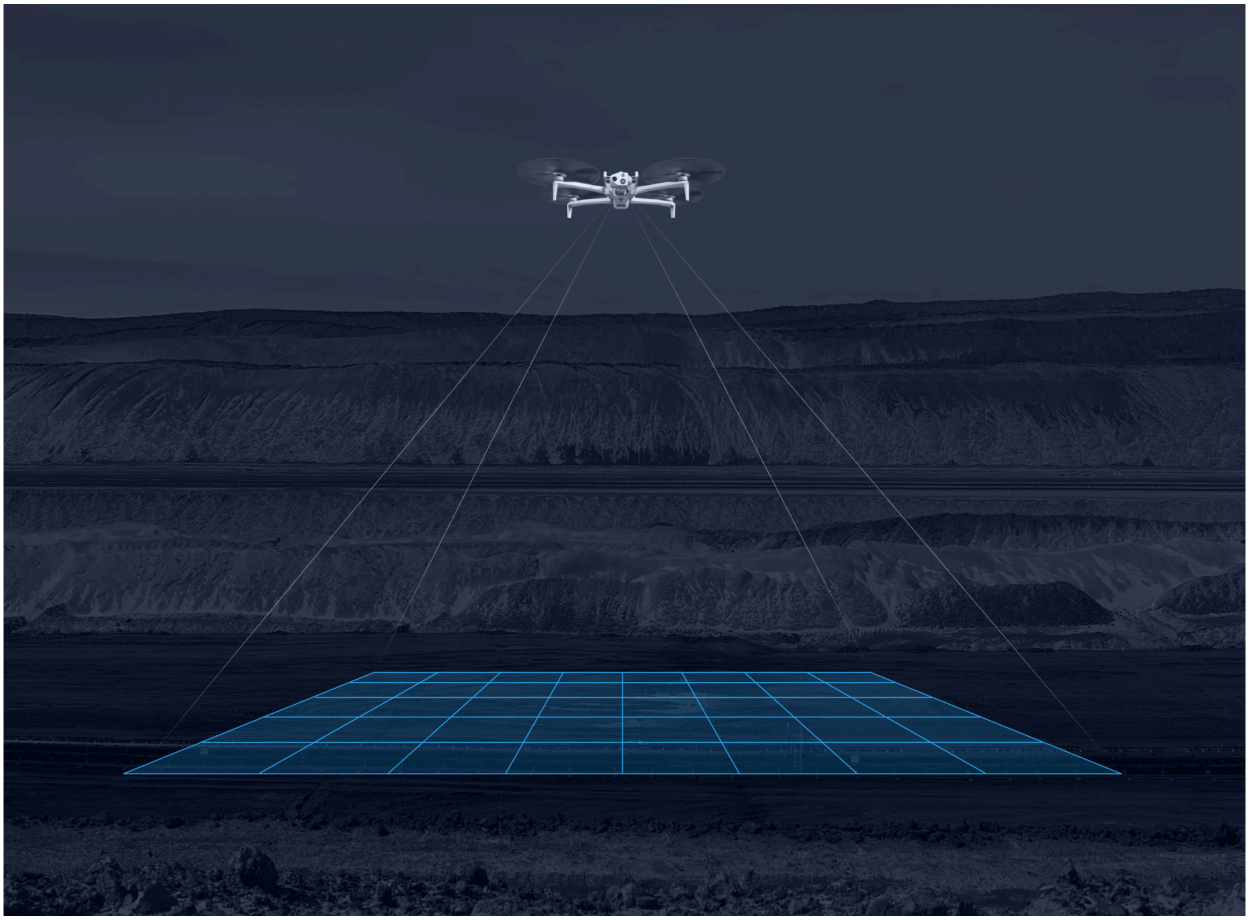

Quantifying Image Resolution with Effective GSD

A practical extension of nominal GSD for real-world conditions

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Introduction

In construction, infrastructure inspection, and geospatial surveying, aerial imaging is now foundational. Yet ensuring image accuracy and data reliability remains challenging. Ground Sample Distance (GSD) has long been the standard metric for spatial resolution in aerial imaging, but it is a geometric idealization that often diverges from real-world performance.

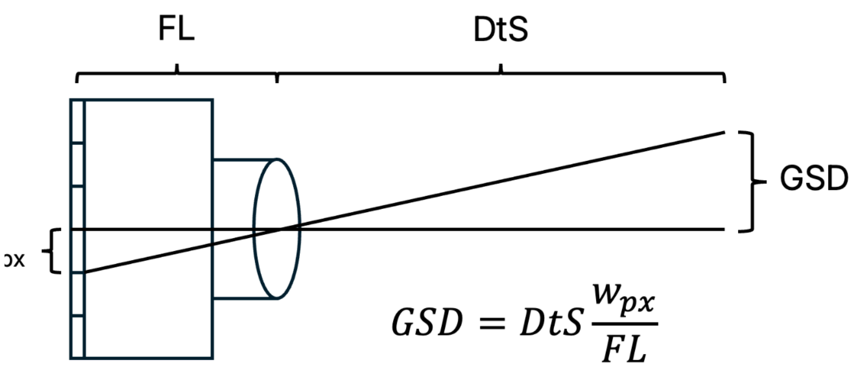
To address these gaps, **Effective GSD** is introduced as a metric that reflects a camera's true resolving power under real-world conditions. This paper describes why Effective GSD provides a more representative measure, introduces effective camera resolution, and presents empirical evidence from comparative testing.

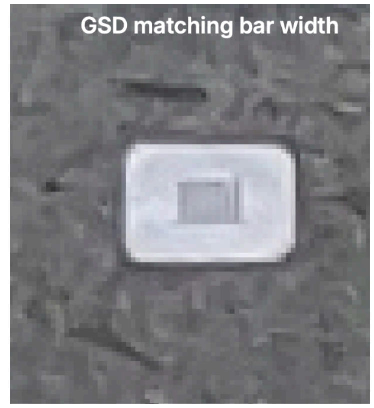
Limitations of Traditional GSD

GSD estimates the nominal ground distance represented by adjacent pixels as a function of focal length, pixel size, and distance to surface (DtS). While useful for planning, GSD ignores factors that degrade real-world image quality, including:

- **Lens imperfections** (aberrations, diffraction)
- **Environmental conditions** (humidity, lighting, vibration)
- **Sensor characteristics** (noise, pixel crosstalk)
- **Image processing** (sharpening, compression)
- **Surface geometry** (incidence angles, reflections)

These factors create a gap between theoretical resolution (GSD) and the smallest detail that is actually resolvable. Relying on GSD alone can lead to overestimation of achievable detail, with downstream effects such as missed defects, measurement bias, and re-flights.





Standard test target photographed at distance suggested for a GSD matching bar width clearly lacks visual detail, showcasing GSD's tendency to over-estimate resolution capability

Defining Effective GSD

Effective GSD is defined as:

> *The minimum ground distance between two distinguishable points on the ground, factoring in real-world conditions.*

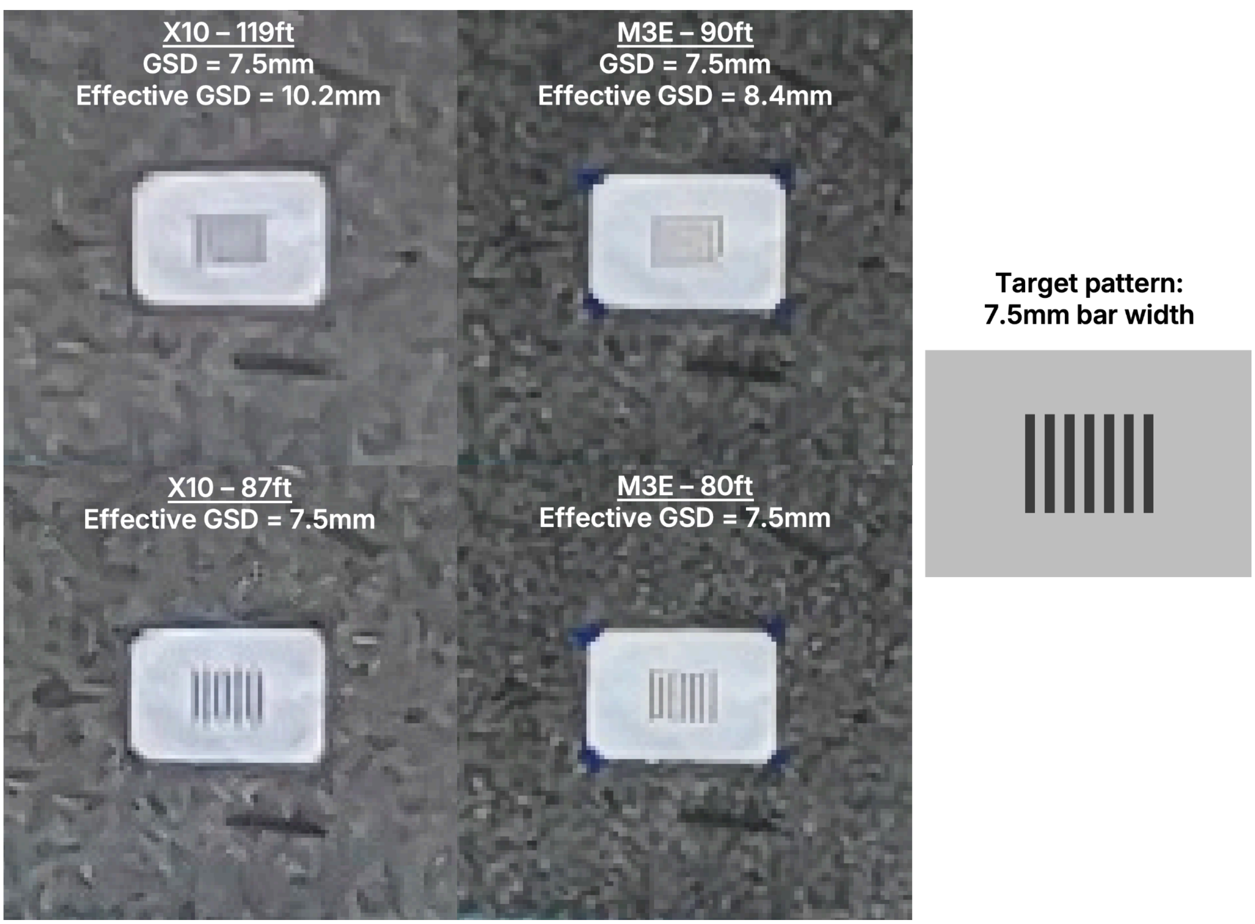
Unlike traditional GSD, which is a theoretical construct, Effective GSD accounts for real-world factors, incorporating lens performance, operating conditions, and image processing. This makes it a more reliable and practical measure of resolution for industries where precision is paramount.

Test target photographed at a distance suggested by Effective GSD shows clear details

Effective GSD is quantified using the **ResolvingPower** tool developed by the German Aerospace Center (DLR). This tool analyzes images of a bar chart resolution target to determine the smallest detail a camera can resolve, based on the Modulation Transfer Function (MTF) at a 10% contrast threshold. The process is automated, removing subjective interpretation and ensuring repeatable results across different camera systems.

Why Effective GSD Matters

- **Accuracy:** Reflects actual resolving power of the imaging system.
- **Planning:** Enables altitude and overlap planning that meet resolution requirements.
- **Efficiency:** Reduces re-flights caused by overestimated resolution.
- **Fitness for purpose:** Confirms that image quality is sufficient for inspection, surveying, and mapping tasks.



From Effective GSD to Effective Camera Resolution

While Effective GSD measures how fine details can be resolved, effective camera resolution estimates the number of resolvable elements across the field of view (FOV)—equivalently, the pixel count of an ideal sensor that would deliver similar resolvability.

This balance depends on:

- **Effective GSD** (spatial resolution)
- **Field of view** (coverage per image)

We compute effective camera resolution as:

$$R\_eff = R\_actual*(GSD/Effective\ GSD)^2$$

Where:

- **R_eff** = effective camera resolution (number of elements the camera can resolve over the whole FOV. Equivalently, it's the sensor resolution of an ideal camera that yields similar image quality to the camera in question.)
- **GSD** = Ground Sample Distance (theoretical resolution)
- **Effective GSD** = Real-world resolving capability
- **R_actual** = Sensor pixel count (e.g., 20MP)

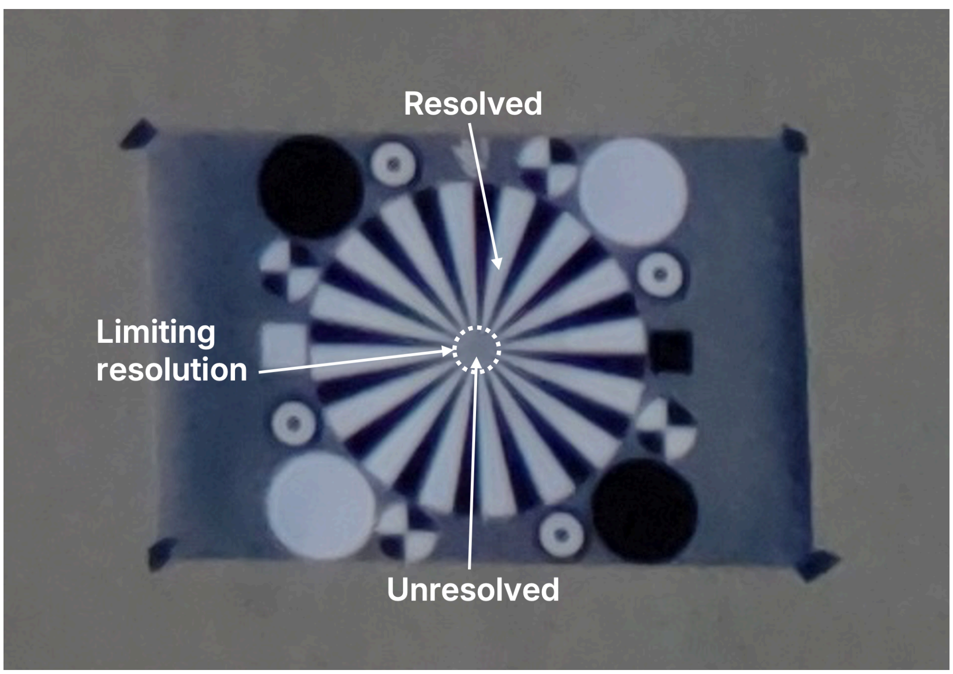
This metric enables **direct comparison across camera system**s, considering optical quality, sensor characteristics, and real-world performance.

Experimental Validation: Skydio X10 vs. DJI Mavic 3 Enterprise

We evaluated the Skydio X10 Wide camera and the DJI Mavic 3 Enterprise (M3E) Wide camera using **ResolvingPower**. The tool identifies each target and classifies resolved, unresolved, and limiting-resolution regions to determine Effective GSD without operator bias.

Test Setup

To evaluate each camera's Effective GSD, nine Siemens star targets were placed across the central 50% of the field of view (FOV). The ResolvingPower tool was used to measure the limiting resolution at each target location. These measurements were then averaged to produce a single Effective GSD value for each camera, representing performance across the usable image area. While averaging provides a straightforward summary, other statistical approaches (e.g., percentile-based metrics) could also be considered, depending on specific application needs.



A Siemens star target

Altitude is an important factor in mapping. For example:

To resolve 1.5 cm features in a map capture:

- Fly the X10 at 176ft and the M3E at 157ft
- At these heights, each X10 photo covers 1.53 acres, while each M3E photo covers 0.9 acres

Distribution of the nine Siemens star targets on the ground

Camera	**Effective GSD Ratio (Measured GSD / Theoretical GSD)** *(the lowest, the better)*	**Effective camera resolution (MP)**
Skydio X10 wide camera	0.739	27.5
DJI M3E Wide	0.880	16.2
Zenmuse P1	0.901	39.0
Sony a7R	0.875	46.1

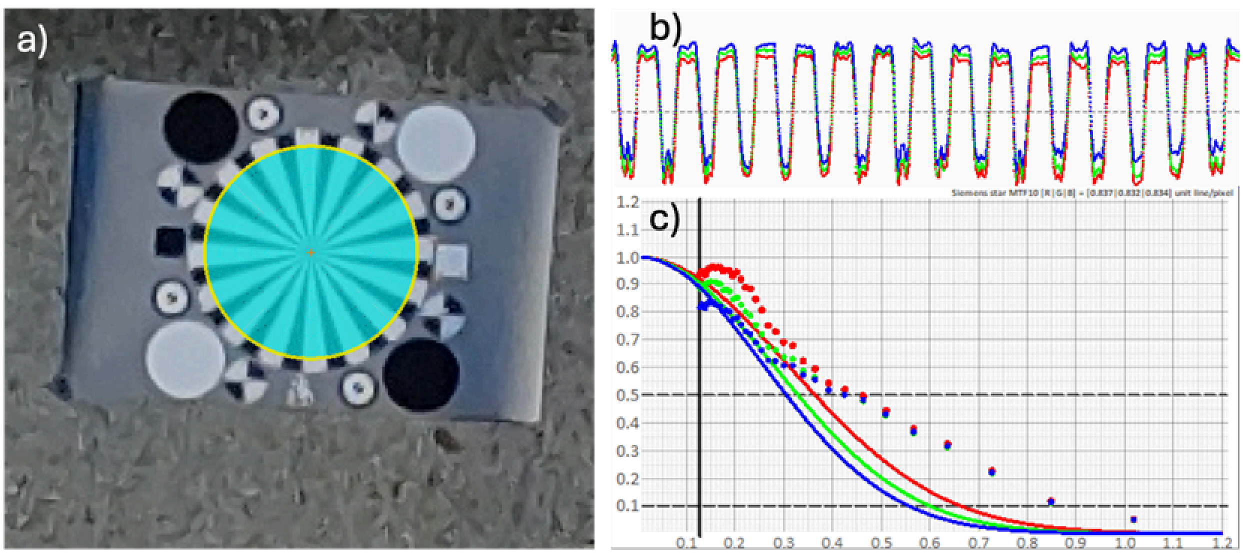


Image of the resolution target showing the automatic resolution calculation in action. a) The target used, with circles used to calculate modulation. b) Modulation of the Siemens star, used to calculate MTF and find limiting resolution. c) MTF from the Siemens star target.

Findings

The Skydio X10 demonstrated greater effective resolving power than the DJI M3E under the measured conditions, resolving finer details at greater distances, leading to sharper images and more reliable data for inspections and mapping.

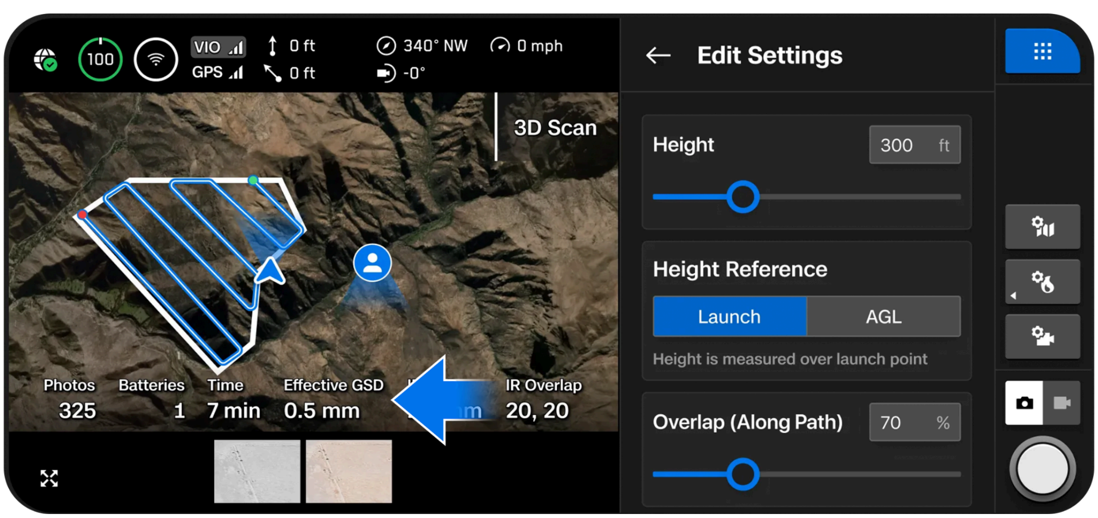
- Compared to the DJI M3E, Skydio X10 has a higher-resolution sensor (50MP vs. 20MP), which allows it to capture more detail despite experiencing a larger drop in Effective GSD (0.739 vs. 0.880). While the X10's real-world resolution deviates more from its theoretical GSD than the M3E, its higher baseline sensor resolution still ensures greater real-world resolving power.

- Compared to larger high-end sensors like the Zenmuse P1 and Sony a7R, the Skydio X10 delivers near-premium resolution (27.5MP) in a significantly smaller and lighter package, all while maintaining full autonomy and efficiency, eliminating the need for complex setups.
- This translates to real-world benefits: fewer re-flights, better area coverage, and lower cost per dataset, making Skydio X10 a strong solution for commercial and government operations.

Applying Effective GSD to Mission Planning

In practice, Effective GSD provides a more representative measure of mapping performance than nominal GSD alone. In Skydio X10 Map Capture, mission planning is informed by Effective GSD to better align planned flight parameters with achievable image detail. This allows operators to set expectations based on measured system performance, improving confidence in flight altitude selection, coverage planning, and map evaluation.

By planning with Effective GSD, operators can more reliably balance resolution requirements and operational efficiency, reducing the risk of insufficient detail.



Map Capture displays Effective GSD to inform mission planning decisions

Conclusion: Making Image Resolution Operational

Effective GSD and effective camera resolution shift aerial imaging from theoretical specs to real-world results. Together, they enable more reliable measurements, smarter flight planning, and fewer costly re-flights—turning data capture into a predictable, efficient operation rather than a trial-and-error process.

With Skydio X10, this approach is operationalized end to end. By combining accurate real-world resolution with autonomous capture, X10 delivers consistently high-quality imagery while reducing field time, risk, and operational overhead. The result is better data, captured right the first time—across construction, energy, and surveying workflows—so teams can move faster, work safer, and make decisions with confidence.

About Skydio

Skydio builds autonomous drones and flight software that enable safer, more efficient operations across public safety, infrastructure inspection, defense, and energy sectors. Designed, assembled, and supported in the U.S., Skydio systems combine AI-powered autonomy with trusted supply chain practices to deliver real-time aerial intelligence in complex environments—empowering customers to scale operations, reduce risk, and improve decision-making.

Learn more at [Skydio.com](https://www.skydio.com)