtX, and UAS provider Workhorse Group, supported by JobsOhio, DriveOhio, The Ohio State University's Airport and Center for Automotive Research, Lifeline of Ohio, Advanced Mobility Collective (AMC) and Transplant Coordinators of America (TCOA)[15]. The team successfully transported 3D-printed kidneys and blood from Ohio State University (Columbus, OH) to a rural hospital (Marysville, OH) by obtaining LAANC authorization to transport medical supplies across airport grounds.

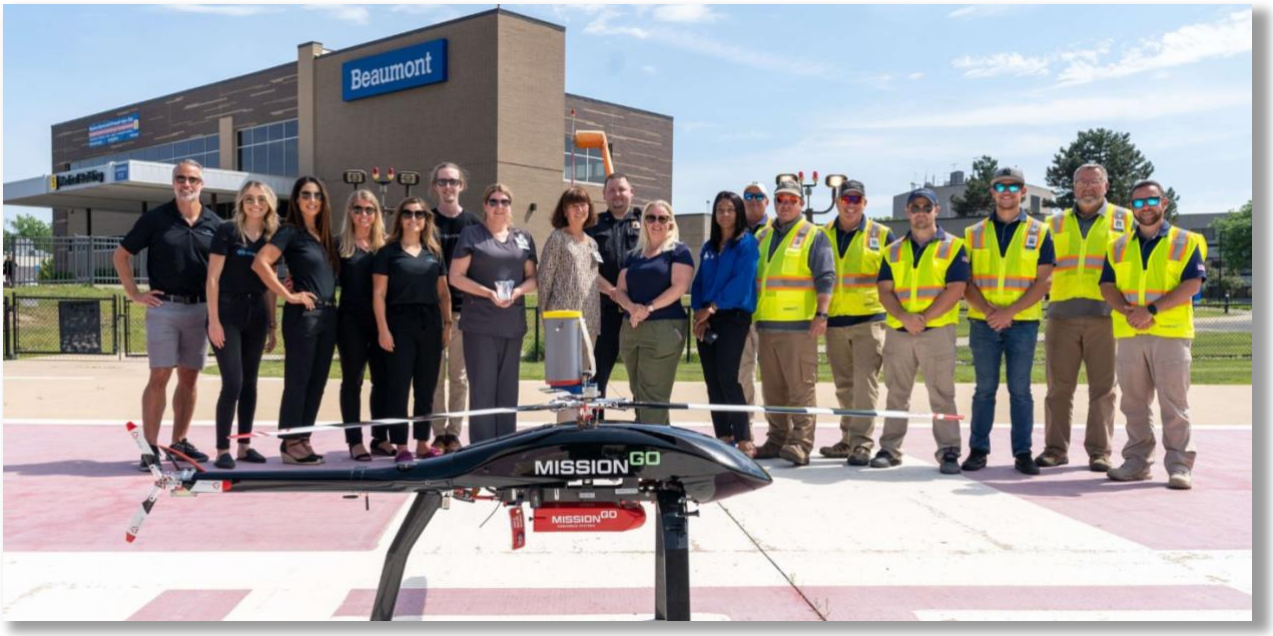

Figure 5: Drone medical delivery pilot project participants from Airspace Link, MissionGO, and Beaumont Health

11. *WakeMed is using drones to rush lab samples through the sky* 2017, Advisory Board, <https://www.advisory.com/daily-briefing/2019/04/04/drones>
12. *COVID Humanitarian UAS Operation CHURP Concludes Delivery Test in Syracuse* 2021, NUAIR, <https://nuair.org/2021/01/19/covid-humanitarian-uas-operation-churp-concludes-delivery-test-in-syracuse/>
13. Geddes, D. 2021, *It's a bird. It's a plane. It's a drone.,* Upstate Medical University, <https://www.upstate.edu/news/articles/2021/2021-01-20-droneland.php>
14. Clark, B. 2021, *Detroit Company Uses Drones to Transport COVID-19 Test Kits in New York*, DBusiness Magazine, <https://www.dbusiness.com/tech-mobility-news/detroit-company-uses-drones-to-transport-covid-19-test-kits-in-new-york/>
15. Knight, R. 2021, *Multimodal Autonomous Systems Organ Delivery Demo Completed in Ohio*, Inside Unmanned Systems, <https://insideunmannedsystems.com/multimodal-autonomous-systems-organ-delivery-demo-completed-in-ohio/>

Expanding upon these test cases, in 2022, Airspace Link completed a pilot project with MissionGO and Beaumont Health, with observation and support by the State of Michigan and Michigan's Economic Development Corporation (MEDC) (Figure 5)[6]. The project's objective was "to enable a representative, real-world operation to demonstrate how drones can be used as a novel mode of sustainable, time-saving, and affordable transportation for last-mile delivery." Completing 10 days (45 flights) of real-world medical package delivery operations, the pilot showed approximately 33%-time savings, a 50% cost savings, and up to 38% in CO_2 emissions between drone and ground delivery.

Matador UAS Logistics has recently ushered in a new healthcare services drone corridor in Texas. They announced in partnership with Swoop Aero, Airspace Link, and the Matador UAS Consortium™ that the FAA has granted a Part 107 waiver enabling remote, autonomous beyond visual line of sight (BVLOS) operations along a 134-mile corridor from Fort Stockton, Texas, to Presidio, Texas to improve rural healthcare access[16]. Airspace Link is following closely the services, research, and development along this corridor.

Reducing Road Congestion

Introducing new transportation solutions enables decreased use of cars and trucks for deliveries and reduces the Vehicle Miles of Travel (VMT) in the area over time. Reduction of VMT is directly connected to the curtailment of GHG emissions and criteria pollutants, as described above. Additional indirect benefits are gained from positive impacts on remaining traffic, including lower traffic congestion and fewer road accidents.

A model based on Airspace Link's recent pilot project in Michigan has yielded that a drone operation saves about 33% of the time dedicated to ground delivery. This time estimate is conservative, considering only short distances per trip for the drone and routes based on the avoidance of people below. These savings translate into 309 hours of operations saved for 16% adoption, 928 hours for 50% adoption, and 1856 hours for 100% adoption.

A study charted by Airspace Link and conducted by xResearch[17] has shown that, on average, 95% of the packages delivered in the United States weigh less than 10 pounds and hence can be delivered by a drone. Even a partial transition to drone-enabled delivery will reduce the Vehicle Miles Traveled by ground transportation. Table 1 shows the package weight distribution for Texas, California, and Michigan.

16. EIN Presswire 2023, *Matador UAS Logistics, LLC Awarded a 4-year FAA Part 107 BVLOS Waiver for 134 Miles to Support Rural Healthcare in Texas,* Newsmatics, KRON4, <https://www.kron4.com/business/press-releases/ein-presswire/671992578/matador-uas-logistics-llc-awarded-a-4-year-faa-part-107-bvlos-waiver-for-134-miles-to-support-rural-healthcare-in-texas/>
17. xResearch 2023, *US Drone Package Delivery and Package Delivery Vehicle Accident Data*.

Table 1: Package weight share (%) by weight category in 2022

Package Weight	Texas	California	Michigan
Less than 0.2 lb.	6.70%	6.90%	6.30%
0.2 to 0.5 lb.	8.10%	9.90%	9.40%
0.5 lb. to 1 lb.	29.10%	26.40%	29.20%
1 lb. to 2 lb.	24.90%	25.70%	23.40%
2 lb. to 4.5 lb.	16.90%	14.90%	15.70%
4.5 lb. to 10 lb.	9.60%	9.40%	9.10%
less than 10 lb.	**95.30%**	**93.20%**	**93.10%**
More than 10 lb.	4.70%	6.80%	6.80%

Building Community Support

There are numerous ways to incorporate drones into the community to make a positive impression and garner community support. These include creating opportunities for personal and recreational use, supporting formal and informal learning programs, and establishing clear communication channels with the community. There are many personal and recreational uses for drones, including hobby flying, photography, cinematography, and drone racing. Creating physical locations for the recreational enjoyment of drones is essential to integrating them into the community so that community members can enjoy flying drones in a safe and fun environment. Formal learning opportunities, such as drone workforce training programs, educate the public about career opportunities and help future drone operators build the necessary skills for success. Informal learning opportunities such as drone clubs and camps provide an opportunity for youth to explore the science, technical skills, recreational opportunities, and future career potential of drones. These efforts create a community of drone users, who, in turn, will educate and share their positive experiences with the greater community. Finally, communicating the rules of use, support, safety, etc., through a public website is essential to support this community of drone users. Airspace Link's Flysafe program offers a dedicated webpage and drone operation tool on the community's website to help governments reach their communication goals.

Drone Parks

Drone parks are designated areas specifically designed for the reactional flying and testing of drones (Figure 6). These parks provide a safe and controlled environment for hobbyists, families, and youth drones without interfering with crewed aircraft or posing risks to people and property in densely populated areas. Drone parks can serve various purposes, from reactional flying through a dedicated space for UAS educational initiatives to a location for UAS competitions and events.

Figure 6: Examples of drone park locations

If you are interested in setting up a drone park in your community, here are some steps to get you started. Industry subject matter experts, such as those at Airspace Link, are available to help you through the process.

1. Conduct a site selection analysis to identify possible locations that are safe for recreational flights.
2. Complete an on-site review to verify the findings of step 1 and to ensure that there are no other inherent risks for the park at that location.
3. Complete the final selection of the site, including any regulatory or community approval.
4. Share the location with the community in the following ways:
   - Add information regarding the park to your community's FlySafe website.
   - Add a park advisory to AirHub® Portal (See Figure 7 for an example of an active park advisory in Ontario, California.)
   - Add information, including a link, about the park on the municipality parks and recreation webpage.
5. Add signage to your park labeling it as "drone friendly" so that community members are aware.
6. If your park is within a LAANC jurisdiction, create QR codes linking to FAA-authorized LAANC providers to share with community drone pilots and prompt them to request LAANC authorization. Post these QR codes at the drone park physical area and nearby community centers.

Figure 7: Ontario, CA, drone park advisory as published on Airspace Link's AirHub Platform

Conditions to Create a Drone Park

Ideally, a drone park would be outside of controlled airspace or in an FAA-Recognized Identification Area (FRIA). FRIA is a defined geographic area where drones can be flown without Remote ID equipment. For more information, please visit the FAA's website: https://www.faa.gov/uas/getting_started/remote_id/fria. It should be noted that "only FAA-recognized Community-Based Organizations (CBOs) and educational institutions such as primary and secondary schools, trade schools, colleges, and universities are eligible to request the establishment of a FRIA."

Today, there are four FAA-recognized CBOs, as shown here:

- Academy of Model Aeronautics
- First Person View Freedom Coalition
- Flite Test Community Association
- STEM+C Inc.

If your organization wants to establish a drone park in controlled airspace, it can:

- Collaborate with one of the four CBOs mentioned above.
- Collaborate with an educational institute.
- Go through the required process of becoming an FAA-recognized CBO (a longer process, details of the application are here: https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_91-57C_FAA_Revised.pdf)

The steps mentioned above are unnecessary if you choose to put a drone park in uncontrolled airspace area.

Drone Clubs and Camps

A drone camp or club's mission is to introduce, instruct, and develop participants into educated drone pilots (Figure 8). Establishing one within your community can help meet your growing requirement for drone experts while creating a shared sense of excitement for emerging technologies. They allow participants to safely explore various aspects of drone piloting, including equipment, safety, piloting skills, site evaluation, and even data collection. To learn more about the benefits of a drone club and how to get started, visit Shemaps.com. To learn about FAA rules and regulations that apply to recreational flyers and community-based organizations, visit the recreational flyers section on the FAA's website.

Figure 8: Drone clubs and camps are excellent ways to engage and excite youth about drone recreation and career opportunities.

Summary

This whitepaper outlines the transformative impact of drones across several domains, including economic development, environmental sustainability, disaster response, public safety, infrastructure inspection, medical deliveries, and traffic congestion reduction (Figure 10). Airspace Link's UAS management software, AirHub® Portal, is designed to enable these use cases and many others. We also highlighted the importance of community involvement, education, and acceptance of drone operations. Airspace Link's FlySafe Program and its implementation services are tailored for community engagement and outreach.

Figure 9: Drone technology benefits communities in numerous ways