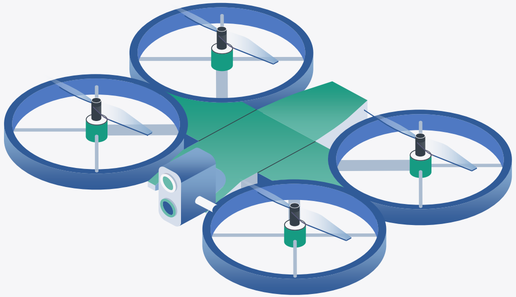

DRONES
In Construction

By Chris Carrino

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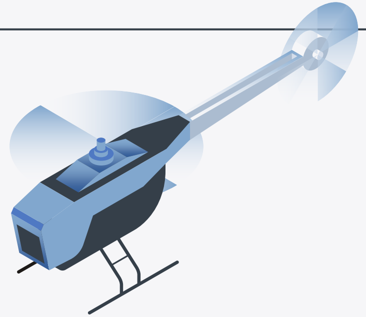
01

INTRODUCTION

My Qualifications



Reality Capture

My reality capture experience began with aligning point clouds captured using terrestrial LiDAR in Cyclone 360, specifically for pre-tensioned bridge cables and MSE walls.

Flight Time

I've been flying drones to create orthomosaic maps for the past five years and have been FAA Part 107 certified for three of those years.

Field Work

Spent two years on-site at Viera Middle School capturing 100 GBs of data, thousands of photos, and producing weekly orthomosaics using RTK and Ground Control Points.

Viera Middle School

02

Photogrammetry & LiDAR

WHAT SHOULD YOU KNOW FIRST

Photogrammetry uses overlapping images captured by drones or cameras at different angles. Specialized software identifies common features across these images, calculates spatial relationships using triangulation, and reconstructs a detailed 3D model or orthomosaic map. Accuracy improves with high-resolution imagery and ground control points (GCPs)

LiDAR (Light Detection and Ranging) emits laser pulses from a sensor (often mounted on a drone or vehicle). These pulses reflect off surfaces and return to the sensor, with the time delay used to calculate precise distances. Millions of such measurements form a dense "point cloud," representing the environment in high detail, including vegetation, terrain, and structures.

Photogrammetry

Photogrammetry is the science of extracting accurate measurements and 3D data from photographs, typically taken by drones, aircraft, or ground-based cameras. In construction, it's used to create **3D models, topographic maps, volumetric measurements**, and **orthomosaic images** of job sites.

How It Works

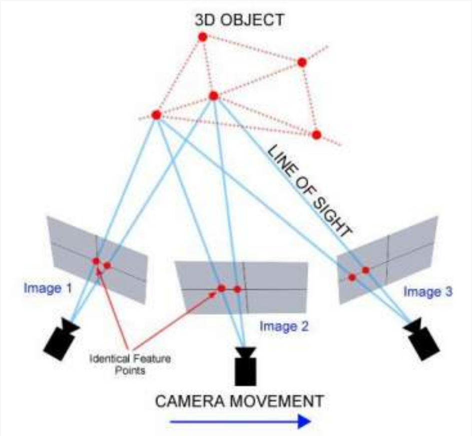
1. **Image Capture**
   A drone or camera captures **overlapping images** of a site from multiple angles. For drone-based photogrammetry, this usually means flying in a grid pattern with about **70–80% overlap** between images.

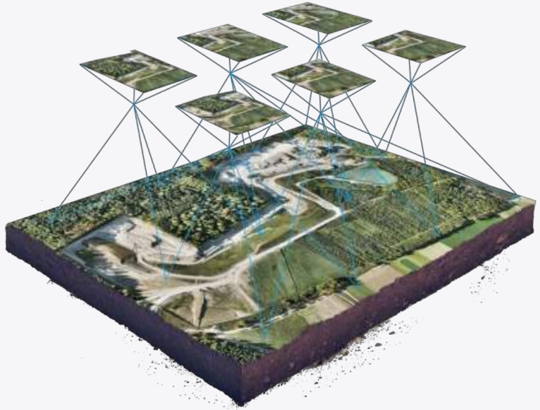
2. **Feature Matching & Triangulation**
   Software identifies common features across images (e.g., edges, textures, objects). Using principles of **triangulation**, it calculates the position of these features in 3D space based on the camera's position and angle during each shot.

3. **Point Cloud Generation**
   The triangulated features are used to generate a **dense point cloud**, which is a 3D representation of the site, similar to what you'd get from LiDAR.

4. **Model Reconstruction**
   The point cloud is used to create **meshes, textured 3D models**, or **2D orthomosaic maps**—high-resolution, geometrically corrected images that align with real-world coordinates.

5. **Georeferencing (optional but recommended)**
   To increase accuracy, **Ground Control Points (GCPs)** or RTK/PPK-enabled drones are used to anchor the model to real-world coordinates. This makes the data reliable for measurements like **cut/fill volumes, distances, and area calculations**.

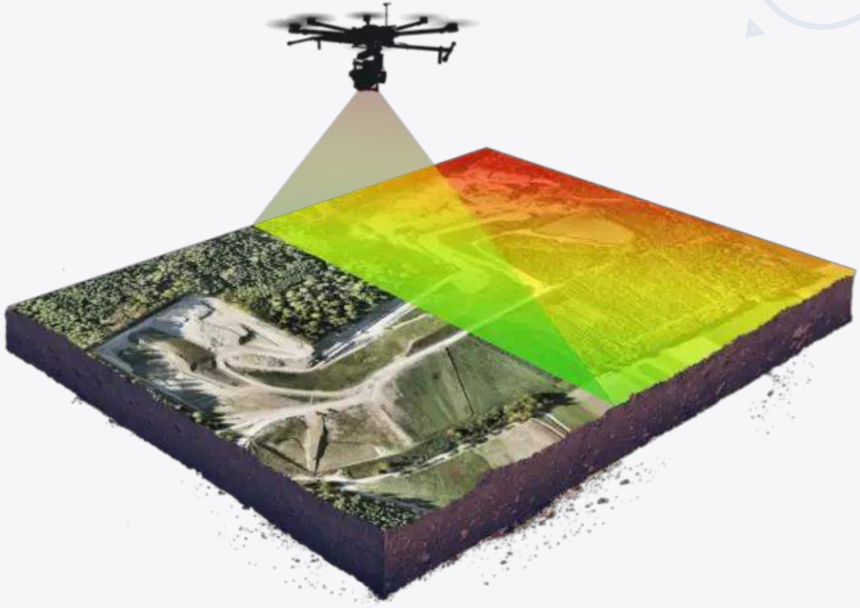


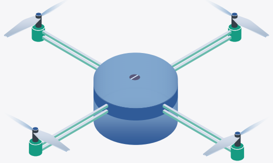


LiDAR

LiDAR (Light Detection and Ranging) is a remote sensing technology that uses laser pulses to measure distances to the Earth's surface. A LiDAR sensor sends out thousands of laser pulses per second; when these pulses hit an object and bounce back, the system calculates the exact distance based on the time it took to return.

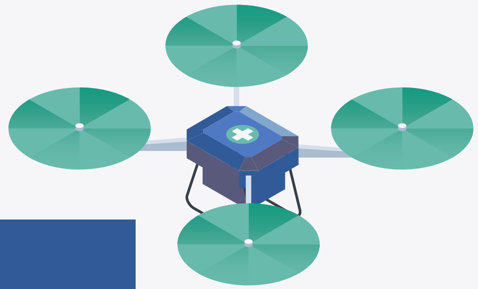
The result is a highly accurate **3D point cloud** representing terrain, structures, and vegetation. In construction, LiDAR is used for **topographic mapping, volume measurements, and as-built documentation**, especially in areas with dense vegetation or complex surfaces.





Feature	Photogrammetry	LiDAR
Produces Orthomosaic Map	✅ Yes – True orthomosaic with high-res imagery	❌ No – LiDAR doesn't capture imagery
Point Cloud Accuracy	Moderate to high (especially with GCPs or RTK/PPK)	✅ Very high, sub-inch vertical accuracy
Penetrates Vegetation	❌ No – Surface-level only	✅ Yes – Can capture ground beneath trees/brush
GCP Requirement	Often needed for high accuracy	Not always needed if using RTK LiDAR
Cost	💲 Lower – Affordable drones and cameras ($2,000 - $12,000)	💲💲💲 Higher – Expensive sensors, heavier drones ($15,000 - $250,000)
Flight Time & Planning	Longer due to image overlap (70–80%)	✅ Faster – Minimal overlap needed
Lighting & Weather Sensitivity	❌ Sensitive – Needs good lighting & weather	✅ Less sensitive – Works in varied light/weather
Visual Detail	✅ High – Photo-realistic imagery	❌ Limited – Pure geometry unless paired with camera
Software & Processing	Widely supported and easier to use	Requires specialized software and more processing power
Use Cases	Site documentation, progress tracking, orthomosaics, basic topo	Topographic mapping, terrain under vegetation, detailed elevation models

Questions So Far?



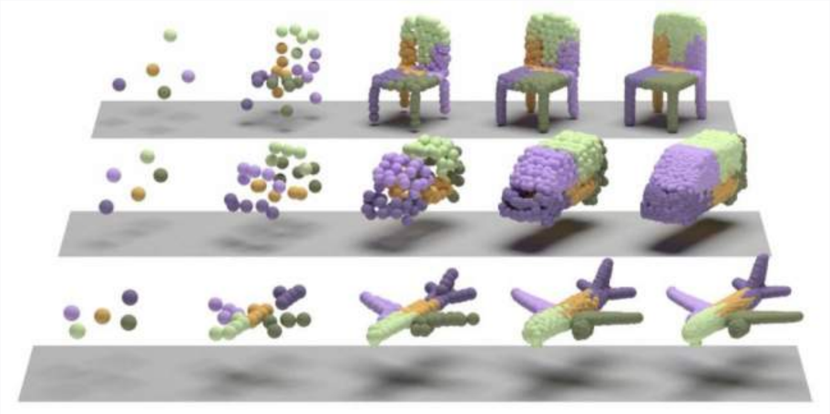
03

Point Clouds & Orthomosaic Maps

Point Cloud

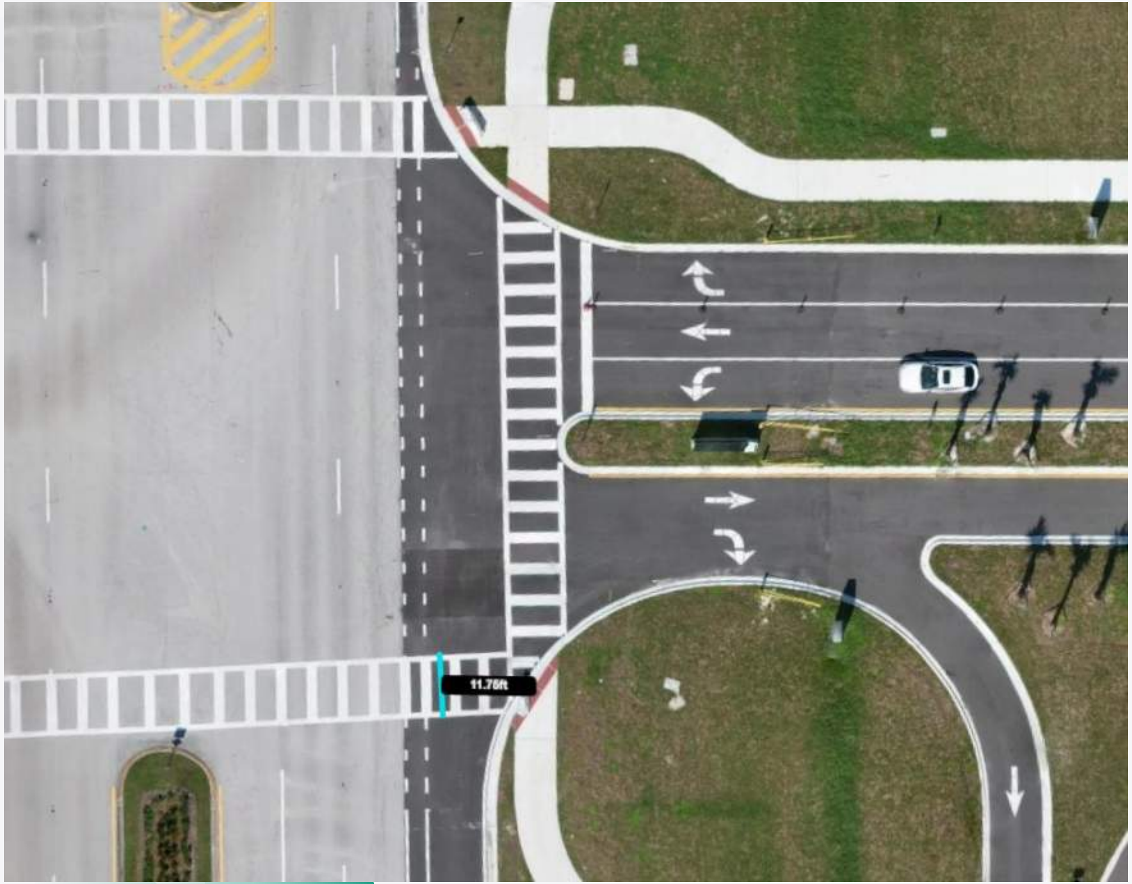
A **point cloud** is a collection of millions of individual points in 3D space, each with precise X, Y, and Z coordinates. These points represent the shape and surface details of objects or terrain in the real world. Point clouds are generated from **photogrammetry** (by matching features in overlapping images) or **LiDAR** (by measuring the time it takes for laser pulses to return).

In construction, point clouds are used to create **3D models**, perform **measurements**, and support **as-built documentation** or **progress tracking** with high spatial accuracy.



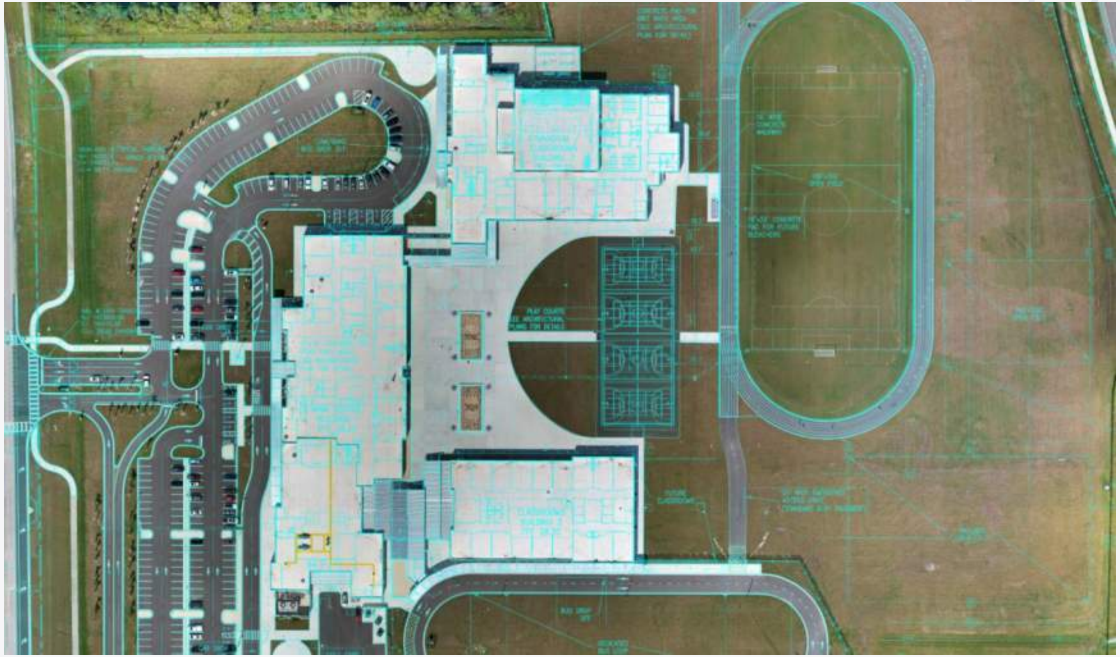
Applying a Mesh

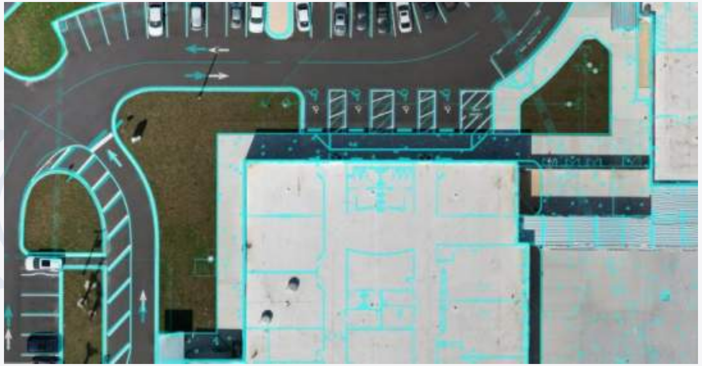
A mesh is a 3D model made up of connected triangles or polygons that form the surface of an object or terrain. It's created from a point cloud by connecting nearby points to define shapes and surfaces. Meshes provide a smoother, more detailed visual representation than point clouds and are often used for rendering, measurements, or creating realistic site models in construction.

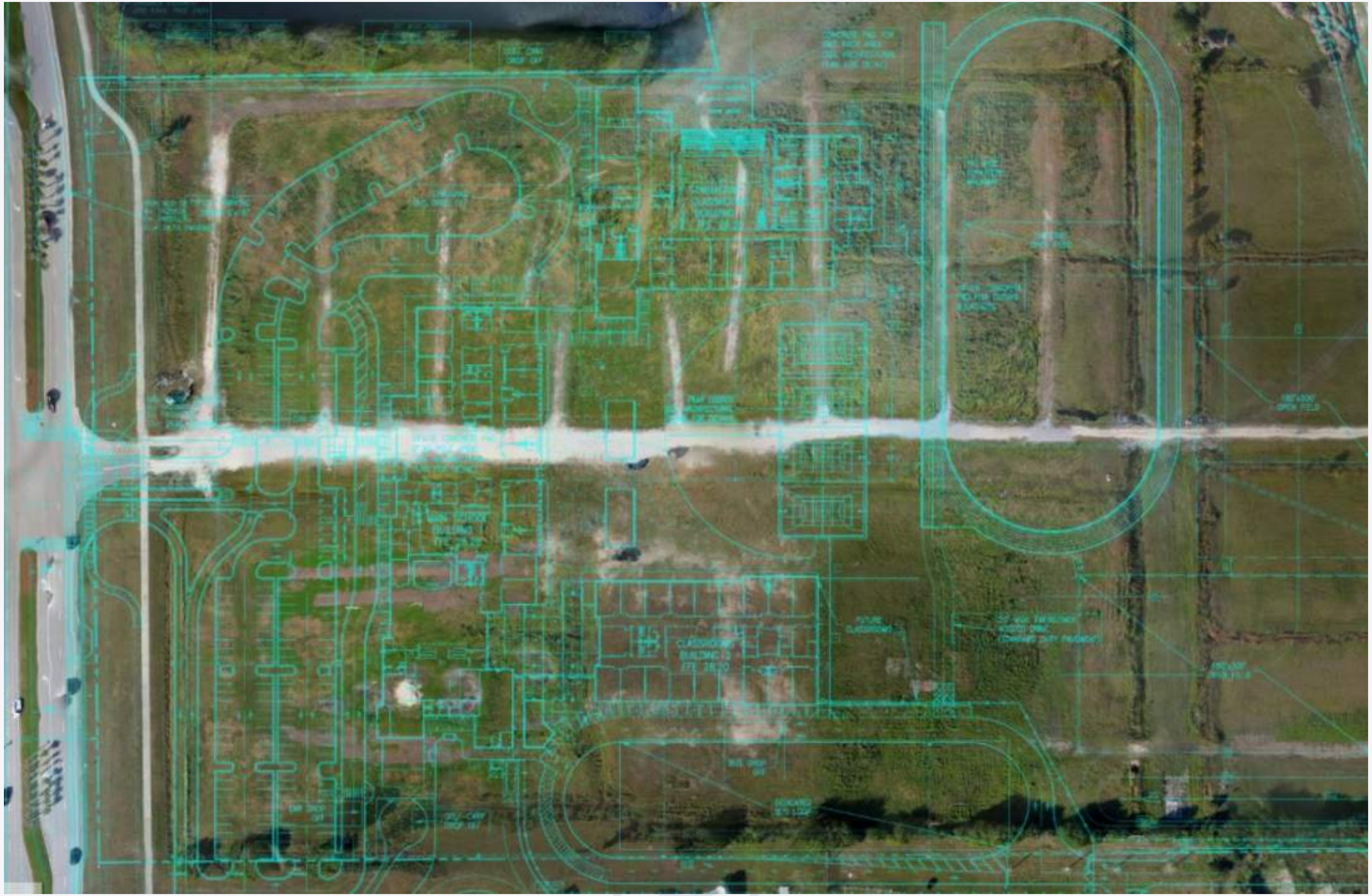


Orthomosaic Map

An **orthomosaic map** is a high-resolution, geometrically corrected aerial image made by stitching together many overlapping photos taken by a drone. Unlike regular photos, it's **scale-accurate** and aligned to real-world coordinates, so you can **measure distances, areas, and positions** directly from the map. It's commonly used in construction for **site planning, progress tracking**, and **documentation**.








BUILDING
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04

Accuracy

What is Accuracy?

1. Absolute Accuracy

- Refers to how accurately points in your model align with **real-world coordinates** (like a survey benchmark or known GPS location).
- It's essential when your model needs to tie into **site plans, property boundaries, or engineering data**.
- Example: If a corner of a building in your point cloud is off by 50 cm from its actual surveyed location, that's a **50 cm absolute error**.

2. Relative Accuracy

- Measures how accurately features relate to **each other** within the model.
- For example, the distance between two points on a road in your model may be correct (say 30 meters), even if the entire model is offset by a meter.
- This is often sufficient for **progress tracking, earthwork volumes**, or **visual reference** if precise coordinates aren't needed.

Photogrammetry Accuracy

🛰️ Drone & GPS
Use drones with RTK or PPK for centimeter-level geolocation.

Inaccurate GPS = distorted models or misaligned point clouds.

📷 Camera Quality & Calibration
High-resolution cameras capture more detail per pixel.

Proper lens calibration corrects distortion and improves 3D reconstruction.

🗺️ Flight Parameters
Altitude: Lower = more detail, but slower coverage.

Overlap:

75–80% frontlap

70–80% sidelap

Consistent speed reduces motion blur.

📌 Ground Control Points (GCPs)
Anchors model to real-world coordinates.

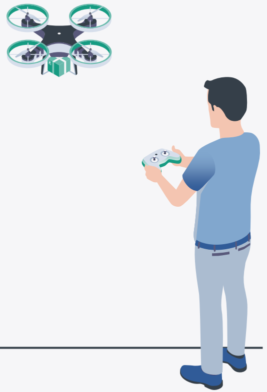
Strongly improves absolute accuracy (±1–3 cm typical).

⛅ Environmental Conditions
Good lighting = better image clarity and feature detection.

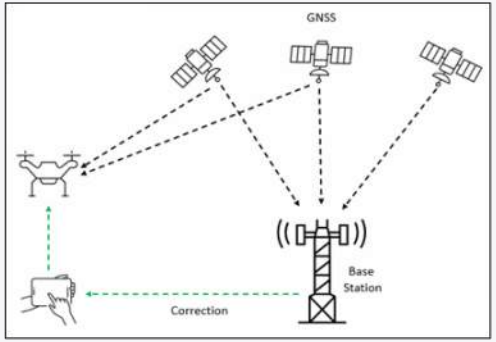
Avoid high winds, shadows, rain, or glare.

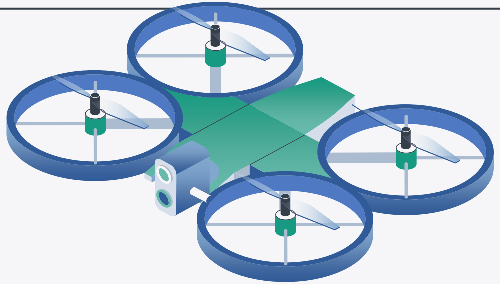
🧱 Surface Characteristics
Shiny, dark, or uniform surfaces can reduce matching accuracy.

Textured, varied surfaces yield better reconstruction.



RTK & PPK



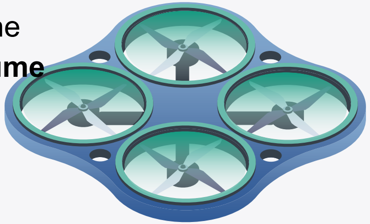


(GNSS stands for Global Navigation Satellite System)

- **RTK (Real-Time Kinematic)** corrects the drone's GPS location in **real time** using a nearby base station or network, providing **centimeter-level accuracy** as the drone flies.

- **PPK (Post-Processed Kinematic)** records the GPS data during flight and applies corrections **after the flight** using reference data from a base station or satellite service.

Both methods significantly improve the **geolocation accuracy of your images**, which directly enhances the **accuracy of your point cloud, 3D model, and orthomosaic map**—especially important when doing **volume measurements, site layouts**, or tying into survey benchmarks.



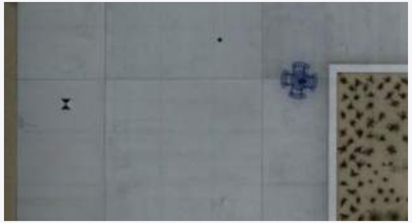
Ground Control Points & Check Points

Ground Control Points (GCPs) are **clearly marked, surveyed locations** on the ground with known X, Y, and Z coordinates. They serve as **reference points** during photogrammetry processing to align the 3D model or orthomosaic map to **real-world coordinate systems**.

How GCPs Are Used:

1. **Placement**: GCPs are evenly distributed across the survey area, especially near edges and elevation changes.
2. **Surveying**: Each point is measured using high-accuracy GNSS equipment (RTK rover or total station).
3. **Marking in Software**: When processing images, the GCPs are manually marked in the photos so the software can tie the aerial data to their true positions.
4. **Georeferencing**: The software adjusts the model based on the GCPs, improving **absolute accuracy** in both horizontal and vertical dimensions.

Purpose: To **anchor** your model to real-world coordinates and ensure **accuracy. GCPs provide a ground-truth reference**, eliminating vertical drift and ensuring that **elevations in your point cloud and mesh are survey-grade accurate** (±1–3 cm).



What are Checkpoints?

Checkpoints are surveyed ground targets similar to GCPs, but they are **not used during model alignment**. Instead, they are used **after processing** to **verify the accuracy** of the photogrammetric model.

How Checkpoints Are Used:

1. **Placement**: Check Points are placed like GCPs but kept **independent of processing**.
2. **Surveying**: Their real-world coordinates are collected, just like GCPs.
3. **Validation**: After the model is generated using GCPs, the software compares the Checkpoints' known coordinates to their positions in the model.
4. **Error Reporting**: This provides a **Root Mean Square Error (RMSE)** value that tells you how accurate the model is in terms of horizontal and vertical deviation.

Purpose: To **validate** the accuracy of the model and **document performance** for reporting or QA/QC.

GCPs	Check Points
Used **during** processing	Used **after** processing
Improve model alignment and accuracy	Evaluate and validate model accuracy
Required for **georeferencing**	Required for **quality control & reports**
Must be visible in multiple images	Should not be marked during processing

Accuracy Benchmarks

What is Survey-Grade Accuracy?

Survey-grade accuracy means your geospatial data (e.g., point clouds, orthomosaics, or 3D models) meets the precision required for engineering, construction, legal, or land surveying applications. This typically refers to centimeter-level accuracy in both horizontal (X,Y) and vertical (Z) positioning.

What is RMSE and Why It Matters

RMSE (Root Mean Square Error) is the standard metric used to measure the **difference between known surveyed locations (like GCPs or Check Points)** and the corresponding positions in your generated model.

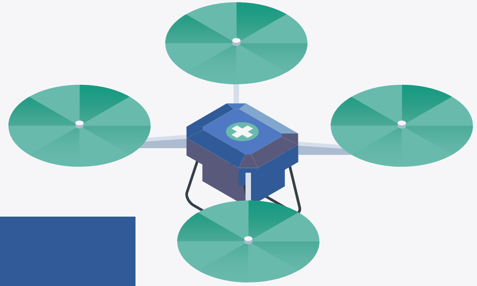
RMSE Explained Simply:

- It calculates the **average deviation** (error) between true coordinates and model coordinates.
- A **lower RMSE** means a more accurate model.

RMSE Type	What It Measures	Survey-Grade Threshold
RMSE X/Y	Horizontal accuracy (East/West, North/South)	≤ 3 cm (≤ 1.18 inches (≈ 1 3/16"))
RMSE Z	Vertical accuracy (elevation)	≤ 5 cm (≤ 1.97 inches (≈ 2"))
RMSE Total	Combined 3D positional accuracy	≤ 5–7 cm (varies by application) (≤ 1.97–2.76 inches (≈ 2–2 3/4")

🔍 Key Takeaways

- **RMSE** tells you how accurate your model is compared to reality.
- **Survey-grade accuracy** is typically defined as ≤ 3 cm horizontal and ≤ 5 cm vertical error.
- To meet these thresholds, you need:
  - High-quality GCPs or RTK/PPK positioning
  - Consistent image overlap and coverage
  - Well-planned flight paths
  - Clean image data and well-distributed control/check points



Questions So Far?

05

Drone Types

TYPES OF DRONES

TYPE	PROS	CONS	USES	PRICES
MULTIROTOR	Accessibility	Short flight	Aerial inspection	$5k-$65k
FIXED-WING	Fast flight	Expensive	Aerial mapping	$25k-$120k
SINGLE-ROTOR	Long endurance	Harder to fly	Aerial scanning	$25k-$300k
HYBRID	Long endurance	In development	Drone delivery	In development

DIFFERENT DRONES (Top Picks)

DJI Matrice 350 RTK (~$15,000)

Type: Multirotor (Quadcopter)

Use Cases: Photogrammetry, LiDAR, thermal inspections, infrastructure, power lines

Key Features:

RTK for centimeter-level accuracy

Supports interchangeable payloads (e.g., L1 LiDAR, P1 photogrammetry camera)

~55 min flight time

IP55-rated (weather-resistant)

Why It Leads: Versatile, rugged, and supports both photogrammetry and LiDAR workflows in one platform.

WingtraOne GEN II (~$20,000)

Type: Fixed-Wing VTOL

Use Cases: Large-area photogrammetry, survey-grade mapping, mining, infrastructure corridors

Key Features:

VTOL = vertical takeoff + fixed-wing flight efficiency

Up to 59 min flight time

Built-in PPK for survey-grade results without GCPs

Supports multiple payloads (e.g., Sony RX1R II for ultra-high-res imaging)

Why It Leads: Ideal for large-scale, high-accuracy projects without needing large takeoff space.

DJI Mavic 3 Enterprise (Mavic 3E RTK) (~$6,500)

Type: Multirotor (Compact Quadcopter)

Use Cases: Photogrammetry, site mapping, quick-turn construction surveys

Key Features:

RTK module available

Compact, lightweight, and very cost-effective

20MP mechanical shutter camera for mapping

~45 min flight time

Why It Leads: Perfect balance of affordability, accuracy, and portability for small to mid-size sites.

DIFFERENT DRONES (2nd Picks)

Skydio X10 & X2D (~$18k & $10k)

Manufacturer: Skydio (USA)

Type: Multirotor

Use Cases: Enterprise applications such as infrastructure inspection, public safety, and defense.

Key Features:

Flight Speed: Up to 45 mph

Flight Time: Approximately 40 minutes

Deployment Time: Less than 40 seconds

Durability: IP55-rated for dust and water resistance

Sensors: High-resolution visual and radiometric thermal cameras in modular sensor packages.

DJI Phantom 4 RTK (~$4,000)

Type: Multirotor (Quadcopter)

Use Cases: Surveying, photogrammetry, construction site mapping, topographic surveys

Key Features:

Built-in RTK module for centimeter-level positioning

20MP 1-inch CMOS sensor with mechanical shutter

Integrated TimeSync system for precise metadata alignment

Compatible with PPK workflows

~30 min flight time

DJI Air2S (~$1,000)

Type: Multirotor (Compact Quadcopter)

Use Cases: Aerial photography, videography, recreational flying

Key Features:

Compact and Portable: Weighing approximately 595 grams, it's easy to transport for various shooting scenarios.

Advanced Obstacle Sensing: Equipped with upward, downward, forward, and backward vision sensors for enhanced safety during flight.

Extended Flight Time: Offers up to 31 minutes of flight time under optimal conditions.

Lacks RTK/PPK Support: Does not have built-in Real-Time Kinematic (RTK) or Post-Processed Kinematic (PPK) capabilities, which are essential for achieving centimeter-level accuracy in surveying tasks.

Electronic Rolling Shutter: The camera utilizes an electronic rolling shutter, which can introduce distortions in mapping applications, making it less ideal for precise photogrammetry.

06

Software

Flight & Processing Software

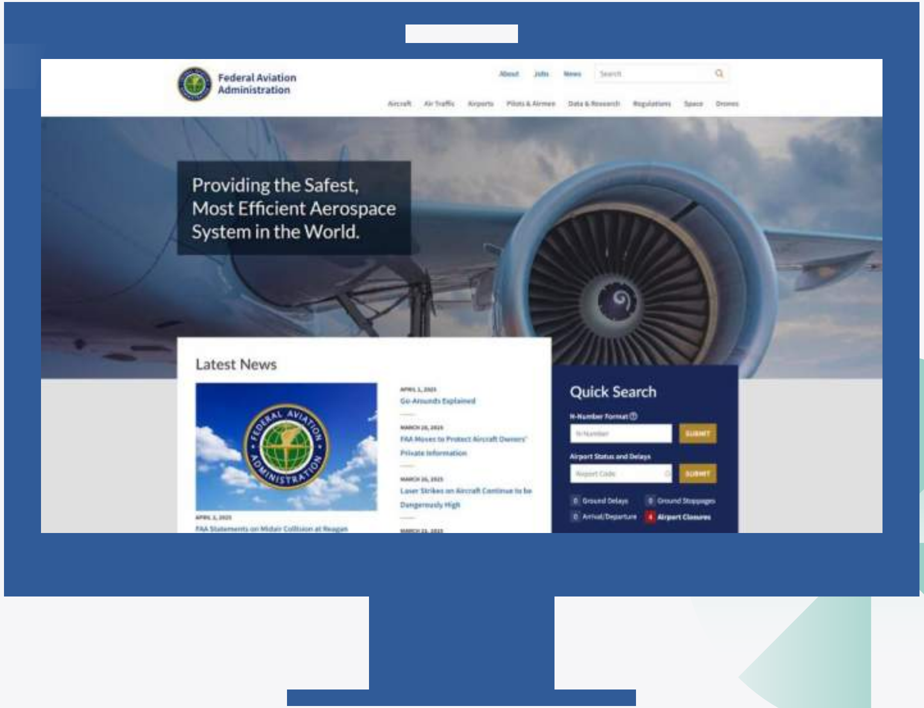
DroneDeploy: A user-friendly cloud platform ideal for construction and inspection teams, offering fast, automated flight planning, mapping, and real-time site analytics.

Pix4D: A powerful photogrammetry engine favored by surveyors and engineers for its advanced control over processing, accuracy, and customizable outputs.

Propeller: Tailored for earthworks and civil construction, Propeller excels at processing drone data with high accuracy using AeroPoints and delivering easy-to-use, survey-grade 3D site maps.

Get Licensed

You need a Part 107 license from the FAA when you operate a drone for any commercial or business purpose in the U.S.—this includes mapping, inspections, photography, or any work that directly or indirectly supports a business or earns money.



Get Licensed

Step 1: Make Sure You Qualify

To be eligible, you must:

- Be at least **16 years old**
- Be able to read, speak, write, and understand English
- Be physically and mentally fit to safely operate a drone

Step 2: Create an FAA Tracking System (FTN) Account

1. Go to https://iacra.faa.gov
2. Click **"Register"** and choose **"Applicant"**
3. Fill out your personal info and create an account
4. Once registered, you'll receive your **FTN number** — you'll need this to book the exam

Step 3: Study for the Part 107 Test

Topics covered on the test include:

- FAA regulations (Part 107 rules)
- Airspace classification and flight restrictions
- Weather and METAR reports
- Loading and performance
- Emergency procedures and crew resource management
- Drone operation and maintenance
- Aeronautical decision-making

Step 4: Schedule the Part 107 Exam

1. Go to https://faa.psiexams.com
2. Create an account and log in
3. Select **"Unmanned Aircraft General – Small (UAG)"** as the test
4. Choose a nearby **PSI testing center**
5. Pay the **$175 fee** and schedule your exam

Step 5: Take the Test

- **60 multiple-choice questions**
- You need **70% (42 correct)** to pass
- Bring a **government-issued photo ID**
- No drone needed — this is a **written knowledge exam only**

Step 6: Get Your Certificate

1. After passing, log back into IACRA
2. Start a **Remote Pilot Certificate application**
3. Submit your exam results (the testing center uploads them automatically)
4. The FAA will perform a background check, then issue your **Temporary Certificate**
5. Your **permanent plastic certificate** will arrive by mail in a few weeks

Tensar
A Division of CMC

WORKSHOP

Date: October 29, 2025

Cost: $35/person

Register online at:
www.TensarCorp.com/psl

Purpose & Background:

Whether we are constructing private development or part of the network of public infrastructure, resiliency, sustainability, & longevity are considerations when selecting design methods for those civil engineering applications, including paved and unpaved roads, working platforms, & soil stabilization. Tensar has invested significant resources into research to determine how constructing these structures can provide enhanced performance utilizing a mechanically stabilized layer (MSL). This workshop is intended to provide decision-makers in civil design and construction the tools to address structural performance enhancements, initial & life-cycle cost benefits, & reduced construction timelines.

Topics Include:

- Unique characteristics of Tensar geogrids, & how they enhance & interact with aggregates to create a Mechanically Stabilized Layer that has strength, stiffness & ductility. These characteristics contribute to improved material performance.
- Full-scale research & validation of design methods,including third party review & support of design methods & their predicted outcomes.
- Use of Tensar+ software for design & specification of paved & unpaved roads, working platforms & soil stabilization.

Learning Outcomes:

Confidence & ability to design paved and unpaved roads, working platforms, soil stabilization, & other structures utilizing Tensar+ software with the knowledge that it will address all design criteria pertinent to the project while gaining performance enhancements, initial & life-cycle cost benefits, reduced construction times, & other construction activity benefits, all while addressing resiliency & sustainability.

Registration:

Seating is limited to approximately 30, & registrations will be taken in the order received. Coffee, beverages, & lunch are provided. Dietary restrictions can be accommodated with advance notice.

Please bring an electronic device able to connect to the internet with you to access Tensar+. Upon receiving your registration, you can expect to receive an email confirmation which will include additional details on how to access the design software. **Attendees will receive 7 PDH credits.**

Cost: $35/person

Location:

Hilton Garden Inn PGA Village
8540 Commerce Centre Drive
Port St. Lucie, FL 34986
(772) 871-6850

Speakers

George Charalambous, P.E.
George.Charalambous@cmc.com

David Fuqua, P.E.
David.Fuqua@cmc.com

Jim Sanneman
James.Sanneman@cmc.com

ASCE ASCE ASCE

Our **Biggest** Event of the Year!

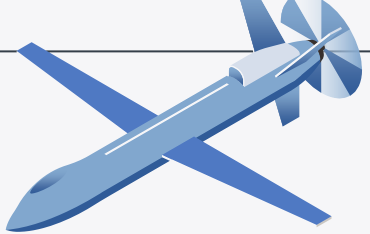
ASCE Space Coast Branch Icebreaker Networking Event

Time & Place www.ASCEspacecoast.org

21 October

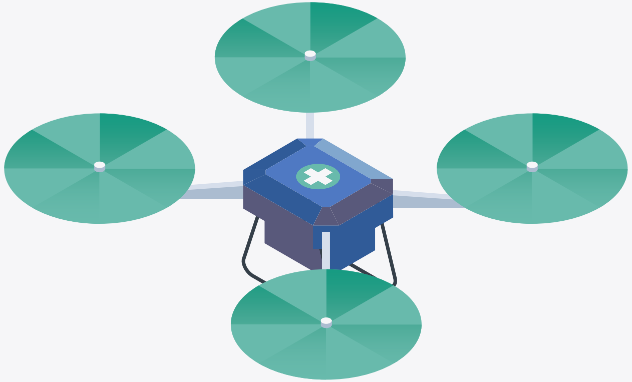
Icebreaker | **Location: Valiant Air Command Warbird Museum**
6600 Tico Rd, Titusville, FL 32780
5:30pm - 8:00pm

THANKS!



DO YOU HAVE ANY QUESTIONS?

Christopher.Carrino@cmc.com



Christopher Carrino, EI