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Drone Automation for Warehouse 4.0

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FlytBase, Inc.

April 2019

Executive Summary

The digital transformation of warehouses - driven by safety, cost and revenue benefits – is underway across the world. Technologies such as IoT, AI and drones are augmenting the business value created by adoption of RFID, robots and real time analytics. UAVs have started playing a central role in the intelligent automation of warehouse operations – given their ability to fly & hover autonomously, carry payloads, avoid obstacles, navigate indoors & land precisely, operate in fleets and be remotely used. The business benefits from drones are significant and immediate given low CapEx & infrastructure investments, access to commoditized drone hardware, and SaaS-based solutions for warehouse operations. The cloud-connectivity of drones, combined with API-based integration, make it easy for existing warehouse management systems to onboard autonomous drone fleets into enterprise workflows. Capabilities such as custom dashboards, remote control via telepresence over 4G/5G, high-quality video recording are key to realizing the value in warehouse applications such as inventory reconciliation & audit, safety & surveillance, item search & recognition, etc. The pioneers in Warehouse 4.0 have already done PoC projects on multiple use-cases, by involving stakeholders from R&D, IT, operations and senior management. These are now running pilot programs that involve repeatable missions of drone fleets – thus building a wider set of business cases that mature into large-scale drone deployments across the supply chain.

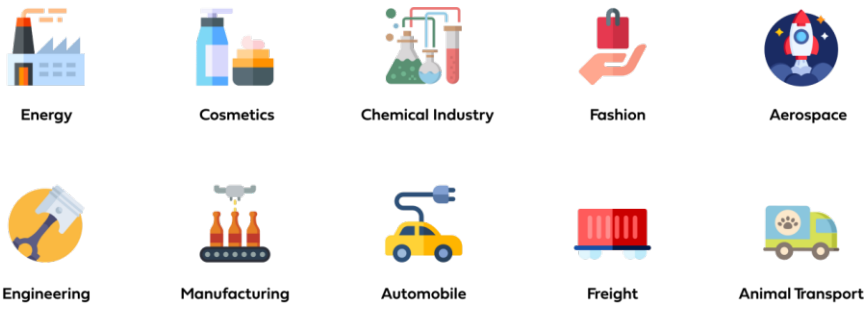
https://flytbase.com/warehouse-management/

Warehouse Diversity & Complexity

Like every other industrial sector, the warehousing industry is being transformed by software, worldwide. From QR codes, EDI and RFID to autonomous robots and machine learning algorithms that predict demand, warehouses are proactively adopting digital technologies with the intent of 100% inventory accuracy, real-time demand & supply insights, fully secure facilities and world-class worker safety.

Warehouses differ widely in terms of - size (less than twenty-five thousand square feet to greater than a million square feet), geographic location, nature of goods stored, proximity to seaports and airports, nature of ownership, layouts (U-flow or through-flow), bonding requirements, etc. These may be designed and used as distribution warehouses, manufacturer or production warehouses, raw material stores, finished goods stores, semi-finished goods store, spares stores or contract warehouses. The function that a warehouse plays in the supply chain also varies – ranging from a consolidation or transit warehouse to trans-shipment centers, bulk break centers, cross dock centers, sortation centers, fulfillment centers, etc.

To add to this complexity, each industry has its unique warehousing demands. Railways use open yards and car companies use large parking lots, whereas perishable goods require continuous cold storage and flammable goods require extra security and surveillance.



Business Drivers for Warehouses

Warehousing contributes up to 30% of the cost of logistics in most developed economies. Billions of dollars of capital are locked up at a time, in high-volume-high-value inventory - driven by the global shift to e-commerce, a trend towards mass customization and consumer expectations on short delivery times. The shortage of skilled labor further complicates the economics of warehouse operations, as do the swings in the global economy, inventory shrinkage and spoilage, vandalism and theft.

The technology, of course, plays a central role in driving revenue, profit margin, and safety improvements for warehouses, across numerous use cases such as:

- Inventory search & reconciliation
- Cycle counting & audits
- Roof inspection
- Security & surveillance
- Worker safety & productivity
- Item marking & recognition
- 2D/3D space optimization
- Order picking optimization
- Empty & full slot detection
- Yard management
- Forklift guidance
- In-warehouse transport

Most of the above involve tasks that are laborious, tedious, risky, redundant and expensive. They require shutdowns, slowdowns, and downtime that result in lost revenue, inaccurate inventory counts, and harm or loss of life. Warehouses have hence been early adopters of technologies that help continuously locate, identify, store, count, secure and/or protect their valuable inventory.

Warehouse 4.0

A modern warehouse is expected to leverage technologies such as RFID, QR code, biometrics and CCTV, warehouse management software solutions, autonomous ground vehicles, pick-and-place robots, computer vision and networked sensors.

Nevertheless, these technologies remain inadequate in view of the increasing supply chain volatility, demand uncertainty, and operational complexity.

Current Solution	Manual	Automated Guided Vehicles	Radio Frequency Identification
Limitations	• Costly, inefficient & tedious • Prone to human error • Risk to human life	• High capital investments • Decreased flexibility of operations • Routine maintenance & occasional repair	• Not compatible with materials such as liquids, metals • Prone to interference • Lack of global standards

Hence the emergence of Warehouse 4.0 - the next wave of technology adoption by warehouses, driven by AI, IoT, digital twins and commercial drones. The promise of Warehouse 4.0 is inventory counting that takes hours and days instead of weeks, zero safety and theft incidents, nearly 100% accuracy of inventory reconciliation, minimal downtime, predictive maintenance, and most importantly – intelligent automation at the heart of warehouse operations.

Warehouse Safety & Security

Human, financial and infrastructural capital is extensively involved in warehouse operations – making safety & security a prime business driver for Warehouse 4.0.

Safety incidents involving forklifts, loading docks, goods conveyors, hazardous materials storage, and manual lifting and handling account for thousands of human injuries and millions of lost worker-days each year. Insurance premiums, OSHA fines, healthcare/death compensation settlements, safety training & audits all put a significant dent in profit

margins for many warehouses. Worse, warehouse vandalism and theft account for hundreds of millions of losses each year. Goods, machinery and equipment are all vulnerable – but so are confidential documents, personal archives, and financial records in a fully digitized world.

Proactive technology adoption, involving fully autonomous drone fleets, can directly reduce safety incidents and losses caused by:

- Manual inventory counting in high, hard-to-reach or hazardous areas.
- Worker slips, trips & falls, movement near forklifts or in narrow spaces.
- Manual monitoring and engagement with vandals and thieves.
- Shifting/falling heavy items, dangerous goods, blind spots, etc.
- Manual inspection of warehouse roofs for weather-related damage.

Drone Adoption in Warehouse 4.0

- Drones (unmanned autonomous vehicles) are an essential ingredient in the digital transformation of warehouses. They are inherently advantageous given their ability to carry payloads, operate at heights, fly autonomously, scale via fleets, and survey assets & premises. Drones can reach narrow storage areas, localize hard-to-find items, and send real-time data via the cloud, for easy integration into warehouse management systems. By augmenting the existing technologies adopted by warehouses, drones help improve the RoI on existing infrastructure, yet offer capabilities and insights unimaginable to date.

- The business benefits of UAVs are rapidly realizable for warehouse applications – given minimal capital expenditure, simpler regulatory requirements and immediate access to data & insights resulting in short time to value. Warehouse drones thus represent the logical-extension that integrates virtual-information processes with physical warehouse processes.

Minimal cap-ex and infrastructure investments

- Airspace and aircraft regulators across the world remain wary of commercial drone applications that involve a) flying over crowds, b) flying at night and c) flying beyond the visual line of sight.

Stable drone navigation in narrow warehouse aisles

- Warehouse 4.0 has the unique advantage of being able to leverage the existing UAV laws for full-fledged drone adoption - without awaiting regulatory progress on the above three restrictions.
- Warehouse environments tend to have no/poor GPS connectivity – whereas drones, by default, navigate using GPS signals. Thus, drone deployments in warehouse use-cases require novel indoor navigation capabilities – besides the ability to read standard (bar, QR, RFID) codes. Equipped with low-light, infrared or other special cameras, warehouse drones can monitor temperature-controlled items, vermin, items in dark corners, faulty wiring, etc.

Automated cycle count & real-time inventory

By improving inventory data integrity, drone adoption by digitally transformed warehouses immediately improves KPIs such as cycle time, cycle counting frequency, employee

turnover rate, on-time deliveries, inventory and fulfillment accuracy, planogram compliance, etc.

Improved safety & operations reliability

Based on numerous proof-of-concept and pilot projects executed at modern warehouses across the world, it is estimated that billions of dollars of revenue, cost and safety benefits are realizable via large scale adoption of commercial drones by stakeholders across the supply chain industry.

For example, inventory audits using drones could save more than 50% time of worker time, e-commerce click-to-ship times can be reduced by up to 75%, and inventory per-square-foot can be increased by as much as 50% since drones can navigate in tighter spaces. UAVs also offer governance benefits to warehouses in the form of (auditable) geolocation data, (AI-based) item verification, and continuous surveillance of staff, inventory and infrastructure. By directly improving worker quality-of-life, drones can mitigate employee turnover, stress and injury risks for warehouses.

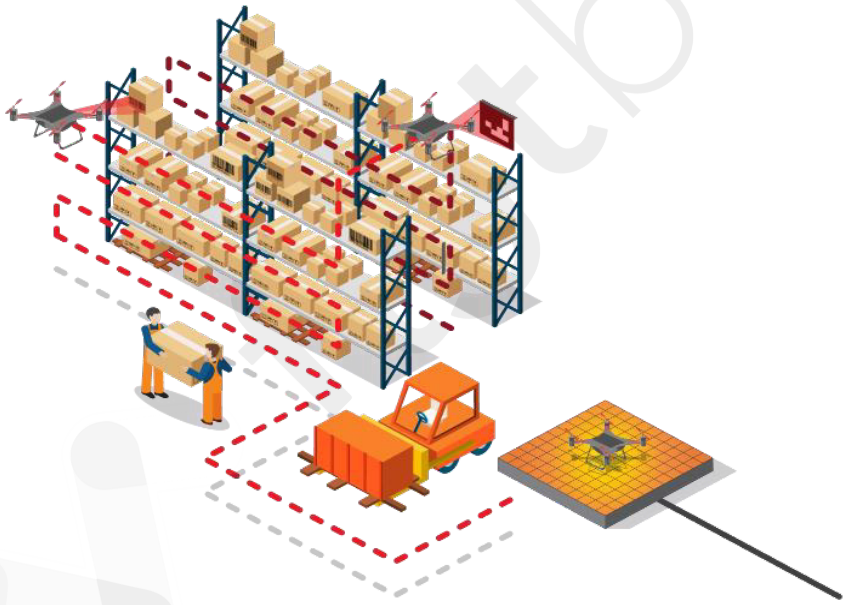
Challenges to widespread drone adoption in Warehouse 4.0 fall into 4 categories:

1. Capital expenditure on drone hardware and batteries, given expensive proprietary drones and short battery life.
2. Coordination of drone fleets and missions without having to rely on skilled, certified UAV pilots.
3. Safe operation of drones in a warehouse environment with static (e.g. storage racks, conveyors) and dynamic (e.g. forklifts, workers) elements.
4. Integration with existing warehouse workflows and information systems.

Fortunately, commercial drone software is poised to provide robust, scalable solutions to these challenges in the immediate future.

Drone Automation in Warehouse 4.0

Computers and smartphones provide a perfect analogy for commercial drone hardware. This segment is being disrupted by DJI, which has brought drones to the market at a feature-price combination that is 10X better than proprietary drones built for specific industrial applications. By building a fleet of small, light-weight COTS drones, complemented with a few high-end application-specific ones, warehouse operators and system integrators can drastically lower both the upfront and operating costs of large-scale UAV adoption.

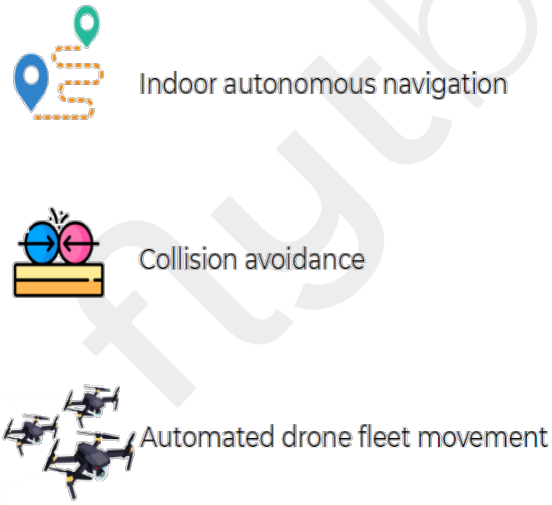


Integrated with affordable charging pads and docking stations, drones can fly for hours inside a warehouse, by automatically recharging their batteries at strategically placed charging stations.

Of course, this requires the software stack to be not only hardware agnostic, but also enable software developers and system integrators to rapidly build intelligent plug-ins at the edge and cloud layers of the drone technology stack. This, in turn, enables autonomous flights of fleets of drones – without any dependence on pilot-operated UAVs. In fact, coordinating a set of complex, repeatable missions involving

dozens of drones, while ensuring no collisions take place, is possible only via software automation.

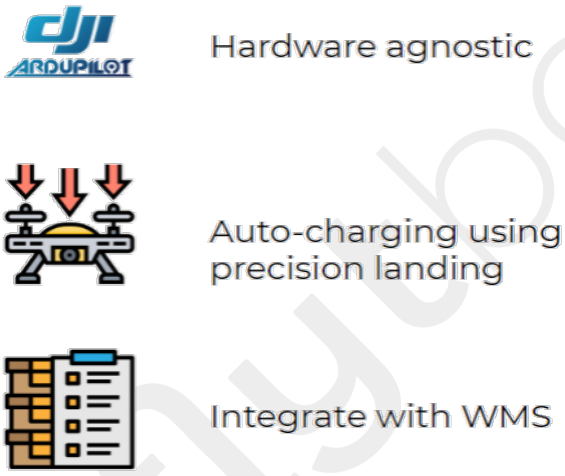
In very large - or outdoor - warehouse applications, the drone fleets may have to operate beyond the visual line of sight – facilitated by telepresence over 4G/5G communication channels. The flight path planning, takeoff, precision landing, return-to-home and obstacle avoidance capabilities must be entirely software-driven for warehouses to transition from drone PoC projects and pilot programs to enterprise-wide adoption.



The choice of drones matters a great deal for warehouse safety; heavy proprietary drones can be safely operated only in restricted areas, whereas small lightweight drones (with shrouded propellers) can be used in human proximity. Drones can be programmed with fallback mechanisms such as automatically climbing to heights, returning to home, or circling around obstacles to ensure worker safety. Equipped with sirens, flashlights and other warning devices, drones can not only make workers aware of their presence but also augment warehouse evacuation efficiency in case of fire or other emergencies.

From a business point of view, data plays a central role in such digital transformation of warehouses. With a large amount of near-real-time data streaming in from drones,

logistics executives and hub managers need to seamlessly integrate such data into the existing information systems and workflows. This high-volume data can be analyzed using AI to provide new insights for better decision-making related to inventory management, responsiveness to supply chain demand, security & safety.



Again, software plays a central role – APIs at appropriate layers in the stack allow for easy integration of drones into legacy warehouse workflows as well as application-specific workflows such as empty slot detection, automatic item recognition, narrow aisle navigation, etc.

Drone Program for Warehouse 4.0

The following best-practices will accelerate the success of drone adoption for warehouse applications:

1. Minimize CapEx budgets and infrastructural changes by building a fleet of (primarily) COTS drones, complemented by charging pads and docking stations.
2. Opt for cloud-connected drone fleets powered by intelligent automation, complemented by certified pilots who focus on supervisory and regulatory aspects.
3. Ensure that drone hardware and software both have collision avoidance capabilities that can be continuously improved.
4. Leverage high-quality image, video capture and recording capabilities of UAVs to build a rich, real-time view of warehouse operations.
5. Involve a comprehensive set of stakeholders (such as in-house R&D teams, innovation leaders, system integrators, warehouse managers, IT staff, drone operators, and technology consultants) early on to prioritize use cases.
6. Start with a couple of medium complexity use-cases involving up to three drones, especially applications where case studies of successful drone PoCs and pilots already exist.
7. Validate the business case (investment, payback period, RoI, impact on KPIs) for these use cases within weeks, and grow the fleet to ten or more drones for validation of additional use-cases.
8. Use customized, cloud-based dashboards to coordinate missions across stakeholders i.e. warehouse workers, drone operations management, subject-matter experts and senior executives.
9. Leverage software APIs to seamlessly integrate drone mission control and data collection into Warehouse 4.0 management systems.
10. Adopt cloud-based SaaS offerings, instead of on-premise enterprise software, wherever possible – to benefit from

rapid scalability, continuous upgrades, prompt technical support, and flexible pricing.

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Glossary

AI	*In computer science, **artificial intelligence**, also called machine intelligence, is intelligence demonstrated by machines.*
APIs	*In computer programming, an **application programming interface** is a set of subroutine definitions, communication protocols, and tools for building software.*
CCTVs	***Closed-circuit television** also known as video surveillance.*
COTS	***Commercial off-the-shelf** products are commercially available and can be bought "as is".*
Digital Twin	***Digital Twin** refers to a digital replica of physical assets (physical twin), processes, people, places, systems and devices that can be used for various purposes.*
EDI	***Electronic Data Interchange** is the electronic interchange of business information using a standardized format.*
GPS	*The **Global Positioning System** is a satellite-based radio navigation system.*
IoT	*The Internet of things is the extension of Internet connectivity into physical devices and everyday objects.*
IT/IS	*Information Technology/ Information Systems.*
KPI	*A **Key Performance Indicator** is a measurable value that demonstrates how effectively a company is achieving key business objectives.*
OSHA	*The **Occupational Safety and Health Administration** is an agency of the United States Department of Labor.*
POCs	***Proof of Concept** is a realization of a certain method or idea in order to demonstrate its feasibility, or a demonstration in principle with the aim of verifying that some concept or theory has practical potential.*
QR codes	***Quick Response Code**. QR codes often contain data for a locator, identifier, or tracker that points to a website or application.*
R&D	***Research and Development** is the process by which a company works to obtain new knowledge that it might use to create new technology, products etc*
RFID	***Radio-frequency identification** refers to a technology whereby digital data encoded in RFID tags or smart labels (defined below) are captured by a reader via radio waves.*
RoI	***Return on Investment***
SaaS	***Software as a Service** allows users to connect to and use cloud-based apps over the Internet.*
UAVs	***Unmanned Aerial Vehicle** is an aircraft with no pilot on board. UAVs can be remote controlled aircraft (e.g. flown by a pilot at a ground control station) or can fly autonomously based on pre-programmed flight plans or more complex dynamic automation systems*
WMS	*A **Warehouse Management System** is a software application, designed to support and optimize warehouse functionality and distribution center management.*