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CS501702

Photogrammetry Startup with the Architecture, Engineering & Construction Collection and Autodesk Construction Cloud

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BL Harbert International

Learning Objectives

- Learn how to process aerial imagery with ReCap Photo.
- Learn how to use AutoCAD and Civil 3D tools for mesh, orthophoto, and point cloud analysis.
- Learn how to use annotation tools in BIM 360 and the hypermodel in Autodesk Build to highlight and share findings with stakeholders.
- Gain practical advice for starting and scaling a drone program.

Description

The focus of this class will be how to make the most of tools available in the Autodesk Architecture, Engineering & Construction Collection and Autodesk Construction Cloud to start processing, analyzing, and utilizing drone photogrammetry to improve construction processes. Once at scale, many companies will likely opt for a purpose-built product designed especially for this entire workflow, but it is crucial to secure company buy-in before making this investment. At BL Harbert International, we found that the best way to accomplish this is by providing concrete examples of useful applications on our own projects. To achieve that, we've used several tools in the AEC Collection and Autodesk Construction Cloud that are already at our disposal. This class will step through a workflow of setting up for photogrammetry imagery capture, processing imagery in ReCap Photo, then analysis in AutoCAD, Civil 3D, Navisworks, and other Autodesk softwares, and then finally sharing with stakeholders and making annotations in the Autodesk Construction Cloud (BIM 360 and/or Autodesk Build).

Speaker

BIM/VDC Manager for the BL Harbert International Domestic Division. A mechanical engineer by degree, I have a passion for coordination, quality analysis, and visualization all in 3D. My goal is to continuously seek ways to improve the jobs of our field personnel and other stakeholders through better implementation of these three processes, either through improved workflows or new technology implementation.

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Class Overview

The point of this class is to help organizations figure out what improvements or additions to standard business practices can be made by the inclusion of photogrammetry. Any photogrammetry initiative has to be based on actual business needs or potential for improvements in standard workflows. BL Harbert International found that we had a suite of tools already at our disposal that allowed us to investigate what uses for photogrammetry we're truly interested in as a company, and which types or jobs would be best suited for the different uses.

The remainder of this handout covers the following:

1) The research we performed to get setup to capture imagery for photogrammetry
2) How we used Recap Photo for processing aerial imagery
3) How we used AutoCAD for doing 2D QA/QC and as-builting for concrete pours
4) How we used Civil 3D for different types of cut/fill analysis,
5) How we tested Navisworks for 4D progress monitoring,
6) How we intend to trial Navisworks, Infraworks, and/or FormIt for site logistics planning on a capture of a site
7) How we share data with the necessary stakeholders via Autodesk Construction Cloud to make sure we got the feedback we need

With this research, we're now solidifying business cases and working on selecting the right product(s) to demo and use to scale our initiative.

Step 1: Background Research & Setting Up for Photo Capture

Before you start making point clouds, geotiffs, meshes, and tin surfaces and showing off flashy content around your organization, you must make a decision on how your organization is going to collect imagery for photogrammetry. There are two options for this:

1) Pay a drone services company to collect imagery for you
2) Get certified and go fly a drone on a a jobsite yourself

Drone Services

If you have a R&D or other budget available, and your if your organization doesn't have a certified pilot, drone, or personnell with the time or interest to work through the process, contracting out drone flights is the easiest and best option for you. Most services companies will handle any FAA authorization needed (if flying in restricted airspace), will have the software and hardware to perfectly capture images in whatever resolution you want, and will be able to deliver the resulting photos to you remotely (and more than likely can do some of the photogrammetry processing for you as well). A quick Google search in your area will probably result in several drone service providers.

DIY

If you have no budget to contract out flights though, have access to a drone, and have some time and motivation to learn, here are some helpful hints on getting started:

Step 1: Get Certified

You have to be Part 107 Certified to fly drones for any commercial purposes. Even if you're just researching to see if this is going to work for your organization, it's best to go ahead and get certified before flying on any actual jobsites. You can start the process here: [Become a Drone Pilot | Federal Aviation Administration (faa.gov)]

Doing the studying on your own is possible, but not advised. It's a large amount of potential material that the Part 107 Study Guide suggests you go through, and many resources reference other resources with even more information. After going through this method myself, I now suggest using an online training program (or in-person if they're offered in your area). This will help you focus on what parts of the enormous amount of potential material are most important.

Part 107 Remote Pilot Certificate

BL Harbert is now trying Pilot Institute with our employees currently seeking Part 107 certification: [Pilot Institute: Drone and Airplane Pilot Courses - Aviation Made Easy].

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Step 2: Get a Drone

This potentially isn't as straight forward as it sounds. Not if you're looking to purchase a new drone and get started right away. One of the key components when selecting a drone is compatibility with whatever flight app you're going to use. This step is somewhat tied to selecting your flight application for taking photos. Some findings BL Harbert had in the past year are the following:

1) Each flight app has a list of drones it's compatible with. This list is based on the SDKs they keep up with from drone manufacturers
    a. SDKs are Software Development Kits. Drone manufacturers have to release these to the public for 3rd party apps such as Drone Deploy and Pix4D to be able to control the drone with their flight app.
2) Some drones may have SDK updates by the manufacturer that aren't shared with 3rd party app companies, making them incompatible
    a. Lesson learned – the old hand-me-down Phantom 3 Pro isn't very useful anymore
3) Some new drones have SDKs that have yet to be shared with 3rd Party Apps (Examples: DJI Mavic 3 and Mini 3 Pro)
4) Some drones that are supported by just about everything, aren't manufactured anymore or are being phased out (Examples: Mavic 2 Pro and Phantom 4 Pro)

At BL Harbert we ended up purchasing a used DJI Mavic Pro 2 to use until SDKs are available for the newer drones being manufactured. We looked at Skydio as well, but currently it's only compatible with the Skydio App and Drone Deploy, and we ultimately decided against it (for now). We also looked at Autel (which has it's own flight app), but decided against that as well. Even though it's used, the Mavic Pro 2 gave us the best flexibility in testing different flight apps, and the form factor lends itself to later being deployed to a jobsite (the Phantom 4 Pro didn't seem ideal for keeping on a jobsite).

Update: Since this initial draft of this handout, the DJI Air 2S SDK is now support by Drone Deploy. It effictievly has the same image sensor as the Mavic 2 Pro in a smaller form factor (which results in longer flight time).

DJI Mavic Pro 2 and DJI Air 2S

Step 3: Figure out how you're going to capture the images

The most straightforward method to capturing photos is to do a manual flight and then take the photos manually or set a capture interval in your drone's default flight application. This may work for some applications, but won't typically produce sufficient results for the use cases covered in this session/handout. The suggested method is to set up an automated flight path using a mapping flight app of some sort. BL Harbert has tested the following:

- Pix4D Capture (PIX4Dcapture | Pix4D)
- DroneDeploy Flight App (Drone Mapping App | DroneDeploy)
- Hammer Missions (Home | Hammer Missions)
- DJI Groundstation Pro (iPad only) (DJI GS Pro - DJI)
- Site Scan for ArcGIS (iPad only) (Site Scan for ArcGIS (esri.com)).

This only scratches the surface of apps available out there though. Each of these apps have different pluses and minuses to them based on intended application, but all allow you to draw up a flight plan and set capture settings for gimbal angle and overlap. After testing, BL Harbert now uses Pix4D Capture and Hammer Missions.

- Pix4D Capture: We picked Pix4D for the simplicity of the app and creating missions. Remote jobsites with drones already deployed were able to pick up use of this app easiest and tended to prefer it.

- Hammer Missions: We picked Hammer Missions based on the pricing structure and ability to create more complex missions and strings of missions without necessarily having to purchase a complete end to end product like Drone Deploy. It also works on an iPhone. We liked ArcGis Site Scan and DJI Ground Station Pro, but having to use the iPad proved to be too cumbersome for our field personnel to actually utilize the app. Hammer Missions also gives us the option to export flight plans in 3D to Google Earth and compare against a geo-located building model.

3D Flight Path for complete building capture, missing collision with condo next door

We did find, however, that when stringing missions together, there is a limit before the flight plan is too long to upload reliably to the drone. Lost communication and having to restart resulted in the one complex plan having to be being broken into several. Despite this, we still have access to facade inspections and polygonal 3D mapping missions with Hammer Missions (DroneDeploy has polygonal 3D mapping available in its free app, but façade inspections are only available with a subscription).

Utilizing the complex shape instead of a standard rectangle allowed us to capture the entire critical portion of the site with only 2 batteries instead of 4, which is great, because I only had 2 batteries

Step 4: Go get the Photos

So now you're certified, got a drone, picked a flight app or two, did some research on the best parameters (we'll cover optimal parameters for each intended photogrammetry use in the appropriate sections), and you're ready to go capture a jobsite (or you got to this point and decided you're not as motivated as you thought, and it might be a better idea to find some funding to pay for drone services).

Either way, now you have to pick which jobsite to go capture. The keys are to first pick the right application(s) for the right jobsites, and then be strategic and opportunistic on when to go fly. This will involve talking with your project teams and operations managers to figure out what information would be helpful to have, and what may not be helpful. You may not need a point cloud of an entire building when the only concern is seing 2D positions of post-tensioned cable in concrete decks. You may not need to do any 2D overlays of a site with basic engineered metal buildings. And you may not need to do a stockpile analysis of a site with little to no earthworks. If you aren't communicating with your teams you may not know what they need, and you may miss the right timing to collect what they do need. Figure these details out, and then you're ready to go capture your photos, and proceed to the next sections on how to process the photos and then analyze and share the results.

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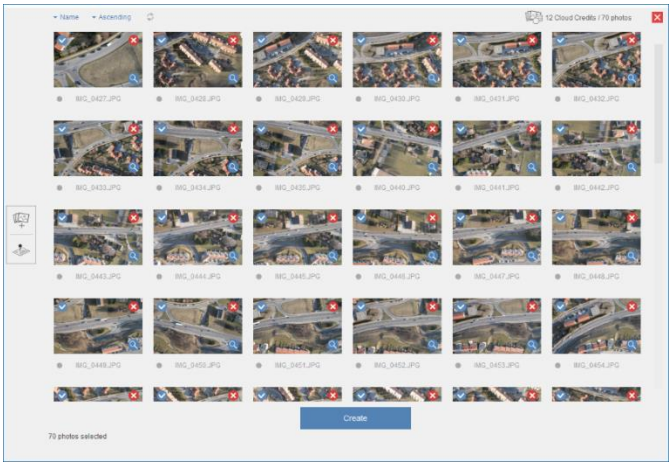
Processing in Recap Photo

Recap Photo is Autodesk's Photogrammetry processing engine. The overall process for adding photos and generating a point cloud, mesh, and orthoimage is fairly straightforward, but there are some important details to pay attention to in the processing. The following section covers the process and pulls references from the Autodesk Product Overview that can be found here: Product overview | ReCap 2019 | Autodesk Knowledge Network and here: Autodesk ReCap Help | Product overview | Autodesk

Importing Images and Ground Control Points



After opening Recap Photo simply click New Aerial Project and then select add photos on the left side of the screen. Navigate to your capture images and group select them to open them. In the top right, you'll see how many tokens it will cost to process these images. Recap Photo may be included in your collection, but it's important to know that you will need to also purchase tokens to be able to process photogrammetry.

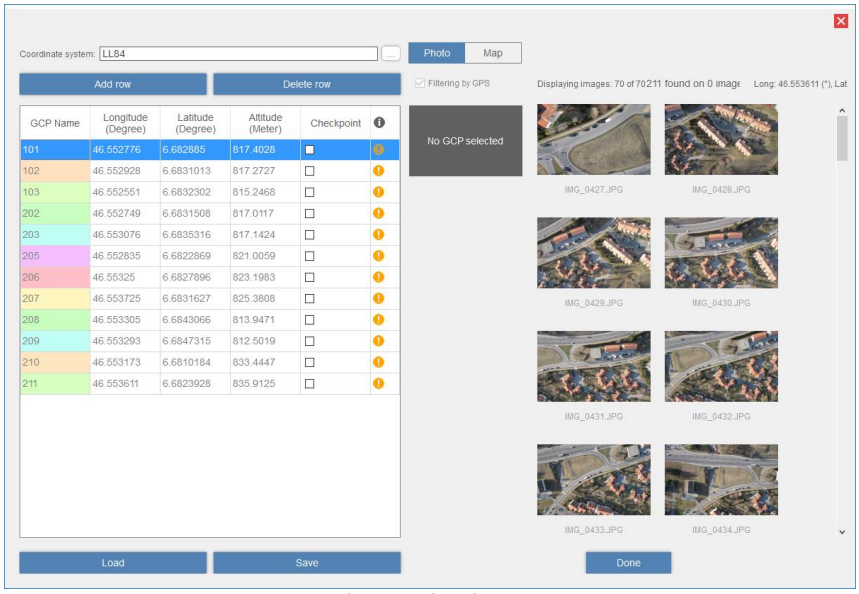
You can find an explanation of cost per project here: ReCap Photo Frequently Asked Questions | ReCap | Autodesk Knowledge Network and how to purchase here: Autodesk Flex | Pay as You Go Pricing for Occasional Use. In summary though, one token costs $3, and photogrammetry processing uses 1 token per 50 photos (rounding up). So for example, a dataset of 140 photos will use 3 tokens, and cost $9 to process.

Ground Control

Ground Control can be critical for some photogrammetry applications. It's established by creating points on your site that have known coordinates and elevations. Purchase or make some aerial ground control targets (such as these: Sky High Bull's-Eye (24"x24") UAV Drone Ground Control Points (GCPs)/Aerial Targets) and establish the exact location of the center of these targets using a Total Station or GPS Rover. Targets can be placed on top of existing control points, or placed in other strategic locations and their center points determined afterwards. At Harbert we place aerial targets and then use a GPS rover to quickly define points at the center locations. It's important to create at least 3 points and locate them towards the extents of your site to prevent pushing any deviation towards one side of the site. More is better though, as the more points you establish, the more you even out any deviation between the points or in your photogrammetry results.

If you collected ground control points, add them to Recap Photo by clicking “add ground control points” underneath “add photos” to open the add ground control points screen. Ground Control Points are then created in two steps:

1) Add the points and then then their state plane coordinates in the panel on the left
2) For each point created, zoom in on at least 3 photos for each point select it in the image



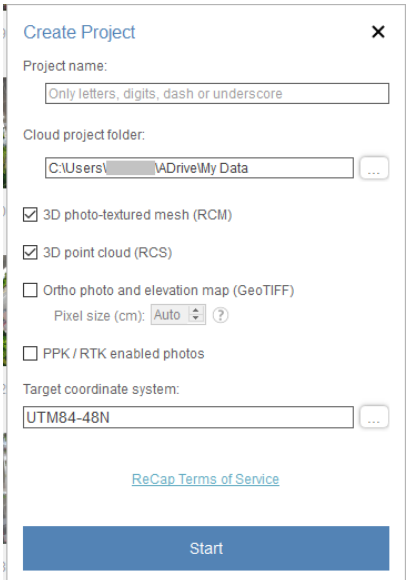
Ground Control Points Screen

Processing

After adding photos and ground control points, choose your project name and location to save the project to, and the desired outputs. At Harbert we go ahead and create a point cloud, mesh, and Ortho photo for each project (we’ll cover all 3 in the remainder of the handout)

Lastly, select your target coordinate system. There is a long list of systems to choose from in here, so do some research on which system you need to be using. In the US, it’s likely you’ll be using the State Plane Coordinate System of 1983: [Maps - State Plane Coordinate Systems (SPCS) - Tools - National Geodetic Survey (noaa.gov)](). Find your system and make sure you select feet or meters, whichever you used.

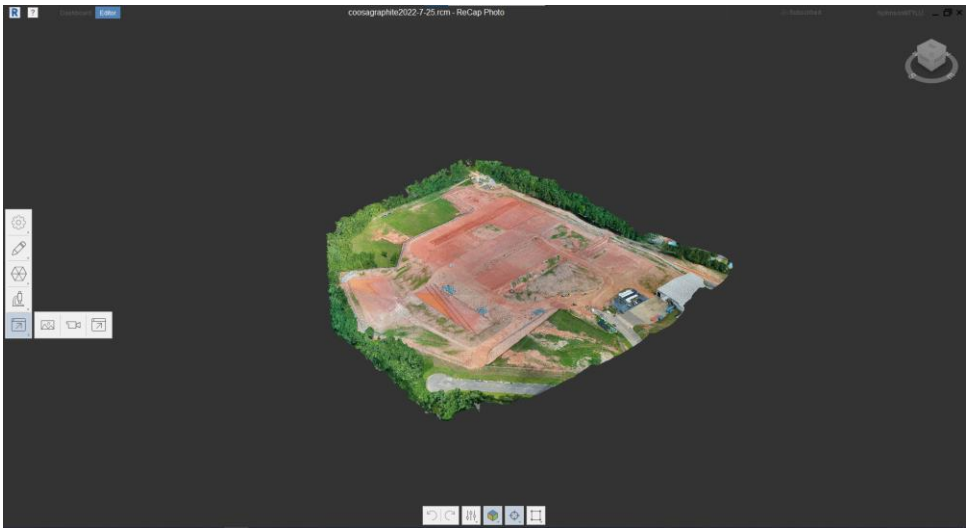
Now hit start, and let the process run for a few hours.



Create Project Window

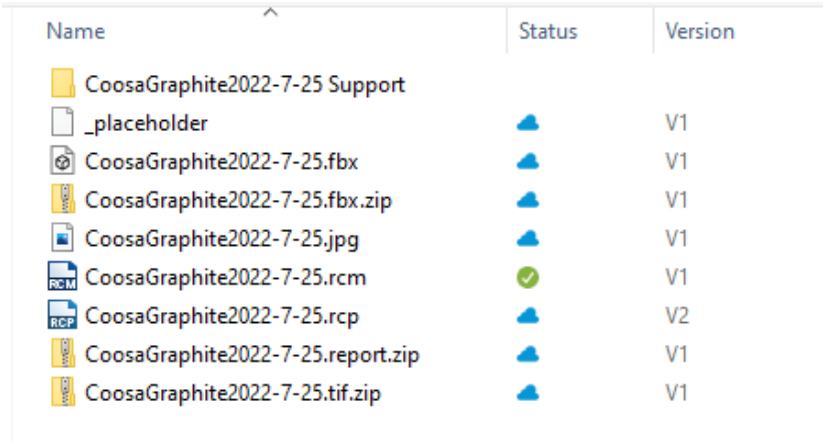
Results

Once the process is finished, you'll be able to open your created mesh within Recap Photo. You can spin it around and there are a few basic analysis tools available.



Example Mesh

You'll also have a folder full of the other outputs. The RCP project, RCS, FBX model, and Ortho Image are all in here.



Example Outputs Folder Structure

In the next sections we'll cover how to use these outputs.

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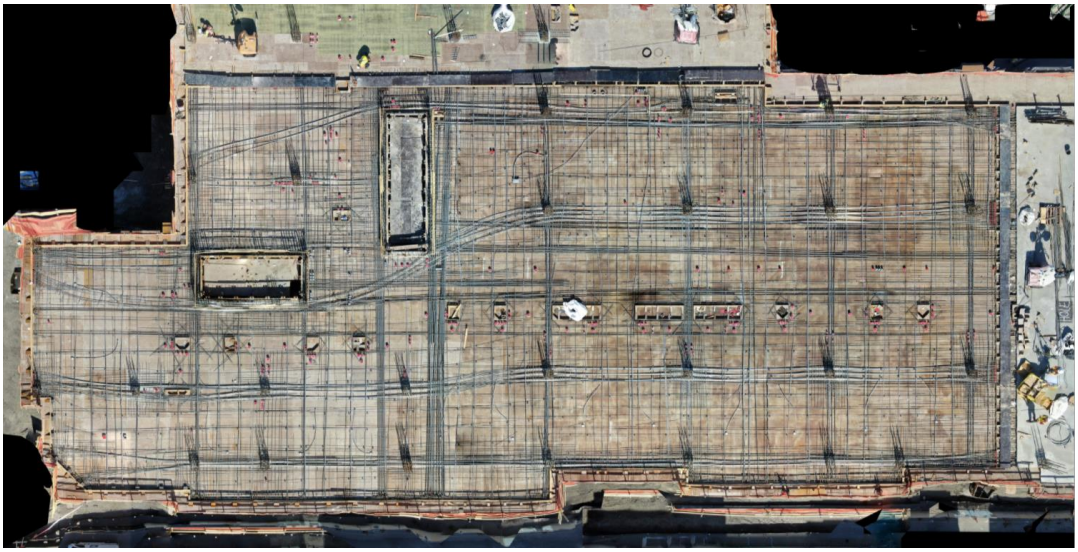
Use-Case 1: 2D QA/QC and "As-Builting"

For Harbert so far, the most obvious beneficial photogrammetry output has been 2D ortho photos. The compiled ortho photo has the appearance of being a mosaic image of all the images taken compiled into one large photo. This is somewhat correct, but what actually happens is Recap Photo (or any other photogrammetry engine) generates a point cloud by finding common vertices between the images you took. Next it create a surface mesh from the point cloud, and texturizes the mesh by applying sections from each image to the surface of the mesh as appropriate to create a photo-realistic surface. Finally, the ortho photo is generated by rendering a plan view snapshot of the mesh.



Orthoimage of deck pre-concrete pour

After generating the image, we can then compare against a 2D penetration layout, site plan, or other 2D plan for QA/QC or other purposes. There are multiple ways to do this in the AEC Collection, but Harbert leverages AutoCAD for this workflow.

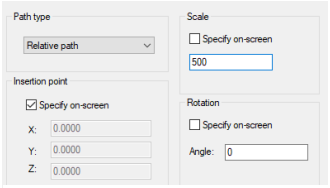
Suggested Settings

- Gimbal Tilt: 90°
- Overlap: 75-85%
- Ground Control Points: not necessary, but useful when higher accuracy is needed or if a large site is being overlayed
- Elevation: <100 ft (lower is better, but be sure to avoid cranes or other obstacles)
- Flight pattern: back and forth coverage over entire site (at least in one direction)

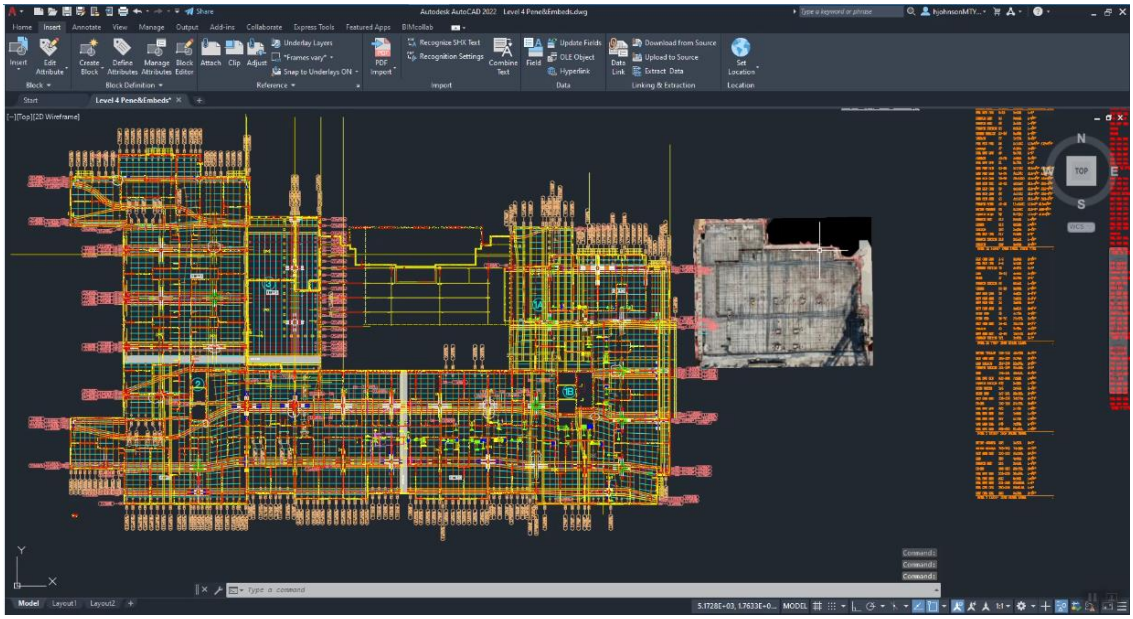
Workflow in AutoCAD

To create an overlay in AutoCAD, begin by opening the .dwg drawing that you wish to overlay on top of the image, then use “attach image” to bring in your orthoimage. You can find a detailed description of how to perform the process here: [To Attach an Image | AutoCAD 2021 | Autodesk Knowledge Network]

Note: One topic not covered in photo processing was setting the pixel size. We have yet to figured out the best settings for this, and still use Auto every time. The result is when you attach the image in AutoCAD, it is incredibly small. When importing the image, I go ahead and set the scale 500 to get a head start on getting it to the right size.



Insert image settings



Orthoimage in AutoCAD

Aligning

Once your image is in, you’ll want to determine a common basepoint between the image and the drawing. If you used ground control points, use those. If you didn’t, use an edge or corner in the image that should have a high degree of accuracy.

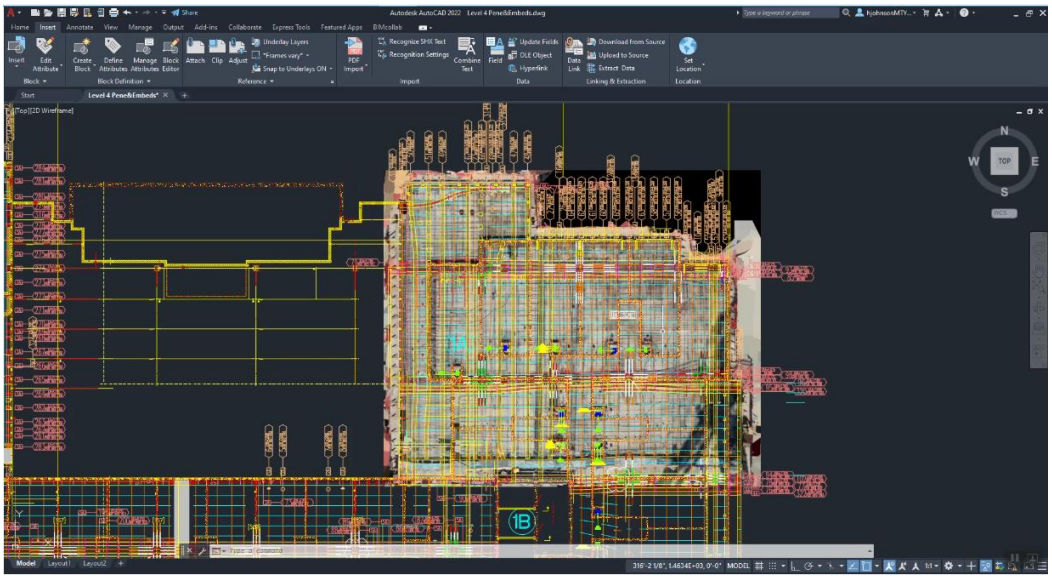
Next use the move command ([MOVE (Command) | Autodesk Knowledge Network]) to move the image so that the points align. You’ll probably also need to use the send the back command on your image so you can see you drawing.

Then pick a 2nd control point to use between the image and drawing. You’ll use this to set the scale and rotation correctly.

Once you've identified the second control point, use scale (SCALE (Command) | Autodesk Knowledge Network) to make your image the correct size. Be sure to select the reference option. This will allow you to capture the known distance between the control points on your drawing, and apply it to the image (without taking measurements).

Lastly, use the rotate command to rotate your image to align with the drawing. Again, use the reference command to find the required rotation angle instead of taking measurements. See detailed instructions here: How to rotate an object based on an existing angle | AutoCAD | Autodesk Knowledge Network.

Now you have an aligned overlay:



Aligned image

After completing the overlay, we add any measurement annotations that are required in AutoCAD and then print to PDF. We then upload the PDF to Autodesk Construction Cloud to be shared. There we can continue to add additional markups and use Issue pushpins to drive action on items that need it. This workflow will be covered in more depth later in the handout.

Additional Notes

To create orthoimages for this application, Harbert also uses Reality Capture (RealityCapture: Mapping and 3D Modeling Photogrammetry Software). Reality Capture gives us some editing capabilities that aren't available in Recap Photo. For a specific project, ground control wasn't used, and innacurate elevation data for photos was making meshes tilted. We weren't able to correct this in post-processing in Recap Photo. As a result, the rendered orthoimages were skewed and innacurate. Reality Capture allows us to adjust the mesh as needed prior to creating the orthoimage. The only drawback is it processes photogrammetry locally instead of in the cloud, and so requires a dedicated Graphics Card to run.

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Use-Case 2: Cut/Fill Analysis

Earthworks analysis is one of if not the most popular uses for photogrammetry in the construction industry. Stockpile quantification, modeling of as-built conditions, and earthworks QA/QC are all important use-cases. In the AEC Collection, Civil 3D is the analysis tool of choice for most applications. The photogrammetry input used here will be the point cloud generated in Recap Photo.

Suggested Settings

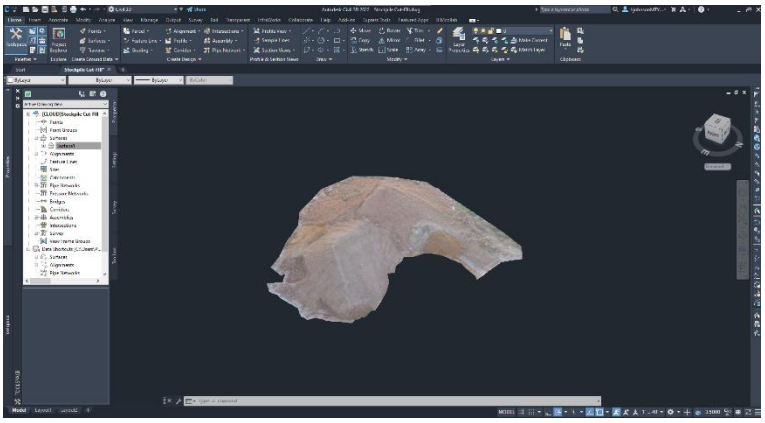
- Gimbal Tilt: 60-70°
- Overlap: 60-70%
- Ground Control Points: for stockpile analysis, not necessary. For site QA/QC, HIGHLY suggested.
    - It is possible to generate a 3D site surface without ground control points, but very difficult to align confidently.
- Elevation: 100-200 ft (lower is better for improved resolution, but balance against battery usage as necessary)
- Flight pattern: orbit or 3D map depending on specific application

Application 1: Stockpile Calculation

One of the simplest uses of a surface from a point cloud in Civil 3D is calculation of a stockpile volume to quickly determining quantity of material on your site. Before beginning the process in Civil 3D though, it's suggested to first import the point cloud (.rcs) into Recap Pro, where you can can crop the point cloud to the boundaries of the stockpile or stockpiles. (See details on cropping point clouds in Recap Pro here: About Clipping and Deleting Points | ReCap | Autodesk Knowledge Network). Taking this step saves processing time and creates more accurate results. Once the point cloud is trimmed, save it as a new point cloud, and then you're ready to attach it and proceed in Civil 3D

Attaching Point Cloud to Civil 3D and Creating a Surface

Regardless of the desired analysis to be performed, the first steps within Civil 3D are typically to import the point cloud and then create a surface from it. Find detailed instructions on how to attach a point cloud here: To Attach a Point Cloud to a Drawing | Civil 3D | Autodesk Knowledge Network



Attached point cloud in Civil 3D

Once the point cloud it's attached, navigate to the surfaces tab, and create a surface from the inserted point cloud. Find detailed instructions on that process here: To Create a Surface from Point Cloud Data | Civil 3D | Autodesk Knowledge Network

After stepping through the options, just hit "create surface" and let Civil 3D run the creation process in the background for a few minutes.

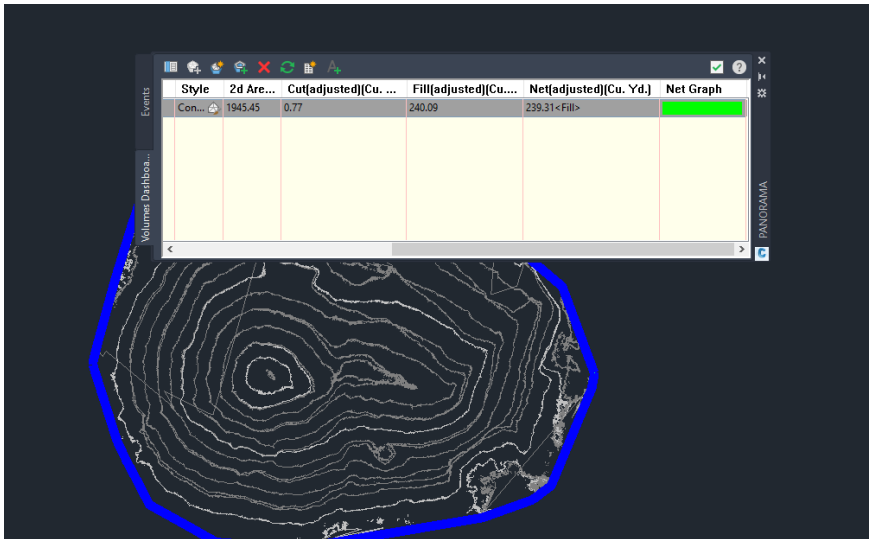
Create Base Surface and Volume Surface

Volume surfaces in Civil 3D are an analysis feature that displays the volume between two surfaces. They are used for all sorts of cut/fill analysis. For both applications covered in this session/handout, it's necessary to create a volume surface. We have already created a surface from point cloud of the stockpile top, but still need a second comparison surface to create the volume surface.

To do this we'll create a surface for the bottom of the stockpile. Start by extracting the bottom boundary of the created surface, and create a second surface out of it. A detailed explanation of the process can be found in this video: Workflow: Calculating a Stockpile Volume from Point Cloud Data using Civil 3D – CIVIL3D.TV

After creating the second surface, navigate to the Analyze tab and Volumes dashboard, and create a volume surface between the two surfaces previously created. Find detailed instructons on that process here: To Add a Volume Surface to the Volumes Dashboard for Analysis | Civil 3D | Autodesk Knowledge Network.

Once the volume surface is created, you can view the cut, fill, and net amounts for your select stockpile.



Volume Surface Results

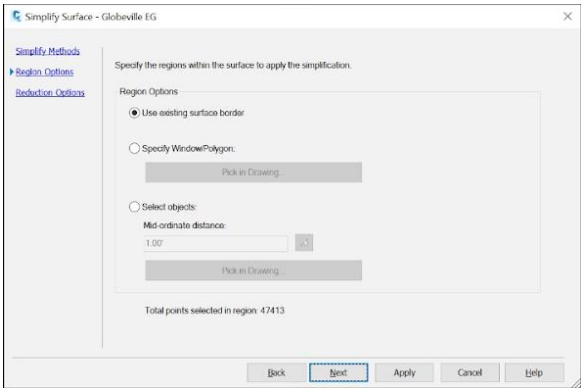
Application 2: Design vs Actual Comparison

Photogrammetry really proves it's merit in it's usefulness to quickly perform QA/QC checks on a vast amount of siteworks/earthworks. The measurement of time saved using photogrammetry over traditional survey methods typically isn't in hours, but instead in days. The rest of this section explains the steps to create a comparison between your actual surface created and an available design surface. The assumption though is that a design surface is already available for this. The process to generate one from an available 2D grade drawings is not covered in this session, but there are several resources available to learn this process, such as this video: 4 - Creating TIN surface from contours in Civil 3D - YouTube.

Once you have a design surface available, the initial setup to create the comparison surface in Civil 3D is almost identical to the process for performing stockpile analysis. However, the interim step of editing the point cloud in Recap Pro prior to importing into Civil 3D can potentially be skipped. It may still reduce processing time (especially if a large area of the point cloud isn't relevant to area of interest), but won't necessarily affect the accurate creation of a stockpile base like it would in the other use case.

Simplifying and Smoothening

Once the point cloud is generated in Recap Photo, you can attach it directly to Civil 3D and proceed to create a surface for it. After this process however, it is beneficial to simplify and then also potentially smoothen your surface. This will improve rendering and processing times down the road. Also the vast number of triangles in a raw point cloud surface make the data very difficult to analyze. See these links for the detailed processes To Simplify Surfaces | Civil 3D | Autodesk Knowledge Network and How to smooth a surface in Civil 3D? | Civil 3D | Autodesk Knowledge Network.



Simplify Surface Dialog Box

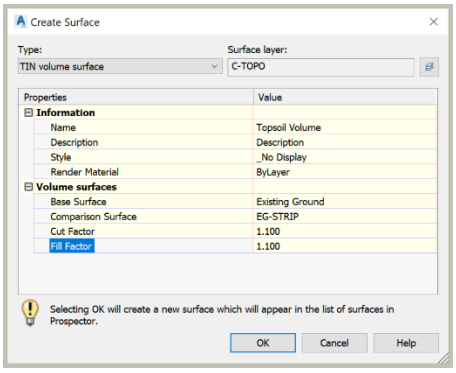
Data Shortcuts

Regardless of the size of the site, it is also advised to save the created surface as a data shortcut. Data shortcuts allow objects within a Civil 3D model to be referenced by separate models. The benefit here is that the model containing the comparison surface doesn't end up getting weighed down with three different surfaces existing in it. The process to create data shortcuts is somewhat lengthy, but this tutorial from Autodesk walks through the entire process: Tutorial: Using Data Shortcuts | Civil 3D | Autodesk Knowledge Network. If the site or area of analysis is small, it may be sufficient to only create a data shortcut for the actual surface. If the site or surface is large, it is suggested to create data shortcuts for both the actual and design surfaces, and reference them both in a 3rd comparison model.

Create Volume "Comparison" Surface

Using data shortcuts, open both design and actual surfaces in the same model. Once this is done, repeat the process reviewed in Application 1 to create a volume surface. For this application however, use the design surface as the base surface, and actual as comparison surface.

Next hit OK and wait for Civil 3D to create the surface.



Example Create Volume Surface Dialog Box

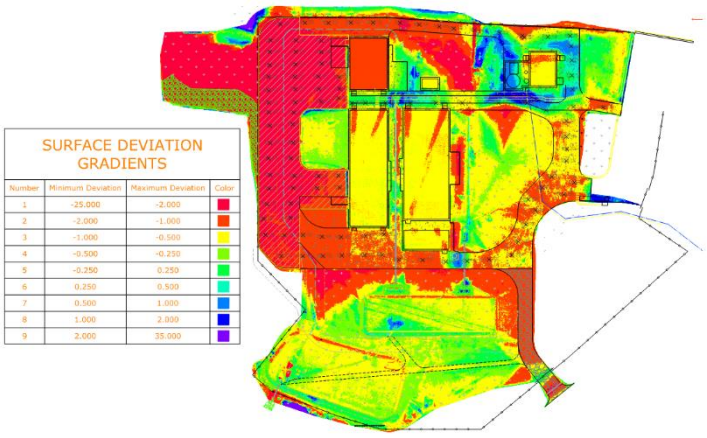
Displaying Information

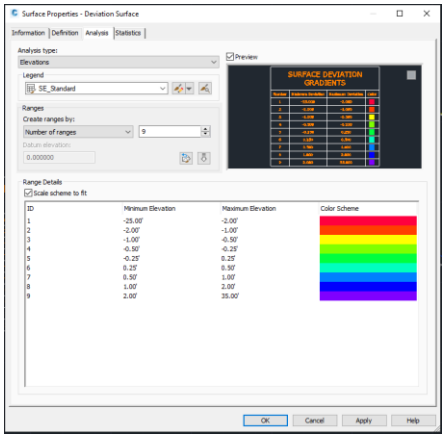
The same cut/fill report from Application 1 is generated for this surface volume as well, but for QA/QC purposes, more specific information is needed from this surface. The key interest is which areas are high and which are low relative to design. Some additional steps are necessary to make that information visible.

Color Banding

The first step Harbert has implemented is to add color banding to the surface to quickly identify which areas are close to design, which deviate slightly, and which deviate significantly. This immediately brings up areas of interest in the plot.

This plot below is created by adding color banding in the surface properties. Right click on the surface in the Prospector, select surface properties, and navigate to the Analysis tab. From there, set your analysis type to Elevation, and set up banding similar to the dialog box shown. See this article for more detailed information on the process: [Making CUT/FILL Maps in AutoCAD Civil 3D | Part I | ZenTek Consultants]

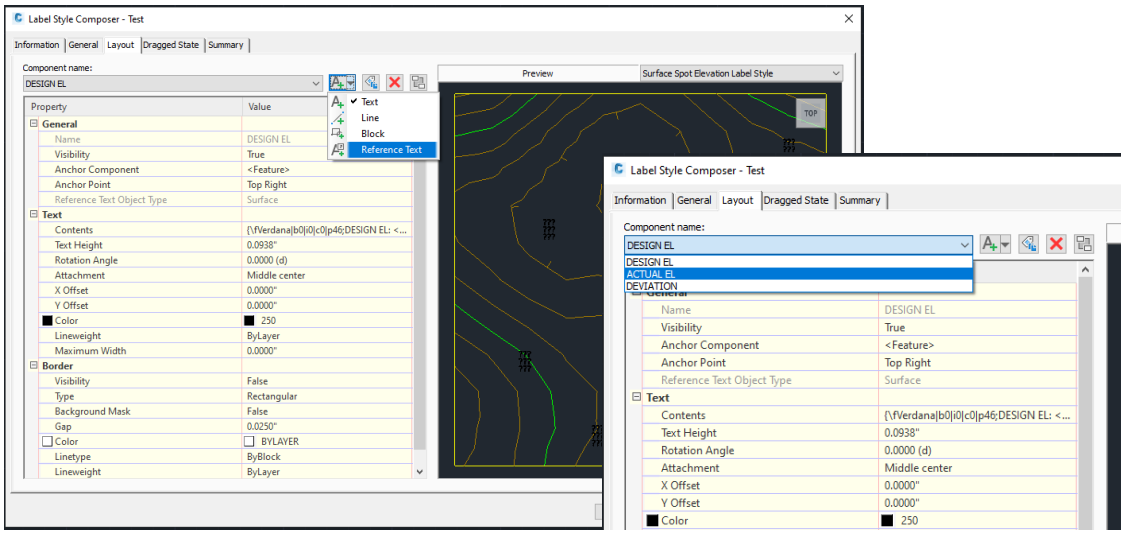




Labels

Once the areas of interested are identified, labels are also useful for determing exact deviation amounts. Spot Elevations Labels will give this value for the surface that is selected. See here how to add them: [To Add Surface Spot Elevation Labels | Civil 3D | Autodesk Knowledge Network].

Surface elevation labels can also be edited to include information on multiple surfaces. Harbert choose to display design, actual, and deviation all in the same label. To create this label, first open the label style composer using these instructions: [To Display the Label Style Composer | Civil 3D 2020 | Autodesk Knowledge Network]. Once open, find the add dropdown and click “Add Reference Text”. Then add reference text lines for the remaining two surfaces you want to show data for.



Label Style Composer

The resulting label displays accordingly:

With all these steps complete, we have a completed deviation plot for our site that we can share and review with stakeholders as necessary. Just as with the 2D overlay from AutoCAD, Harbert plots this to PDF and uploads to Autodesk Construction Cloud for review.

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Use-Case 3: 3D QA/QC and 4D Progress Monitoring

2D QA/QC and as-builting and siteworks analysis are excellent use-cases for photogrammetry, but the end-result in both scenarious is a 2D deliverable to be shared. Photogrammetry is a 3D product itself, so it stands to reason that there should also be some 3D deliverables that are beneficial as well. Harbert has tested a couple of 3D use-cases for photogrammetry.

Settings

- Gimbal Tilt: 30-70% (change as necessary to capture all critical angles of structure, but try not to capture the horizon)
- Overlap: 60-70%
- Ground Control Points: useful if available, but not necessary
- Elevation: whatever is necessary to capture full structure
- Flight pattern: combination of whatever is necessary to capture entire building (orbit, overhead crossing pattern, manual flight, vertical elevation inspection, etc)

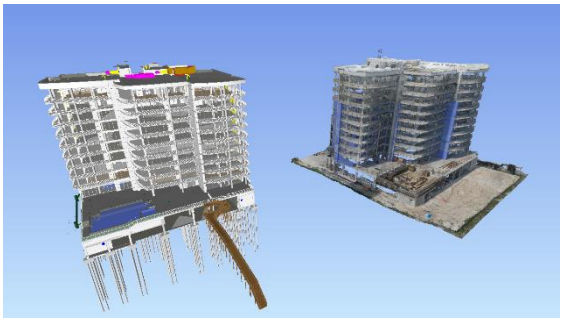
3D QA/QC

Bringing the point cloud into Navisworks to compare against the BIM is a fairly straightforward process and allows for 3D comparison against the BIM for macro-level QA/QC. Photogrammetry does not have the same level of accuracy as 3D scanning, so should not be relied upon for precise deviation analysis on structures (floor flatness, plumb, steel deviation, etc.). It can be used to check if anything has been overlooked or missed during construction, or if content is grossly out of tolerance (walls, windows, columns, structure in wrong locations or missing).

Attaching and Aligning in Navisworks

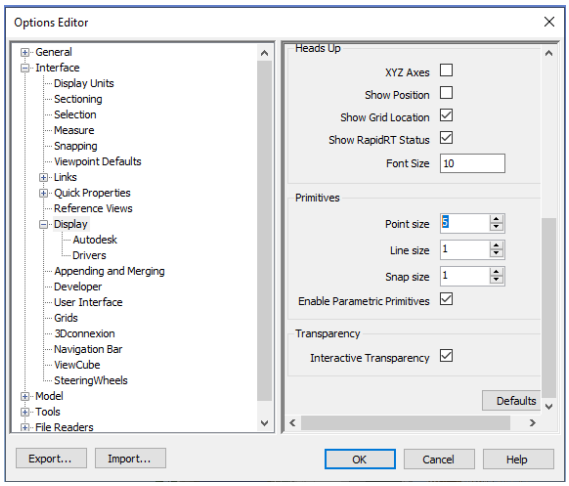
Point clouds are brought in to Navisworks using the append function in the same manner as every other type of 3D model. If 3D QA/QC is going to be performed on a regular basis, the best practice is to use permanent ground control points on the site, and put the BIM on state plane coordinates. The combination of these two practices should align the point cloud and BIM almost perfectly, and prevent the need for adjustments to the alignment on subsequent updates to the point cloud.

If ground control points weren't used, the point cloud will very likely need to be aligned to some degree. Even if the BIM is located on state plane coordinates, the point cloud location is based on GPS data collected by the drone and attached as meta-data to the images. This GPS data is generally not perfect (unless using a RTK-enabled drone, which is a discussion for another session), and so will skew the overall position of the BIM slightly.



Unaligned Point Cloud in Navisworks

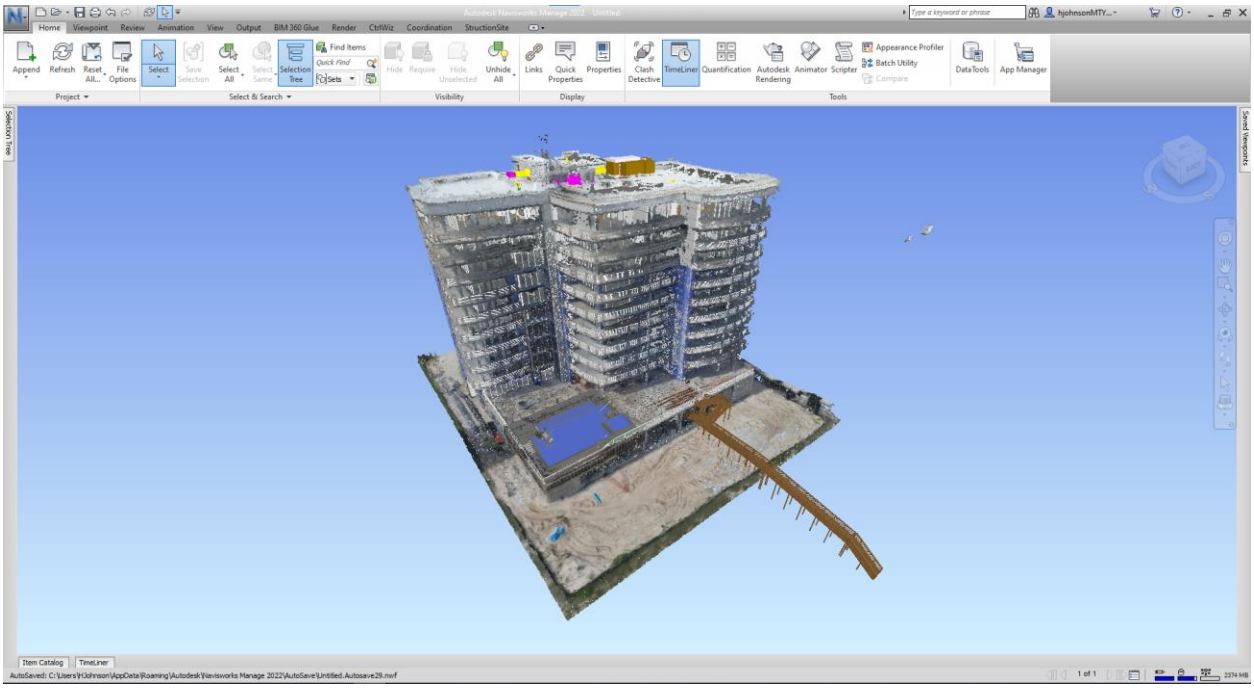
If alignment is necessary, use the measurement, units and transform, and rotate tools to bring the two into alignment. This video (although for a 3D scan instead of photogrammetry point cloud) by Faro shows the general process for achieving this: [FARO Workflow Guides - Laser Scan and Model Alignment in Navisworks - YouTube](). Also see this article on how to perform a point-to-point transformation in Navisworks using the measure tool: [To Move an Object with a Measure Tool | Navisworks Products | Autodesk Knowledge Network]()



Options Editor

It will likely take several iterations of adjustment of translation and rotation to get point cloud and BIM completely aligned. This is why it is strongly suggested to use Ground Control Points if planning on doing this comparison multiple times.

Tip: When completing the fine adjustment of the point cloud, change the point size on the point cloud to be able to tell where vertices are on model. The default point size is 1, and is very difficult to see when zooming in. Go to Options>Interface>Display>Primitives to change the point size.

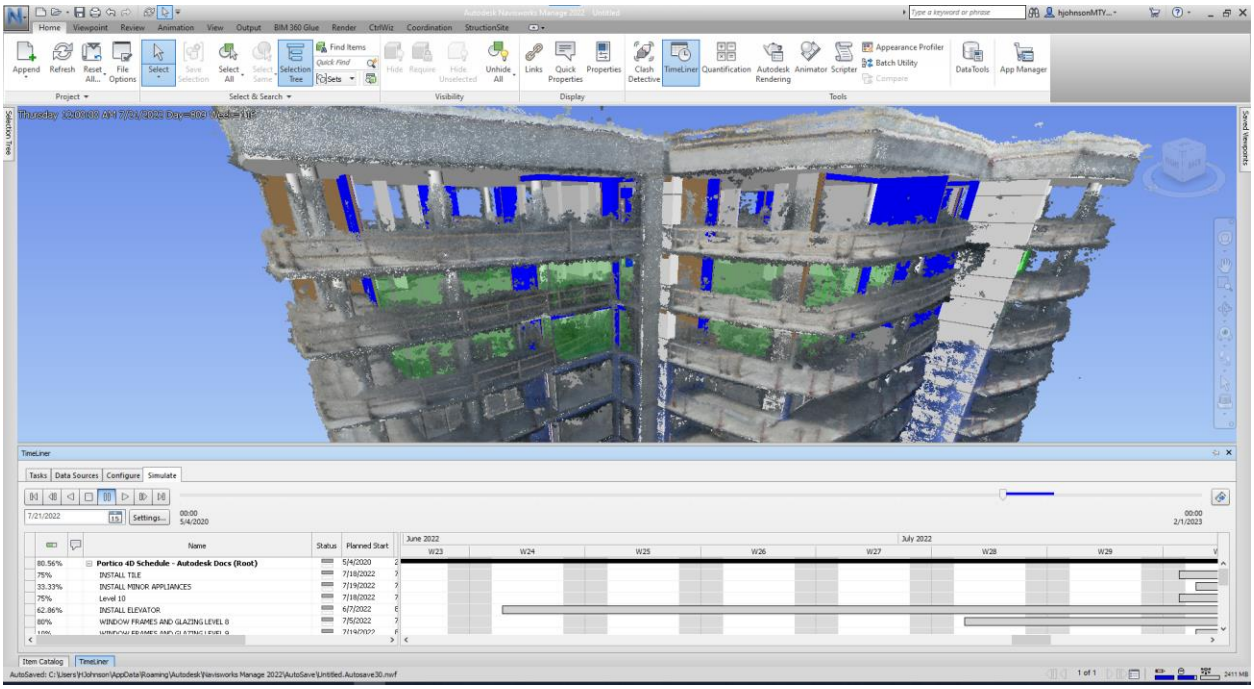


Fully-Aligned BIM and Point Cloud

4D Progress Monitoring

If a 4D schedule was created using the Timeliner tool, it can obviously also be used to check progress in 3D against the schedule once the BIM and point cloud are aligned.

Harbert tried tracking exterior framing and EIFS installation this way for the shown project, but unfortunately didn't end up having much success with this application. The project team wasn't able to find much use from the imagery, because it ended up being difficult to see the discrepancies between the plan vs actual on the wall components.



Viewing planned progress in 3D vs actual

The Harbert BIM/VDC group still thinks this is a potentially usefull application for photogrammetry, but may be more applicable for tracking progress of structural erection (steel, CIP, or precast panel) instead. We think the optimal project would be something that has a lot installation that needs to occur simultaneously or according to a tight schedule, and is difficult to track via photos alone. Tracking the application of wall panels and EIFS via comparison of standard drone images vs P6 schedule proved to be sufficient on this project.

Use-Case 4: Logistics Planning

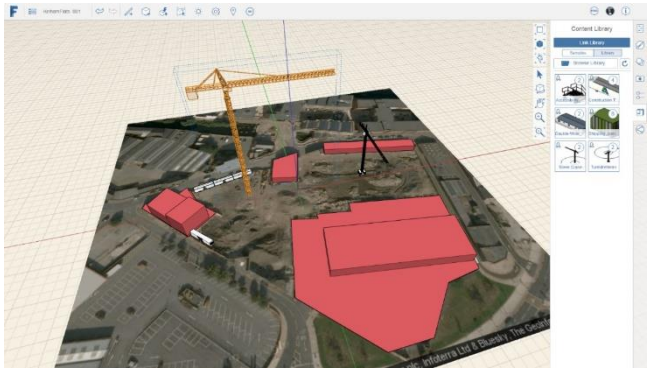
Harbert has yet to experiment with this use-case, but has future plans to. Site logistics in 3D is incredibly useful for planning out work and being able to easily see consequences of different decisions in all dimensions at once. There are multiple options for bringing elements and photogrammetry together in 3D in the AEC Collection

Navisworks

A site point cloud can be brought in in the same manner as for 3D QA/QC. Building, crane, and equipment models can all also be brought in and moved around. It has limitations compared to other options, but most personnel in the BIM/VDC world are fairly confident with Navisworks.

FormIt

FormIt has an edge over Navisworks in that 2D PDFs can be brought in for site plan reference or to use to mass model buildings. See this Autodesk Knowledge Network Article on creating Site Logistics Plans in FormIt: Expand logistics planning in the conceptual design stage from 2D to BIM | FormIt Pro 2021 | Autodesk Knowledge Network. Take notice of the photogrammetry layer added to show actual site conditions.



Site Logistics Plan in FormIt Pro

Infraworks

Infraworks is another incredibly useful for 3D site logistics, and provides the most realistic-looking current conditions of all the AEC Collection Products.

These two Autodesk University Presentations give an in-depth look at leveraging Infraworks for Site Logstics plans. The second Presentation dives into leveraging photogrammetry within Infraworks:

1) Using InfraWorks 360 for Better Site Logistics | Autodesk University – 2018
2) Using InfraWorks 360 for Better Site Logistics: Part Two | Autodesk University – 2019

There are also several other resources such as this one Connecting ReCap Photo to Civil 3D and InfraWorks - YouTube on bringing photogrammetry into Infraworks.

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Sharing with Autodesk Construction Cloud

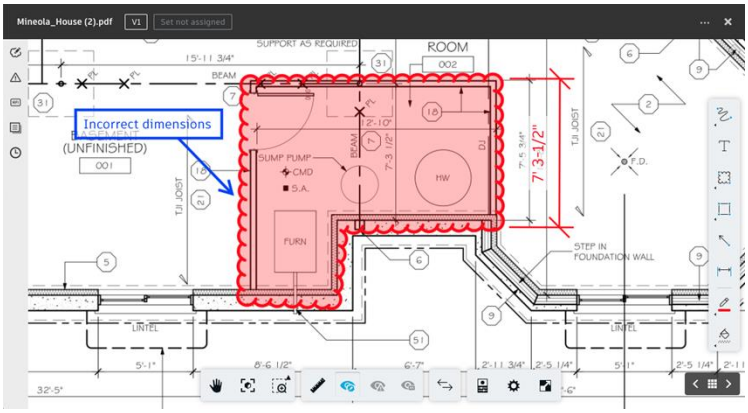
So far this session has covered several different potential uses for photogrammetry in construction (and has probably only scratched the surface), but none of the applications reviewed are very meaningful or useful if the outputs aren't shareable.

Your owners, project team, operations managers, subcontractors, and other stakeholders likely don't have access to most of the software that was utilized up until this point, and in construction, these parties are generally the parties that need to see this data the most. This being the case, a simple means of sharing the results across all stakeholders and initiating action from them is necessary. The Autodesk Construction Cloud is the tool of choice to fulfill this need. Autodesk Docs supports both 2D and 3D file formats, and also gives options to combine the two. The following sub-sections review the potential methods to share the outputs already developed and drive activity.

2D Outputs

The AutoCAD linework and images from Use-Case 1: 2D QA/QC and surfaces from Use-Case 2: Sitework Analysis are all viewable in their native formats within ACC. But at BL Harbert we've found that the data is more easily reviewable by other parties if printed to a PDF. This may harken back to the old way of doing things, but with ACC we're still able to locate the deliverables in a centralized location that is accessible by all project members. The markup and Issues functions within Autodesk Docs and Build also help to drive activity.

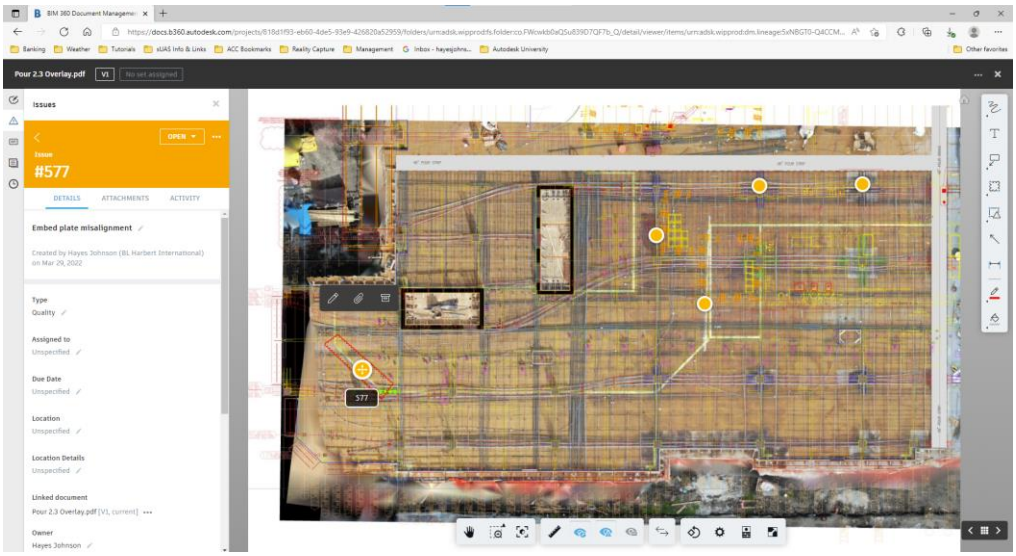
Markups



All of the common markup tools available in most PDF editing applications are also available in the document viewer in Autodesk Docs. Callouts, lines, various shapes, clouds, etc. can all be added to a document to highlight various content that needs to be reviewed, addressed, or documented for future reference. See more information on markups and how to add them at this link: Markups | Build | Autodesk Knowledge Network.

Issues

Autodesk Construction Cloud Issues are also used to call-out items that need attention, but are then additionally used to designate responsibility, add information, and link to other content within the Autodesk Construction Cloud (RFIs, Submittals, Assets, other Documents, photos, etc.). Find out more about Issues here: About Issues | Build | Autodesk Knowledge Network.



Example of Issues and Markups on Overlay in BIM 360 (same operation as Autodesk Construction Cloud)

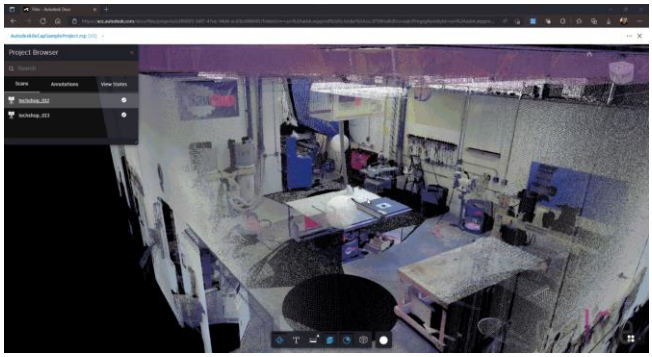
3D Content

Point clouds, mesh models, civil 3D surfaces are all viewable within the Autodesk Docs Viewer. Navisworks models also are viewable, but unfortunately once a point cloud is appended to a Navisworks model, it is no longer publishable to Docs. For the 3D QA/QC and 4D comparison, the go-to method of sharing content is still to render an image of specific viewpoints, and publish those to Autodesk Construction Cloud for Review.

For the other formats, see additional notes for each in the sections below:

Point clouds

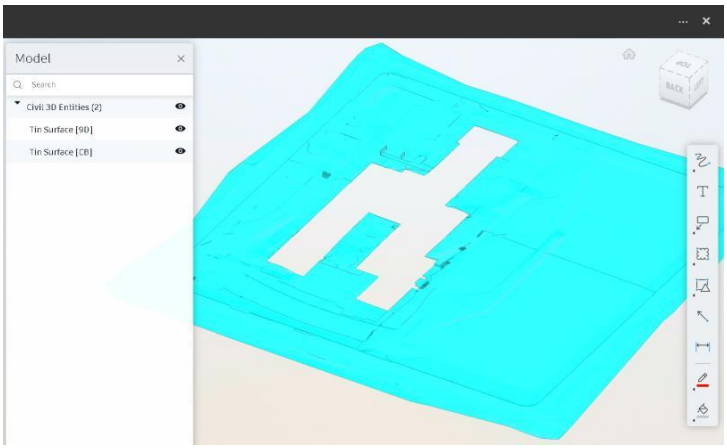
Each Recap project (.rcp) is now viewable within the web browser. If a stakeholder needs to see further information or more detail in a point cloud, they can open the project within BIM 360 or Autodesk Docs or Build and the point cloud will open in the Recap online viewer. Issues are not available in the Recap viewer, but Recap notes can be added.



Recap Online Viewer

Civil 3D Surfaces

Civil 3D surfaces are also pubishable to BIM 360 and Autodesk Construction Cloud. Althought large surfaces are not publishable. This means a surface for a full site needs to be broken up or simplified prior to publishing. See more information on publishing surfaces here: [To Publish Surfaces to Autodesk BIM 360 to Reference into an Autodesk Revit Model | Civil 3D 2021 | Autodesk Knowledge Network](#).



Example of TIN surface in BIM 360

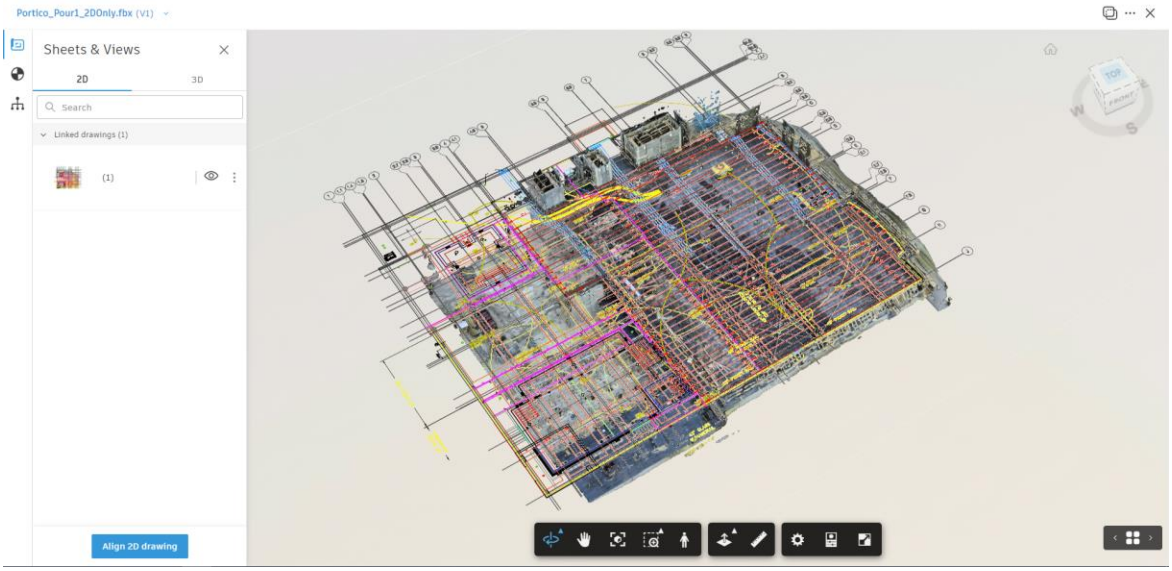
Publishing surfaces to Civil 3D is very useful as Issues can be added to them. This combines the benefit of the Issues workflow with the ability to zoom in and see more detail as needed.

Mesh Models

Recap Photo also creates a FBX file when it creates the Recap Mesh Model (.rcm). This is automatically placed in the Output folder, and is viewable within the Autodesk Docs viewer. Unfortunately however there still isn't support for issue placement on FBX models. FBX models are useful to leverage in the Construction Cloud though. They can be used in the same manner as point clouds would be, to view more detailed information side by side next to a Civil 3D surface, but they can also be used to set up a Hypermodel, the 2D overlay feature that is now a part of the Construction Cloud.

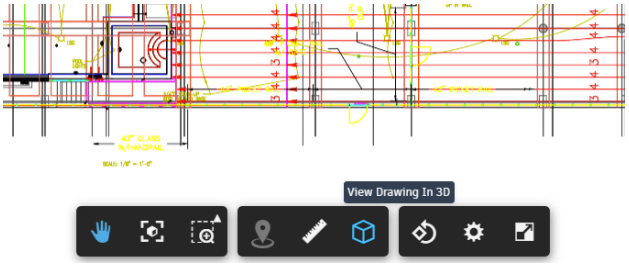
Hypermodel

The Hypermodel is Autodesk's workflow to align 2D drawings to 3D models within the construction cloud. It's useful for a number of reasons in 3D coordination and to aid with navigation between a BIM and drawings, but can also be leveraged for analyzing photogrammetry data.



2D Overlay in Autodesk Docs using Hypermodel

Because Issues and markups are not available on FBX models, the workflow to add Issues and markups to an overlay would require flipping back and forth between the model and the aligned drawing. This is possible without exiting out of the viewer though. In the 3D view, clicking on the aligned drawing will take you to it. There, Issues and markups can be added. When ready to go back to the aligned view, click "view in 3D" at the bottom of the drawing. This take you back to the model. This workflow is still a little clunky though, so Harbert has yet to use this as a replacement for 2D alignment in AutoCAD yet.



View in 3D Option in 2D Drawing Viewer

Despite the lack of Issues and Markups, some benefits to doing alignments via the Hypermodel are the following

1) AutoCAD is not required to perform the alignment. Field personnel can fly the drone, process the imagery in the cloud via Recap Photo, and perform the alignment between the FBX model and pdf drawing without the need of AutoCAD skills.

2) Additional insights can be gained by being able to rotate the view instead of being stuck in plan view only (see how content is stacked, use a different angle to identify what an object is, etc)

3) Multiple drawings can be aligned to the same model. If another comparison is desired, you aren't required to go back to AutoCAD to re-do another overlay.

Setting up the Hypermodel involves manually aligning a 2D drawing on a specified surface in your model. Note: This means a somewhat-flat control surface is required somewhere in your flight to make this work properly. For more information on setting up the Hypermodel, see this link: DOCS Help | Hypermodel | Autodesk.

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Final Thoughts/Starting Up

Aerial photogrammetry can be a powerful tool in the construction industry. There is an immense amount of data that can be collected and insights pulled by just taking photographs of a jobsite. Autodesk has included tools in the Architecure, Engineering, and Construction Collection to help pull out this data, and the Autodesk Construction Cloud is built to share this data and drive action.

There are also several purpose-built platforms for collecting, processing and sharing drone imagery and photogrammetry products (such as Drone Deploy, Pix4D, Propeller Aero, ArcGIS Drone2Map, and others) that make creating some of these deliverables easier. They require fewer clicks to get and do what you need, and because they are either entirely cloud-based or have cloud-based options, require less computing power and are usable by a more diverse sector of the company (not just VDC Coordinators). Obviously these products come at an additional cost though. So once you've determined the benefit or photogrammetry to your organization, you'll need to choose between two options:

1) Continue to use the AEC Collection and ACC to bring photogrammetry outputs into your processes.
    a. This may be because your organization doesn't want to incur additional cost, because you haven't yet found enough applications to merit the investment in an additional software tool, or your organization has a specific reason not to add anything to the tech stack.
        i. A note though: If photogrammetry becomes popular within your organization, you will likely need to invest in more manpower and hardware to speed up processes and spread out workload.

2) Invest in a cloud-based purpose-built platform to deploy on one or multiple jobs.
    a. If one or more jobs sees a need to produce photogrammetry outputs on a regular basis, and you don't have availability to meet this need, this is probably the better option. There's no need to make an investment in additional machines that can run CAD applications, and because the processing occurs in the cloud and requires fewer button clicks to complete, it can be performed by other personnel potentially.

Either way, photogrammetry should prove to be a useful asset in your organization if leveraged correctly. For that reason, you should find yourself down the road looking to justify an investment to scale you operation. There are three keys we briefly covered at the beginning of the handout that will once again be relevant here:

Key 1: Seize Opportunities

Some contractors mostly work on the same style of projects, and so the same opportunities come around on a semi-regular basis. BL Harbert International works on Federal, Commercial, and Industrial projects, and a lot of our projects are very different. For that reason, most of the above use-cases don't come up on a regular basis. For this reason, we've found that we've had to be very strategic with our timing to collect imagery and share results with project teams.

- On our Charleston job we needed to start reviewing the potential benefits of collecting as-built imagery on our concrete decks well in advance of when we started pouring the 2nd floor. As a result we had our process worked out well before the 4th floor. There we ended up with a design change after that deck was poured, and needed the as-built data to confirm there would be no issues with the new proposed penetrations to be cored. If we had started coordinating with this job after pours had started, we may not have been able to capture this crucial data.

- On our Alabama Industrial job, we coordinated with the project team and went to pick up site data as it was being turned over to us. Our superintendent had some concerns about the accuracy of the sitework, and some potential owner-directed changes that weren't captured in the design drawings or model. If we had waited any longer, we might have missed a key opportunity to show the benefit of this technology.

The point is, communicate with your jobsites, and make sure you don't miss opportunities to show how photogrammetry can help.

Key 2: Figure out what actually works for your company

There are a lot of potential uses for photogrammetry, but some just may not be hepful for all organizations. At Harbert we found that trying to track 4D progress of skin application vs a Timeliner model just wasn't helpful. The personnel weren't necessarily in place to consistently get captures, and when we did, the deliverables didn't prove to be helpful enough to justify the work. Sometimes the use-cases just may not work out. Don't continue putting effort into trying to promote a use-case that you're struggling to justify. Concentrate your efforts on improving the use-cases that are proving to be useful, and stick to those.

Key 3: Get the information in front of the right people, and show management examples from your own projects

This is where the Autodesk Construction Cloud shines. Being able to share deliverables with co-workers in different areas is crucial to being able to sell a new technology. Showing co-workers your results in your office on your own computer screen won't advance any efforts. At Harbert we find these results and examples from our own projects are the best examples to show to upper management when it comes to getting funding approved. It shows that you've spent the time and effort to get with projects teams, work with them, and deliver them something that they find value in.

In summary, keep in mind that the main objective of utilizing photogrammetry is not be the technology itself. Instead the goal is how the technology can help your people and how it can help your organization. How can you cut costs, be more efficient, and win more jobs using this? If this is your goal, and you use the available tools effectively, your photogrammetry startup will be successful.