A Case Study on Drones in Construction: Easier than You May Think

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Learning Objectives

- Learn the benefits of photogrammetry for construction monitoring and how easy it is to utilize
- Hear how orthomosaics were used for better site communication and collaboration
- See how you can utilize point clouds with your models
- Learn drone laws and how they apply to flying on an active construction site

Description

There are many things to manage on a construction site. There is communicating with subs, tracking construction progress, maintaining safety on site, keeping track of quantities, and so on. We have been using drones to help with these things by capturing photos and videos during the construction of Allianz Field, a soccer stadium in St Paul, Minnesota. We are able to use cloud processing that stitches the photos together and gives us a couple of useful file formats. We want to share with you all of the workflows and benefits that have come from the data that we have collected. From tracking volume of dirt to overlaying DWG™ technology, there are many workflows for the data that are quicker and easier than you may think. We have a lot to share with you, and we want you to come away with a better understanding of why you may want to use drones on your next project, and what you need to do to get value from the data they can collect.
Speaker(s)

Andrew Gibson is a Senior Integrated Construction Coordinator for Mortenson Construction where he is currently leading the VDC charge at Allianz Field in St. Paul, MN. He has been with Mortenson for 5 years in the Virtual Design and Construction department. Prior to Mortenson Andrew worked in Architecture for 4 years focusing on multi-family housing and restaurant/retail in the Minneapolis area and surrounding states. Having been on both sides of Architecture and Construction Andrew brings a unique perspective to his current field which helps create a common bridge between the Design Team and Contractor. Andrew’s strong passion for innovation and technology combined with his daily desire to figure out new ways to make AEC processes more efficient and valuable has been essential to his success in the construction industry. With technology advancing exponentially he feels extremely fortunate to be in this field and loves that every day has the potential to bring something completely new. It’s no surprise at all to find out that Andrew continues to ‘Nerd Out’ in his free time by using his own drone to document travel and experiences from a different perspective.

John (JT) McManmon is an infrastructure Technical Specialist for ATG USA, an Autodesk Platinum Partner. He has presented at some regional conferences around the upper mid-west as well as Autodesk University in 2016. He worked for a couple of civil engineering firms before moving to Cad Technology Center, now ATG, in the summer of 2015. With a practical background as a civil drafter, as well as having worked in land surveying, he has valuable real-world experience and truly understands the application of Autodesk, Inc., software in the infrastructure industry. He is also a drone pilot for ATG. He has been involved in discovering ways that drones can help aid the engineering design and capture processes as well as construction site progress.
Getting Started

Picking the right drone and the right software.
- Picking the right drone is not as important as picking the right software. The first thing you will want to identify is which software/app you want to use to capture the data that you are trying to capture. Different apps have different flight modes and some may be more suitable for the kind of projects that you are working on. Once you pick the app that you want to use it will be important to see which drones it supports. Then you can pick from which drone from that list will be meet your needs.
- I use Site Scan by 3DR for flying the drone and processing the data. They support the common DJI drones and the Yuneec H520-G.

When it comes to software selection there are two decisions to be made.
- Which app to use for capturing the data in the field?
  The app connects to the drone controller’s Wi-Fi. Specify your flight type and flight area on the app and the app will tell the drone what to do. The app essentially does the flying for you. You tell the drone to take off and then wait for it to come back and land. Having photos that are georeferenced is a key advantage to using an app to capture the photos for you. Running an app that is manual capture only, typically will not geotag the photos.
- Which software to use to stitch the pictures together?
  Once the photos have been taken, they need to be stitched together. This process is typically done in the cloud. ReCap Photo is one option and costs cloud credits. Other photo stitching software like Site Scan, Pix4D or DroneDeploy will require the purchase of a license to use their software.
- What laws apply to flying a drone on a construction site?
  In order to legally fly for commercial purposes, you need to be certified by the FAA. This certification is obtained by passing a written test from an FAA certified testing center. More information about the FAA certification can be found later in this document or at this website [https://www.faa.gov/uas/getting_started/part_107/](https://www.faa.gov/uas/getting_started/part_107/).

Drone Flight Walkthrough
- The first step to flying a busy construction site is to plan how and when the drone is going to be used. It is ideal to find a time when the site is not active to do the flights. This will minimize the amount of “noise” in your results. Another important thing to know is the maximum height of the tallest structure or object that the drone will fly over. That way you can plan your automated flights to be above that object.
- When conducting the flight, you will need to be in position to see the drone at all times, despite the fact that the drone may be flying itself. If there is an elevated spot on the site that can be used it is often times a good choice for a takeoff/landing location.
- After the drone has landed you will need to get the photos from the drone and into the cloud for processing. One option will be for the drone to wirelessly transmit the data to the tablet that was used to layout the flight. Another option will be to use an SD card that can be removed from the drone and plugged into a computer.
Cloud Processing

- Processing of the data will happen in the cloud. In order to locate the photos most accurately you will need to use ground control points. A ground control point is a point that represents a single static location. For greatest accuracy and real-world coordinate location GCPs need to be items/locations that are shot by a surveyor so that their exact location is known. Otherwise, you can assume coordinates and build ground control points after the first flight. Typically, you want to have several GCPs that surround the edges of your site. You will “tag” the GCPs by clicking on a photo taken by the drone and then clicking on the point in that photo. You will repeat that for several photos per GCP.
- After tagging the GCPs the photos will be processed in the cloud. You will have options as to what kinds of data you want to be able to download or view once the processing is done. You may experience different amounts of time before your data is available to you based upon which types of data you have requested for output.

Different applications may have different output types. The three main types of data are point cloud, mesh and orthomosaic. Point clouds can be brought into ReCap and then other Autodesk software like Civil 3D or Revit. An orthomosaic is a single image of everything that was stitched and are typically produced by top down photos only. A mesh is similar to point cloud but may be preferred in a presentation setting because it will offer a sooth image instead of colored points.
Why Drones and Why Now?

Imagine the value that would be created if you could have up to date site and project data available to the entire project. Everyone would be aware of restricted areas, truck routes, where high traffic areas are, etc. would help with safety and potentially increase efficiency in a trades workflow. Now add simple tools that can be used with that data and you start to see even more value for your project. Tools that give you the ability to overlay a PDF design file onto the orthomosaic image, let you measure areas and volumes of concrete poured or soil that has been moved, or give you a way to easily compare flights to track progress and productivity on site.

For those that don’t know a lot about drones, you are probably thinking “sure this is cool, but it sounds expensive”. The reality is that it isn’t very expensive at all. You could have your own drone and annual subscription to one of the platforms for under $10K. It’s a no brainer for the data and use you will get out of it.
Hear How Orthomosaics Were Used For Better Site Communication and Collaboration

Site Logistics and Planning
By using drones in conjunction with Sitescan we were able to provide the entire project team with updated and accurate site logistics plans. This enables everyone on the project site to be in the know on locations of gates, truck routes, closures on site, inclement weather areas, flow of traffic and the list goes on. By uploading this plan to the project document control program anyone on site can view it from their computer or mobile device.

• The project site is safer because everyone knows where everything is on the site at any given time.
• Provides a more informed project team
• Material drop-off is safer and more efficient with specified routes available to all.
• Planning upcoming work and figuring out laydown areas is simplified and to scale without having to survey points.
• Site utilities are overlaid on the orthomosaic and provide our superintendents with key information of where things are and where utilities will go so they can plan accordingly.
• Provides current and accurate data for a clear and concise emergency response plan that is distributed not only to the whole project but also to the local first responders.
• Parking on site is always an issue and these site plans help clearly identify where craft can park and where they cannot.
• Laydown areas are easy to specify and we can pull dimensions on the plan in sitescan to ensure the area has enough room for whatever materials need to go there.
• Helps efficiently plan and layout the project site from a material standpoint.
Utility Coordination and Layout Example
A situation arose where the city power company needed to add a power box and run lines for their permanent power feed. In order for them to do this we needed to verify that they had a clear path and that our trailer farm wasn’t in the way. Below are the 2 different processes to get to an informed decision by using drone data and not using drone data. Please keep in mind that the scenario without drone data is a perfect world scenario. Odds are good it would have taken much longer than the 2 hrs and 10 min I estimated below.

**Without Drone Data:**
- Have our layout guy get coordinates for trailers and large objeccts( 1 HR+)
- Ask City power for CAD file tied to city coordinates (1 HR+)
- Use APL to bring in the locations of all the trailers and large items (3-5 min)
- Draw or model those items (5-10 min)
- Check model for conflicts with proposed power box and routing (2 min)

**Time to Informed Decision: 2 Hours 10 Mins (Perfect World Scenario)**

**With Drone Data:**
- Flights take place bi-weekly so the data is already collected and useable
- Overlay City Power PDF in Sitescan via Georeference points (2 min)
- Measure required clearances and check if anything is in the way (3 min)
- **Bonus:** Export overlaid data back to PDF and Markup so it’s easy to read and understand for the whole project team and distribute. (5 min) See Image 1.4 on Page 7

**Time to Informed Decision: 5 Minutes (Total w/ Bonus – 10 min)**
VIDEO OF UTILITY COORDINATION W/ DRONE DATA:
https://mortenson.box.com/s/6vogl8z8fva9chzyynoi927qvp0z1k8j

Measuring Capabilities w/ Drone Data
There is a lot of value in just having a constantly updated plan view of the site, but to be able to actually pull accurate dimensions, calculate areas and volumes, as well as keep track of and count equipment on site has proven to be incredibly valuable to our superintendents and engineers. The video below shows how you can utilize some of these tools within 3DR Sitescan's online platform.

MEASURING CAPABILITIES VIDEO:
https://mortenson.box.com/s/b85prtcwucxn05lz80tixccwbfwh8pk4
Learn the benefits of photogrammetry for construction monitoring and how easy it is to utilize

Quality Check and Tracking Work (Site Work)
On this particular project we were self performing the majority of the site hardscapes. I put together a coordinated CAD file for our layout guy to use and then turned that same file into a PDF that I could then bring into Sitescan and overlay it on top of the project site. This allows me to do a couple of things:

1. I can double check the layout to ensure quality and accuracy.
2. I can easily track what site work we have completed as well as how much site work we have left.
3. I can help plan and coordinate where we are going to be pouring next since I can see what may be in the way or what predecessor work still needs to be done before we pour our concrete sidewalks.

SITE WORK VIDEO:
https://mortenson.box.com/s/mslopovzdhh52ym9pdfkmwd055ef2d2j

Tracking and Comparing Work Put into Place
We do a lot of self perform concrete work at Mortenson and having these updated plan views of the project helps our project team track work that has been put into place as well as help make sure we aren’t missing certain items with the help of the PDF overlay tool. With the drawings overlaid on the image we can see that all the footings have been installed in the correct locations and identify any that we may have missed. This works for multiple scopes of work besides concrete. We also can compare dates and see the differences from one date to another which helps track productivity and is a visual key that our superintendents can use to drive our schedule.

TRACKING AND COMPARING WORK VIDEO:
https://mortenson.box.com/s/3swchra6dfx7ixvnwyxpp2exy58wvg

Inspections (High Risk Safety Areas)
Being that Safety is our number one priority we wanted to find a way to reduce or eliminate certain safety risks that can be associated with certain inspections of work like the roof canopy. Through the use of the sitescan website, in conjunction with the video footage, we were able to inspect the roof from the convenience of our computer screen. We also used the images to get approval for the logo without having to have the design team go up on the roof and look. Another example of how we utilized the drones was by using it to get flashing and connection details on the edges of the driver tubes and PTFE approved by our design team that was all the way in Kansas at the time. Because we were able to get the go ahead without them being here, we were able to continue the installation and not hold up the schedule or other trades’ of work.

INSPECTIONS VIDEO:
https://mortenson.box.com/s/29p06og1s1nsqti5v3an8b6e9q3qswgs
Inspections (Rebar and Concrete Deck)
Using Sitescan our Engineers are able to get a plan view look at the installed rebar and forming pans for the upcoming elevated concrete deck pour. They can utilize a few different tools within sitescan to do an inspection to ensure the rebar design is being met. They can use the measure tool to confirm rebar lengths and spacing or they can overlay the rebar shop drawings onto the orthomosaic and perform a visual quality check on whether anything is missing or out of place. This kind of quality documentation is simple and efficient. It minimizes and even can eliminate the task of taking inspection pictures and then trying to figure out where they all were taken.

CONCRETE INSPECTIONS VIDEO:  
https://mortenson.box.com/s/0jra9lamsb3mpfqz9bou8sqo1iezbw5i

Project Documentation
Documentation in general is a must on any construction project. It becomes even more vital on larger more complex projects. Through the use of Sitescan and Multivista we hit documentation from all different angles.

We used Multivista to help document enclosure, structure, and the field in a more cohesive manner that was user friendly to our team and easily accessible.

Basics:
- Complex structure and enclosure led to project management wanting an efficient way to fully document the exterior of our building throughout key milestones.
- Flew a DJI Inspire up and down steel driver tubes and enclosure taking pictures of details and penetrations we deemed critical.
- Provide Exact-Builts via drone for the in-field utilities and roof progressions that will be integrated with those drawings(Mapping).
- Not done via drone but they are also providing 360 Immersive MEP In-Wall Exact-Builts, 360 Finished Interior Exact-Builts, Finished Exterior Exact-Builts

Deliverable:
- Access to information from both computer and mobile devices.
- Elevations from Architectural set with all images tagged in correct location via their proprietary software.
- Timeliner for images to show progress or comparison
- Built-in Matterport viewer for 360 Exact Builts
- Integration with Procore – Ability to create observations, inspections, and punchlist items from any image or plan within the multivista app or website.
- In the words of project leadership, “Cheap insurance for a complex structure”.

PROJECT DOCUMENTATION VIDEO:  
https://mortenson.box.com/s/19i8u1u5pj9xprx94gy8v1596mihurlh
See how you can utilize point clouds with your models

**Point Cloud and 3D Mesh built in to 3DR Sitescan Platform**

One feature of Sitescan that we really enjoyed was the built-in viewer for the point clouds and 3D meshes that were created from each drone flight. Normally viewing these types of files would require someone to have a specific program like Autodesk Recap, but with the Sitescan website you can view the data directly within their platform. (See Image 1.5) This enables engineers and superintendents to be able to pull dimensions in 3D, grab profile elevations, measure heights, etc. without the need for any additional program.

**IMAGE 1.5 - 3D MESH VIEWER IN 3DR SITESCAN PLATFORM**

**Point Cloud Export for Revit and Navisworks**

Besides being able to view the point cloud on the website you are also able to export the point cloud data from the drone flight and then import it into your Revit model. This makes it easy to verify anything from footings and foundations to whether or not the logo was placed correctly on the roof. The point cloud can also be brought into Navisworks and overlaid on top of your coordinated model.

**POINT CLOUD AND 3D MESH VIDEO:**
https://mortenson.box.com/s/kcpsrxwzrmw8875hpknqcu6oiaxlin8ca
Using Point Cloud in Revit to Track Work

We do a lot of self-perform concrete at Mortenson so we use Revit to track work put into place through parameters. Before we would have to go on site and mark what has been installed on our iPads and then come back to the office and change the parameters of those footings and foundations in Revit. Now we simply bring in the point cloud and are able to overlay the model to see exactly what footings/foundations have been installed and mark them in Revit without having to walk out on site. (See Image 1.6) Basically eliminating thirty minutes to an hour of walking the site and documenting from our workflow on a weekly and sometimes daily basis.
Drone Use in Construction Takeaways

Challenges:
- Getting initial buy-in from project team (while the interface is simple and easy it’s still ‘another’ program the project team has to learn and use)
- Finding a time to fly where we weren’t flying directly over anyone
- Figuring out how the data can be used to help processes and workflows

Opportunities:
- Flights more frequently than bi-weekly
- Create a drone program within Mortenson, allowing flexibility and frequency of flights for any project
- Now that we have a baseline of what we can do with the data we need to make sure others in the company know about it and get their input on how it could potentially be used going forward
- Potential for AI to automatically track progress of work

Successes:
- Constantly updated site logistics plan available to entire project team which created a safer site
- Site coordination of utilities – eliminating need for layout and empowering superintendent to use tool for quick resolution
- Canopy roof logo review with design team for approval
- Tracking of work and QC (site work, concrete, rebar, steel, roofing, in-field heat)
- Aided in planning of work coming up in weekly work plan meeting
- Provided quality control by being able to inspect and measure rebar as well as have documentation that it was installed correctly

Drone Use for Marketing and Proposals

Customer Impact and Use
The customer absolutely loved the use of drones on their project. It not only provided them with a different perspective of the project, but it also aided in the ‘hype’ of the stadium and getting fans excited for what is to come. The team was able to use the images and video footage to create videos that gave fans update on the construction progress and got them excited for the opening of the new stadium in 2019. These videos were posted to the teams website as well as played on the jumbotron at each home game at TCF bank stadium.

Hype Videos:
https://mortenson.box.com/s/c426ilcb03901apic2gn5b7drqd8n223
https://mortenson.box.com/s/cmmv9umu06cqd6w6ba6ktrdfiky3trk

News Story Example Video:
https://mortenson.box.com/s/uc0curcnrip8603xcoqh4mlmqd6qk6uy
Mortenson Use
As you can see from the data presented above there are lots of ways to use the data to add value to your projects. Outside of the construction process there are still different ways to use the data that can benefit your company. You can start to use the data for proposals and pursuits or just use it to provide progress videos for the team or company meetings.

Proposals and Pursuits
Recently we started to look at utilizing drone flights to aid in pursuits and proposals. Imagine if we were able to fly the site of a potential project and could extract and digest that data before the proposal was even due. We would be able to provide the potential client accurate up to date information during the proposal process as well as clearly establish Mortenson’s continuous commitment to both innovation and improving the construction process as a whole in the industry.

Progress Videos
We also use the images and videos to create progress videos that can be used for our clients, marketing, or to show the project team so they can visually see how much work they have done in the past year. The perspective the drone provides is unlike anything we have seen before. It allows the viewer to feel immersed in the project and gives them the ability to see ALL aspects of the work being done on the project.

**PROGRESS VIDEO EXAMPLE:**
[https://mortenson.box.com/s/7dd29mqyshbya8mybun36aebpl3ok4ru](https://mortenson.box.com/s/7dd29mqyshbya8mybun36aebpl3ok4ru)
Drone Laws and Safety

As previously stated it is necessary to attain a certification from the FAA in order to conduct commercial drone flights. This certification is called a Remote Pilot Certificate. For more information on how to become a certified drone pilot look here:  
https://www.faa.gov/uas/getting_started/part_107/remote_pilot_cert/

These are some of the important regulations to know:
- You need to receive permission from the Air Traffic Control Tower at any large airport if you are flying within 5 miles of the airport.
- You cannot fly higher than 400’ above the ground or 400’ above an object that is <400’ away.
- You must be able to see the drone at all times. This includes automated flights.
- You cannot fly over people that are not covered by a structure
- You cannot fly over roads with moving cars

If an exception to one of the part 107 rules is needed it is possible to file a waiver with the FAA. The review of the waiver by the FAA may take up to 90 days though, so be sure to plan ahead.

I have received one such exemption. The project required us to fly next to the Minneapolis-St Paul International Airport. I filed a waiver to the FAA and was granted permission to fly during a specific period of time on a specified day. I also had to promise not to fly higher than 150’ above the ground. So, keep in mind that you may need to tighten regulations when filing a waiver. Someone representing the FAA called me and helped me coordinate the final exemption request so that it would be most likely to receive approval.
Useful 3DR Sitescan Links:

3DR Site Scan Overview

Pricing (Oct 2018)

3DR Site Scan — Drone Options

3DR Customer Success Program

Surveying with Site Scan Field

Site Scan Manager Walkthrough

Fleet management