The Truth about Drones

in Construction and Infrastructure Inspection

They're great tools for design, site monitoring, and asset maintenance, but you need to learn how to integrate their data into an ecosystem of software.

By Colin Snow, CEO and Founder of Skylogic Research

Introduction

There are significant economic and environmental benefits to keeping buildings and other types of facilities operational and construction sites safe. But doing so requires dull, dirty, and dangerous work of inspection and monitoring. For example, inspecting cell and radio towers would be less risky if a drone could be sent up first to take pictures, allowing experts to figure out what – if anything – needs to be repaired before sending a worker to begin a dangerous climb.

Drones – aka unmanned aircraft systems (UAS) – are poised to perform many of these types of functions, because they can take high-resolution images, capture video, and do laser scanning remotely by an operator on the ground. They can also deliver some new capabilities for architectural and construction

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firms. Multirotor drones in particular are highly adept at this, since they can get into tight spaces and provide low-altitude data capture that traditional aircraft cannot. With the advent of smaller/lighter survey-grade LiDAR, the combo provides a stable and portable platform for precision scanning of large structures like bridges.

As we have written here, there are some pretty fantastic and unrealistic forecasts for how fast the commercial drone industry will grow overall. We believe demand and growth for drones will be selective by use case and industry vertical, and we believe inspection and monitoring is one sector that will do better than others. Goldman Sachs estimates that of the total global spending over the next five years on drones in the commercial market, about $11.2 billion will be generated by the construction industry, with $1.3 billion in the U.S. alone. This is a reasonable TAM forecast and shows the potential scale of this sector for drones.

In this paper, we'll show how drones have been used successfully in construction and infrastructure asset management as aerial image and data capture devices thus far, review competitive and traditional approaches using incumbent technology, discuss the opportunities and challenges posed by the technology itself, outline the lessons learned, and discuss what's next for drones in this industry.

Use cases

Construction giant Bechtel was one of the first to use drone technology in construction. In 2013 they teamed with Skycatch to prove the technology's viability at one of the largest liquefied natural gas projects in Australia. Bechtel used the technology

to do things like collect real-time environmental data (e.g., air quality, temperature, etc.), survey difficult and inaccessible terrain, and track real-time construction progress.

Since then, hundreds of firms across the globe have put in place proof-of-concept projects for drones – not just for construction but also for civil infrastructure and asset management purposes. The list of all projects is too long for this paper, but we'll explore the major project types according to a commonly used building lifecycle framework of design, construction, operation, and demolition.

1. Design
Drone imagery and data have been found to be useful tools in design and preconstruction workflows for commercial construction and architectural firms like The Beck Group, DPR Construction, and SANDIS. One prominent use is taking an aerial shot of what potential tenants and investors see when they look out from their East-facing 10th floor office. These visuals include:

• Future building face/reface views for development
• Building models in neighborhood context
• 180- or 360-degree visualizations from each floor

The other major use for drone aerial imagery and data is Building Information Modeling (BIM). BIM is a fairly new concept that describes the process of designing a building collaboratively using one coherent system of computer models rather than as separate sets of drawings. It involves generating and managing digital representations of physical and functional characteristics of places. This digital representation then becomes a shared knowledge resource for information about a facility and forms a reliable basis for decisions during its entire life-cycle. Figure 1 shows an example of BIM used in planning.
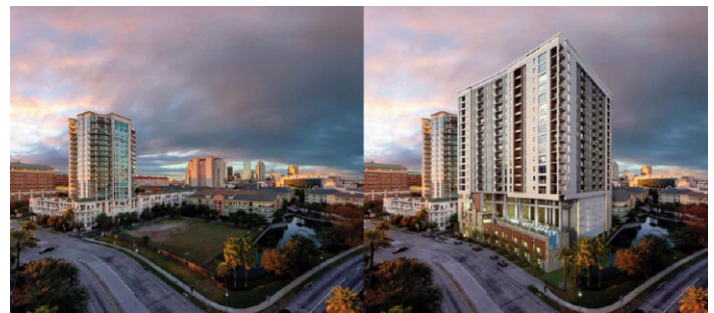
Figure 1 - Aerial Photos for BIM Rendering

Image: The Beck Group

2. Construction
Construction jobsite monitoring can involve using drones to simply capture pictures for daily, weekly, and monthly progress reports or, in a more complex example, as site survey maps that provide a foundation for work plans. Drone images used in daily progress reports are great for change detection. They help identify issues which in turn allow jobsite managers to quickly resolve problems such improper sequencing that can lead to performance delays. Most plans start with accurate current topography maps with elevation contour lines and detailed 2D and 3D models.

Work plans can include:

• Georeferenced cut and fill and earthwork hauling specifications
• Asset management including materials, equipment, temporary roads, and structures
• Stockpile volumes for labor and time estimates to move/remove
• Egress and on-site logistics for vehicles and heavy machinery
• Quality control (CAD plan vs. actual)
• Regulatory compliance and progress reporting

Creating site survey maps and work plans requires more skill than simple aerial photography. It requires knowledge of orthomosaic photography and photogrammetry. Figure 2 shows an example of an orthomosaic used for a work plan on a construction site. Figure 3 is an example of how photogrammetry was used to produce a rendering of building work in progress with exact dimensionality to the plan.

3. Operation (use and maintenance)
Structural inspection is already a multi-billion dollar industry very much on the rise. Inspections include:
• Surface integrity
• Measurements
• Wear and damage assessments

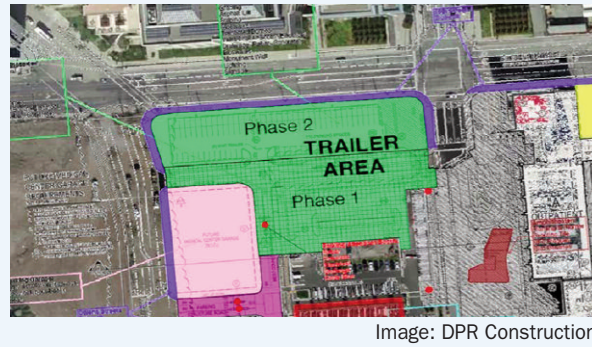*Figure 2 - Workplan Orthomosaic Image Example*

Image: DPR Construction

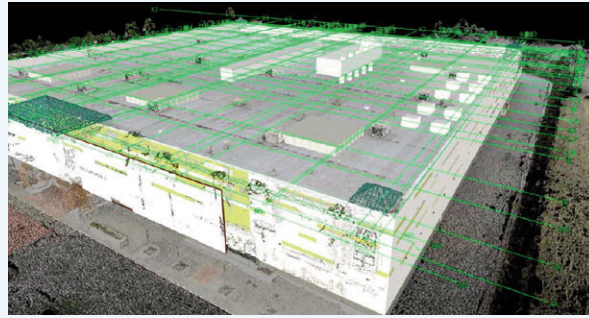*Figure 3 – CAD Design vs. Actual Work in Progress*

Image: DPR Construction

Figure 4 – Solar Panel Inspection

Image: Skylogic Research

to unknown factors that make demolition work particularly dangerous. Occupational Safety & Health Administration (OSHA) says these include:

• Changes from the structure's design introduced during construction;
• Approved or unapproved modifications that altered the original design;
• Materials hidden within structural members, such as lead, asbestos, silica, and other chemicals or heavy metals requiring special material handling;
• Unknown strengths or weaknesses of construction materials, such as post-tensioned concrete;
• Hazards created by the demolition methods used.

However, OSHA believes the hazards of demolition work can be controlled and eliminated with the proper planning, the right personal protective equipment, necessary training, and compliance with OSHA standards.

So where do drones fit in? Besides capturing videos of large-scale destruction like the ones here, there are very few documented use cases for this part of the life-cycle. It's not clear yet how drones can help mitigate the unknown factors OSHA cites, but they can support similar work plan functions for materials and logistics as they do for jobsites in the construction phase.

Drones provide a safe and cost-effective way to perform damage assessment on objects that otherwise require ground crews and a human to perform risky climbs. Inspections using drones can be as simple as visually inspecting a solar panel array (Figure 4) to more complex using sensing technologies like a thermographic camera to inspect flare stacks. In either case, a single pilot can easily fly around whatever it is you want inspected and record a live feed of high-quality video to show to engineers on the ground.

Non-contact optical measurement and photogrammetry have become common nondestructive testing methods for inspections of very tall structures like radio antennas, cell towers, and wind turbines and in hard-to-reach places like bridges, boilers, transmission, and natural gas lines.

4. Demolition
End-of-life building deconstruction and demolition involves many of the hazards associated with construction. However, deconstruction (razing, destroying, or wrecking any building or structure or any part thereof) involves additional hazards due

Opportunities

Never before has the benefit been more evident for using drones in the energy, telecom, and construction verticals. The U.S. Department of Transportation (DOT) recognized this economic benefit when the FAA proposed the small UAS Rule in February 2015. They specifically mention power-line/pipeline inspection in hilly or mountainous terrain and antenna inspections (page 8f) as examples of possible operations that could be conducted under the proposed framework. The DOT evaluation of the rule goes further and dedicates a whole section on bridge inspection (section IV.A.1.d. page 21ff). We would add to this structures like buildings, oil rigs, refinery flare stacks, cell towers, and wind turbines as examples of viable operations under current FAA rules for small drones—also known as "Part 107" and released in June 2016.
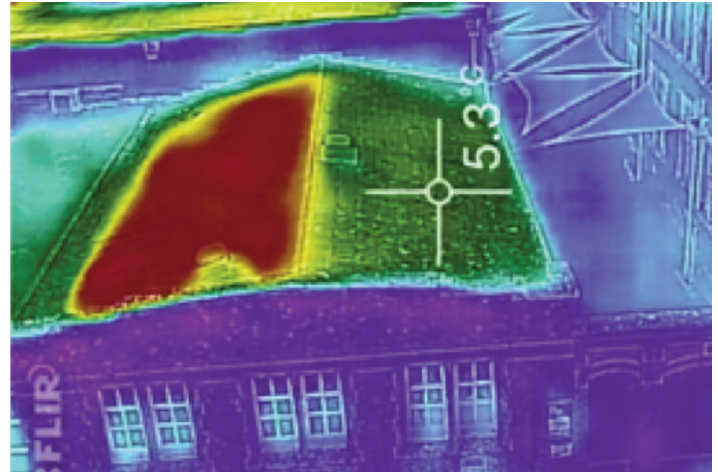
Transportation infrastructure professionals should pay particular attention to the bridge example. The National Bridge Inspection Standards (NBIS) mandates that routine inspections be performed at 24-month intervals. With almost 600,000 bridges in the United States and 300,000 requiring inspection each year, the DOT evaluation report estimates that about 45,000 annual bridge inspections could utilize some form of small UAS. This study by Luis Otero, Ph.D. at Florida Institute of Technology, details the possibilities for drones and includes an evaluation of the applicability of 3-D models from LiDAR data taken from drones. That data can help detect vertical and horizontal displacements of bridge components.

Challenges

Flying drones daily to capture data is both beneficial and challenging. Drones and the data from drone data services do not provide a complete solution, and more likely than not, you'll need to traverse a learning curve. For example, the firms mentioned in this paper had to set up new data integration workflows for their existing ecosystem of software solutions. Those who used aerial images from drones to do BIM design work had to incorporate those images into CAD software like Autodesk REVIT. Those who did work plans with images had to incorporate the images into project software like Navisworks. Both camps had to learn how to manage daily workflows from constantly changing sets of new images. Workflows needed to focus on how to both communicate and manage change – either in the feedback to design or in the feedback to production or to both at the same time.

There are other challenges for using drones in construction and infrastructure asset management. One of the major ones is the regulatory challenge. As of June 2016, under operational limits specified by Part 107 rules, you would need to secure a Certificate of Waiver or Authorization (COA) for operating beyond visual-line-of-sight (BVLOS) or during the night. So roof inspections with a thermal camera would be limited to daytime operations. But this is inadequate because roof temperatures rise during daylight as they absorb light, so it'd be difficult to decipher warm air escaping from the building from a naturally hot roof. Therefore, it's better to do thermal roof inspections at night (Figure 5), but you'll need to apply for a COA and have

Figure 5 - Thermal Roof Inspection

Image: FLIR

mitigation procedures in place such as a small operating space, back up spotters for testing, etc.

Lessons Learned

When drone business service providers talk publically about the differentiation of drones, you'll often hear them say: "It's all about the data." But the lessons learned from the construction and asset management industry is that it isn't just about the data. It's about getting good information that provides value for the construction or architectural firm. So whether teams are collaborating around one daily map for a construction site as "the single source of truth" or teams are providing floor-by-floor visualization views for a future building site, ultimately the goal is to provide valuable information for the downstream customers – and drones alone cannot do that. What drones can do is offer a much quicker way of capturing different types of data and digitizing it and making it something you can analyze right now or over time to support construction variance analysis.

BIM offers enormous gains in cost and time savings; much greater accuracy in estimation; and the avoidance of error, alterations, and rework due to information loss. But adopting BIM itself – outside of incorporating data from drones – involves much more than simply changing the software you use.

Terms to Know

An **orthomosaic**—sometimes called orthophoto, orthophotograph, or orthoimage—is an aerial photograph geometrically corrected ("orthorectified") such that the scale is uniform: the photo has the same lack of distortion as a map. Unlike uncorrected aerial photographs, an orthophotograph can be used to measure true distances, because it is an accurate representation of the Earth's surface. It's been adjusted for topographic relief, lens distortion, and camera tilt. Typically, an orthomosaic is a composite of individual photos that have been stitched together to make a larger one.

Photogrammetry is a technique which uses photography to extract measurements of the environment. This is achieved through overlapping imagery, where the same feature can be seen from two perspectives. With photogrammetry, it is possible to calculate distance and volume measurements. Companies use these outputs to create "point clouds" or 3D images used to do things like render a building.

To achieve all the benefits BIM offers, everyone in the architecture, engineering, and construction industries will have to learn to work in fundamentally new ways. BIM plus drones is a whole new paradigm.

Another lesson learned by the early adopters is the value drones provide managers of large construction sites. In this example, oil storage construction site project managers complained that they couldn't get their oversight work done, meaning they just didn't have enough time in the day to properly oversee their many construction projects. On a typical duty day, a project manager visits their various construction sites and verifies the workers have all required equipment, checks general progress, and sees that things are generally being done so that the company can meet the minimum standards of tolerance set by the law. It turns out that a simple data capture and the quick 3D models produced using DroneDeploy software were an incredible resource for these projects.

What's Next for Drones in Construction and Infrastructure Inspection

Perhaps one of the main beneficiaries of drone use are the civil and public entities that perform enterprise asset management (EAM) and facilities/infrastructure management. We are only beginning to understand if these are successful business models. The factors that produce best practices and operational efficiencies are not completely defined yet, but some groups are starting to work on that.

For example, there is a new collaboration between insurance carriers, the construction industry, and their supporting businesses to safely develop UAS inspections called the Property Drone Consortium (PDC). PDC charter members include Allstate, American Family Insurance, Auto-Owners Insurance, EagleView Technologies, Erie Insurance, and Pilot Catastrophe Services. Another example is the National Association of Tower Erectors (NATE), who back in November 2015, established a UAS committee that monitors the trends and regulatory environment. This committee makes recommendations to NATE members and the wireless infrastructure community on best practices. The committee also collaborates with federal agencies and interested stakeholders to develop guidelines to promote the safe commercial and private use of these systems.

Another trend to watch is just how fast drones will grow in this market vs. the others. Our research shows demand for and

Competitive traditional approaches

Unlike The Truth about Drones in Precision Agriculture, where satellite and manned aircraft image services have been available to growers at low costs for years, construction and inspection professionals have had historically few options. Up until now, the process for construction planning and documenting was mostly manual and done from the ground – and hiring helicopters or aircraft to take aerial images was either too costly or logistically impossible due to airspace restrictions. The simple truth is small drones – in particular multirotors – can fly lower and closer than traditional aircraft and capture more useful detailed information.

In the inspection world, unmanned aircraft have a distinct cost and safety advantage over using people on ropes, ladders, scaffolding, and bucket trucks. For example, a rope-access inspection at a wind farm can involve two or three workers who need at least half a day to get the job done in order to produce a series of photos for a report. This can cost $1,200-$1,500 every 12-18 months – in addition to the costs incurred from shutting off the turbines for at least half a day (see details here).

There are many other examples of the benefit of drones vs. traditional approaches. This article points out that the Minnesota Department of Transportation (MDOT) recently completed a study on the benefits of using drones to inspect roads and bridges. MDOT estimated that a standard bridge deck inspection costs $4,600, takes eight hours, a crew of four people and heavy equipment. The same inspection with a drone takes just two people and two hours, at a significantly lower cost.

use of multirotor drones dedicated to construction and infrastructure asset inspection will see a big uptick in the next few years. Investors are already taking positions. Just this month (June 2016), Kespry closed a $16 million Series B round, and software company Autodesk Inc. (via its Forge Fund) made an investment in drone manufacturer 3D Robotics.

There is also a large opportunity for firms like Accenture and IBM to provide information architecture and data integration services for incorporating drone data into existing enterprise and mobile applications like SAP EAM and Oracle EAM. We also see opportunities for companies to provide motion imagery, video analytics, object recognition, and image metadata processing solutions.