Mapware

Mapware Best Practices:
Taking Photos for Photogrammetry

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You Made It!

To consistently capture good aerial images with your drone, you should know your equipment, identify your goals, plan ahead, and practice your capture methods.

THE VALUE OF PHOTOGRAMMETRY

Photogrammetry creates 3D digital models of physical environments—"digital twins"—to help us better understand the world around us. With this powerful visualization capability in your toolkit, you can save costs, reduce risk, make better decisions, and much more. Using a camera on a drone, or unmanned aerial vehicle (UAV), a set of serial images is collected that can be stitched together into a digital twin that gives project planners a detailed, bird's-eye view of the area.

It can be difficult to gain a comprehensive view of large areas from the ground. Using aerial photos and photogrammetry software to stitch them together paints a complete picture of the environment.

These environments may be construction sites, agricultural fields, animal habitats, pipelines and processing facilities, towers, roads, bridges—any physical space can benefit from remote sensing.

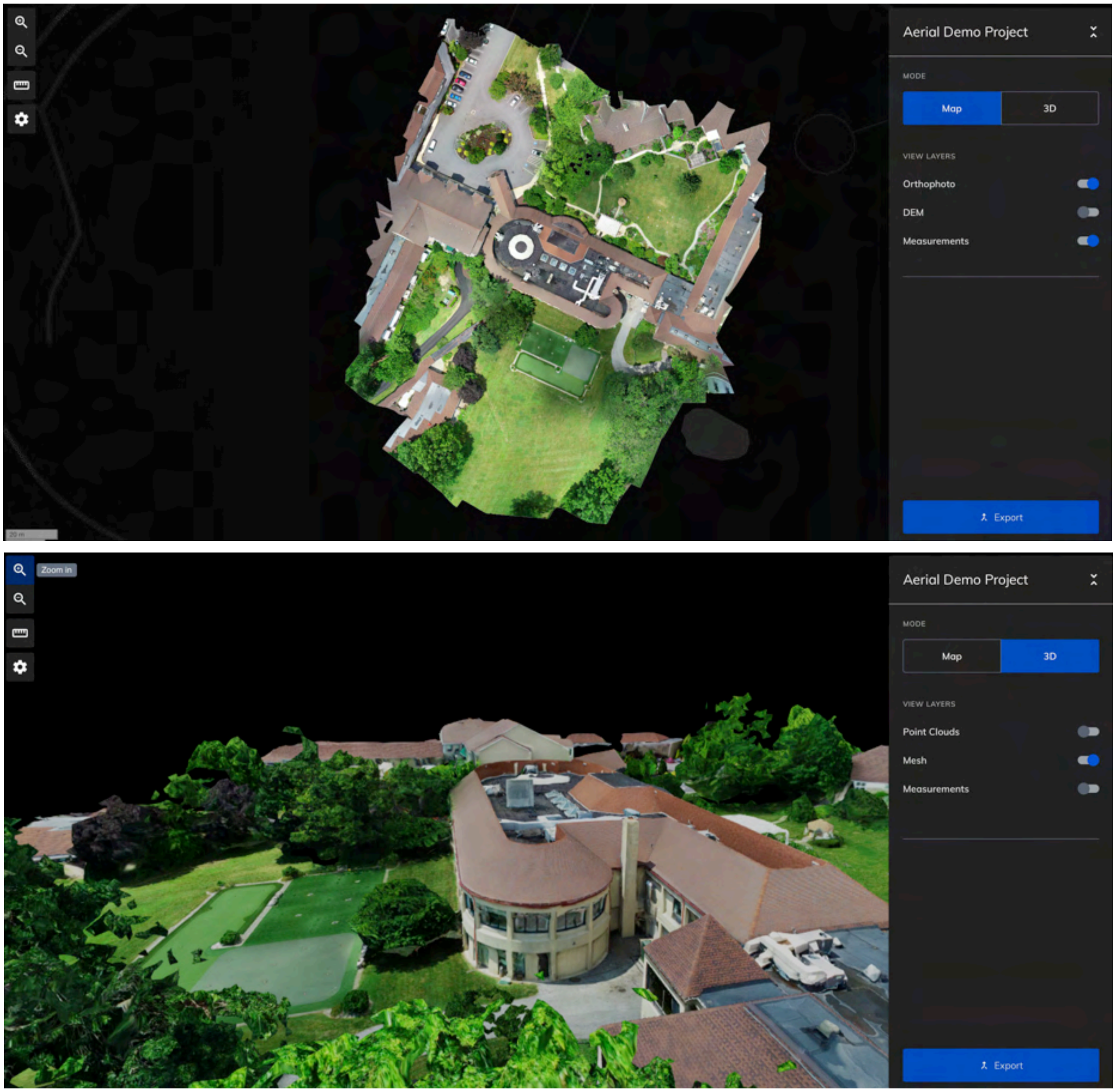
Mapware is photogrammetry software that creates digital models—including orthomosaics, digital elevation models, point clouds, and 3D models—from remotely-sensed image data.

This technology can be used for a wide variety of use cases beyond surveying and mapping, including monitoring crops, assisting with search-and-rescue operations, identifying damaged telecommunications infrastructure, and inspecting energy infrastructure. It can be used by insurance companies to assess damage to buildings, or by companies that want to reduce the risk to staff by using drones in hard-to-reach places or in place of dangerous climbs. For oil and gas industries, drone inspections are revolutionizing pipeline inspections.

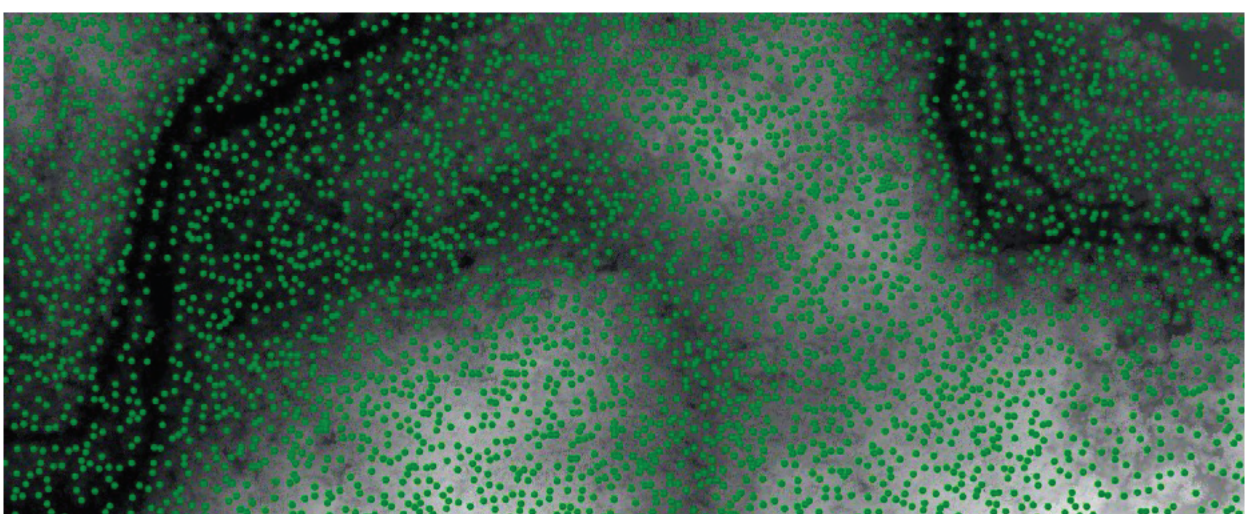
PURPOSE OF THIS GUIDE

A high-quality digital twin starts with a well-planned, well-executed flight. This guide is designed to help you collect high-quality data for generating a 3D model of a physical environment.

Let's go over some best practices for data collection you can follow to create better orthomosaic maps and models.



3D models can help you visualize and measure features of the environments that matter most to you (Image © Mapware 2022)



High-resolution digital elevation models can be used to extract individual treetops in the imagery. Using AI technology in development by Mapware, vast areas of forest can be analyzed for the species composition, diameters of tree crowns, tree clustering, and other factors that indicate the health of the forest or habitat under study (Image© Mapware 2022)

SAFETY FIRST

Before you fly your drone, review the following safety considerations for protecting your equipment, your crew, bystanders, and the environment you're photographing.

Is your equipment charged and operational? Make sure to charge your drone or pack extra batteries, and take care of any maintenance issues before your flight.

- **Is your crew prepared? Are your pilots on the same page about the flight plan, contingency scenarios, and mission goals? Are they well-rested and prepared to work for the planned duration outdoors?**

- **Is the environment safe? Are there any hazards or restrictions that might damage your equipment or injure your crew? Make sure to maintain a safe altitude that is high enough to avoid collisions with any objects in the area.**

- **What's the weather forecast? Develop contingency plans if weather conditions such as wind, rain, or lightning may endanger the operation.**

- **Do you know what regulations you need to follow? Stay aware of Federal Aviation Administration (FAA) airspace restrictions and any regulations applicable to your jurisdiction. For example, in the US, operating under 400 ft. above ground level (AGL) altitude and maintaining a direct line of sight with your aircraft is a requirement under Part 107 of the Code of Federal Regulations (CFR).**

More safety tips are available on the FAA's online UAS portal.

To fly a drone for commercial purposes, you must pass an initial aeronautical knowledge test and obtain a remote pilot certification from the FAA, as mandated by Title 14, Part 107 of the Code of Federal Regulations. For more detailed information on getting your license, read the article, "Getting a Remote Pilot License for Commercial Drone Operation." Also, the FAA requires that all drones be registered at https://faadronezone.faa.gov.

SENSOR CONSIDERATIONS

The most common remote sensing tool is an electro-optical camera mounted on a drone, otherwise known as "a drone with a camera." Most commercial off-the-shelf (COTS) drones have a camera. You may see manufacturers of these drones call their cameras "image sensors," "photo sensors," "optical sensors," or "EO (electro-optical) sensors."

Here are some considerations to help you select an image sensor:

» **Resolution —** All else being equal, higher resolution is better. You'll get better, more detailed results from a 20-megapixel sensor than from a 10-megapixel sensor.

» **Sensor size —** Larger sensors can capture images with less noise. If reducing noise is important for your project, we recommend selecting a larger sensor. One popular vendor's consumer drone has a 0.43" sensor, whereas its higher-end model has a 1" sensor.

» **Optical image stabilization —** If available, use a sensor with optical image stabilization. This feature generally provides higher-quality results than digital/electronic image stabilization because it happens before the light hits the sensor.

» **Lens —** We suggest using a prime (or fixed focal length) lens. Avoid zoom, wide-angle, and fish-eye lenses, which can distort images and 3D models.

Super-high-end industrial and military drones may have mounting systems for third-party cameras and other sensor types. Though they are uncommon, these custom drone and payload solutions can be optimal in cases where there are specific sensor requirements during data collection (e.g., thermal, multispectral, LiDAR, etc.). However, you can accomplish a lot with electro-optical camera imagery and powerful image-processing software like Mapware.

Camera Settings

Always test out your camera settings (shutter speed, aperture, and overall exposure) to determine the best configuration.

Low-ISO settings are preferable to noisier high-ISO settings, so always shoot in good lighting conditions that don't require high ISO settings. Pay particular attention to the brightness and contrast qualities of the light shining on the objects you're photographing.

ISO represents light sensitivity as a numerical value on a camera's settings. A higher number indicates a higher sensitivity and a greater ability to capture light and a lower number indicates a lower ability to capture light.

Autofocus should be turned off during the flight to maintain a consistent depth of field across all your images and crisper results in the final 3D model. A faster shutter speed will reduce blurring and create sharper images, thereby creating better models.

Processing images into 3D models using Mapware will work using RAW, PNG, TIFF, or JPEG images. However, RAW images converted to TIFF format are preferable because RAW compression has less data loss. If possible, set your camera to save images in RAW format, and be sure you have enough SD cards to hold this higher quality image data.

ENVIRONMENTAL CONSIDERATIONS

Lighting

Inadequate lighting is a big reason why photographs turn out poorly. If the lighting is too low to capture the details of each object, or if the lighting is so bright that smooth areas or bright objects are washed out, your images will not fully capture the details of the scene.

For drone photography, you'll get the best images when lighting is flat, even, and produces minimal hard shadowing.

Even, flat lighting (left) is preferable to lighting that produces hard shadowing (right)

Bad lighting that hides detailed features in an image can result in gaps in the data and holes in your 3D model. Ensure the scene is well lit, and pay attention to extremely black, white, or smooth surfaces.

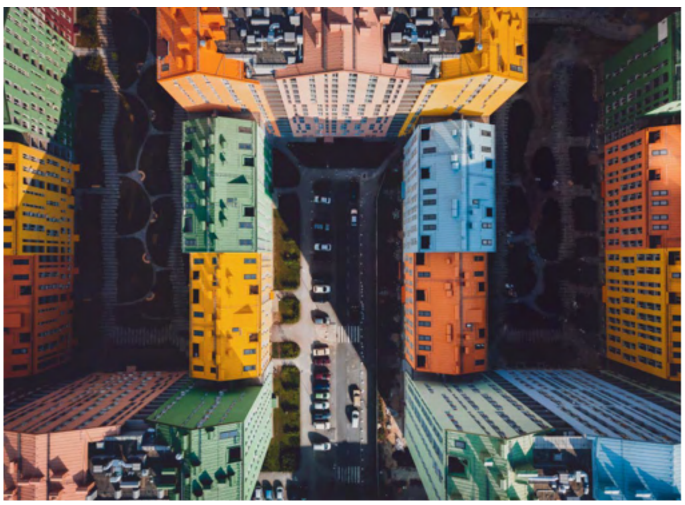
Choose the best time of day and the best weather conditions for your location to achieve even lighting across the scene. Some cloud cover to prevent glare and reduce shadows produces good results.

Remember, the position of the sun in the sky at certain times of day changes throughout the year, which will affect shadows. Images taken in the early morning or evening will present the biggest lighting challenges. If you're taking photos for longer than a couple of hours, the sun's position may change substantially—plan your flights accordingly and keep an eye on the time.

Weather

Weather can impact everything about your data collection, from image quality to safety. As described in the previous section, mild days with some cloud cover are optimal for good data collection. Weather conditions to watch out for are described below.

- **Fog, dust, smoke, ash, and sand.** These conditions can all obscure details of your target subject or region of interest. Poor-visibility conditions can also be a flight hazard, endangering equipment, bystanders, or property. Avoid flying in conditions with poor visibility.
- **Wind**. High, sustained wind can drain your drone's battery faster, reducing your time in the air. Gusty wind can also cause your drone to take blurry images, resulting in inconsistent or insufficient overlap between images.
- **Rain.** Many drones cannot fly in the rain. Consult your drone's manual to find out the conditions in which you can safely operate your drone.
- **Heat.** Check the temperature before heading out for data collection on hot sunny days. Remember that the temperature your drone reaches may exceed the temperature in the weather forecast because your drone will also produce heat. Check your drone's maximum operational temperature before flying and ensure the weather conditions will allow your drone to stay cool enough to operate safely.



High-contrast scenes (left) may result in better models than low-contrast scenes (right)

Features in the Environment

Some surfaces and environments are not well suited to photogrammetry. Avoid objects like glass or water that are highly reflective or transparent.

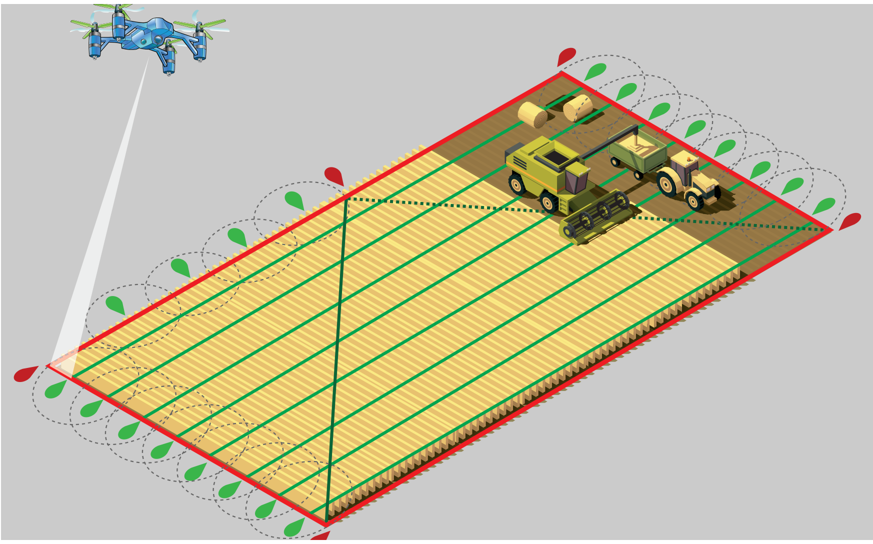
Similarly, uniform or shiny areas with little differentiation over large expanses, like a sandy desert, are unlikely to produce good results without adjustments to your plan, such as a specialized sensor or multiple types of data. Because low-contrast scenes lack clear features, it's hard for the photogrammetry application to differentiate features in the environment and stitch the images together.

PLAN YOUR FLIGHT

Flight Path

Most flight apps come with pre-planned flight patterns. For most users, these flight paths will be sufficient to collect high-quality data.

However, if needed, you can create your own flight paths. In these cases, your data acquisition strategy will depend on the scene you want to model. A grid pattern is preferable if you want to map a large area, such as a rooftop or field. However, if you want to model a large object, like a cell tower or building façade, a circular pattern is ideal.



Flight planning for large areas involves breaking the scene into a grid the drone can fly, moving from waypoint to waypoint to capture a series of images

Number of Photos

Part of being a good drone pilot is striking a balance between the number of images you capture and the flight time. The more photos you collect, the more detailed your resulting map. If you don't have enough images and sufficient overlap between them, you **undersample** the scene, resulting in a poor-quality model. However, you can't always collect as many images as you want—most drones have a limited flight time, and operators need time to rest.

Planning is the answer. Carefully plan your flights based on the needs of the mission, staying aware of pilot fatigue, the power needs of your drone, and the optimal amount of overlap between images (described in the following section).

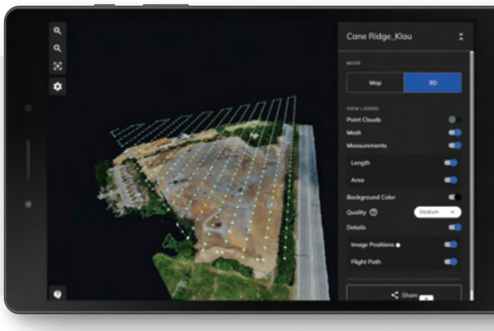
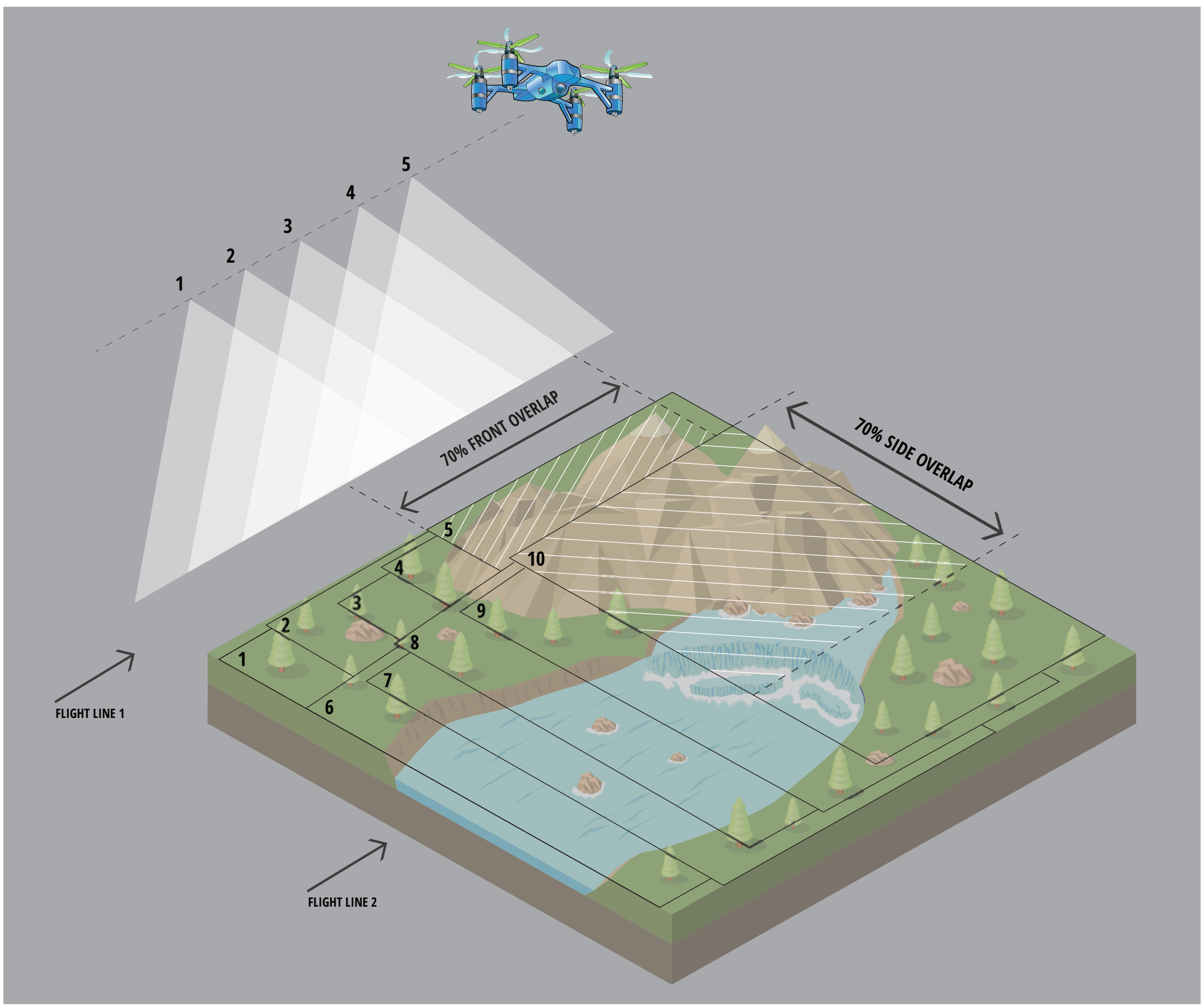


Image Overlap

Much like how our two eyes give us depth perception, photogrammetry applications like Mapware rely on overlapping imagery from different vantage points to figure out the size, shape, and location of objects in the scene. Photogrammetry applications search for interesting features ("key points") that show up in multiple images. This information is critical for producing a 3D model from 2D imagery.

Thus, it's essential to measure and plan the overlap between your images. Mapware recommends 70% front overlap and 70% side overlap on the main area of interest. Your flight app should offer settings for image overlap. Note that different manufacturers may use different terminology for different types of overlap—for example, front overlap may be called "forward overlap," "frontlap," or simply "overlap."

Mapware recommends 70% front overlap and 70% side overlap on the main area of interest.



Images should overlap across the scene, so pay attention to both front overlap and side overlap. Every set of imagein the series should overlap in both directions

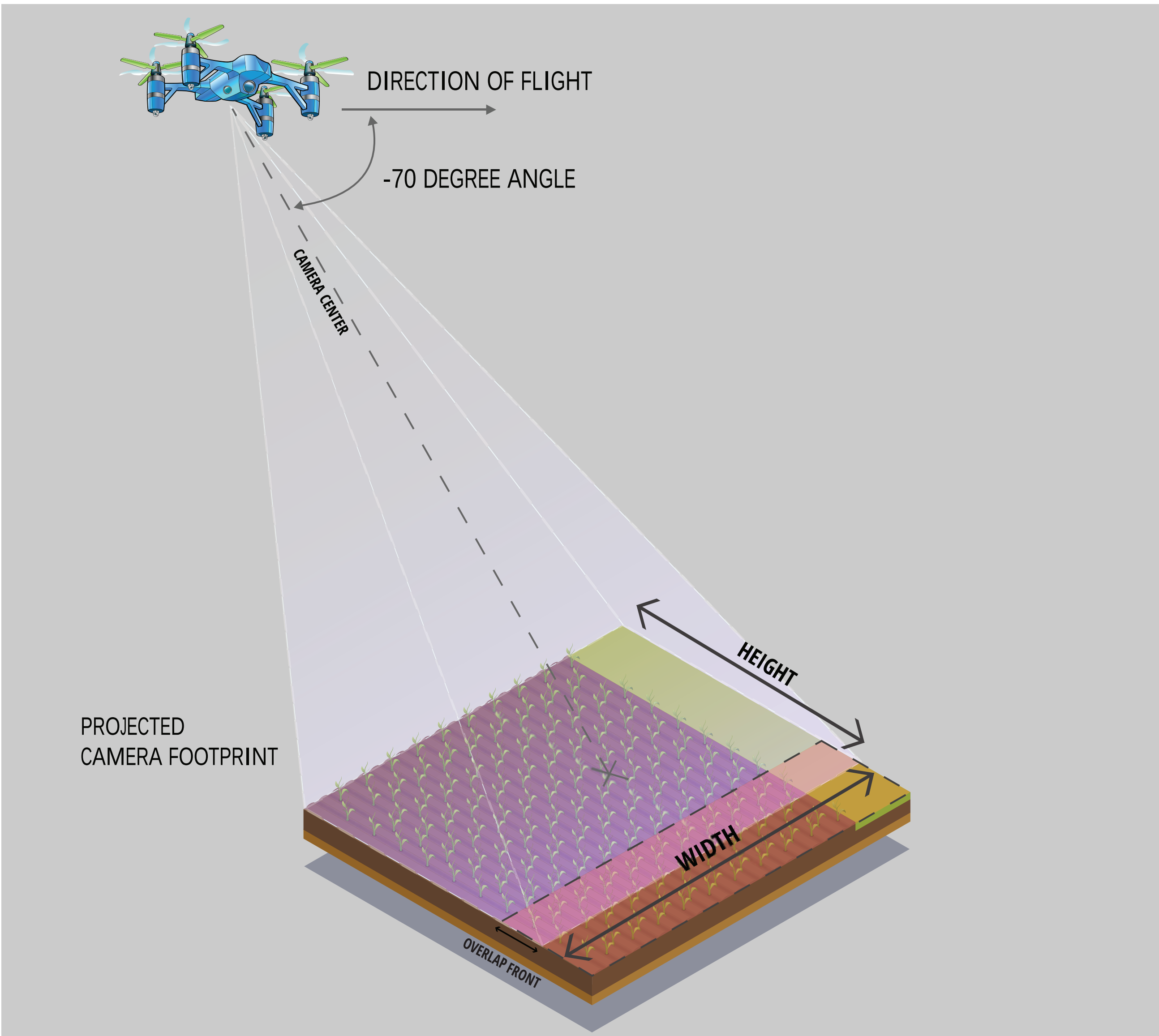
Image Angles

Images for 3D models and orthomosaic maps should be taken at an angle—that is, not from straight overhead. This helps the photogrammetry software create accurate 3D models with detailed depictions of the vertical surfaces of objects in the scene, such as trees, buildings, and cell towers. If all imagery is taken directly overhead, the resulting model will have substantial gaps because the software lacked information about the vertical surfaces that the camera couldn't capture.

Pitch Angle

The angle between the longitudinal axis of the aircraft and the horizon

We recommend taking imagery at a -60 to -70-degree **pitch** angle. Note that this angle should be -60 to -70 degrees from the projected horizon of the drone, not the ground (see illustration).



We recommend taking drone photos at a -60 to -70 degree angle from the horizon

Altitude and Speed

Lower altitudes allow for more detailed images, which means the final 3D map will contain more visual information. However, low altitude combined with high speed can create blurry images that are difficult for processing software to stitch together.

The ideal speed and altitude will vary by landscape, drone model, and camera, so conduct tests to determine the best combination for your project.

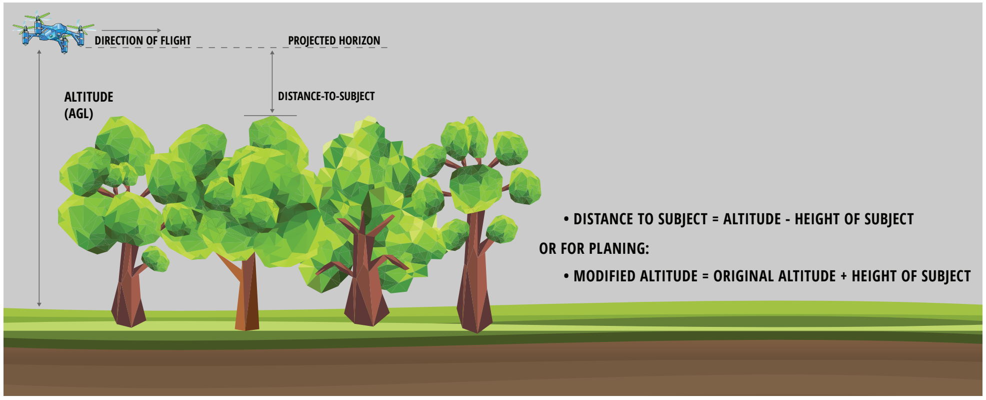
Also consider your desired **ground sampling distance (GSD)**—the distance (often expressed in meters or centimeters) between the centers of two adjacent pixels in an aerial photo. GSD is a way of measuring the spatial resolution of your photos and is determined in part by the altitude at which you take your photos.

Remember, altitude needs to be set as distance above the object(s) of interest. If your flight control app has a **distance-to-subject or distance-to-target setting** (rather than a distance-to-ground setting), we suggest you use it to set an altitude that will keep your object(s) of interest in focus.

If you are imaging a region with variable elevations, you may experience blurriness or **undersampling** (not having enough overlapping images to reconstruct a 3D model of the scene successfully). If your drone or flight application has a **terrain-following** feature, like Mapware Fly, we suggest using it. Drones with this feature will automatically change altitude based on the elevation of the terrain underneath them. Terrain following will help you capture high-quality imagery over areas with significant elevation variability.

If your drone doesn't have a terrain-following setting and you're having issues with environments with dramatically varying elevations, try imaging the areas with different elevations separately at an appropriate distance-to-subject altitude for each. Also, consider setting the distance-to-subject altitude to match the distance to the objects most important for the data collection to ensure that those objects are clear in the resulting model.

Finally, make sure your altitude is within local and federal regulations and is high enough to avoid collisions with any objects in the area. Be mindful of hazards like tall buildings, trees, and electrical wires. For more information on flying at a safe and compliant altitude, refer to the Safety First Section.



Use your flight app's distance-to-subject setting to ensure objects of interest are in focus

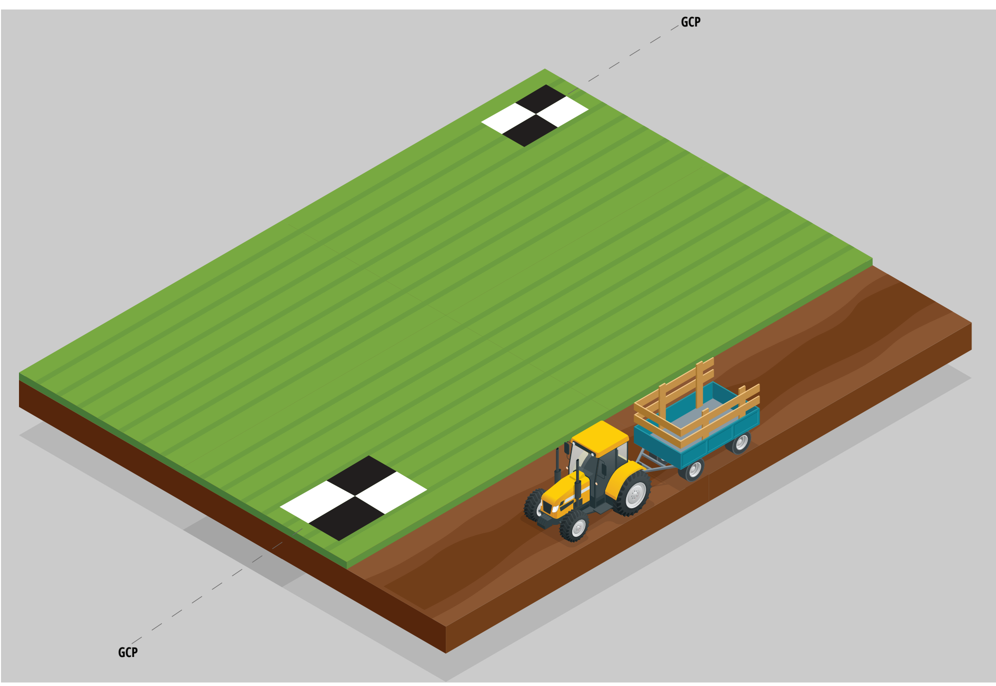
Geolocation

The Global Positioning System (GPS) is one of the most common ways to locate objects on the Earth's surface. Most images you take will be tagged with GPS coordinates. However, these coordinates are only accurate within 3 to 5 meters, so the GPS information tied to your images will be slightly inaccurate. This inaccuracy will not impact the quality of the model—it just means that specific points in your map will not be accurately tied to real-world coordinates. In some cases, a few meters' difference might not be detrimental. However, if you need high-precision data, especially for sub-meter accuracy, adjustments are needed.

There are three primary ways to improve the geolocation accuracy of your model: placing ground control points (GCPs), acquiring GPS correction files (for free or via a paid service), and real-time kinematics (RTK).

Ground control points. GCPs are unique points on the ground with precisely known latitude and longitude coordinates. They are used during the creation of 3D models to adjust orthorectification—the process of aligning your images to reduce distortions and achieve spatial accuracy. GCPs are not required, but they can improve the accuracy of any measurements you plan to make in the model. To use GCPs, you must go into the field where you plan to photograph and set GCPs at strategic locations on the ground where they will be most useful. Once placed, each GCP must be measured with surveying equipment to determine its precise location.

Many users measure the area they intend to survey ahead of time and place markers on the scene at pre-measured locations. They use a numbering system to document the coordinates of each GCP, enter the data in a file, and upload GCP information along with their images. GCPs should be spread evenly throughout the area of interest for best results.



Ground control points (GCPs) improve measurement accuracy in orthomosaic maps by serving as ground truth reference points in the scene

GPS Correction Files. GPS corrections are files of GPS information based on specific measurements of the area in which you fly your drone. These corrections are used to adjust the geolocation of your images, mitigating GPS error to make the final map more accurate. GPS correction data is based on networks of continuously operating reference stations. Some government organizations offer free corrections.

Note that the corrections will be more accurate the closer you are to one of these reference stations. If you're collecting data far from a reference station, your correction files will not be as accurate. If you want to take imagery far away from a reference station or would like the flexibility to collect geospatially accurate imagery from anywhere, RTK may be a better option for you.

To obtain GPS correction information for free, search online for "GPS corrections" and use a reputable website to enter your coordinates and download GPS correction. Try the National Oceanic and Atmospheric Administration (NOAA) 's Online Positioning User Service (OPUS), the US Geological Survey (USGS), or GPS.gov. These sites and others will give you information about reference stations in your flight area and the corrections available to you. However, note that corrections may not be available until 48 hours or more after the data was collected.

Alternatively, several companies provide GPS correction information as a paid service. This service often results in better results and more flexibility.

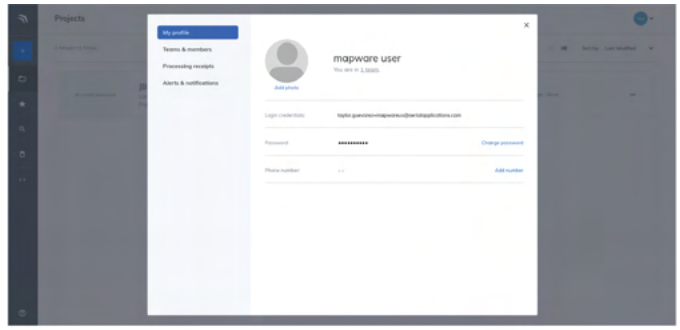
Real-time Kinematics. Real-time kinematic positioning provides higher precision for geolocation during data collection. This advanced positioning equipment provides real-time positioning and corrections on-site using a combination of sensors, including GPS receivers and inertial measurement units. Many RTK options require a subscription to networks that broadcast corrections based on local base stations. This technique usually produces the most accurate results and is typically the only way to achieve sub-centimeter accuracy.

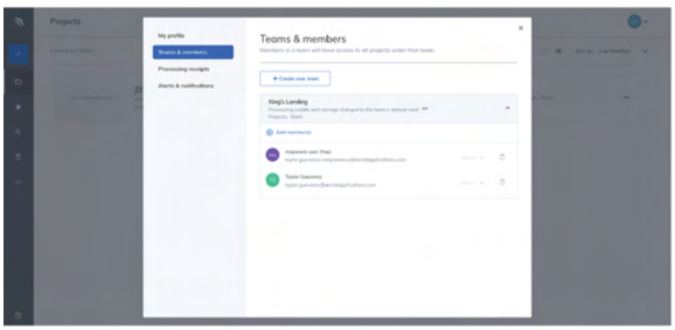
Test, Test Again

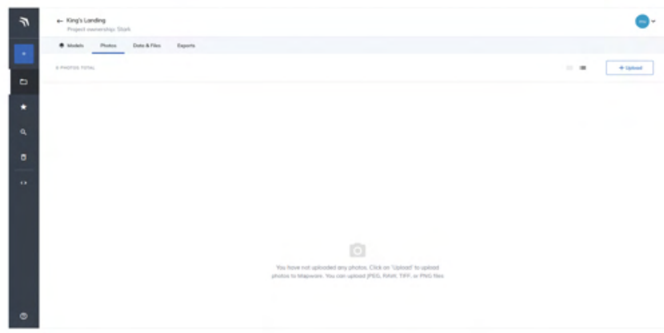
Remember, a high-quality 3D model or orthomosaic map results from a well-planned, well-executed data acquisition mission. Test all your equipment until you are comfortable and familiar with the settings. Run additional tests to adjust for time of year, time of day, weather, lighting, and location so you can get good, high-fidelity images. Familiarize yourself with how long your drone's batteries last and how many photos fit on its memory cards. Also, make sure to do any applicable preparatory work, such as measuring the site, laying ground control points, and testing various flight patterns to find out the best way to cover the site.

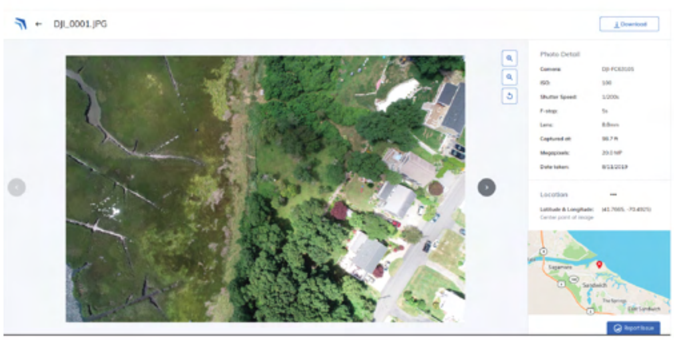
The more you understand your equipment, the better you can use it. Test, and test again. The time and effort dedicated to preparation will show in your outcome, and better 3D models will result. Plus, fieldwork is more fun when you walk in feeling like a pro.

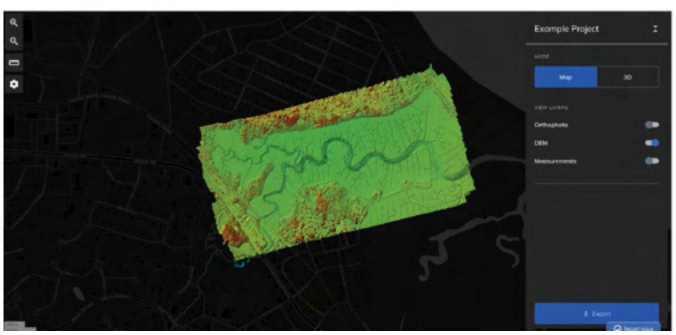
YOU MADE IT - PROCESS YOUR DATA WITH MAPWARE

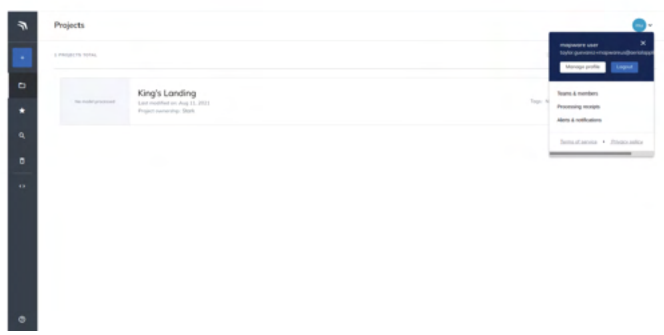












How your 3D model turns out depends on the quality of the data you upload. Many factors influence model quality, including the distance from the camera to the subject, the camera's focal length, the ground sample distance, and georectification points.

Some factors are within your control, whereas others are fixed. For example, you can't buy a new camera for every shoot, but you can adjust your camera's settings and the drone's altitude.

Some image sets will never result in good 3D models:

- **Modified images**
- **Images missing GPS metadata**
- **Images with blurring due to flying at high speed at a low altitude**
- **Images taken with a distorted lens (not a fixed focal length lens)**


Overexposed (left) and blurry (right) images will not result in good 3D models

Image Editing

Do not crop, edit, rotate, or modify your images before processing them with photogrammetry software. Unless you're working with RAW images and you are a power user who really knows what you're doing, image editing can result in problems. Differences in framing or missing overlap can be detrimental to your processing outcome.

GPS Metadata

Your images should have GPS information attached to them when you upload them to Mapware. This metadata is used to accelerate photogrammetric processing, making it more efficient and increasing the geospatial precision of your final 3D model.

Adjusting Your Next Capture

Want to get better results? Be sure to review a few of the following important factors:

- **Plan and measure your image overlap: your flight settings should specify both front and side overlap.**
- **Specify your altitude: use distance-to-subject settings (if your drone has them), not distance-to-ground.**
- **Set your camera exposure settings to match your scene, including shutter speed, aperture, and ISO (or light sensitivity) settings.**
- **Plan for the time of day, time of year, and other considerations that affect the lighting on the scene and weather conditions.**
- **Avoid taking photos near the sunset or sunrise, such as the early morning or late afternoon or evening. This harsh lighting creates long shadows that distort 3D models.**

Simplify flight control and capture for accurate, detailed 3D mapping. Mapware Fly is loaded with features designed to help you fly photogrammetry mission right - the first time, and every time.

Get started

Aperture

The aperture is the opening through which light travels in a sensor. By adjusting the aperture, you can adjust the depth of field captured in a photo.

Digital twin

A digital twin is a virtual representation of a real-life object, place, or process constructed using real-life data. Mapware creates digital twins that are photorealistic replicas of scenes imaged by drones. These digital twins are 3D models created through the process of photogrammetry, in which real photos are stitched together and geometrically corrected to make a virtual representation of the physical space or object.

Electro-optical sensor

Electro-optical sensors, also called optical sensors, are cameras that capture images by turning light into an electronic representation of a real-life scene. Mapware processes electro-optical sensor images to create orthophotos and 3D models.

Exposure

Exposure settings determine how light or dark a photo will be.

FAA – Federal Aviation Administration

The Federal Administration Agency (FAA) falls under the Department of Transportation and regulates all civil air traffic in the US. The FAA manages drone registration and clearances to fly in certain areas in the US.

Focal length

The distance between the array of photodiodes (the electro-optical sensor) and the center of the lens. Adjusting the focal length impacts how much of a particular scene will be captured.

GCP – Ground control points

Ground control points (GCPs) are uniquely colored points on the ground in the region to be flown with precisely known latitude and longitude coordinates. They are used during the creation of 3D models to adjust orthorectification—the process of aligning your images to reduce distortions and achieve spatial accuracy.

GPS corrections

GPS corrections are files of GPS information based on specific measurements of the area in which you fly your drone. These corrections are used to adjust the geolocation of your images, mitigating GPS error and atmospheric effects to make the final map more accurate.

GPS error

GPS error refers to the difference between the drone's actual GPS location and the GPS location recorded by the GPS receiver on the drone. Many factors can impact the level of accuracy that the GPS receiver is recording, including atmospheric conditions and interference.

GPS metadata

GPS metadata refers to the coordinates stored alongside each photo by your drone's GPS receiver. Photogrammetry software uses these coordinates to determine the real-world locations of the features captured in your images.

GSD – ground sampling distance

The ground sampling distance is the distance (often expressed in meters or centimeters) between the centers of two adjacent pixels in an aerial photo.

ISO

ISO represents light sensitivity as a numerical value in your camera settings. A higher number indicates a higher sensitivity and a greater ability to capture light and a lower number indicates a lower ability to capture light.

Orthorectification

Orthorectification refers to the process of aligning your images to reduce distortions and achieve spatial accuracy.

Overlap

Overlap refers to the percentage of each photo that depicts the same part of the environment as the previous or adjacent photos. Flight operators can adjust drone settings to achieve the desired percentage of side and front overlap. Overlap is necessary for creating a cohesive model of the scene using photogrammetry.

Pitch angle

The pitch angle is the angle between the longitudinal axis of the aircraft and the horizon.

Real-time kinematic positioning (RTK)

Real-time kinematic positioning is the process of using advanced positioning equipment to make real-time geospatial positioning corrections on-site while flying the drone. RTK equipment can improve geolocation accuracy down to the centimeter.

Remote sensing

Remote sensing refers to the process of monitoring a physical space and the objects within that space using sensors to measure the emitted radiation from a distance.

Sensor

A sensor is a piece of hardware that collects data about the physical world. Several types of sensors are used on drones to collect geospatial data, including electro-optical, thermal, LIDAR, and multispectral sensors.

Terrain following

Terrain following refers to the capability of specific drones to adjust their altitude during flights to maintain a consistent distance from the subject you are trying to capture. This feature helps drones take photos with more consistent overlap and focus, improving the quality of the resulting model.

Undersampling

Undersampling is the condition in which there are not enough photos of a particular subject or area for the photogrammetry software to successfully identify key features, which are needed to construct a model.

UAV – unmanned aerial vehicle

An unmanned aerial vehicle, also known as a drone, is an aircraft that can operate without a human pilot, crew, or passengers. UAVs are part of a more extensive unmanned aircraft system (UAS), which may include flight control, flight planning, and communications systems within the UAV.

Mapware

About Mapware

Mapware is a U.S.- based software-as-a-service (SaaS) platform ideal for resource-intensive mapping and situational awareness projects.

Mapware's cloud-native, GPU-accelerated photogrammetry, geospatial data management tools, and innovative 3D environment technology help our customers (government and commercial) create dynamic GIS workflows that integrate with their existing systems. Learn more at www.mapware.com.