HUNTER COLE: Hey guys, good afternoon. Thanks for joining us on this afternoon session that seems like late night. I know it's tempting to bail and hit the casino, but we're really appreciative that you decided to come join us. I'm Hunter Cole. This is Jesse Creech. We are both from Brasfield & Gorrie, General Contractors, and we are headquartered and based in Birmingham, Alabama.

So we're both part of our virtual design and construction group. I come from a mechanical engineering background, Jesse, a building science background. And we're just really honored and appreciative to be here tonight and talk a little bit about what we've been doing with unmanned aircraft systems over the last couple of years.

So with that in mind, if you signed up, I'm sure you've read the summary. We will hope to share a little bit about how to use drones to generate models and how that's impacting our construction process and BIM workflows, and kind of a two-pronged approach. We also want to share about what's necessary for your organization if you want to get started in this space. There's a lot of red tape and a lot of intricacies with FAA and insurance. And we hope to share a little bit about what we've learned.

Our objectives today-- we hope that at the end of this course, you'll be able to help your organization develop a strategy to operate drones in a compliant manner, commercially, and then become familiar, if not experts, on all the various outputs possible via drones and aerial photography. Also, we'd like for you to leave being able to plan a safe, automated flight mission resulting in accurate 3D maps and models, and then incorporate that data into your existing BIM workflows.

So about VDC at B&G, I think it helps to understand why a construction company is interested in drones if you understand a little bit about what our group does. First off, about B&G-- we're one of the largest privately held construction firms in the nation, little over 50 years old with over 2,500 employees, and over 200 active jobs. And we span the entire gamut of market sectors from building water treatment plants to the Braves' stadium and everything in between.

We're heavily awarded, number one contractor ENR Southeast, number one green contractor ENR Southeast, ABC's 2014 National Contractor of the Year. We're doing about $2 and 1/2 billion in annual work. And I just say all this to really illustrate the strength of our company and how far we've come over the last 50 years from a small regional contractor to now having

completed work in close to 40 of the 50 states.

About VDC-- if you're in the BIM world, you've probably heard of VDC, virtual design and construction. We're a BIM group, ultimately. So we touch every phase of the construction process, from marketing, assisting with rendering, to helping our precon teams estimate quantities. We help our scheduling teams with 40 schedules and animations, all the way to our safety and field operations with robotic layout, drones, everything in between, QA, QC.

So because of that, we are in a place where we get to work with a lot of emerging technologies, drones being one of them. We're also kind of reality capture experts across the gamut with a scanning group and operation in-house. AR/VR is big for us, and many other initiatives.

So why are we interested in using drones to build 3D models? Well, our group sees it as our mission to make the virtual model mimic the actual job site. So all of those technologies feed into that 3D model. So obviously drones, we can get point clouds, bring into the model, our preconstruction softwares. We're all pushing information back to a centralized model so that project teams have current and up to date information at all times and that model becomes the true source of information for an active job. And drones right now are a really good tool to help bring that content to the model.

So a little bit about drones in general-- if you're not familiar, we try to tailor this to every area of expertise or level of expertise. UAS is what we call them. We're not going to fight that battle of UAS versus UAV versus just drones. FAA goes with UAS, so that's what we've decided to stick with internally. And it's not just a children's toy but a serious tool in the right hands with the right software.

So many of you may own drones. Your children might own drones. Even with consumer level drones, in the right applications, can get really valuable data. And that becomes a great tool for construction.

So we're seeing a exponential demand for drone services on our projects, both being driven from internal, like our project teams, and external. Our clients are starting to expect and request drone-based services on our jobs.

About the industry in general-- over the next three years it's estimated that drones are going to create a $14 billion economic impact in the US alone and create 70,000 jobs. So it's a real

technology that's here to stay.

And then as of late December of 2015, Brasfield & Gorrie is officially licensed for commercial use of drones. Those that are more familiar know that as the Section 333 exemption. We were one of the first contractors in our state to get that. And we were really proud to do things the right way.

But how do they actually add value to our projects? Instant return on investment with drones-- the cost of getting started with drones has come down so much that you can really fly the thing once and pay for itself. Everybody knows they're great for high quality aerial progress photos and video. But that's really just the low hanging fruit. Of course we can do some other cool stuff in that nature like time lapse videos, quick site familiarization, hazardous area inspection, which is really becoming big for our safety teams. But when you take that further and you start creating 3D models, you get a much deeper level of project insight. So we're able to generate that point cloud and 3D mesh, be able to take measurements within that environment, quantify stockpiles, quantify area, so on and so forth. And then we can start to daily monitor our progress such as, how much earth did my site work subcontractor move yesterday? Or where are we according to schedule? And we're able to get that information real time really quickly by using unmanned aircraft systems.

So to get these models, how does that work? Many of you in the reality capture field are probably familiar with photogrammetry, big long word, really complex algorithms, basically. So by taking 2D images that are geolocated and running that through specialized software, we're able to stitch those images together based on common parameters into a 3D point cloud. Basically you can just think of it as a method to take 2D images into a 3D model.

How does the drone do that? The drone flies over the site, kind of like a lawnmower would cut grass, and take hundreds of images that are geotagged at each point with a latitude, longitude, and elevation. Than we process or register those images into orthomosaic kind of like Google Earth style, really detailed 2D images. But that goes further into digital surface models where we can start to understand the changing topography of the site, 3D point clouds, and meshes. But it wasn't always this easy and it took a lot to get here, so I would hope to share a little bit about where we've come from next.

JESSE CREECH: All right, so kind of our first, I guess, getting our feet in the water with drones and uses and trying to figure out whether or not this is something we were going to actually pursue, let me

tell you a little bit about a project. This is actually located in Birmingham, Grandview Medical Center. And it began construction about 10 or 12 years ago, and the project stalled after we completed the shell of the building due to insufficient funding and some other things.

When the project got picked back up, there were concerns with the integrity of the facade of the building. So we saw this as an opportunity to see what possibilities there were out there. So we partnered with Auburn University and Leica Geosystems and went out to the site, and actually utilized the drone to go through and take very detailed photographs at every intersection of emollients on the curtain wall, and actually used that basically as an inspection. So the value of this would be instead of having a swing stage or something like that set up and having personnel out there and setting up multiple times and having people go back and forth and manual inspect it, we we're able to fly a drone out there. And then actually we geolocated all the photos and linked them to a model as well.

So testing and challenges-- not very long after that first flight though, the FAA released new regulations and stuff and basically we were grounded. So commercial flight became a no-no for us. And we started doing testing in a controlled environment on private property and basically figuring out, what are the limitations of this technology? What can we use it for? What can we get out of it? And back then we were doing manual flights and it was very clunky and very high skill level and things like that, and we weren't getting great results out of it. So we needed to eliminate some high skill barriers and streamline the process. So along with our learning the actual technology and how to utilize it and stuff, we actually had to start looking at regulatory overview and things like that and how do we get there legally as well as the ability to fly and utilize technology.

HUNTER COLE: Yeah, so like Jesse said, we quickly realized that we were going to have to get all our ducks in a row if we wanted to start putting this on our job sites. So we wanted to share this timeline that kind of highlights, from that flight at Grandview that was sort of the eureka moment for the company in realizing, hey, drones are coming. They're coming to our jobs quick. There's real value today. What can we do to get all the regulatory pieces in place to be able to put this on our jobs as soon as possible?

So you see, we flew that Grandview job in 2014. Early 2015, the FAA released their first batch, sort of comprehensive guidelines for UAS flight where they outlined the Section 333 exemption process and what that entailed. So we were really fortunate to have in-house aviation teams and legal counsel to come in and help us write that petition to the FAA. And we filed for our

exemption in July of last year with their help.

At the same time, we were not naive enough to think that, with drones being as affordable that they are, that some of our project teams might not know all those rules that were in place. So we wanted to educate the entire company on, hey, we want to be able to use this technology, but there's a framework which we have to operate within to do it the right way. And we really wanted to do everything in a compliant and low risk way. So we actually issued a company-wide kind of stop notice on any drone flight, to contact our group so we could help set it up the right way with a licensed external vendor or do it in-house.

So around that same time, we started developing our own internal safety standards. Because like every other process on our job, from operating a forklift to anything else, we have a set of safe operating procedures, right? So we wanted to do the same thing for drones. So it's just one more piece of how our company operates. So we began working with our safety teams, with our legal teams again on drafting, hey, what's our policy going to be for drones so that if anybody asks, we have something to point to them and say, hey, here's how we do it. We want you to put this on your job, but here's what you need to know.

We actually received that exemption in December of last year. So if you do the quick math on July to December, there was a little bit of backlog with the FAA. But we were still really excited and we still felt like pioneers in that era of being one of the first companies in our state to get that. And then in January of this year, we were able to take that newly registered drone with our newly acquired 333 exemption with a licensed pilot and go fly it on one of our first projects.

So things have changed a little bit since then. So what we wanted to do for those in the audience that are curious about how to set this up at your organization is highlight a little bit about what it takes to operate commercially. Navigating all the FAA waters is still a little complex, but it's gotten a lot better from where it was two years ago. Kind of quick and dirty-- if your site is close to an airport, it might be a little bit more difficult, but not impossible. All commercial operations do still require a pilot. That's a big piece of misinformation that gets out there we've learned. But it's a different type of pilot instead of your traditional type ratings that a traditional airman would have, there's a remote pilot certificate that the FAA developed just for drone operations. So these rules took effect in late August of this year. And so we've been operating under them since.

Quick overview about what makes it commercial use. Quickly, I think anybody in this room

that's interested in taking drones back to your organization is probably going to fall under this bucket of commercial operation. Selling progress photos or video, providing contract services like surveying or hazardous area inspection, progress monitoring, things like that, these are all things the FAA has determined are commercial operations and fall under this category of regulation.

And what do we have to do to get that certificate? There are a few requirements for the pilot themselves. Must be 16 years of age. It's not on here, but I think being able to speak English is a requirement. You have to pass a TSA background check. These are all things that must be in place to earn that remote pilot certificate.

There's a few drone specific regulations. This list is by no means all inclusive. But it's got to be less than 55 pounds. So larger drones require specific exemption petitions. You've got to check the drone out each fly. There's a lot there. It can't fly faster than 100 miles an hour. And then the location of your site matters greatly as well. There are certain airspaces that are prohibited for drone use without special permission.

But kind of what's cool about the whole drone space and how fast it's moving is that we've seen the industry kind of respond with a lot of neat tools. This on the right is an application called AirMap. They have an iOS app, Android app, desktop app, where you can quickly share your location and see what airspace you're in. Is it a no go? It'll turn red and tell you that, yeah, you're not cleared for flight here. So it's made it a lot easier as companies have responded to all these challenges.

So what about when you're flying the drone itself? This, again, is no means every rule. There's probably 30 pages of documentation just for during the flight. But a quick overview, under 400 feet above ground level, daylight only, less than 100 miles an hour. You have to maintain line of sight on the actual aircraft at all times. But you can enlist the help of other dedicated visual observers to help maintain that requirement. And then a big one is not over people that aren't direct participants in the operation. And no flight from moving vehicles, although that might be more challenging than it's worth.

So with all these rules in place, kind of what can we get from it? Why is it worth it? We're going to go through some of that next.

JESSE CREECH: Thanks. So I'm going to go through some of our outputs that we get from flying these drones on our sites and just kind of a brief overview. Aerial images, videos, things like that,

inspections, 3D models-- we can do measurements from all these sorts of mosaics that we're producing, and we just do a lot of progress tracking and things like that. So the low hanging fruit this is just aerial progress photos. This is something that we would traditionally get from a large aircraft, and maybe we'd do it once a month or something like that. With project teams having access to this, they can take photos as often as they need to or want to to keep our managers that are in the office up to date with what's going on on-site.

Videos-- these are great for marketing. Our owners love to see this. And this is just kind of another way of showcasing what's going on on the job site. Most of these come with 4K cameras on it, so we get very, very high resolution and great images from these.

An orthomosaic map-- OK, so this looks like just a single photograph from a very high altitude. However, it is not. This is, I would say, probably several hundred images stitched together to create a map of a campus. And because these images are taken from a very high resolution camera, you're actually able to zoom in and see a lot of detail such as rooftop units, things like that, from this entire campus. And this is great for a lot of site logistics, planning and safety analysis and things of that nature.

Elevation height map-- so this shows you-- and this is not a thermal heat map. This shows elevation breakdown of colors. So this helps us understand from a very quick glance what exactly is going on on our site, with red being a higher elevation and blue being a lower elevation. You can see that our site is falling away to project east.

Point clouds-- so from these high resolution images, like Hunter alluded to earlier, you can actually generate a three dimensional point cloud and maneuver through it and walk through it in Navisworks or whatever other software that you're using. And the resolution that we're getting from these is quite astounding. And if you see in just a second, you can see individual studs in this point cloud. You can actually even see the power lines that are going to the site. So this is a huge tool for us as far as logistics planning, where's our equipment at, where are pedestrians at, where's parking, and things of that nature. So this is a very good way for us to get an in-depth look at the site.

So kind of the end all, be all for us BIM guys is, we have our federated model that has been coordinated. We have architecture models, structural models, all of our systems and things like that. But with that point cloud being generated from a drone flight, we can overlay that using ground control points and align it with our models, and actually track progress of design

intent versus what's getting installed in the field. And we can actually use that to monitor scheduling progress as well.

I'll just point out a little bit right here, you can see those rooftops. And then our utilities underground are lining up.

So, what have we learned as we're getting all these outputs? What are we doing with this and what are some actual real world examples of what we're doing?

HUNTER COLE: Yeah, like Jesse said, we learned a lot. And showcasing these outputs, you might be tempted to think it's really hard to get this. But the software's come such a long way. We like a product called DroneDeploy that we fly with a lot. And what you're actually seeing in this video is how simple it is to plan one of these flight missions, to get a 3D point cloud, an orthomosaic map, and a digital surface model.

So what you're seeing right now is just on standard-- sorry, I was looking at the laser. What you're seeing right now is just standard-- can you click Play real quick? It's fine if not. One second.

JESSE CREECH: One

HUNTER COLE: Here, I've got it. I got it. Sorry guys, one second. Should autoplay again. There we go.

So what you're seeing right now is just standard satellite imagery that's available from Google or Mapbox or things like that. And you can plan the extents of the site in which you're looking to map right in this web environment. It's also possible to do this on your mobile phone and tablet, Android, iOS, the whole gamut. And it makes it really simple to set up your automated flight, to map the area you're interested in.

So they give you a lot of parameters you can adjust like altitude, overlaps. So some general rules of thumb that we'll talk through later is the higher the overlap, lower the altitude, kind of the better quality model you can tend to expect. But that comes at the expense of battery life. Because as you see adjusted, there's a lot more flight paths crossing over that site, so it might take longer to accomplish that. That said, overall, we've mapped 60 acre sites, 70 acre sites, 300 acre sites in a matter of just an hour or two actually on site. So it's still very, very quick, these flight operations.

Because what's going to happen after you hit Save and Sync, you would mobilize to the site.

You'd open up the drone, power it on, sync it to your iPad, open this app, pull up this map in particular or this flight plan. And then you just hit Fly. It'll go through a handful of safety checks. And once you've conducted your preflight checklist, you can launch the drone. The drone is going to ascend to the altitude you planned it at. It's going to conduct that green back and forth flight route over the whole site, come back to x and y where it took off from and land on a dime. It's been really impressive to see how well this technology works.

AUDIENCE: [INAUDIBLE] manufacture drones?

HUNTER COLE: We're flying with DJI products. And I'll share a little bit more about our kits here in a second. But there are several other manufacturers that do the same thing.

So what do you get back? So the drone lands. You pop out the SD card, upload the images to their processing engine, which is all cloud-based. And then it's going to crunch for a couple of hours. And what you get back is this interactive map bench where you can take-- your see that orthomap. You see that elevation map. You can take measurements and make annotations all in this environment. And you can share this with the whole project team. So you can invite all your key stakeholders, project managers, superintendent, architect. The whole team can collaborate in this environment and start really sharing kind of what is that current status on the site. And those guys have insight into a job site in real time that wasn't really possible before this type of technology, at least to share it that easily.

So there's a Share button at the top. It's just like inviting someone to a Box or a Dropbox folder. And then you can begin to explore this data.

So the final result is that same 3D model which we'll load here in just a second. So this was the first job site we mapped back in January, big industrial stone cutting facility in Birmingham, Alabama. This one wasn't quite enclosed yet, so there's a little distortion on the sides of the model. But when you export the point cloud and bring that in to Navisworks or something like that, like Jesse showed, aligned with the federated model, it's a lot higher res data. So we've really enjoyed mapping with this solution and similar solutions.

So like you asked, a typical question we get is, "Hey, what are you guys flying with?" And attending other drone talks, you tend to think that big industrial operations need $50,000 or $70,000 rigs with multiple sensors and everything. We've been getting some really cool data with just standard off the shelf DJI equipment. So our fleet right now consists of DJI Inspire series drones, and even the DJI Phantom 4. Both are compatible with that app we just

showed, and both have about the same camera specifications at 4K video, 12 megapixel still images. Those that are really in the drone space might have seen they announced new versions of both of those products yesterday. So we're excited to maybe get our hands on those and start testing them and see the quality of our models continue to improve as the equipment improves.

So if I'm mobilizing to a job site to fly, I'm going to bring this whole kit, which is concealed nice in a watertight, construction grade case. This is sensitive equipment. Construction can be rough on equipment. So we try to protect our investment in nice cases. That we'll bring the drone, all the batteries we need, multiple iPads, multiple controllers. So someone can operate the camera and someone can operate the actual drones position. But you really don't even need both controllers if you're just doing automated mapping missions.

So speaking of mapping missions, what are some things we've learned? As we've done many of these now, we have kind of come across some tips that we apply for ourselves to get better results each and every time. The more imagery, the better-- I mean, there's a fine line before you're probably just wasting your time. But you want to maximize that overlap. And if you can fly lower, then do that. You're going to get a more clear imagery of the object and what you're trying to map.

But like I said earlier, that does come at the expense of battery life. So it's a balance of, what quality data do you actually need for the deliverable you're trying to execute on? If it's a flight for marketing purposes, you may not need a quarter inch resolution visibility in that point cloud. But if you do have a particular structure, like this parking deck in the center of this map-- this is actually the Brasfield & Gorrie campus in Birmingham. We haven't flown it yet, but this is just a mapping example.

So if I was interested in this parking deck in the center, I could conduct an orbit flight after the automated, kind of lawnmower-style flightpath at varying degrees of angles, 45 degrees, and altitude. So you're kind of creating multiple orbits around that particular structure. And when you supplement that nadir imagery or the straight down imagery with oblique imagery, as they call it, you're going to tend to get a better point cloud in your end result.

Bring your necessary amount of batteries. Your time is expensive. It's probably more expensive than batteries are. So don't get in a situation where you're waiting around on site to charge batteries. Just go ahead and invest in that up front. Always field verify your data before

leaving the site. We've been burned where we've gotten back to headquarters, had a corrupt SD card, had missing photos, had to go back to the job site, which may or may not have been a couple of states away, and then conduct that flight again.

So it's not the end all, be all, however. We've been really impressed to see the data we can get from it, but it does have limitations. If you're looking for accurate grade information and elevation and you've got vegetation or trees on your site, a drone's probably not the right tool. Or if you need really critical, accurate point clouds, maybe in an industrial setting, it's probably best to supplement your drone data with traditional terrestrial laser scanning data. And so we've married those two data sets together a couple of times now on a few different projects and seen really cool results when you align that point cloud from your laser scanner and that point cloud from your drone. The drone enables you to capture the whole site really quickly, in an hour. Whereas those that have laser scanned, that would take a great amount of time longer. But when those data sets are married together, that's when we start to see kind of the best 3D data for our job sites.

And then best practices for flying commercially-- like we said, this is by no means exhaustive or comprehensive. But you should definitely be doing the following as a minimum if you're flying in an industrial setting or even just any type of commercial setting. Even if you're just taking wedding photographs, I mean, you should be doing these things. You need to secure permission from the property owner. We also like to secure permission from our project teams and owners, our clients. Verify that airspace that you're going to be flying. Use those tools like we showed you. It's not that difficult to use AirMap now to get a quick go, no go before you ever go out there.

Verify the weather. You don't want to get in a situation where you're fighting thunderstorms. Being in the Southeastern United States, we battle that a good bit. So try to optimize the time you're going to be out there to combat that weather. You don't want to be in high wind or extremely bright settings or extremely dark settings. And of course rain would be detrimental as well.

Try to schedule your flight at a date or time where there's minimal personnel present. We want to send everybody on a B&G job site home as good as or better than they came into work that day. So if we can fly Friday afternoon, that might not be ideal for us, but that's ideal for our projects. And then ensure you do have that licensed pilot present and that your aircraft is registered.

So spend time with your site personnel that know that job site best to identify potential safety hazards. You've got overhead power lines that could be a hazard, tower cranes, blind spots, vertical structures. Walk the whole job before you ever even open up that drone case and try to put the thing in the air. And then once you've kind of done all these things, then plan your flight mission, because you're going to have a much better understanding of what you're trying to accomplish. And always inspect the actual drone itself for cracks, deformed batteries, things like that. You don't want to put it in the air if it's improper equipment.

So how have we been applying all these things we've learned to some of our actual jobs?

JESSE CREECH: So I'm going to talk about a couple of case studies here real quick. This one is actually probably my personal favorite. It's a very large hospital down in Orlando. And I got a phone call from a couple of our field engineers, CJ and Roddy. And they were tasked with quantifying how much dirt we needed to take off-site. And a traditional method of doing this would be basically using a total station and staking a point about every 50 by 50 feet. With a 62 acre site, that's going to take some time. And our field engineers, like their workflow, [INAUDIBLE] a lot of work. So they've got a day job being busy laying out our formwork, concrete, establishing control for our subcontractors and things like that. So this would have been a time extensive process. So they called us and wanted to know, with the drone technology coming out, was there a better, faster, more accurate way to do this?

So we went out there. And in a day, we flew the job site and got back and crunched the data. And we used control points, that you can see right here, here, and here, from our field engineers to align that with our model. So what we did is we did a comparison between the Civil CAD file for the end of the project, what the dirt was supposed to be like, and utilized that to compare against our drone data to quantify how much soil still needed to be exported from the job site.

So this is our output. On the left hand side, you can see this is the actual contour map generated from the point cloud that we got from DroneDeploy. On the right hand side, this is the cut fill analysis of how much dirt actually still needed to be exported from the site.

So like I said, we saved a lot of time, at least two weeks or so in just man hours and things like that, plus postprocessing and things like that. That really sped us up being able to just take that 3D model and export it, a topo file directly from that instead of a field engineer having to go and build that file and then do the cut fill analysis.

Another case study that we found is-- we actually have our own equipment and supply division of Brasfield & Gorrie, which supplies anything from spinning laser levels to tower cranes. And typically on a job site, we would outsource the sizing and logistics of that crane to a third party company. It takes some time. We wanted to bring that in-house and have us be responsible for the placement and sizing of all of our trains.

So we developed a parametric family in Revit that is the exact model of what tower cranes we use on our job site. And we use that and place it in our Revit models and use it to figure out how many tower sections and what are jib sections will look like for our sizing of the cranes and our radiuses and clearances and things of that nature.

Where drones play into this is we're able to fly a job site and not only look at how these cranes interact with each other, as you can see here, and the proposed building, but also how they interact with the current site. And this plays a huge role in figuring out where our assist cranes are going to come in, where our freight's going to be delivered, how this interacts with existing conditions.

So that's a building that's going to be demoed. And actually this project-- and this is over in Atlanta-- we found out that the initial placement of the cranes would have been an existing mechanical yard that is not to be demoed. So we were able to go through and figure out exactly what parameters our cranes were going to be using on this project well in advance. And this is still an actually schematic design at this point.

Another use case we've seen is actually with virtual reality. So it's a very new technology. And people associate it with video games and kind of a gimmick. Where's the actual real value in this for construction? So what we're finding value is with these very detailed point clouds, we can take and load this into an HTC Vive or an Oculus Rift or whatever and have our safety managers go and be able to walk a job site that is all the way across the country and be able to identify hazards, potential safety concerns, and things like that and get a very, very detailed and specific job site safety plan without ever having stepped foot on the job site.

So that's where we're at today. These are all things that we're doing. But what does the future hold? What are we doing next?

HUNTER COLE: So like we talked about earlier, we got our 333 exemption in December of last year. Part 107 came out in August of this year. What have we been doing since then? So we've actually used

drone systems on 19 Brasfield & Gorrie job sites in 2016 alone. And the majority of those have been since late August when the new rules enabled people like myself to go get their remote pilot's license that weren't traditional pilots.

So initially earlier in the year we were dependent on the availability of our pilots internally to come help us out and supervise when we were flying. But since then, we've been flying a lot, lot more. And we've got 10 on the books before the end of the year. So it starts to paint a picture of the exponential nature of these requests coming from internal project teams and our clients.

To that end, we've mapped over 1,400 acres of Brasfield & Gorrie job site through September. And we now have seven full time Brasfield & Gorrie employees that are also Part 107 certified. That's compared to zero in August. So you can really start to see how that's growing. And we have plans in place to go ahead and train more and more in different regions of the company over the next year.

And all this might be intimidating, you don't have to have a hundred drones to accomplish this. We only have five. Again, we see that number growing greatly over the next few years. But up until this point, that's the nature of our fleet, all DJI product, Inspire and Phantom 4 series.

And you can see just some highlights here from different projects. Like Jesse said, there's that cut and fill analysis on that health care project outside of Orlando where we got actual cubic yards. One tool we didn't even point out is, in that DroneDeploy map, you can actually quantify material stockpiles. A lot of you guys are probably familiar with this. But that's really cool when you're able to show a project manager or a superintendent, hey, you know that pile of rock out behind the job trailer? Well, there's 340 cubic yards in it left. So is that enough for you or not? And that really starts to show people the value in getting this on their jobs.

So that said, Brasfield & Gorrie has over 200 active projects. How are we going to serve all those project teams with drones? Well, we've thought about it a lot. And we think there's three methods to put a drone on a construction site, at least for our company.

In-house perform-- so somebody from our group, the R&D and BIM group can come, fly it for you, plan the mission, do the postprocessing. But that's not always most economical for a project team, especially if they want it done every week. So that's going to get really expensive with people traveling across the country trying to serve these jobs.

So let's bounce down and look at the third option that we think will be the most prominent option in our company, and we're starting to explore this a little bit today, is that our team wants to provide resources for anybody in the company to get certified. So what that means is putting together training courses and study guides and going and doing hands on training on that job site with that operator so that they can fly it as much as they need.

We still plan for the corporate office to own and control all the hardware, because there are insurance concerns. We want to ensure that every drone gets insured. We want to ensure that every drone gets registered with the FAA, and that it's compatible with the software that we've invested in. We see that it makes sense to try to control that equipment from our group.

The third option is, even that may not make the most sense for somebody who just needs a one time flight and they're in a remote location. We've built projects in Montana. It doesn't make sense for me to come to Montana. It might not make sense for somebody on that job to get licensed to fly. So we're going to have to learn how to work with external vendors, and they are a dime a dozen right now.

So speaking personally, I probably get 10 requests a week from people wanting to offer services to our company, which is awesome, because that's really going to help us, and we want to work with those guys. But at the same time if you're bringing a drone onto our job, you're really no different than any other subcontractor that's coming to maybe hang drywall or do site work in that, you're going to need to comply with our safe operating practices and our safety orientations that we would ask of any other subcontractor, along with minimum insurance protections that we would ask of any other subcontractor.

So we've worked with our legal teams to kind of develop, hey, what are we going to ask of these guys? We don't want to make it impossible for them to offer us services. But at the same time, we've got to protect ourselves and protect our employees and make sure that who we're letting on our job sites are up to the same quality as the subcontractors we'd select to build that project. So we've had to implement a lot of controls, which means making a lot of boring documentation. But it's necessary so we have things to point to and say, this is what we ask for an external vendor. This is how we operate. This is the comprehensive checklist if you want to fly a drone on a Brasfield & Gorrie job. It doesn't matter if it's me. It doesn't matter if it's Mr. Vendor. We want hold everybody to the same standard of excellence, that they would be operating in a safe manner.

So that means we've had to generate memos. We've done a poor job of educating the whole company. Like we said, we want to provide the easiest way possible for our project teams to use this technology. So we've got to do a better job of educating everybody. So we've had to issue multiple memos, just saying, hey guys, we know that you want to put drones on your job. Contact us. We'll help you out in getting it done the right way, so outlining that, hey, this is a commercial operation. There are requirements to operate this equipment.

Standardize our best practices in our safe operating procedures-- like I said, we've made a study guide in how to get your license. If somebody is interested, you can read this document real quick. It's got PDF embedded hyperlinks to study material. So somebody can just get one PDF off of Box and then go study, pass their tests, and be on the road to getting their drone. And then have worked with our aviation teams to standardize a training syllabus. So hey, if somebody does pass their test and I have to go train them hands on, what do they need to be able to do at the end of the day before we feel safe letting them fly a drone on the job on a daily basis?

So that said, how do we help that person get that drone that might be interested? Well we've set up kind of a checklist or an equipment request flow that will kind of protect us to make sure equipment isn't issued before somebody is licensed and insured. So we set that up just like somebody would request a laptop for their project or an Apple TV or a Leica total station. It's the same document. Hey, I need a drone on my job. I know it's coming up. We're a few months out. I have time to train somebody. This is how we're going to do it.

So they request that. We reach out to that would-be operator and start giving them that study content. Hey, here's how you take the test. Having taken the test, I think anybody that studies 15, 20 hours could go and pass it. You're not going to walk into it cold and pass it, but it's not impossible for anybody with zero experience with drones to study for a short amount of time and then then pass that test.

So once a would-be operator has passed that test, we'd order their equipment, assemble it, update it, register it with the FAA, get it enrolled in our software, and then insure it. So we're insuring our drones the same way we ensure our typical aircraft with the company. And this affords us a lot of flexibility in protecting ourselves if an accident were to occur on one of our jobs.

Once all that's in place, we'd schedule time for somebody from our group, like myself or Jesse,

our regional drone leads in other officers to go train that person and get hands on flying time, because it is possible to get that blue and green license card without ever having flown one of these. And that would not be a good recipe for putting a drone on a construction site. So we want to train people how to scout your lookout point, how to be aware of what the tower crane is doing and how to communicate to those involved on the radio what you're planning to do and check in and check out on the job and so on and so forth, and really make sure they fully understand everything that's involved with flying a drone on a construction site.

After all that's complete, that operator would then be set up, hopefully, to fly that drone on their job site as much as they want and start generating those maps. And that's what we're excited to see next is just once we start doing these point clouds weekly or monthly and being able to monitor progress and change over time, change analysis-- that will be the next big wave in the software has been able to just report how much earth has changed. Instead of having to do a bunch of analysis and third party applications, it's just going to be able to tell us with a heat map deviation report.

So how do we track it and maintain traceability in this equipment? We really didn't want to reinvent the wheel here. Anyone in the construction industry is definitely familiar with the hardhat sticker. It's kind of a rite of passage or a badge of honor. So we wanted to kind of honor that and not try to do something totally different. So if somebody passed their test and they have their FAA certificate, then we're going to issue them a hardhat decal. Just like their OSHA 30 hour sticker, we're going to issue them an approved drone operator sticker.

And same thing with the hardware itself. We want a quick and easy way for our field teams to identify, hey, this operator and this drone is legitimate, or hey, it potentially might not be. You need to ask some more questions. So this is hopefully just going to provide a better level of understanding for everyone to identify and separate legitimate drone operations from potentially illegitimate drone operations.

We've been talking a lot about how it's going to scale in the future. And we think we're starting to get a better idea of what that's going to look like. These new rules that came out in August have added a lot of flexibility for us at B&G, as you've seen, as we've flown more and more jobs over the last few months. So that pilot requirement changing really helps us out. We're more flexible in the airspace we can operate in. They're provided channels for us to request flying in areas that may be more congested, like bigger urban areas. There are easy ways to request that exemption online now.

And then the next generation of technology is going to be equally as impressive. If anybody's followed drones for some time, you've seen what we bought last year as the top of the line system, the better system now is a fifth of the price in this size and has nearly all the same specs, if not more. So it's moving really, really fast. And we're going to see things come soon like object tracking and machine learning where the software is going to be smart enough to identify that excavator and its exclusion zone and that guy over there that's maybe down in a trench and his exclusion zone. And when those things line up, it's going to send a notification to somebody in the job trailer that, hey, we might have an accident we need to go check out and prevent it before it happened. So that stuff is not far away.

We're going to see more and more sensors come onto these drones. Thermal's huge right now in ag. It's making its way to construction. We haven't done a lot with it so far, but we've seen some interesting case studies with building envelope confirmation by thermally scanning and producing a 3D mesh that's a thermal heat map and being able to confirm that building's envelope for LEED certification and things of that nature. So that will be a huge application we look to get in to. LIDAR sensors are becoming affordable and small enough now where they'll be mounted to these consumer level drones soon and produce even more rich point clouds.

So with all that in mind about how much it's changing, if you're heading up your drone organization or starting it from scratch, keep it fluid. Don't get caught up in the analysis paralysis, thinking everything has to be concrete and set in stone. Definitely make an effort to do things the right way. But don't write 300 pages of internal documentation about the regulations because they'll probably be different next year. Same with the technology.

What's cool about working with drones is the finish line is pretty obvious. We have over 200 active projects. It makes sense that we'll have over 200 drones on those projects. In two or three years, we want to set our organization up to do that in a controllable and scalable manner and that we don't make it harder on ourselves in the future. So we want to set it up the right way now.

But we look forward to that future because our goal is to just give all stakeholders involved in the construction process a new level of insight to what's going on our projects and make everyone feel like they're actually there so they can participate in the decision making. Whereas construction is typically, you have to be there to participate. And drones help remove that burden a little bit.

So that's where we think it's going. And we hope that you learned a little bit about what we've been doing the past couple of years. We haven't claimed to be the total experts. We're really humbled to be here and get to present on it. But hopefully you learned from what we've learned ourselves over the last couple of years.

So I think we do have a little bit of time for questions at this point for anybody that might want to come ask a question about one of the case studies that Jesse talked about or our organization and our policies.

AUDIENCE: I was just wondering, with the mass amount of data that you're gathering, how you guys are managing that?

HUNTER COLE: Yeah, it's a great question. So that's what is really attractive about the cloud-based solutions like DroneDeploy is, I can upload those image sets. The question real quick-- I meant to repeat-- is he asked how we're managing the burden of large amounts of data that we're having to track and keep up with. And just bouncing back real quick, I said that that's what makes these cloud-based solutions really attractive is we can upload those image sets. They're stored. They're backed up. And they're there to share with the whole project team.

So that's been a burden we've faced in other parts of our workflows, like laser scanning, that we have these massive footprint, gigabyte level point clouds that makes it really difficult to share that information, especially across the organization or across different offices, where, if you've got a cloud-based solution, it's really easy to share that. So if it's images and videos, we've been just using our internal enterprise Box accounts for that so we can share easily with project teams. Do you have any other thoughts?

JESSE CREECH: Just the fact that it's so scalable. So any person, any stakeholder in the project can be added very easily to a DroneDeploy account for a project. So it's very specific, however exactly you want to set it up, much like we used Box. And whoever is added to that project can access it from anywhere they have an internet connection.

AUDIENCE: Have you ever crashed a drone and caused property damage?

HUNTER COLE: Fortunately no, we have not yet, thankfully. So we've got a good track record, much like B&G has a great safety track record overall. We've tried to echo that and imitate that in the drone space. And we're really fortunate not to have an accident yet.

The technology has come such a far away with all the fail safes that are built into it, it's claimed that you can take that controller and just smash it and cause a total loss link, and the drone already has the waypoints from where it took off from and its distance from there. So in theory it's supposed to come back and land on a dime even if the link to the controller was totally severed. We haven't tested that yet. We haven't attempted to destroy any of our own equipment.

AUDIENCE: DJI [INAUDIBLE]?

HUNTER COLE: That's what we've been flying with. So I can only speak to what we're experiencing with. But yeah, they've become really stable and reliable.

AUDIENCE: Can you give a scale about approximately how many flight hours you guys have?

HUNTER COLE: That's a great question. 1,400 acres-- I don't have hours. They're in logs that I could go tally up for sure. I would estimate 60 to 100 in our group.

AUDIENCE: Have you guys ever gone around the requirement or the restrictions [INAUDIBLE] fly over long distance, if you're trying to capture a site in an urban area?

HUNTER COLE: Great question. And I'm not a member of our legal team, so I don't want to speak too in depth to what they would want me to say or not say. But I will say that through conversations about that, that we have determined that people on our sites are contractually participants in our construction operation. But we definitely make an effort not to leave the extents of our property. Because you're right, if we're in an urban area like Atlanta or Birmingham or something, you can encroach upon sidewalks where you might have pedestrians.

So that's where we err on the side of caution when we're planning those maps and pull those extents really far inboard of any roadways or pedestrian ways to avoid that. So no, we make sure not to fly over the head of people that aren't involved in the construction of our projects.

AUDIENCE: Have you confirmed that with the FAA?

HUNTER COLE: Confirmed what part?

AUDIENCE: Your construction [INAUDIBLE]?

HUNTER COLE: I don't think they've added any information to that yet.

AUDIENCE: Can you talk about cut and fill analysis workflow and what was the software that you used [INAUDIBLE]?

JESSE CREECH: So the workflow, the software that we use for that specific project, we actually brought it in and used Pix4D to bring our ground control points and align it with the actual coordinate system that our field engineers were using on-site. So we'd run an analysis of that and constrain all the points in that software. And then we actually confirmed it by having our field engineers go back out and take a bunch of as-built shots in an x and y location and check the elevation against, like using ReCap. Once you constrain that point cloud to whatever coordinate system you're using, you can literally hover over a point and it'll tell you exactly x, y, and z, where it's located. So that was our gut check for that was to have them go in as-built and then check ours against it.

Further beyond that, you can export a 3D topo map, a CAD file, basically straight from Pix4D. And then for the cut and fill analysis, we used an estimating software that we use. It's called AgTech. And it'll basically just take your design versus your existing CAD files and do an overlay and then do a volume analysis, between the two.

AUDIENCE: Do you guys do that more frequently, more frequently in [INAUDIBLE] basis or [INAUDIBLE]?

JESSE CREECH: That was kind of a one time deal for that that one project. Moving forward though, it's becoming more of a request from our field teams to be able to do that.

HUNTER COLE: I was going to add to it, we did do it again on a site in Lexington, Kentucky a couple of months after that flight. And then I did get a request earlier this afternoon from a project team that wants to do it again. So I think it will be much more frequently a part of our operations.

AUDIENCE: What's the file format of the scan from Done-- is it DroneDeploy? Is that a ReCap file?

HUNTER COLE: They export in XYZ or LAS. So you can bring the LAS into ReCap and then generate your RCP and RCS to take it to the Autodesk suite. So that's kind of been our workflow so far.

AUDIENCE: Do you guys ever take meshes, like [INAUDIBLE]?

HUNTER COLE: So they actually-- DroneDeploy makes the mesh and posts to Sketchfab as part of their standard process. So you have that ability to go and download that mesh in the format of an OBJ file. Which then you can do some cool things with VR. That's how we bring it into the Vive and things like that is through that OBJ mesh format.

AUDIENCE: Is the mesh really clean or do you have to do a lot of post [INAUDIBLE]?

JESSE CREECH: That's very dependent on the quality of your flight and elevation and how much overlap you do and all that kind of stuff. So that was one of our lessons learned is obviously the lower the altitude and the more overlap you get, the better your point cloud and your mesh is going to be, absolutely. And a lot of site conditions too-- if you've got a lot of trees and things like that, you can have like a draping kind of a mesh.

HUNTER COLE: I will say that sometimes we might get a mesh that might be disappointing. But if you can supplement that particular area of interest, if we were flying a building the size of this conference room right here, those orbit flights at different angles, lower, that imagery directly to the side of the building. We even did a flight one time on a campus in Birmingham where we took the drone physically in our hands after it was landed and went around and took additional photos. The drone was still powered on so it's still geotagging those images. And so we really take pictures looking up underneath canopies, behind columns, things that weren't visible. And that definitely improved the quality of the finished mash. Yes sir?

AUDIENCE: I've heard about this feature in some of the apps where you can program it to do multiple passes and angles [INAUDIBLE] vertical. Have you experimented with that to get better results?

HUNTER COLE: Yeah, absolutely. I think you're speaking towards the Pix4D mapper app does that. And you can tweak that. And I know there's three or four apps right now that are all basically doing the same thing. They're competing with features here and there. And yeah, that tends to produce a better result. But the roadblock with Pix4D that we see is just the ability to share the data easily until they get kind of a more robust, kind of cloud-based solution.

So if it just lives on my laptop, it's really not that valuable for the project team. Or it's not as valuable as if they could get into and work with it, really simply and easily.

AUDIENCE: So you're just kind of using that nature because the apps that you're using don't have it and don't [INAUDIBLE]. And the ones that have the feature don't share with [INAUDIBLE]?

HUNTER COLE: It totally depends on the deliverable requested I think. If we were going to go and do another cut and fill analysis, that might be a good time where we would use that multiple flights at different orientations and different angles because we really are going to be making a critical decision off of that data. So we absolutely would probably want to supplement the quality of

that map.

AUDIENCE: For smaller companies that don't have a legal team, do you have any specific errors that you would recommend for drafting that safe standards guidelines before [INAUDIBLE]?

HUNTER COLE: And just in the spirit of full transparency, don't overburden yourself with trying to come up with all this stuff from scratch. Sorry, we're supposed to be repeating the questions. The question was, how would you manage to implement these policies or create these policies without the help of a legal team?

There's so much great content online. That's where we learn about the most. A really good one is J. Ruppercht Law blog. He's an attorney and an ex-pilot that provides a lot of legal commentary in the drones space. And we've learned a lot from him as a resource. And there's just tons of other guidelines and webinars and things of that nature. So that's what's cool about the space is it's moving so fast that there's tons of content out there.

AUDIENCE: You mentioned earlier about combining laser scanning with the drone scan. I assume you could combine the interior of a building with the exterior?

HUNTER COLE: Sorry, could you repeat the question?

JESSE CREECH: So he was asking, combining, supplementing drone data with terrestrial scanning, right? So you wanted to know, we're combining the interior of the building with the exterior from the drone? That's absolutely correct.

And so what we would do is have the same control that we were using for our ground control points from our drone data, and basically bring that inside and use black and white targets or spheres or whatever else so that those actually line up correctly once we bring them together. Yes?

AUDIENCE: How are you controlling tolerances?

JESSE CREECH: As far as?

AUDIENCE: From photogrammetry versus the laser scanning. Are you visually aligning or site control?

JESSE CREECH: No. So it depends largely on the project. If we're doing something like crane logistics or something like that, the tolerances aren't as important. We're just getting rough ideas of where we're at. But if we're doing something like cut and fill analysis, we actually will have a field

engineer or whoever on site to establish control. And that's how we utilize that. We constrain that drone data to our control.

HUNTER COLE: Maybe you can tell him a little bit about the markers that you made and used on Apopka and how you shot those in and how Pix4D recognizes that.

JESSE CREECH: So you ground control points, the way that I think most aerial surveying companies do it is kind of a 4x4 or something like that, just a piece of plywood or a flag or whatever else with an X in the middle of it or some kind of unique identifier. So we're able to go through there and in Pix4D zoom in on maybe even 20 photos that capture that same ground control point, and zoom in and hit the dead center of that, and then constrain-- once it's crunching and creating the mesh or all the points from those photographs, it knows where that point is on all of those photos. So you do that several times throughout the job site and it locks in all that control. Does that answer your question?

HUNTER COLE: Yes sir?

AUDIENCE: There's also that capability within ReCap, right? Is there a reason why you guys choose to use Pix4D as opposed to ReCap for that particular workflow of getting ground control points?

JESSE CREECH: So you can go in post, or I guess after the fact, go in and constrain your point cloud in ReCap. Pix4D was the software that we used actually for photogrammetry to stitch all those points together. And that was just inherent the process. Before we actually went through and created the point cloud, we constrained all the photos where they needed to be. So once it went and crunched all the stuff, it was already on our control. But yes, you could retroactively do that in ReCap.

AUDIENCE: [INAUDIBLE] drones versus using a regular GPS [INAUDIBLE]? I guess that's what your accuracy you need for your projects. Have you ever had your other projects that need higher accuracy than [INAUDIBLE] 2K?

HUNTER COLE: Well I was going to add that it depends on the deliverable again, the decision we're trying to make from the drone data. If it's an actual construction decision that's going to impact dollars and cents on the job, we're absolutely going to use ground control and remove that deviation that would be associated. Because yeah, you don't want to depend on DJI's internal GPS system to make cut and fill decisions and things like that. So if we're setting up a job that's going to be flown repeatedly for monitoring volumetric changes, we're absolutely going to link

to ground control on every one of those flights. And Pix4D does it really well. DroneDeploy has that as a feature now where you can incorporate GCPs and get that precise same alignment every time.

JESSE CREECH: And I think speaking to the accuracy as well, so going back to our Apopka job, the hospital cut and fill analysis, the logic being that, yes, OK, the photogrammetry is not as accurate as, say, using a total station and things like that. However, the difference being that where we may have an inch or two of play here and there and the elevation differences like that, its much better because we're generating millions of points as opposed to just a 50 by 50 foot grid. And all that in between is just kind of a guess almost when you're creating a trimesh or whatever from those points and as-built a new CAD file. So it may not be as accurate at that one point, but we're having a much more complete picture of what all is happening on site.

AUDIENCE: Does anybody have a need to do any night flights?

HUNTER COLE: We haven't yet. I could see it being a request soon. A lot of times for temperature reasons we pour concrete at night. So if we wanted to monitor the progress of that or as built reinforcement that was going in before the pour, that request might come soon. But we haven't done it yet and we haven't put in that exemption request thus far.

AUDIENCE: [INAUDIBLE] FAA regulations?

HUNTER COLE: Yeah, they have a nice landing page. If you haven't seen it yet, if you just Google FAA UAS, it comes in and it's one of the main hyperlinks on the right, how to request a waiver or an airspace authorization. It's all in digital form on their web site now.

Well I think we're down to under a minute. We might have time for one more question. If not, we'll go ahead and wrap it up.

All right, well thanks guys. We'll be up front if you need to talk to us. We appreciate you letting us come and talk.

JESSE CREECH: Thank you.

[APPLAUSE]