

# Drones and Rewriting of Low-Altitude Mobility: Promise, Limits, and the Road to Integration

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**Abstract:** This paper focuses on the applications and governance of drones in modern society, highlighting their value in agriculture, disaster response, infrastructure inspection, medical logistics, and ecological monitoring. Drones feature high mobility, rapid information acquisition, and the capability to access high-risk or hard-to-reach areas. However, their large-scale deployment also raises challenges concerning airspace safety, privacy protection, and public trust. The article further analysis regulatory frameworks such as Remote ID, UTM and U-space being promoted by the FAA, ICAO, and EASA. It demonstrates that the future development of drones depends not only on technological progress but also on the coordinated advancement of regulations, supporting infrastructure, and social acceptance.

**Keywords:** Drones; Low-altitude mobility; Airspace integration; Unmanned aviation regulation; Enabling technology

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## 1. Introduction

Few technologies have moved as quickly from novelty to necessity as drones. In a little more than a decade, unmanned aircraft systems have expanded from consumer gadgets and hobby craft into serious tools for aviation, logistics, public safety, environmental science, and infrastructure inspection. Regulators now treat drone integration as a core aviation question rather than a peripheral one: the FAA says drones are “fundamentally changing aviation” and is working to integrate them into the national airspace, while ICAO frames unmanned aviation as a global safety and standards challenge with opportunities in cargo transport, delivery of life-saving materials, wildlife monitoring, disaster support, and infrastructure inspection. EASA makes a similar point for Europe, describing rapidly evolving drone and eVTOL technologies alongside a growing regulatory ecosystem built around safety and shared rules.

That rapid growth matters because drones are not merely smaller aircraft. They are a platform technology: a flying sensor, a flying communications node, a flying courier, and sometimes a flying robot. Their value comes from combining mobility with data collection and increasingly with automation. That combination makes drones unusually useful in places where human access is costly, slow, dangerous, or impossible. At the same time, it creates new policy problems, because the same features that make drones useful for surveying a floodplain or carrying medical supplies also make them capable of entering sensitive airspace, collecting intimate data, or being misused near airports and critical infrastructure. ICAO explicitly notes that safety, security, reliability, privacy, and responsible

automation are all part of the broader acceptance problem for unmanned aviation.

## 2. Analyze Specific Applications

### 2.1 Drones as an enabling technology

The most important way to understand drones is to see them as an enabling layer rather than a single product category. A drone’s airframe matters, but so do its onboard sensors, navigation system, communications link, battery endurance, payload capacity, and software. A drone outfitted with a thermal camera can become a search-and-rescue asset; the same platform with multispectral imaging can become a precision-agriculture instrument; with a small cargo box it can become a logistics tool; and with mapping software it can become a surveying system. ICAO’s unmanned aviation materials emphasize exactly this broader ecosystem, linking drones to traffic management, standards, and integrated airspace operations rather than to aircraft hardware alone.

This platform logic is why the drone sector has been so flexible. Instead of waiting for a single “killer app,” drone applications have emerged in parallel across industries. The FAA describes drones as new entrants to the national airspace system and provides separate resources for public safety, certificated remote pilots, model aircraft flyers, and recreational users, reflecting

the fact that drones now serve very different operational roles. In Europe, EASA reports more than 1.6 million registered drone operators under a common rule set, which suggests that the technology has already reached a scale where regulation, not invention alone, becomes the main constraint on further expansion.

## 2.2 Agriculture and food systems

Agriculture has become one of the clearest demonstrations of drone utility. Recent reviews of smart agriculture describe drones as a central tool in digital farming, especially for yield estimation, pest detection, and 3D mapping. More broadly, drone-based precision agriculture uses aerial imagery and analytics to help farmers see what cannot be observed easily from the ground: crop stress, irrigation problems, uneven growth, disease spread, and spatial variation across fields. That capability matters because agriculture is increasingly shaped by labor shortages, climate variability, and pressure to reduce waste. Drones help farmers make targeted interventions rather than blanket applications of water, fertilizer, or pesticide.

The significance of this use case is not only productivity; it is also sustainability. When a farmer can identify a stressed patch in a field early, the response can be smaller, faster, and more precise. That can reduce input use, lower environmental impact, and improve margins. Reviews of AI-enabled UAV farming systems describe drones as part of a broader move toward data-driven crop management, where aerial imaging feeds decision support systems rather than operating as a stand-alone gadget. The practical challenge is that adoption still depends on cost, technical skill, battery life, and the ability to process the resulting data into actionable advice. In other words, drones are already useful in agriculture, but their value rises most when they are embedded in a wider digital workflow.

## 2.3 Disaster response, public safety, and infrastructure inspection

Drones are also reshaping emergency response. In disaster and emergency management, UAVs are used for damage assessment, search and rescue coordination, and rapid situational awareness. This makes intuitive sense: after earthquakes, floods, wildfires, or industrial accidents, ground access may be blocked or too dangerous, while a drone can fly over the affected area quickly and return imagery within minutes. The result is not just better pictures, but faster decisions about where to send people and resources first. ICAO similarly lists disaster management support and infrastructure inspection among unmanned aviation's core opportunities.

Infrastructure inspection is another strong case. Bridges, power lines, roofs, towers, and other hard-to-

reach assets often require workers to operate at height or in awkward positions. Drone-based inspection reduces exposure to those hazards and can shorten inspection time. Recent research on bridge inspection notes that traditional methods are labor-intensive, expensive, and pose safety risks to inspectors, which is exactly the environment in which drones gain an advantage. This does not mean that drones replace human expertise. Rather, they shift the human role toward analysis, verification, and maintenance planning while the drone performs the dangerous or repetitive data collection.

## 2.4 Medical and humanitarian logistics

One of the most socially compelling applications of drones is medical logistics. Reviews of drone-based healthcare delivery indicate that UAV transport can improve timeliness and last-mile access for selected time-critical, lightweight medical payloads. That includes blood products, vaccines, laboratory samples, and emergency medicines. In remote or underserved areas, a drone can avoid poor roads, traffic congestion, and long detours. In humanitarian settings, that can mean the difference between a delayed delivery and a clinically useful one.

The value here is easy to overstate, so it is worth being precise. Drone delivery is not a universal replacement for ground logistics. It works best when payloads are small, routes are difficult, and time matters more than bulk capacity. Studies and reviews repeatedly suggest that drone systems are most effective for urgent, lightweight, or hard-to-transport items rather than ordinary parcel delivery. In practice, this makes drones a niche but important logistics layer: not the backbone of health supply chains, but a powerful supplement for gaps in those chains. That is why the most mature medical drone programs are often integrated into broader healthcare logistics systems instead of being treated as isolated pilots.

## Environmental monitoring and wildlife research

Drones have also become important in environmental science because they can observe places and species without the same footprint as ground teams or manned aircraft. Recent work on wildlife monitoring describes drones as flexible platforms for collecting data on terrain, land use, wind, thermal conditions, and animals themselves. Other research shows drones being used in marine mammal behavior analysis, coastal monitoring, harmful algal bloom detection, and conservation surveys. Their appeal lies in repeatability: the same area can be revisited frequently, often at lower cost than crewed aviation.

Still, environmental use is not automatically benign. Wildlife studies also caution that drone disturbance can affect animals differently depending on species, altitude, environmental conditions, and flight path. In some cases, drones are useful as complementary tools

rather than primary survey methods, especially in dense habitats where detectability remains limited. That nuance matters because it shows the drone debate is not “technology good” versus “technology bad.” The real question is under what conditions drones produce reliable information without creating unacceptable ecological disturbance. As with medicine and agriculture, the answer depends on how the platform is deployed, not simply on whether it is deployed at all.

### 2.5 Safety, regulation, and the problem of shared airspace

The rise of drones has forced regulators to rethink airspace governance. The FAA requires Remote ID for drones that are required to be registered or have been registered, and describes Remote ID as a broadcast of identification and location information intended to support safety, security, and enforcement. The agency also notes that Remote ID helps locate a control station when a drone appears to be flying unsafely or where it is not allowed to fly. In Europe, EASA has built a regulatory architecture around common rules, with more than 1.6 million registered operators and an evolving U-space framework for safer, more scalable operations.

These regulatory systems are not bureaucratic ornament; they are the precondition for scaling drone use. ICAO’s UTM framework explains that unmanned traffic management is meant to provide the safe, orderly, and expeditious management of UAS operations through interoperable services, while remaining compatible with conventional air traffic management. The same document stresses that drone operations must coexist with manned aircraft in finite airspace, that safety must be paramount, and that operators need to be legally accountable if routine operations are to be accepted by the public. In short, the future of drones depends less on whether the aircraft can fly and more on whether the airspace can be shared safely.

### 3. Drone Endurance and Battery Limits

Drone flight endurance is primarily constrained by battery capacity and power draw, approximated by:

$$\text{Flight Time (min)} \approx [\text{Battery Capacity (Ah)} \div \text{Average Current (A)}] \times 60 \times 0.8$$

The 0.8 factor provides a safety margin for real-world conditions.

#### Coverage Area in Precision Agriculture

The area covered in one flight can be estimated as:

$$\text{Coverage Area} = \text{Speed (m/s)} \times \text{Time (s)} \times \text{Swath Width (m)} \times (1 - \text{Overlap})$$

For example, a drone flying at 5 m/s with a 4 m swath and 15-minute endurance can cover roughly 14,400 m<sup>2</sup>.

#### Time Savings in Infrastructure Inspection

Drones improve inspection efficiency. The time savings ratio is:

$$\text{Time Savings Ratio} = 1 - (\text{Drone Time} \div \text{Traditional Time})$$

Drones can reduce high-risk inspection time by 50%–80%.

#### Payload-Endurance Trade-off in Medical Delivery

In medical logistics, flight time depends on available energy:

$$\text{Flight Time} \approx \text{Available Energy (Wh)} \div \text{Average Power (including payload)}$$

Higher payloads reduce endurance nonlinearly, making drones best suited for small, time-critical shipments.

#### Power Consumption Breakdown

Total power required during flight can be expressed as:

$$\text{Total Power (W)} = \text{Induced Power} + \text{Profile Power} + \text{Parasite Power}$$

This highlights why increased speed and payload significantly raise energy demand.

## 4. Conclusion

Drones are best understood as a bridge technology: they connect sensing and mobility, fieldwork and data science, emergency response and logistics, local operations and national airspace. Their value is strongest where time is short, access is difficult, and information is scarce. Their risks are also real, because they operate in shared skies and can affect safety, privacy, and trust. The central challenge is therefore not whether drones will matter, but how they will be governed. If regulation, infrastructure, and industry standards keep pace with innovation, drones may become one of the most useful civil technologies of the coming decades. If they do not, the technology will remain powerful but fragmented, held back by mistrust and operational limits. The evidence today suggests both outcomes are still possible. What happens next will depend on whether societies treat drones as toys, threats, or serious infrastructure.

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