Precision UAV Photogrammetry: Performance Analysis of Skydio X10 RTK Module for Mapping Applications

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Introduction

Skydio has introduced an advanced Real-Time Kinematic (RTK) module attachment for the X10 unmanned aerial system, representing a significant advancement in precision positioning technology for professional drone operations. This module enables RTK corrections to be applied to photogrammetric data capture during flight missions, fundamentally enhancing the geometric accuracy of resulting mapping products. The RTK integration transforms the X10 from a standard mapping platform into a highly accurate system capable of achieving single-digit centimeter-level positioning accuracy.

This white paper presents a comprehensive analysis of the positional accuracies achieved from three-dimensional photogrammetric products generated through RTK-enabled flight operations. The study encompasses systematic testing across four diverse mapping sites ranging from 2 to 80 acres, evaluating accuracy performance across varying terrain conditions, site complexities, and operational scenarios. Through rigorous statistical analysis following American Society for Photogrammetry and Remote Sensing (ASPRS) Digital Geospatial Accuracy Standards, this research demonstrates the RTK module's capability to consistently deliver professional mapping accuracy while streamlining field operations and reducing traditional ground control requirements. The findings establish performance benchmarks for RTK-enhanced UAV photogrammetry and validate the technology's suitability for demanding mapping applications requiring high precision.

RTK Technology Overview

Traditional photogrammetry relies on ground control points (GCPs) to establish accurate geographic positioning and scale for the photogrammetric model. Some RTK-equipped UAVs capture precise camera exposure positions with single-digit centimeter-level accuracy, enabling more efficient GCP distribution strategies and significantly reducing the number of control points required for optimal results. Instead of needing dense GCP networks with 30+ points per mapping area, RTK missions can achieve near-equivalent accuracy with fewer, strategically placed control points. RTK makes use of a secondary Global Navigation Satellite System (GNSS) receiver to correct for atmospheric delays, satellite timing errors, and other sources of positioning uncertainty. These corrections compensate for these errors, and other sources of positioning uncertainty that typically limit standard single-receiver GNSS accuracy to several meters. When properly implemented, RTK can achieve horizontal and vertical accuracies of +/-0.2ft. The system operates through differential positioning, where a base station is an accurately computed or published position on which the resulting measured points are anchored to. The base station corrections are then transmitted to nearby rovers, in this case, RTK-equipped drones, enabling them to apply these corrections to their own GNSS observations in real time, resulting in a high-accuracy position.

RTK Module Integration

The RTK module houses a Septentrio Mosaic X5 GNSS receiver, a professional-grade positioning system that delivers accuracy and performance with specifications of 0.6 centimeters horizontally and 1 centimeter vertically under optimal RTK conditions, according to their data sheet. The Mosaic X5 represents GNSS technology with multi-frequency, multi-constellation tracking capabilities that enable robust positioning solutions across challenging environments. This receiver supports L1/L2/L5 GPS frequencies along with comparable bands from GLONASS, Galileo, and BeiDou constellations, providing redundancy and improved geometry for enhanced positioning reliability and accuracy maintenance even in partially obstructed signal environments. The RTK module demonstrates rapid operational readiness with fast initialization times when connecting to established correction streams, reducing pre-flight preparation time and enabling efficient mission execution. This rapid initialization capability stems from the Mosaic X5's signal processing algorithms and optimized firmware that quickly establishes carrier phase tracking and applies incoming corrections to achieve fixed RTK solutions.

Skydio X10 RTK Module

User Interface and Network Configuration

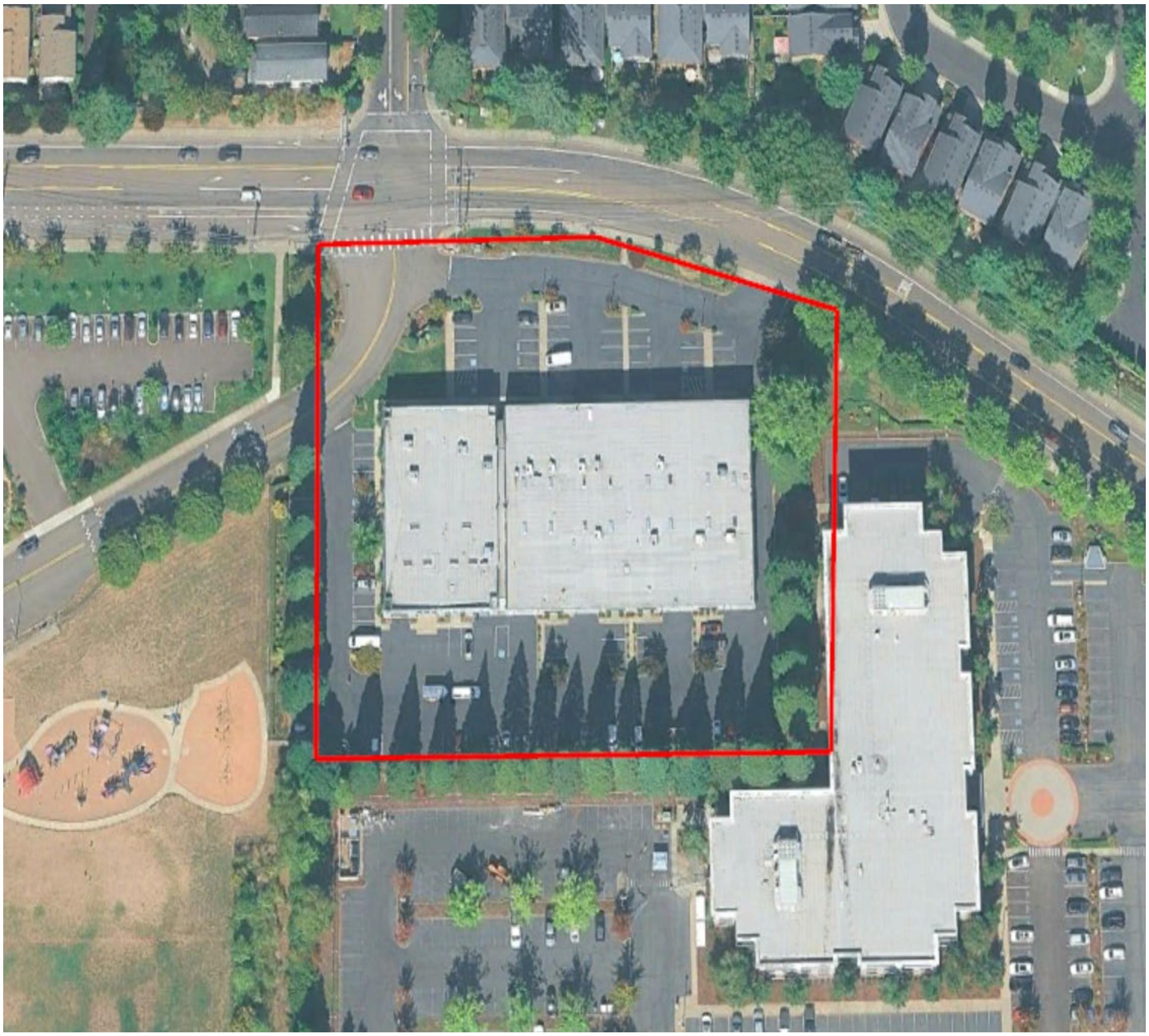
To access RTK corrections, operators must configure the system with their specific network credentials including host address, port number, username, and password provided by their correction service provider. The X10's integrated interface streamlines this configuration process through an intuitive setup workflow that guides users through credential entry and network validation. Once the NTRIP address and credentials have been verified through successful network authentication, the system automatically queries the correction service to retrieve available correction streams.

The system then displays a list of available mountpoints on the correction network, intelligently sorted by proximity to the aircraft's current location to optimize correction quality and minimize latency. This proximity-based sorting ensures operators can quickly identify the most suitable correction source for their specific operational area, as correction accuracy typically degrades with increased distance from reference stations. Each mountpoint listing provides essential metadata including station identifier, approximate distance, and correction stream format, enabling informed selection based on project requirements and accuracy specifications. This automated mountpoint discovery and organization significantly reduces setup complexity while ensuring optimal correction source selection for maximum positioning accuracy.

Sites Flown

Site 1 | Tigard

Site 1 is an office Park in Tigard, OR. The site is 2.5 acres, containing buildings, a parking lot, and minor elevation shift throughout the area. 5 GCP's were used for horizontal/vertical accuracy testing, and 30 check shots were used for vertical only accuracy testing. 90 images were taken with a ground sampling distance (GSD) of ~1.1cm.



Frontier Precision, Tigard, OR

Site 2 | Columbus Park

Site 2 is a park in Tucson, AZ named Columbus Park. The area flown was approximately 2 acres in size. 4 GCP's were used for horizontal/vertical accuracy testing, and 76 check shots were used for vertical only accuracy testing. 86 images were taken with a GSD of ~1.2cm.

Columbus Park, Tucson, AZ

Site 3 | Skydio HQ

Site 3 is Skydio's Headquarters in San Mateo, CA. The site is approximately 12.5 acres in size and includes several office complexes and varying elevations. 42 GCP's were used for horizontal/vertical accuracy testing, and 64 check shots were used for vertical only accuracy testing. 651 images were captured with a GSD of ~1.1cm

Skydio Headquarters, San Mateo, CA

Site 4 | Rodeo Grounds

Size 4 is a rodeo ground in Apache Junction, AZ. The site is roughly 80 acres in size and contains many areas of small elevation changes throughout most of the site. 5 GCP's were used for horizontal/vertical accuracy testing, and 31 check shots were used for vertical only accuracy testing. 1287 images were captured with a GSD of ~1.2cm.

Lost Dutchman Days Rodeo Grounds, Apache Junction, AZ

Control Point Methodology

Control points at each site were methodically planned to test the horizontal and vertical accuracy of the RTK module. Ground control points (GCPs) and checkpoints were distributed evenly throughout each site. A Trimble R12i was used to capture these coordinates. Per the data sheet, the Trimble R12i is specified to a horizontal accuracy of 3mm + 0.5ppm and a vertical accuracy of 5mm + 0.5ppm for static and fast static measurements.

The R12i was positioned over each base control point location and configured to collect static observations for 2-4 hours at a rate of 1Hz. Each static session file was then uploaded to OPUS, and the returned corrected coordinates were used as base station coordinates for collecting GCPs and checkshots via RTK with a second Trimble R12i receiver. Per the data sheet for an RTK measurement, the horizontal accuracy spec is 8mm + 1ppm and the vertical accuracy spec is 15mm + 1ppm. GCP positions were collected by measuring with a two-minute observation, while the checkpoints were measured with 15 second observations.

Trimble R12i observing the location of a static point

Flight Parameters

Each site was flown with a Skydio X10 V300-L, utilizing the RTK module. All flights were flown at a standardized altitude of 200 feet above ground level (AGL) to maintain consistent ground sampling distance and image resolution across all mapping locations. This flight height provided an optimal balance between coverage efficiency and image detail capture while ensuring safe separation from ground obstacles. Frontal and side overlaps were configured to 80% for all missions to ensure robust photogrammetric reconstruction and comprehensive stereo coverage. The high overlap percentages guaranteed sufficient tie point distribution between adjacent images, enabling reliable bundle adjustment solutions and dense point cloud generation while providing redundancy for feature matching in challenging terrain or areas with limited texture.

Flight speed was maintained at 10 mph throughout all missions to optimize image acquisition parameters while maintaining aircraft stability and precision. This controlled speed allowed adequate time for camera stabilization between exposures and ensured sharp image capture without motion blur, while providing sufficient time for RTK positioning solutions to stabilize between photo locations. Flight missions were comprehensively planned and executed using the native Skydio flight planning software integrated within the X10 controller, which enabled precise mission design with automated flight path generation and real-time mission monitoring. The integrated planning system automatically calculated optimal flight patterns based on specified parameters, generating efficient coverage patterns that minimized flight time while ensuring complete mapping area coverage and maintaining safety protocols throughout each operation.

Accuracy Testing Methodology

Each dataset was produced in Pix4Dmatic utilizing generated geolocation .csv from mission folder. A resultant photogrammetric point cloud was then compared to measured GCP's and checkshots utilizing Trimble Business Center. Each measured point, including both GCP's and checkshots, was compared against the photogrammetric data. The measurement results were then applied to the equations prescribed by ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 2, Version 2 (2024), to generate Root Mean Square Error (RMSE) values for X, Y, and Z coordinates. The resulting RMSE values were subsequently used to calculate the 3D RMSE values for each site.

$$RMSE_x = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_{i(map)} - x_{i(surveyed)})^2}$$

$$Horizontal\ Product\ Accuracy\ (RMSE_H) = \sqrt{{RMSE_{H_1}}^2 + {RMSE_{H_2}}^2}$$

$$Vertical\ Product\ Accuracy\ (RMSE_V) = \sqrt{{RMSE_{V_1}}^2 + {RMSE_{V_2}}^2}$$

$$RMSE_{3D} = \sqrt{{RMSE_H}^2 + {RMSE_V}^2}$$

Source: American Society for Photogrammetry and Remote Sensing, *ASPRS Positional Accuracy Standards for Digital Geospatial Data,* 2nd ed., Version 2, ASPRS, 2024.

Computed Results

Site 1 | Tigard

Number of Measured Points	X: 5	Y: 5	Z: 35
Mean Error	X: 0.137 ft (0.042 m)	0.131 ft (0.04 m)	-0.064 ft (-0.02 m)
RMSE	0.139 ft (0.042 m)	0.153 ft (0.047 m)	0.198 ft (0.06 m)
Fit to Checkpoints RMSEH1	0.162 ft (0.049 m)		
Fit to Checkpoints RMSEV1	0.198 ft (0.06 m)		
RMSEH	0.163 ft (0.049 m)		
RMSEV	0.201 ft (0.06 m)		
RMSE3D	0.203 ft (0.06 m)		

Site 2 | Columbus Park

Number of Measured Points	X: 4	Y: 4	Z: 87
Mean Error	-0.047 ft (-0.014 m)	0.041 ft (0.012 m)	0.081 ft (0.024 m)
RMSE	0.079 ft (0.024 m)	0.078 ft (0.024 m)	0.118 ft (0.036 m)
Fit to Checkpoints RMSEH1	0.085 ft (0.025 m)		
Fit to Checkpoints RMSEV1	0.117 ft (0.036 m)		
RMSEH	0.085 ft (0.026 m)		
RMSEV	0.120 ft (0.037 m)		
RMSE3D	0.100 ft (0.03 m)		

Site 3 | Skydio HQ

Number of Measured Points	X: 42	Y: 42	Z: 106
Mean Error	0.068 ftUS (0.021 m)	0.055 ftUS (0.017 m)	0.044 ftUS (0.013 m)
RMSE	0.081 ftUS (0.025 m)	0.077 ftUS (0.023 m)	0.111 ftUS (0.034 m)
Fit to Checkpoints RMSEH1	0.087 ftUS (0.027 m)		
Fit to Checkpoints RMSEV1	0.111 ftUS (0.034 m)		
RMSEH	0.088 ftUS (0.027 m)		
RMSEV	0.114 ftUS (0.035 m)		
RMSE3D	0.101 ftUS (0.031 m)		

Site 4 | Rodeo Grounds

Number of Measured Points	X: 5	Y: 5	Z: 36
Mean Error	-0.074 ft (-0.023 m)	-0.086 ft (-0.026 m)	-0.078 ft (-0.024 m)
RMSE	0.082 ft (0.025 m)	0.091 ft (0.028 m)	0.190 ft (0.058 m)
Fit to Checkpoints RMSEH1	0.090 ft (0.027 m)		
Fit to Checkpoints RMSEV1	0.190 ft (0.058 m)		
RMSEH	0.091 ft (0.028 m)		
RMSEV	0.193 ft (0.059 m)		
RMSE3D	0.128 ft (0.039 m)		

Conclusion

The RTK Module for the X10 has been proven to provide consistent accuracy results across small-medium size sites (2-80 acres) through comprehensive field testing that demonstrates reliable sub-decimeter performance across diverse terrain conditions and site characteristics. Through systematic evaluation across four distinct test sites ranging from compact urban environments to expansive agricultural areas, the RTK module consistently delivered positioning accuracies well within professional mapping standards, with all test locations achieving sub-0.2 foot (6 centimeter) accuracy in X, Y, and Z coordinates.

Every dataset collected for this whitepaper was **produced** to meet ASPRS Digital Geospatial Accuracy Standards, Edition 2, ASPRS 2024, demonstrating the module's capability to support professional-grade mapping applications requiring rigorous accuracy specifications. The testing methodology incorporated extensive ground control point networks and independent check shot validation to provide statistically robust accuracy assessments that exceed industry standards for UAV-based photogrammetric mapping. These results establish the RTK module as a reliable solution for applications demanding high grade accuracy, including topographic mapping, construction monitoring, and infrastructure assessment where precise positioning is critical for project success. The consistent performance across varied site conditions with elevation changes validates the module's versatility and reliability for diverse professional mapping requirements.

Credit

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