WORKtoZERO
an nsc program

Drones for Working at Height and Confined Space Inspections

National Safety Council

Executive Summary

Inspections are a vital component of operations performed in every industry. Some inspections are inherently more dangerous, particularly those that require work at height or confined space entry. While inspections accounted for only 2% of non-roadway workplace fatalities in 2017, work at height and confined space entry collectively contributed 25.34% towards these fatalities (NSC, 2020).

The objective of the Work to Zero initiative at the National Safety Council is to eliminate workplace fatalities through the use of technology. Drones, also known as unmanned aerial vehicles (UAVs), can act as a supporting tool in mitigating the systemic and situational risks associated with inspections. Drones can be flown into high-risk situations and hard-to-reach areas to perform reality capture and take accurate measurements that otherwise would have required employees to expose themselves to risky environments (Karakhan & Alsaffar, 2019). Leveraging drone technology to reduce or eliminate the risk of vertical and confined space inspections has the subsidiary benefit of improving productivity and efficiency by enhancing the data capture process.

The commercial and industrial UAV market is undergoing rapid expansion. The competitive landscape is diverse and includes three core categories of vendors: hardware providers with proprietary software, pure-play software vendors targeting different usage scenarios and service firms with a drone offering.

Drone technology and its use in the Commercial, Industrial and Civil Government (CICG) sectors is still emerging. Interest has been growing despite facing adoption barriers due to data privacy concerns, complex regulations and technological limitations, such as short battery life constraining flight times. In the next five years, as the technology and regulations surrounding UAVs become more established and mature, we can expect a second wave of growth in drones for CICG as market uncertainty decreases and investment proliferates. As one of the most rapidly developing aspects of aerospace, science and technology, there is no doubt that drones will increasingly disrupt traditional processes as the technological and adoption barriers are overcome.

Introduction and Background

Work to Zero

Despite concerted efforts to reduce serious injuries and fatalities (SIF), workplace fatalities have not seen a drastic reduction in the U.S. Between 1992 and 2017, the OSHA (Occupational Safety and Health Administration) recordable injury rate dropped from 8.9 injuries per 100 workers to 2.8 injuries per 100 workers, a 67% decrease (National Safety Council, 2018). In the same time span, the workplace fatality rate (preventable fatalities) only dropped 26%, with 4,414 preventable workplace fatalities occurring in 2017 (Bureau of Labor Statistics, 2018). Additionally, 5,250 total fatal work injuries were recorded in the U.S. in 2018, a 2% increase from the 5,147 in 2017, according to the U.S. Bureau of Labor Statistics. Between 2017 and 2018, the fatal work injury rate remained unchanged at 3.5 per 100,000 full-time equivalent workers. The expansive efforts by companies to reduce workplace injuries do not seem to translate into impactful reductions in workplace fatalities.

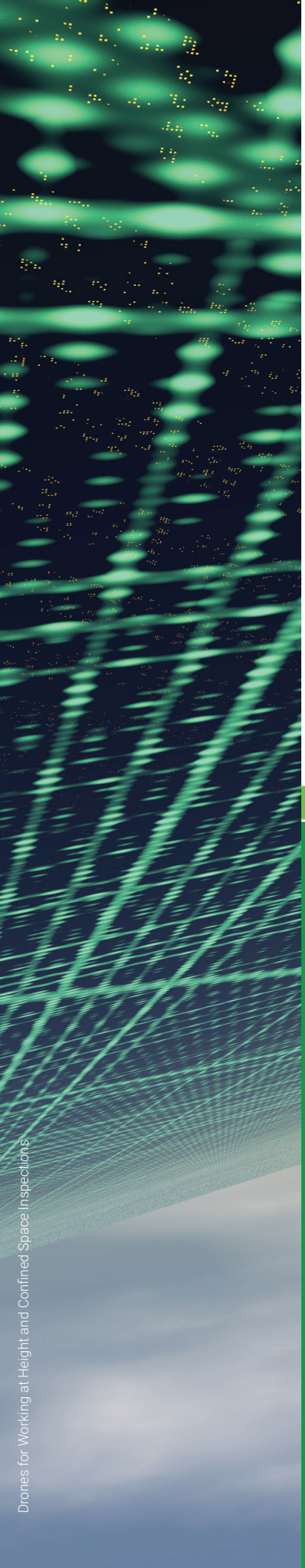
Recognizing this trend, the National Safety Council (NSC) kicked off its Work to Zero initiative in 2019 – supported by a grant from the McElhattan Foundation – to focus on combatting the lagging decline in workplace fatalities and serious injury events. The end goal of the Work to Zero initiative is to eliminate workplace fatalities through the use of technology. Using decades of insight and data, and leveraging the expertise of NSC members and networks, Work to Zero will identify promising technology innovations geared toward eliminating workplace fatalities within our lifetime.

Digital Technology as an Approach to Reducing Workplace SIF Events

In 2020, the Work to Zero initiative released its first white paper detailing the top 18 hazardous workplace situations (e.g. work at height, machinery operation, confined space entry) and associated situational risks (e.g. falls, struck-by, hazardous gas exposure). The report further identified the systemic contributing factors (e.g. lack of training, fatigue, work design) that can exacerbate risk within these hazardous situations. Next, NSC worked with Verdantix researchers to identify and map over 100 relevant EHS technologies that could help mitigate both situational and systemic risks. These risks were also mapped in ways that surveyed EHS professionals perceived to be most effective.

The initial Work to Zero report identified several key technologies that garnered the most interest and value among the surveyed professionals. In addition, safety leaders within the Campbell Institute at NSC have demonstrated interest in assessing and evaluating certain technologies – such as virtual reality, wearables, sensors and unmanned aerial vehicles (drones). This report is one in a series of reports taking a more focused look at specific hazardous risks and associated promising technology.

Specifically, this report will look at the use of drones for vertical and confined space inspections. It will explore the various use cases associated with drones in the commercial, industrial and civil government sectors. Additionally, it will investigate the identified and proposed benefits of this technology as well as limitations and risks associated with adoption. Finally, this report will shine some light into the vendor landscape associated with drones to provide education on the market and offerings.



The Hazards of Inspections

Inspections are a crucial component of most operations regardless of industry. While inspections are critical to ensuring the proper maintenance and health of assets, these activities often require inspection teams to expose themselves to hazardous situations, volatile environmental conditions and evolving risk landscapes.

In the Work to Zero Safety Technology 2020 white paper, NSC found the situational risks with the greatest relevance to serious injuries and fatalities (SIF) for inspections were confined space risks and falls to a lower level. Work at height and confined space entry respectively contributed approximately 22.59% and 2.75% of non-roadway workplace fatalities in 2017 (NSC, 2020). The systemic risks with the greatest relevance to SIF for inspections were lack of training, improper fall protection and lack of workplace awareness (NSC, 2020).

As technology advances, firms are exploring new methods of data collection that avoid placing inspection crews in dangerous environments, such as working inside boilers and pressure vessels or climbing towers and cell masts. Drones, also known as unmanned aerial vehicles (UAVs), can act as a supporting tool in mitigating the systemic and situational risks associated with inspections while improving productivity and reducing maintenance costs.

Research Approach

The methodology of this paper consists of two actions:

1) Identification of case studies, clinical trials and use cases for drones for vertical and confined space inspections

2) Development of a market landscape shortlist of relevant vendors associated with this technology

Data for this paper came from literature reviews of several academic and industrial journals related to this technology (see References). Additionally, Verdantix researchers utilized case studies and interview data from previously published reports and interviews (Verdantix, 2020). The vendor shortlist was compiled through a search of Verdantix market databases and external research. Vendors were selected based on the size and maturity of the firm, relevance to risk area, demonstrable use cases and applicability to the U.S. market.

Overview of the Drone Market

Technology Introduction

Drones, also known as unmanned aerial vehicles (UAVs), have been used for military and defense purposes for decades. The last ten years have seen rapid growth in the consumer UAV market, which has dramatically reduced the price point of the technology. This has opened up a range of new opportunities for commercial, industrial and civil government (CICG) use cases. Spending in the U.S. on drones for CICG reached $455 million in 2017, but the market is still in its infancy (Verdantix, 2018).

Drones are defined as "multi-rotor and fixed-wing unmanned aerial vehicles designed to carry a payload of information collection technology with navigation and control systems that permit remote, semi-autonomous and autonomous flight within and beyond the line of sight" (Verdantix, 2020).

Drones are emerging as one of the most disruptive technologies in human history (Watkins, et al., 2020). Technology for gathering data using drones has improved substantially over the past four years, which in turn has strengthened the value proposition for the use of drones in CICG. Drones can be equipped with 3D cameras, thermal imaging cameras, artificial intelligence, light detection and ranging (LiDAR), and 4K cameras with advanced sensors. This makes them incredibly effective as an 'eye in the sky.' The wide variety of sensors and transducers –including electronic gravitational, thermal, mechanical, electromagnetic and chemical –to sense measures ranging from gas leaks to atmospheric pressures, permits a wide range of surveying tasks, many of which are already being undertaken commercially (Watkins, et al., 2020).

Multi-rotor craft have dominated the drone market due to their ability to hover, relative simplicity to operate and great maneuverability. Multi-rotor drones are highly suited to aerial photography and inspections, as they use automatic stability systems that provide control over position and framing (Watkins, et al., 2020). Multi-rotor craft have limited endurance and speed, with current battery technology enabling an upper limit of 30-minute flight times with a relatively light payload (Verdantix, 2020).

In contrast, fixed-wing drones mimic the wing structure of normal airplanes to achieve lift and are more efficient as they only use energy to propel forwards rather than keep themselves airborne (Watkins, et al., 2020). As such, fixed-wing drones are able to travel much longer distances, but they are incapable of hovering in a single location (Verdantix, 2018). These characteristics make fixed-wing craft highly effective for long distance mapping and surveying, but in turn make them unsuitable for aerial photography, and vertical and confined space inspections.

The UAV market includes 12 key usage scenarios for CICG across four broad categories: inspections, monitoring, surveying and mapping, and emergency response.

Inspections	Monitoring	Surveying and Mapping	Emergency Response
• Vertical infrastructure inspections • Horizontal infrustructure inspections • Confined space inspections • Internal building inspections • Crop, livestock and forestry inspections	• Critical infrastructure monitoring • Environmental monitoring • Maritime safety and security • Site security monitoring	• Environmental mapping, impact assessment and monitoring • Site and volumetric surveys	• Accident investigation and emergency response

The broadest category is inspections of infrastructure, confined spaces, buildings and natural resources, including crops, livestock and forestry. For the U.S. market, vertical infrastructure inspections accounted for the highest share of drone revenues, totaling $95 million in 2017 (Verdantix, 2018). These inspection use cases have cross-industry applications, including looking for fractures in wind generator towers and structural observations of high buildings, such as bridges, oil rigs, rail and power lines. The second category includes monitoring marine and environmental issues, critical infrastructure and secure facilities. Surveying and mapping for construction sites, land surfaces and commodity volumes is the third category. The last category includes emergency and accident response involving first responders.

Vendor Landscape

The commercial and industrial UAV market is undergoing rapid expansion. The competitive landscape is diverse and includes three core categories of vendors: hardware providers with proprietary software, pure-play software vendors targeting different usage scenarios and service firms with a drone offering.

Hardware providers supply different types of drones as well as payloads, such as cameras and sensors, to clients. Although hardware currently garners the majority share of revenues, it is rapidly getting commoditized. To differentiate in an increasingly competitive market, the majority of hardware vendors, such as DJI and Flyability, now also offer proprietary and third-party software for mapping, photogrammetry, flight navigation, planning, and data analysis.

Pure-play software vendors in the UAV market are strengthening the value proposition for the application of drones in CICG settings by providing software that helps drones plan, gather, analyze, detect, decide and act independently. Firms such as MEASURE are embedding advanced analytics and machine learning capabilities into the software that enables firms to transform large volumes of raw data into actionable insights.

UAV service providers are a new category in the consulting landscape. These providers offer end-to-end project services by supplying the best-fit drone hardware with payload, trained pilots to fly the drones and gather data, and software to analyze and interpret the data for end-users. Drone service providers that can offer the hardware, software and services for drone programs, such as consulting giants Golder and AECOM, help firms tap into the benefits of this technology without the requirement of developing costly in-house capabilities. Other service firms with drone offerings include Tata Consultancy Services, Jacobs, ERM, and Ramboll. Smaller consulting firms such as Plowman Craven and CyberHawk also provide drone services to clients. The following vendors provide either technology or software related to drones. Of particular interest is the varying size of the vendor company, ranging from 61 to 6000 employees. An increase in the number of drone technology and software providers is expected as more employers examine and implement the use of drones in the workplace.

Example Vendors

Vendor	Employees
DJI	6,000
FLIR	4,007
AeroVironment	779
PrecisionHawk	171
DroneDeploy	156
DelAir	143
3D Robotics (3DR)	118
MicroDrones	107
Measure	61

Color Code
Drone Technology Provider
Drone Software Provider

Benefits for Leveraging Drones for Vertical and Confined Space Inspections

Drones have the ability not only to minimize safety risks associated with hazardous work conditions, but in certain cases, eliminate them completely (NAEM, 2019). Drones can be flown into high-risk situations and hard-to-reach areas to perform reality capture and take accurate measurements that otherwise would have required employees to expose themselves to risky environments (Karakhan & Alsaffar, 2019). For example, Verizon partnered with drone service provider MEASURE to conduct cell tower inspections post-Hurricane Harvey to assess infrastructure damage. Manual telecom tower inspections typically take a whole day per mast, with rope technicians having to physically climb these 40-feet towers. By using drones to perform the work at height inspections, Verizon was able to eliminate the risk to the inspection crew as well as save time and costs associated with data gathering (Verdantix, 2020).

There is a strong business case for using drones instead of people in potentially hazardous enclosed spaces, such as oil tanks, pipes and reactors in power generation facilities (NAEM, 2019). Chevron, the $142-billion-revenue energy firm, conducted a pilot project using drones from Flyability to undertake vertical pressure vessel inspections. Chevron has since committed to eliminating the use of workers in confined space inspections in 2020 due to the success of their drone-based alternative (Verdantix, 2018).

Where physical interventions are required, UAVs can reduce the risk profile for vertical and confined space inspection through improved hazard recognition and identification. Drones can be mobilized to assess the environmental and structural conditions of the area under scrutiny prior to deploying an inspection crew, allowing management to enhance safety planning, awareness and communication (Karakhan & Alsaffar, 2019).

Leveraging drone technology to reduce or eliminate the risk of vertical and confined space inspections has the subsidiary benefit of improving productivity and efficiency (Verdantix, 2020). For example, Cyberhawk Innovations used drones to inspect Maersk Oil's offshore cargo tank, which is usually performed by a team of four workers using rope access over a three to four-day period. By using drones, the total inspection time was reduced by a fifth, with cost savings of $7,000 per cargo tank (Verdantix, 2018). Furthermore, AT&T, the $181-billion-revenue global telecom firm, has been using drones since 2015 to inspect the condition of its 65,000 cellular towers across the U.S. Using the drones as surrogate tower climbers allows AT&T employees to perform a larger portion of their work in a safer situation with less opportunity for a potential SIF event. It has also enabled faster and more accurate data capture (Verdantix, 2020).

Risks and Considerations in Using Drones for Vertical and Confined Space Inspections

Risks

There are three main types of risk incidents related to drone hardware: ground impact from failed/falling drone hardware, mid-air collisions between UAVs and civil manned aircraft and injuries from contact with drone propellers (Zhang, et al., 2018). These risks are more applicable to vertical inspections than confined space inspections. The risk associated with ground impact is particularly high in sparse, less sheltered areas. Locations with more infrastructure and tree coverage reduce the probability of a fatality at ground level from impacts with failing drones (Zhang, et al., 2018). For mid-air collisions, the majority of fatality risk is concentrated over metropolitan areas with major airports, well traveled civil routes and high-density airways (Zhang, et al., 2018). Finally, as with any industrial equipment or technology, improper use and unqualified operators can drastically increase the potential of a SIF event. Depending on the size and motor of the drone, propellers can cause severe injuries if handled improperly (Johnson, et al., 2019). While many vendors are using propeller guards to mitigate this risk, it is recommended that firms partner with licensed vendors that are properly insured and have an auditable record of prior drone projects.

Barriers to Adoption

A key challenge affecting the growth of the CICG drone market is the unclear, restrictive and constantly evolving regulations surrounding UAV use. Drone regulations differ state-by-state in the U.S. Several restrictions from the Federal Aviation Administration (FAA) govern nationwide drone usage, such as the requirement for a constant visual line of sight of the drone, pilot licenses and bans on flying drones over individuals not directly involved in the operation (Gonzalez, 2018). The FAA specifies approved drone usage based on factors, such as purpose, geography and time of day of the operation (NAEM, 2019). Drone operators can apply for a waiver of Part 107 of the FAA regulations to undertake beyond visual line of sight (BVLOS) flights or allow a single operator to fly multiple UAVs at a time (Verdantix, 2020).

Data privacy concerns are one of the biggest hurdles facing the evolving UAV market. Drones can inadvertently record information from non-employees while performing monitoring procedures, which contribute to liability concerns (EHS Today, 2019). Additional societal impacts, such as noise and visual pollution, can also hinder drone uptake.

Finally, drone technology can be cost-prohibitive, with most firms exploring the feasibility of a drone program undergoing an internal build-it or buy-it debate. Large multinational firms with multiple, recurring use cases for drones may decide to develop these capabilities in house, but this is not financially feasible for many firms. The increasing presence of drone service providers in the vendor landscape makes this technology more accessible and affordable, as firms can contract in these capabilities when required.

Limitations of the Technology

Although UAV technology has improved dramatically in the past five years, a key issue still plaguing the industry is short battery life. Drone flight time is limited by the size of the drone's battery relative to the drone's weight and payload. The average flight time of a multi-rotor craft is seven minutes, with an upper limit of 30 minutes. This constrains the ability to conduct long survey flights to assess extensive industrial sites, for example (Verdantix, 2020).

UAVs dependent on radio line of sight can also be impeded by terrain and other obstacles, such as tall buildings, and can be disrupted by other sources of radio transmissions (Watkins, et al., 2020). Furthermore, most drones are not weatherproof and environmental conditions can significantly limit drone usage. Precipitation, fog, haze and pollution limit the quality of sensor data and effectiveness of communications and navigation systems (Watkins, et al., 2020).

Conclusion and Future Direction

The goal of the Work to Zero initiative at NSC is to eliminate workplace fatalities through the use of technology. Initial research for Work to Zero undertaken by NSC shed light into the situational and systemic risks that play pivotal factors into workplace SIF events. Using expert interviews, NSC identified promising technologies to combat these high-risk activities. Of these technologies, unmanned aerial vehicles were of interest among survey respondents and NSC members.

Inspections are a vital component of operations performed in every industry. Some inspections are inherently more dangerous, particularly those that require work at height or confined space entry. While inspections accounted for only 2% of non-roadway workplace fatalities in 2017, work at height and confined space entry collectively contributed 25.34% towards these fatalities (NSC, 2020). Multi-rotor drones can be leveraged to limit or eliminate the requirement of inspection teams entering these situations, allowing employees to interpret and analyze this information safely.

The business case for drones for hazardous inspections is robust as it contributes not only to risk reduction strategies, but realizes productivity and efficiency gains too. However, drone technology and its use in CICG is still emerging, and companies looking to develop drone programs should be cognizant of the data privacy concerns, complex regulatory environment and technological limitations that exist in the market today.

In the next five years, as the technology and regulations surrounding UAVs become more established and mature, we can expect a second wave of growth in drones for CICG as market uncertainty decreases and investment proliferates. The drone value proposition will also strengthen over the coming decade as artificial intelligence and machine learning pave the way to fully autonomous drones.

As one of the most rapidly developing aspects of aerospace, science and technology, there is no doubt that drones will increasingly disrupt traditional processes as the technological and adoption barriers are overcome.

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