APPLICATION OF DRONES IN INDUSTRY: OPPORTUNITIES AND ADVANTAGES

Use cases of Drones

Persistent monitoring

Operational analysis

Mapping

Digital twin

Inspection

Benefits

Enhanced safety of workers

Improvements in operational efficiency

Data for analysis and modelling

Actionable intelligence on incidents

Comprehensive security of facility
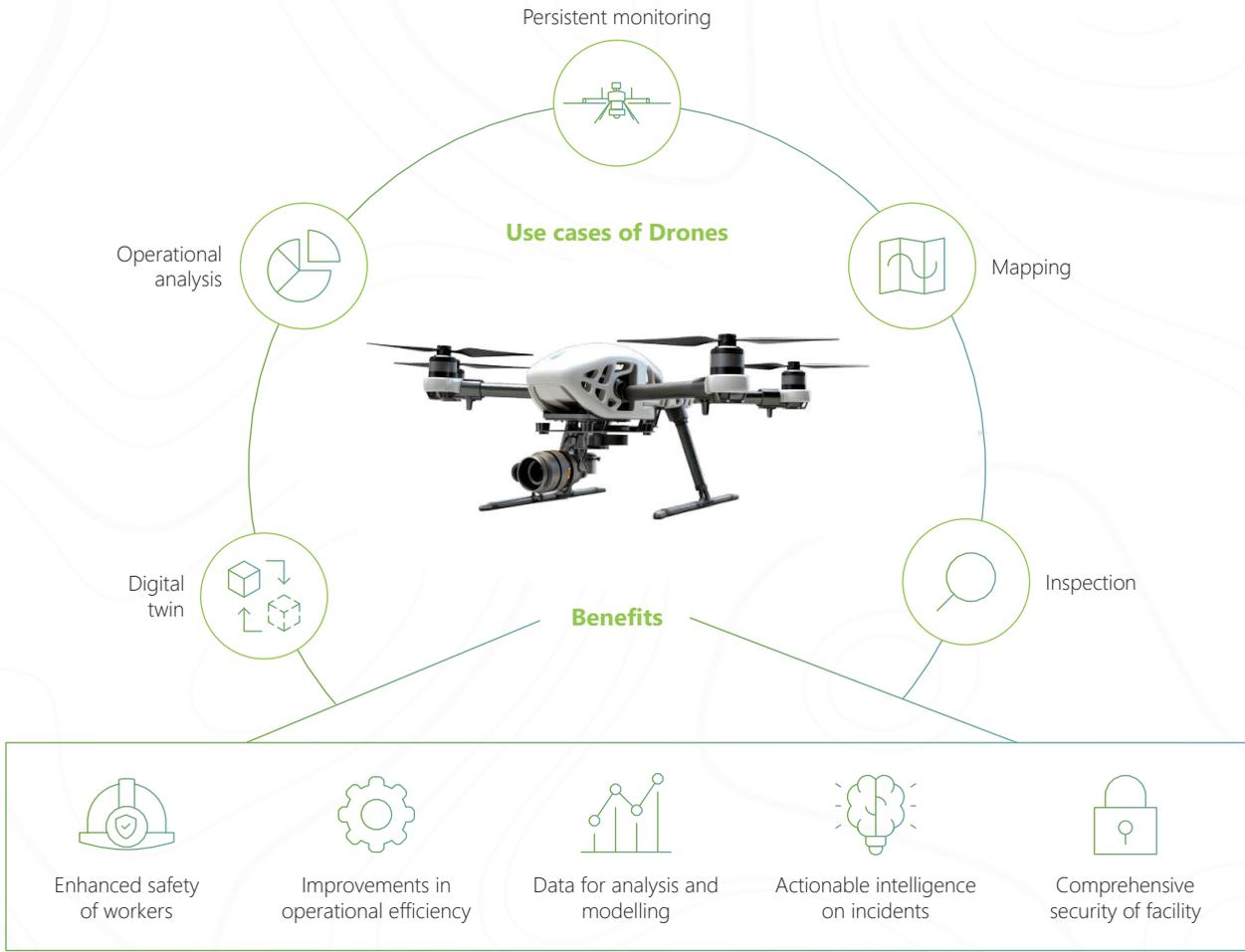
DRONES: A SINGLE SOLUTION FOR NUMEROUS INDUSTRIAL CHALLENGES

While the uptake of UAVs across commercial industries is still nascent, their deployment offers cost savings of 40–90%[14]. In the coming years, drones will resolve several bottlenecks that are common across all industries. For example, **digital technologies**[15] have accelerated at an exponential rate in the past few years with the introduction of artificial intelligence (AI), machine learning, and data science in day-to-day operations. Other trends like 5G, blockchain, cloud computing, and internet-of-things (IoT) are also accelerating to create an entirely new data ecosystem with deeper insights into business processes. Global spending on digital transformation will reach USD 4 trillion by 2027[16]. Not every business is equipped to deal with these technological developments: they lack workflows to collect data; infrastructure to store data; and know-how to analyse data and retrieve actionable intelligence. Moreover, there is still the potential for 'data blind spots'—hidden gaps in the system that can slow down progress and operational efficiency. Enterprises that lack unified data pipelines typically face a 6 to 12 month integration cycle; drone driven data capture compresses that timeline by providing a single, standards-based geospatial feed from day one.

UAVs equipped with high-resolution cameras and sensors collect high-quality, in-depth information on the state of a facility, movements of personnel, state of equipment, operations, inventories, active and potential hazards, and much more. Most UAVs also come with access to a cloud-based analytics platform (for example, FLYGHT CLOUD or DroneDeploy) which has multiple tools to leverage this data into actionable insights. In this manner, UAVs make it easier for industries to integrate the latest digital technologies and ease the transition into a digitally robust and resilient workflow.

UAVs solve several major challenges across industries, revolutionising **supply chain management**[17], security, safety, and ESG. **Logistical delays** in the delivery of raw materials, finished products, and even information cost up to USD 1.7 trillion[18] every year. UAVs have the capacity to pick up and deliver many of these raw materials and products. They also enable seamless communication and insights through the data that they collect. Furthermore, UAVs break up bottlenecks in the supply chain through enhanced route planning and congestion/roadblock analysis on key supply routes.

Inventory management is another avenue where UAVs show tangible benefit; they reduce stock taking time by 85%[19] while providing over 99% accuracy compared to manual inventory. Manual stock taking is a time- and labour-intensive process. Deploying UAVs to estimate inventory in indoor and outdoor settings accelerates stock taking, especially in combination with other technologies such as RFID, IoT-based sensors,

and bar- and QR coding. Further combining this data with other collected data in an analytics platform provides deep insights on stock levels, thereby enabling strategies like **Just-in-Time (JIT)** delivery. This also helps address issues with **workforce inefficiency** since the workforce will no longer be diverted into time-inefficient tasks like manual stock taking. Altogether, adopting drones creates major savings in operational costs.

UAVs are also a transformative and comprehensive solution for **security and safety**. Most industrial facilities cover several hundred hectares, which makes manual patrolling of the perimeter challenging. Theft is a common occurrence. Some studies estimate up to 60% of inventory losses[20] are caused by employee theft. Persistent monitoring by UAVs not only helps identify and track thefts, but also serves as a deterrent to thefts. Moreover, UAVs play a positive role in promoting **workplace safety**. Safety issues constitute a 57% contribution to workforce loss[21] in industrial facilities. UAVs perform work in hazardous environments, such as high-rise areas and narrow crawl spaces, which decreases risk for workers. They can also be leveraged to monitor safety compliance, detect active risks, and trigger alerts and responses to incidents. Drones additionally help with first response during emergency situations and provide active, real-time situational awareness. However, the biggest advantage offered by UAVs and UAV-enabled analytics is the ability to pre-empt an event or accident by identifying high-risk situations much more rapidly than human operators can.

Cost savings from drone adoption

0% 10% 20% 30% **40%** 50% 60% 70% 80% **90%** 100%
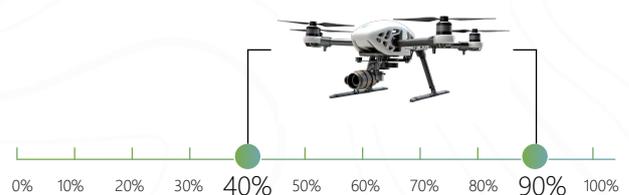
A final area in which drones are leveraged is **sustainability**[15]. There is an urgent, global emphasis on environment protection, carbon emissions, and overall sustainability. Documentation and regulatory compliance are major time inefficiencies for supervisors. The data collected by UAVs streamlines documentation. Persistent monitoring by UAVs also helps to ensure compliance by the workforce. Drones are key facilitators for addressing ESG challenges[22], such as gathering data from large areas, gathering data from hazardous environments, and monitoring pollution levels. Utilising UAVs for drone deliveries within facilities also decreases carbon emissions by around 25%[23].

Greater industrial adoption of drones not just pushes the goal of Industry 4.0 forward, but also brings the world closer to Industry 5.0. This is because, although UAV technologies present solutions to complex challenges, their adoption and deployment is straightforward.

Public safety

Beyond their military use, drones are used by local law enforcement and administration to enhance public safety[33]. UAVs find use in crowd surveillance and management, where reliance on fixed security cameras can be a hindrance. UAVs provide more comprehensive situational awareness, thereby enabling dynamic decision-making. Deploying drones at sporting events, cultural festivals, rallies, and other similar mass gatherings aids with estimating and monitoring crowds, as well as tracking persons-of-interest.

Environmental conservation

Forest management and wildlife monitoring are one of the major ways in which UAVs contribute towards environmental conservation[34]. UAVs are used to identify forest species, estimate forest carbon and biomass fluxes, study canopy health, and more. UAVs equipped with LiDAR are further used to understand the terrain under forest canopies, thereby facilitating modelling of drainage features and other factors. Very-high resolution imaging is also used to track wildlife species in forested and prairie areas. UAVs also provide security against poachers and other nefarious actors in protected areas. In addition to these direct applications, uptake of drones for services such as delivery greatly reduce carbon emissions and fuel consumption[35], which also benefit the environment.

Logistics and e-commerce

The drone industry is expected to see 14.3% CAGR in the delivery and logistics sector[36] between 2025–2030. Companies like Amazon, UPS, and Swiggy are exploring the use of UAVs for package delivery because they significantly decrease delivery times, cost, and carbon emissions. Amazon has been estimated to have achieved up to 50% time- and cost-savings[30] through the integration of drones in last-mile delivery. E-commerce companies are also integrating drones into warehousing operations. Beyond this, drones are used for medical supply and relief aid delivery[37] in under-resourced areas. The primary driver for growth in this sector is the increasing acceptance of BVLOS use of UAVs; several nations are running BVLOS pilots[38] to gather information for policy-making.

Agriculture

UAVs have paved the way forward for precision agriculture through sensors and imaging technology that can classify agricultural areas and monitor crop growth, crop health, and crop diseases. UAVs are further used to perform drought assessments and understand irrigation needs for farmland. The data acquired from UAV surveillance and mapping of agricultural areas is used to optimise resource utilisation and maximise yields. Studies have shown that using UAVs in agriculture increases crop yields by up to 30%[37] while decreasing water and chemical use by up to 50%. Some multi-use UAVs are also equipped with pesticide sprayers for targeted pesticide application, which mitigates the environmental and human impact of harsh agrochemicals.

For most of these use cases, drones are 'plug-and-play,' i.e., they do not require the installation of major infrastructure prior to use, only awareness of local drone regulations. As a result, deploying UAVs into day-to-day operations is not a technological hurdle for enterprises. Instead, the adoption of drones is based on the enterprise's operational needs, investment capital, and business model.

KEY TECHNICAL SPECIFICATIONS
FOR INDUSTRIAL DRONES

- **Platform:**
  This includes the external drone chassis, engines, motors, and other related components.

- **Avionics:**
  The avionics of a UAV consists of all the electronics and peripheral systems that enable flight, such as the navigation system, communications link, and flight controller.

- **Payload:**
  Payload refers to the weight a UAV can carry. Colloquially, it refers to its sensors and cameras.

For industrial drones, the most important aspect of a UAVs is the payload. Payload refers to the various sensors and cameras that a drone carries. Depending on the use case, the payload will require different sensors to capture relevant data for further analysis. For example, hyperspectral sensors are essential for terrain analysis in mining operations but only RGB and thermal sensors may be sufficient for security and perimeter monitoring. These sensors are broadly divided into six categories

- **Optical sensors:** These are either passive or active. Passive sensors detect emitted infrared radiation or reflected solar energy. Active optical sensors send a pulse, such as a laser, towards the target and record the reflected or scattered signal. An example of an active optical sensor is LiDAR. LiDAR data tends to have much higher spatial and temporal resolution than other types of sensor data.

- **Hyperspectral sensors:** Hyperspectral camera technologies are a type of optical sensor. They collect data contiguously across the electromagnetic spectrum. This data is considered 3D data, with the wavelength of the signal forming the z-axis. Hyperspectral sensing is typically passive sensing. Hyperspectral sensing can provide pixel-level information on the composition of a given terrain[47] or object.

- **Multispectral sensors:** These are passive optical camera technologies[48]. Unlike hyperspectral sensors multispectral sensors do not record data contiguously across the electromagnetic spectrum. Instead, they record data from discrete spectral bands.

- **Microwave sensors:** These utilise electromagnetic radiation in the microwave region (wavelength: 1–1000 mm; frequency: 300 MHz–300 GHz). Since the operating window is so large, it is important to carefully match the resolution of the sensor at a given frequency to its use case. Microwave sensors are classified as passive or active based on their mode of detection. Passive microwave sensors gather data by detecting light, molecular vibrations, emitted and reflected radiation etc. Active sensors emit microwave radiations and detect the returned signals. Imaging radar is an example of active microwave sensing.

- **In-situ sensors:** These are primarily used to detect the UAV's surrounding environment. They include chemical sensor arrays and difference frequency generation (DFG) lasers to detect atmospheric composition and gases around the UAV. Meteorological data sensors detect factors that affect UAV operations, such as air density, temperature, and wind. UAVs are also equipped with carbon dioxide detection sensors.

- **External sensors:** External sensors are essential to execute various types of missions. For example, dropsondes are weather reconnaissance devices that are typically dropped from a UAV to measure temperature, pressure, winds, and humidity. Geophysical (seismic) sensors are placed on ground modules of drones to record sound wave velocities and help with post-processing of the recorded data. Seismic sensors can also be delivered using drone swarms. Weather sensors help assess weather changes in real time. Finally, perimeter sensors detect movement in the vicinity of the drone through infrared sensing.
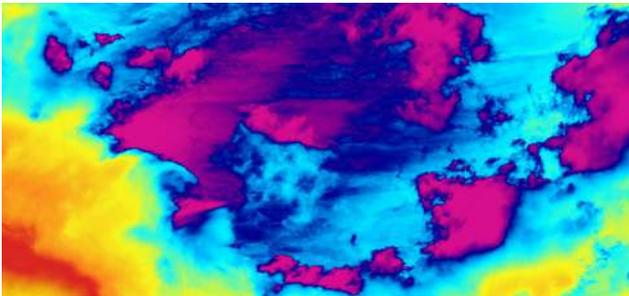
EXAMPLE USES OF PAYLOADS

Optical Sensors:

- Atmospheric characterisation (passive)
- Terrain mapping (active)
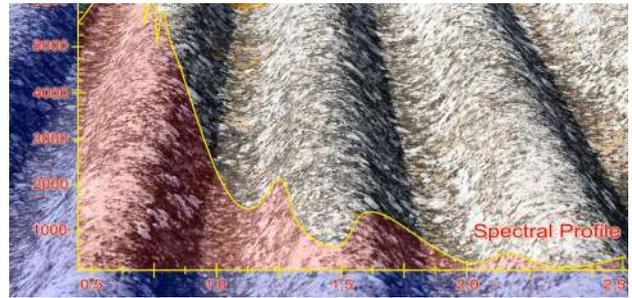
Hyperspectral sensors:

- Mining and mineral exploration
- Environmental monitoring

Multispectral sensors:

- Environmental monitoring
- Material handling

Microwave sensors:

- Soil moisture assessments (passive)
- Sea ice detection (active)

***In-situ* sensors:**

- Exhaust measurements
- Meteorological research

External sensors:

- Perimeter monitoring
- Real-time mission responses

In addition to selecting a suitable payload, it is essential to select a drone with extended battery life, rugged design, and weatherproofing features.

PRESENT OPPORTUNITIES FOR INTEGRATION OF UAVs INTO INDUSTRIAL APPLICATIONS

The data collected by drones during persistent monitoring[62] generates multi-pronged insights across enterprise stakeholders. "What we are finding through our experience on the field is that if we operate a drone for one (governmental) agency, then the output of that drone is useful for multiple agencies, resulting in optimum utilisation of this product and the service," explains Mr. Khomane.

Most drone providers offer multirole drones, which undertake several use cases, including persistent monitoring, mapping, and inspections. The data collected during the course of persistent monitoring operations is leveraged into insights[63] to improve the **operational efficiency**, **occupational safety**, and **environment friendliness of a facility**. Drones also facilitate the monitoring of very large facilities and job sites. In addition to that, data collection through drones simplifies documentation, speeds up situational analysis, and improves traceability and transparency.

Based on industry experience, primary research, and global data analysis, three industrial concentrations stand out when considering the potential for UAVs to revolutionise workflows—mining, manufacturing, and construction.

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