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of
Papua New Guinea Inc.

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Evolution of UAV Surveying: From Traditional Methods to RTK-Enabled Precision Mapping at PNG University of Technology

A Study on the Integration of Modern and Established Surveying Surveying Practices

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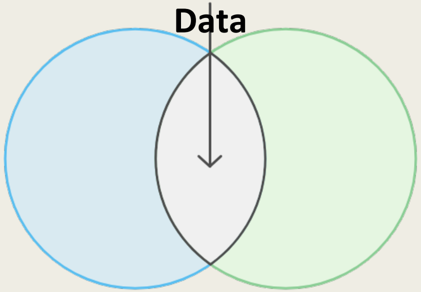
Abstract: A Synthesis of Old and New

The field of surveying is undergoing a significant technological evolution. However, this advancement is not about replacing traditional methods, but building upon their foundational strength. This study, conducted at the Papua New Guinea University of Technology, explores the practical integration of Real-Time Kinematic (RTK) enabled Unmanned Aerial Vehicles (UAVs) with established surveying practices to enhance both accuracy and operational efficiency. By leveraging the strengths of each approach, we demonstrate a synergistic model for modern surveying that maintains rigorous standards of quality and validation.

- Investigated the synergy between RTK UAVs and traditional ground control.
- Tested multiple positioning workflows for the UAV.
- Validated UAV-derived data against existing high-accuracy LiDAR data.
- Outlined a practical framework for surveyors in Papua New Guinea.

The Core Thesis: Evolution, Not Revolution

The central argument of this research is that new technologies like UAVs do not render traditional methods obsolete. Instead, they form a Instead, they form a powerful symbiosis. Traditional methods provide the rigorous control and validation necessary to trust the outputs of the outputs of modern, rapid data acquisition technologies.



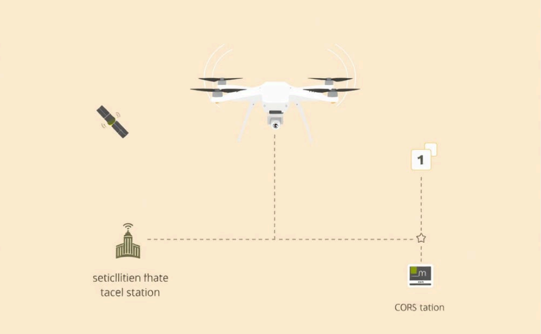
Integrated Precision Mapping: Efficient, Validated, and Comprehensive Spatial Data

Traditional Surveying (High Accuracy, Point-Based, Foundational Control)

UAV Photogrammetry (Rapid Data Capture, Large Area Coverage, High-Resolution Imagery)

Research Objectives

This study was guided by a set of specific objectives designed to comprehensively evaluate the integrated surveying model.

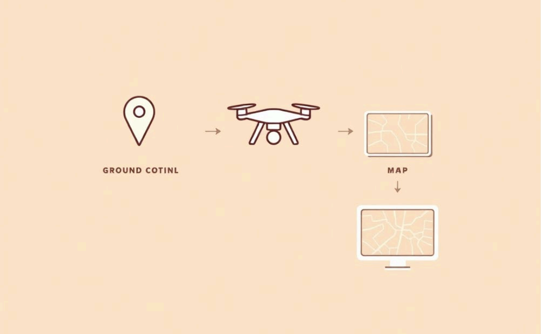


Evaluate RTK UAV Performance Performance

To assess the positional accuracy and operational efficiency of an RTK-enabled UAV using different real-time correction methodologies.

Validate Against Ground Truth

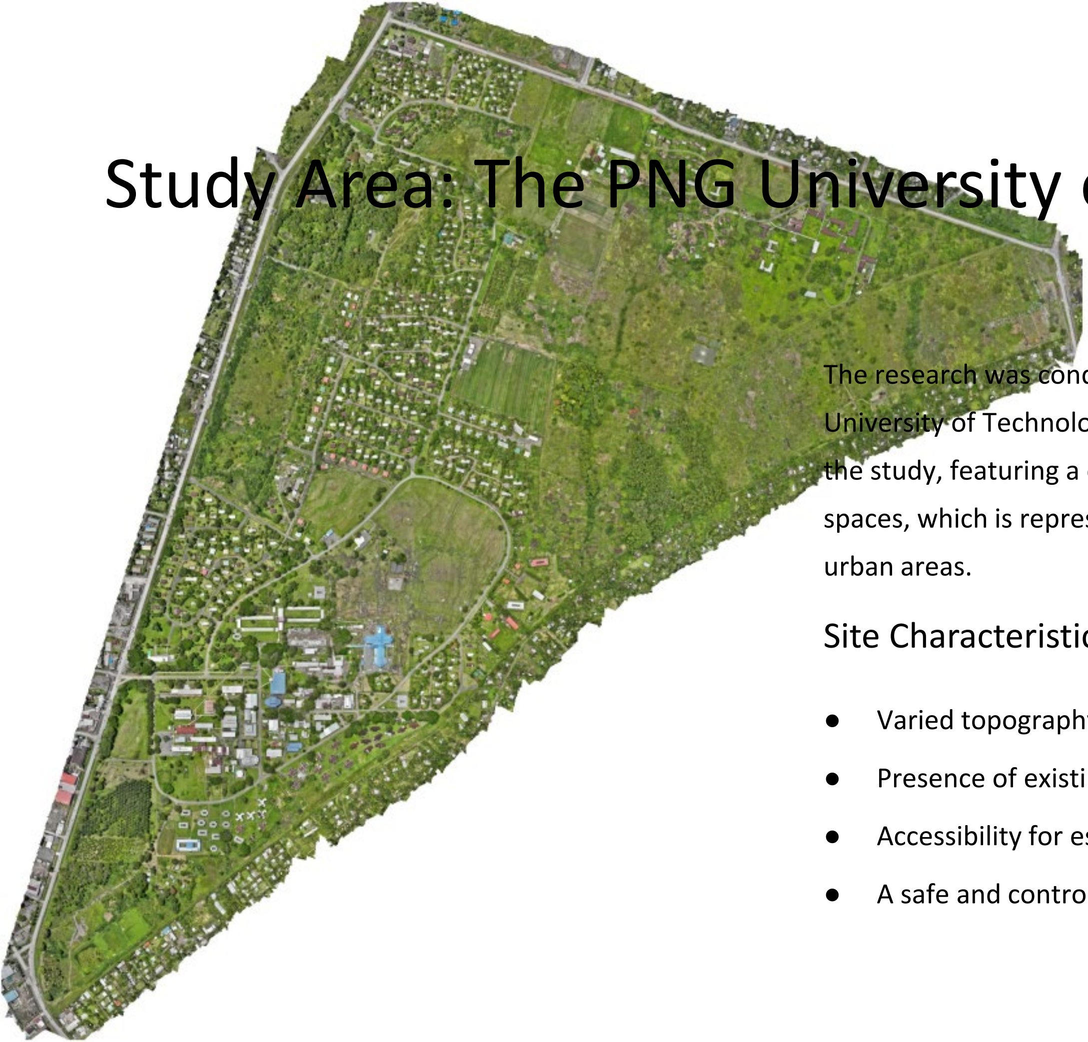
To validate the UAV-generated Digital Surface Model (DSM) by comparing it with datasets derived from established, high-accuracy sources like LiDAR and traditional GNSS static surveys.



Demonstrate Workflow Integration Integration

To showcase a practical workflow where traditional ground control point (GCP) establishment supports and enhances the reliability of UAV-based mapping projects.

Study Area: The PNG University of Technology Campus



The research was conducted within the grounds of the Papua New Guinea University of Technology in Lae. This location provided an ideal environment for the study, featuring a diverse mix of terrain, buildings, vegetation, and open spaces, which is representative of typical surveying projects in urban and semi-urban areas.

Site Characteristics:

- Varied topography and surface features.
- Presence of existing survey control infrastructure.
- Accessibility for establishing new Ground Control Points.
- A safe and controlled environment for UAV flight operations.

Methodology: The Foundational Layer

Establishing a High-Accuracy Ground Control Network

Before any aerial operations commenced, the bedrock of the project was established using traditional, high-precision techniques. This ensures that all subsequent data collected by the UAV can be referenced, corrected, and validated against a known, reliable frame of reference.

Ground Control Points (GCPs)

Ten Ground Control Points were strategically distributed across the study area. These points serve as the 'ground truth' for the photogrammetric processing.

Instrumentation

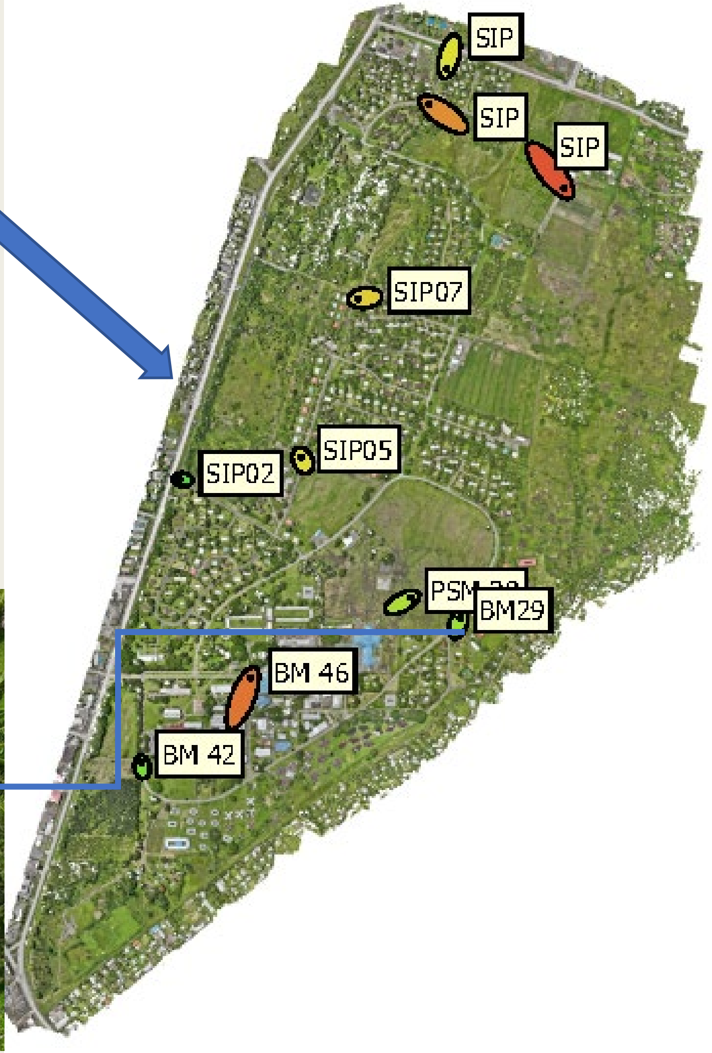
Topcon Hyper SR GNSS receivers were used to conduct static surveys on each GCP. This method involves long observation times to achieve millimeter-level accuracy.

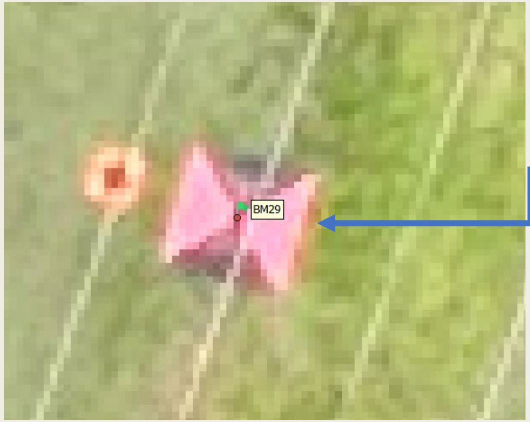
Processing and Datum

The collected GNSS data was meticulously post-processed. All final All final coordinates were computed and expressed in the official official geodetic datum for Papua New Guinea, PNG94.

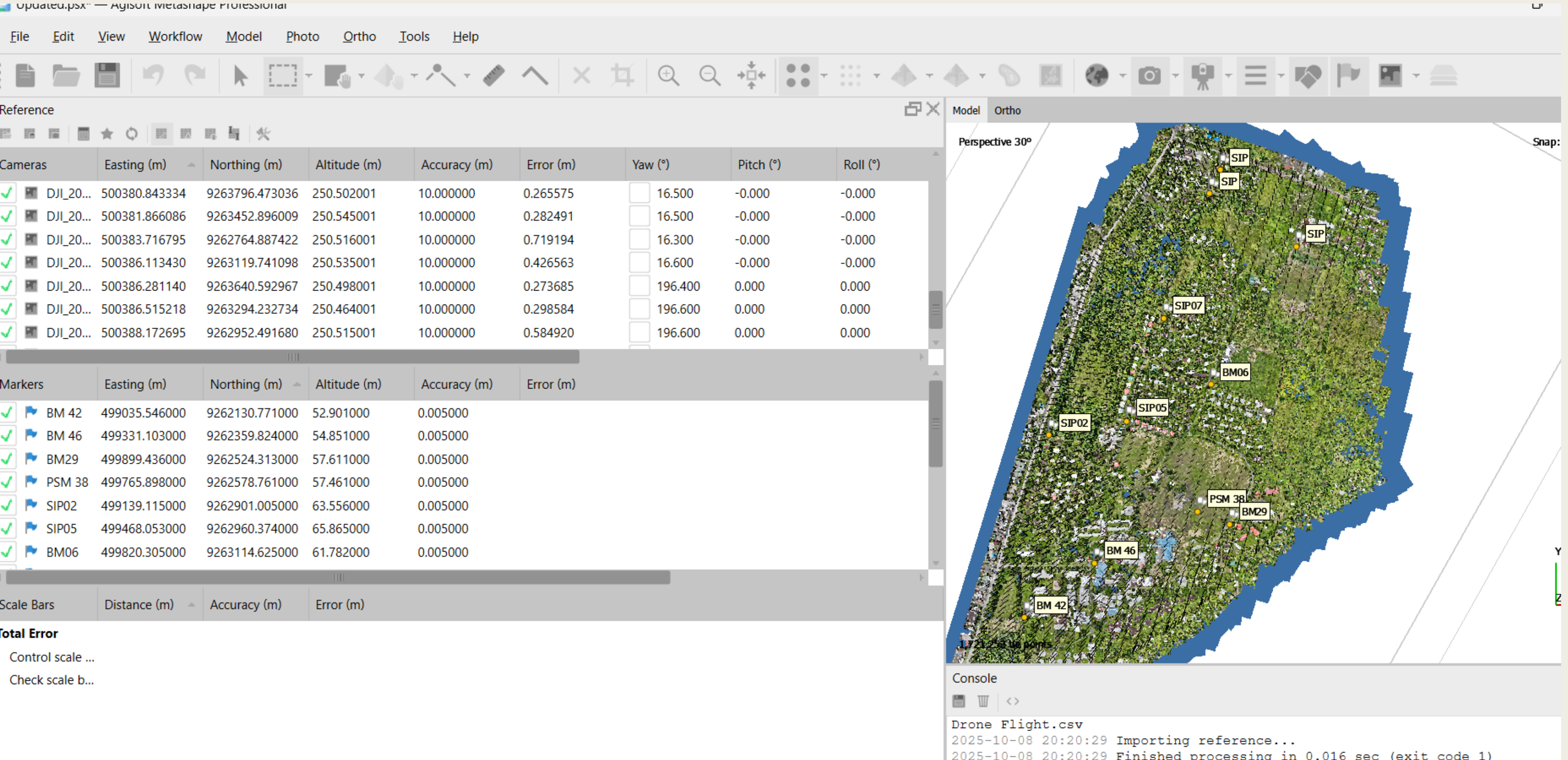
Ground Control Points (GCPs) – Static GPS control Points & Check Points

BM 42	499035.546	9262130.771	52.901	Palm Plantation Curb
BM 46	499331.103	9262359.824	54.851	Library Front Lawn
PSM 38	499765.898	9262578.761	57.461	Rugby Field
BM29	499899.436	9262524.313	57.611	Catholic College
SIP02	499139.115	9262901.005	63.556	Warongoi Drive Roundabout
SIP05	499468.053	9262960.374	65.865	Behind Uniforce Field
SIP07	499622.838	9263390.642	69.017	Backroad Behind Area 4
SIP	500179.038	9263692.49	68.73	Unitech Farm
SIP	499816.036	9263917.572	67.723	KilaKila Drive
SIP	499861.358	9264015.104	68.517	KilaKila Drive Roundabout





Ground Control Points (GCPs) – Static GPS control Points & Check & Check Points



Cameras	Easting (m)	Northing (m)	Altitude (m)	Accuracy (m)	Error (m)	Yaw (°)	Pitch (°)	Roll (°)
✓ DJI_20...	500380.843334	9263796.473036	250.502001	10.000000	0.265575	☐ 16.500	-0.000	-0.000
✓ DJI_20...	500381.866086	9263452.896009	250.545001	10.000000	0.282491	☐ 16.500	-0.000	-0.000
✓ DJI_20...	500383.716795	9262764.887422	250.516001	10.000000	0.719194	☐ 16.300	-0.000	-0.000
✓ DJI_20...	500386.113430	9263119.741098	250.535001	10.000000	0.426563	☐ 16.600	-0.000	-0.000
✓ DJI_20...	500386.281140	9263640.592967	250.498001	10.000000	0.273685	☐ 196.400	0.000	0.000
✓ DJI_20...	500386.515218	9263294.232734	250.464001	10.000000	0.298584	☐ 196.600	0.000	0.000
✓ DJI_20...	500388.172695	9262952.491680	250.515001	10.000000	0.584920	☐ 196.600	0.000	0.000

Markers	Easting (m)	Northing (m)	Altitude (m)	Accuracy (m)	Error (m)
✓ BM 42	499035.546000	9262130.771000	52.901000	0.005000	
✓ BM 46	499331.103000	9262359.824000	54.851000	0.005000	
✓ BM29	499899.436000	9262524.313000	57.611000	0.005000	
✓ PSM 38	499765.898000	9262578.761000	57.461000	0.005000	
✓ SIP02	499139.115000	9262901.005000	63.556000	0.005000	
✓ SIP05	499468.053000	9262960.374000	65.865000	0.005000	
✓ BM06	499820.305000	9263114.625000	61.782000	0.005000	

Scale Bars	Distance (m)	Accuracy (m)	Error (m)
Total Error			
Control scale ...			
Check scale b...			

```
Drone Flight.csv
2025-10-08 20:20:29 Importing reference...
2025-10-08 20:20:29 Finished processing in 0.016 sec (exit code 1)
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Methodology: The Aerial Data Acquisition Platform

RTK DJI Mavic 4 Enterprise

The primary tool for aerial data capture was a DJI RTK DJI Mavic 4 Enterprise Enterprise

series UAV, equipped with an integrated Real-Time Kinematic (RTK) module. This module. This advanced capability allows the drone to receive real-time correctional data, enabling it to determine its position with centimeter-level level accuracy while in flight.

Key Features:

- Integrated RTK for high-precision positioning.
- High-resolution imaging sensor for detailed photogrammetry.
- Automated flight planning for consistent area coverage.
- Enhanced flight time for efficient mapping of large areas.

Methodology: RTK Positioning Approaches

A key aspect of this study was to compare two distinct methods for delivering real-time corrections to the UAV. Both methods aimed to methods aimed to achieve high accuracy but utilized different data transmission workflows. The reference data for both was sourced from the sourced from the Lae 2 ***Continuously Operating Reference Station (CORS).***

Approach 1: Onboard RTK System

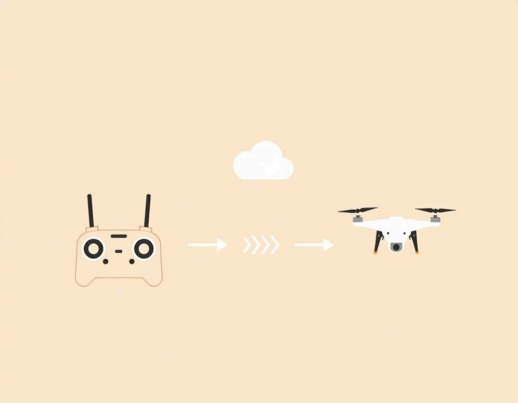
This approach uses DJI's native RTK ecosystem. The ground station ground station controller connects directly:

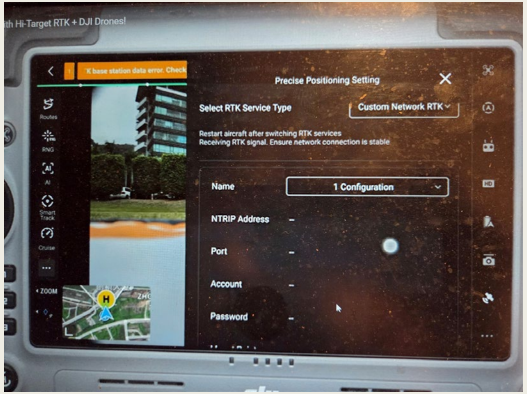
Using a compatible GNSS RTK receiver (e.g., DJI D-RTK 2 or third-party).Configure it to broadcast RTCM 3.x correction messages.

Connect to the drone via, radio, or Wi-Fi.

Approach 2: NTRIP-Based Service

This method utilizes the *Networked Transport of RTCM via Internet Protocol (NTRIP)*. A separate device (like a smartphone) connects to an NTRIP caster to receive the correction stream from Lae 2 CORS and then feeds this data to the UAV's controller, typically via a local Wi-Fi or Bluetooth link.





ith Hi-Target RTK + DJI Drones!

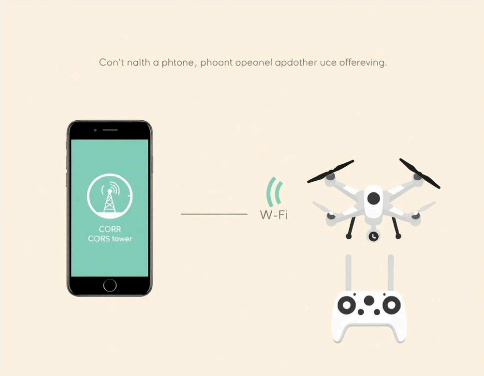
'K base station data error. Check

Precise Positioning Setting

Select RTK Service Type: Custom Network RTK

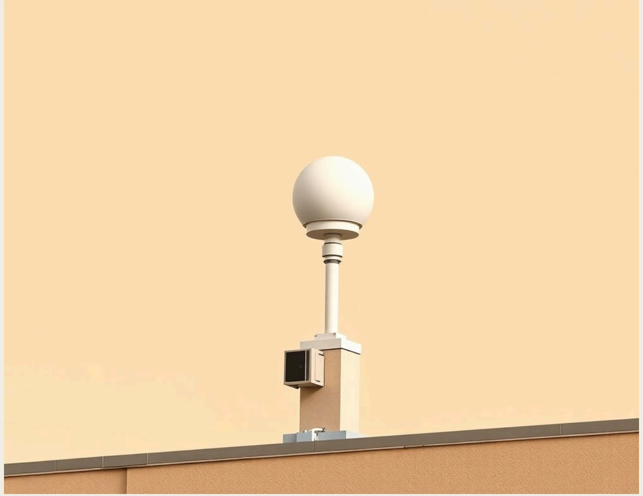
Restart aircraft after switching RTK services
Receiving RTK signal. Ensure network connection is stable

Name: 1 Configuration
NTRIP Address: –
Port: –
Account: –
Password: –



Con't nalth a phtone, phoont opeonel apdother uce offereving.

The Role of the Lae 2 CORS



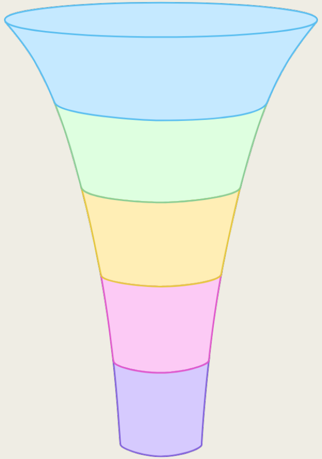
The Lae *2 Continuously Operating Reference Station* is a critical piece of survey infrastructure that underpins high-accuracy GNSS positioning in the region. It is a survey-grade GNSS receiver at a precisely known, fixed location that continuously streams raw satellite observation data.

How it enables RTK:

- By knowing its exact position, the CORS can calculate errors in the GNSS signals caused by atmospheric delays and satellite orbit inaccuracies.
- It broadcasts these error corrections in a standard format (RTCM) - Radio Radio Technical Commission for Maritime Services.
- The RTK UAV (the 'rover') receives these corrections and applies them to its own satellite observations, effectively cancelling out the errors and achieving centimeter-level accuracy in real time.

Data Processing Workflow: From Pixels to Points

Once the aerial imagery was captured, it was brought into specialized photogrammetry software to reconstruct the 3D environment. This complex process transforms thousands of overlapping 2D images into a precise 3D model and orthomosaic.

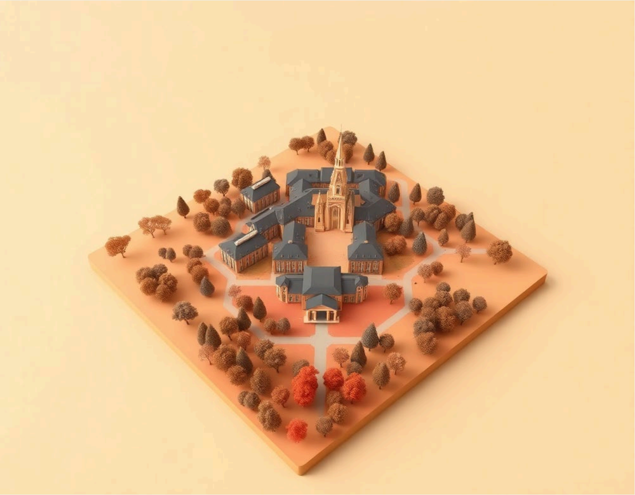


1. Image Import & Geotagging: Loading of UAV images with initial RTK-derived coordinates. coordinates.
2. Ground Control Integration: Marking of the precisely surveyed GCPs on the images.
3. Aerial Triangulation: Aligning all images and refining camera positions and the 3D geometry. geometry.
4. Dense Point Cloud Generation: Creating a detailed 3D point cloud representing the surface.
5. DSM & Orthomosaic Export: Generating the final deliverables - the Digital Surface Model and a distortion-free aerial map.

Software Platforms Used:

The processing was conducted using two leading photogrammetry platforms, Agisoft Metashape and WebODM (Web OpenDroneMap), to OpenDroneMap), to compare workflows and results from both commercial and open-source solutions.

Primary Output: The Digital Surface Model (DSM) (DSM)



The main output from the photogrammetric processing is a Digital Surface Model (DSM). A DSM is a 3D representation of the Earth's surface that includes all objects on it, such as buildings, vegetation, and infrastructure. It is typically a raster grid where each pixel's value represents its elevation.

Utility of the DSM:

- Provides a detailed topographic representation of the terrain.
- Allows for volume calculations (e.g., for earthworks).
- Enables line-of-sight analysis and drainage modeling.
- Serves as a basis for generating contour lines and other mapping products. products.

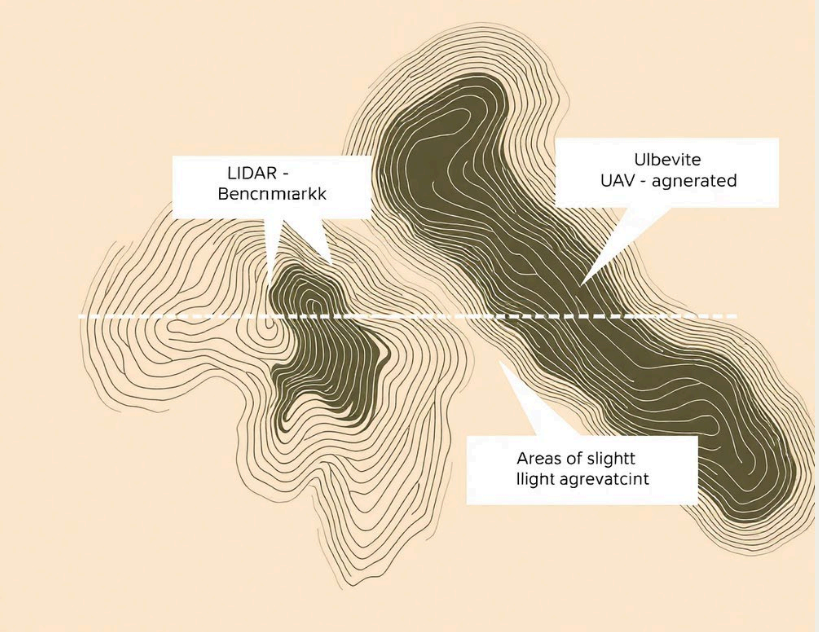
Validation: Ensuring Data Integrity

Comparison with LiDAR-Derived Contours

The ultimate test of the UAV data's accuracy was to validate it against an independent, higher-accuracy dataset. For this study, existing LiDAR-derived contour data for the campus was used as the benchmark. LiDAR (Light Detection and Ranging) is considered a gold standard for terrain mapping.

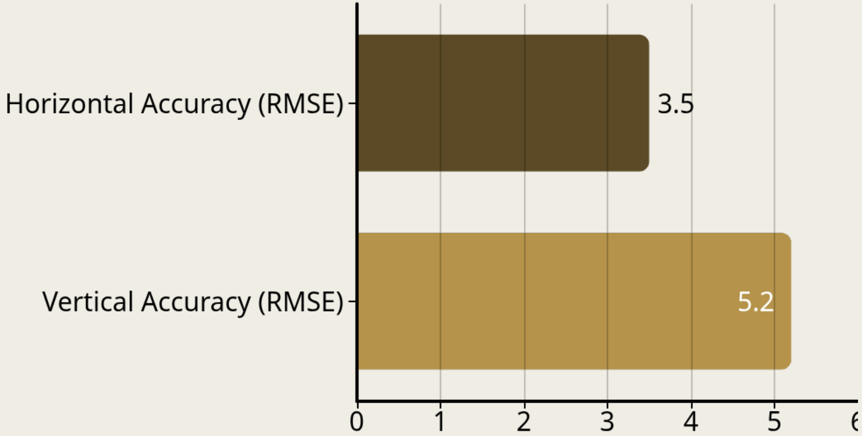
The Process

- The UAV-derived DSM was used to generate a new set of contour lines.
- These new contours were overlaid on the existing LiDAR contours in a GIS environment.
- Vertical and horizontal discrepancies between the two datasets were measured at numerous locations.
- The Root Mean Square Error (RMSE) was calculated to provide a statistical measure of accuracy.



Key Findings: Accuracy and Reliability

The results of the validation process confirmed that the RTK-enabled UAV, when supported by a robust network of Ground Control Points, is capable of producing survey-grade data. The comparison with the LiDAR benchmark yielded high levels of agreement.

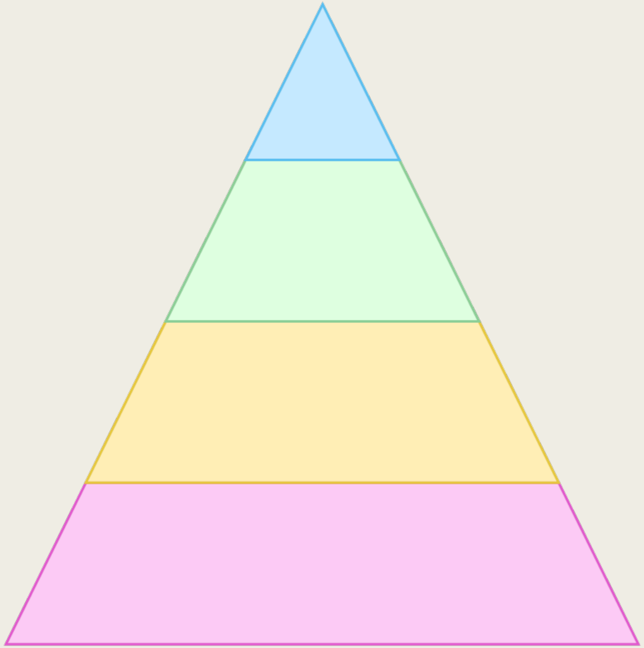


Summary of Positional Accuracy

Both RTK positioning approaches (Onboard and NTRIP) produced comparable, high-accuracy results, falling well within the tolerances required for most topographic mapping and engineering design tasks. The inclusion of GCPs was found to be critical in refining the model and eliminating minor systematic errors, ensuring the highest possible fidelity of the final DSM.

Key Findings: The Synergy of Methods

The study's most significant conclusion is the affirmation of an integrated survey model. Rather than viewing UAVs as a replacement for traditional techniques, they should be seen as a powerful extension of the surveyor's toolkit.



Final Products (Maps, Models, Plans)

Rapid Data Acquisition (UAV Photogrammetry)

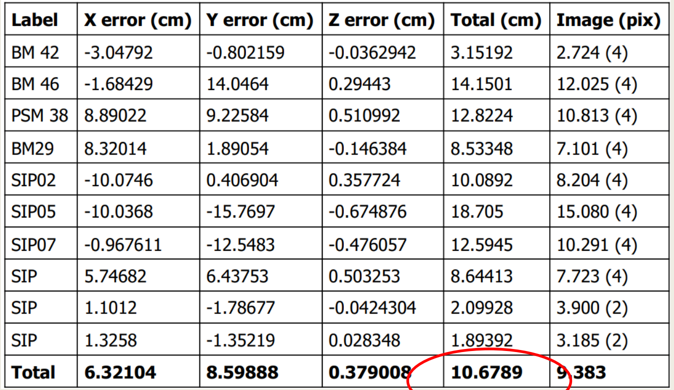
Data Validation & Processing

Foundational Control (Traditional GNSS Static Survey & GCPs)

Each methodology has a distinct, vital role. The reliability of the final products is built upon the foundational accuracy provided by traditional ground survey methods.

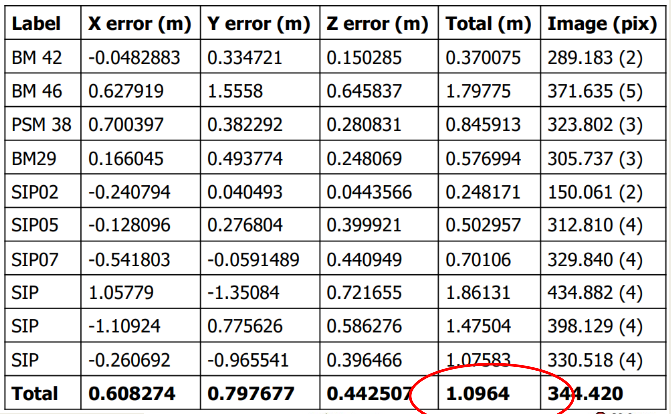
Key Findings – D-RTK Receivers Base with NTRIP

RTK – NTRIP - RMSE

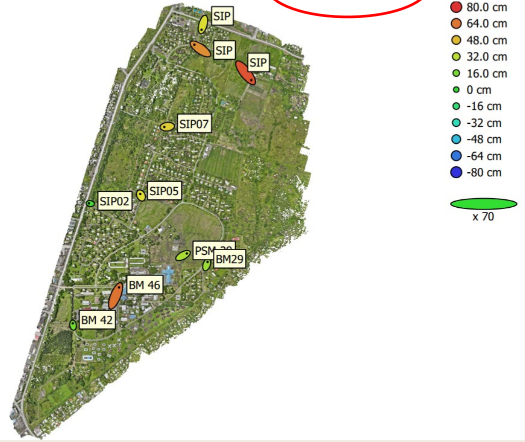


Label	X error (cm)	Y error (cm)	Z error (cm)	Total (cm)	Image (pix)
BM 42	-3.04792	-0.802159	-0.0362942	3.15192	2.724 (4)
BM 46	-1.68429	14.0464	0.29443	14.1501	12.025 (4)
PSM 38	8.89022	9.22584	0.510992	12.8224	10.813 (4)
BM29	8.32014	1.89054	-0.146384	8.53348	7.101 (4)
SIP02	-10.0746	0.406904	0.357724	10.0892	8.204 (4)
SIP05	-10.0368	-15.7697	-0.674876	18.705	15.080 (4)
SIP07	-0.967611	-12.5483	-0.476057	12.5945	10.291 (4)
SIP	5.74682	6.43753	0.503253	8.64413	7.723 (4)
SIP	1.1012	-1.78677	-0.0424304	2.09928	3.900 (2)
SIP	1.3258	-1.35219	0.028348	1.89392	3.185 (2)
Total	**6.32104**	**8.59888**	**0.379008**	**10.6789**	**9.383**

RTK – Receiver Base - RMSE



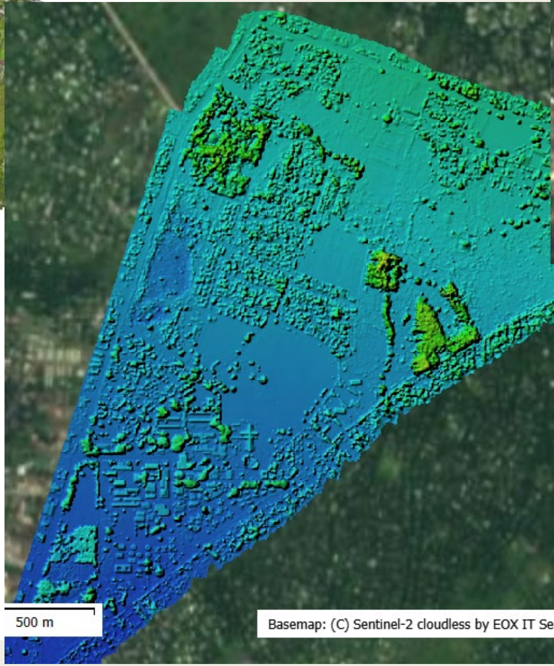
Label	X error (m)	Y error (m)	Z error (m)	Total (m)	Image (pix)
BM 42	-0.0482883	0.334721	0.150285	0.370075	289.183 (2)
BM 46	0.627919	1.5558	0.645837	1.79775	371.635 (5)
PSM 38	0.700397	0.382292	0.280831	0.845913	323.802 (3)
BM29	0.166045	0.493774	0.248069	0.576994	305.737 (3)
SIP02	-0.240794	0.040493	0.0443566	0.248171	150.061 (2)
SIP05	-0.128096	0.276804	0.399921	0.502957	312.810 (4)
SIP07	-0.541803	-0.0591489	0.440949	0.70106	329.840 (4)
SIP	1.05779	-1.35084	0.721655	1.86131	434.882 (4)
SIP	-1.10924	0.775626	0.586276	1.47504	398.129 (4)
SIP	-0.260692	-0.965541	0.396466	1.07583	330.518 (4)
Total	**0.608274**	**0.797677**	**0.442507**	**1.0964**	**344.420**



RESULTS

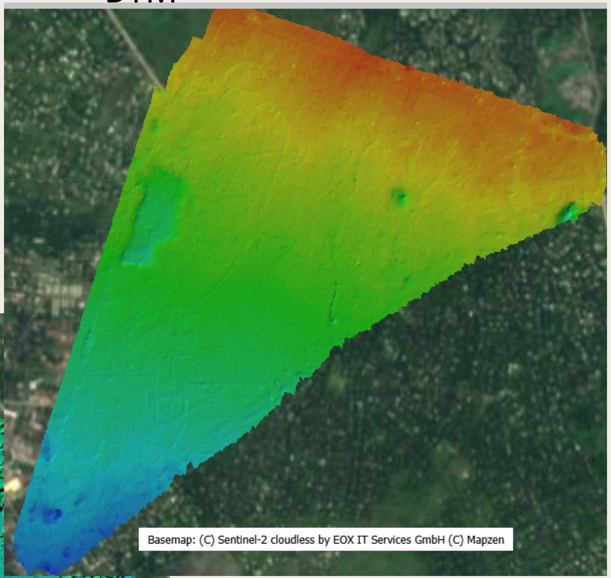
IMAGE

DSM



Basemap: (C) Sentinel-2 cloudless by EOX IT Services GmbH (C) Mapzen

DTM



Basemap: (C) Sentinel-2 cloudless by EOX IT Services GmbH (C) Mapzen

RESULTS


DIAGRAM
Scale 1:10,000
453
394
ROAD
WIDE
LAND
NATIVE ROAD
CABLE EMT 3 WIDE
ROAD 10 WIDE
ROAD 30 WIDE
ADMIN 323 REM LAND 31/70
423
446
454
453
425 31/530
426 31/530
466
223.1 ha
PSM 3374
PSM 8083
GN
To obtain True Bearings add 0° 14' 30"
To obtain FSM Bearings add 0° 08' 10"
To obtain Magnetic Bearings subtract 5° 30' approx.
Sea
Diagram
Scale 1 : 5,000
SURVEYOR GENERAL PAPUA NEW GUINEA
SURVEY OF
PORTION 453
CITY OF LAE
Milinch of LAE
Fourmil of MARKHAM
Cat. No. 31/529

Comparative Advantages

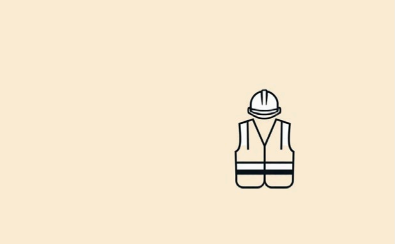
Attribute	Traditional Surveying (e.g., Total Total Station, Static GNSS)	UAV Surveying (RTK-Enabled) Enabled)
Accuracy	Very High (mm-level at specific points) points)	High (cm-level over a large area)
Data Density	Low (discrete points)	Very High (millions of points in a point point cloud)
Coverage Speed	Slow	Very Fast (hectares per hour)
Primary Role	Control, Validation, High-Precision Stakeout	Large-Area Mapping, Topography, Visualisation
Safety	Can involve work in hazardous areas (e.g., roadways)	Operator remains in a safe location

Implications for Surveyors in Papua New Guinea

The adoption of this integrated approach offers a practical and powerful path forward for the surveying profession in PNG. It allows firms and practitioners to leverage cutting-edge technology without abandoning the rigorous and reliable techniques that form the foundation of the profession.

Enhanced Efficiency

Dramatically reduce field time for large-scale topographic surveys, allowing for faster project turnaround and bidding on larger projects.



Improved Safety

Minimize the need for personnel to access hazardous or difficult-to-reach terrain, such as steep slopes, unstable ground, or active worksites.

Richer Data Deliverables Deliverables

Provide clients with not just contour maps, but also high-resolution orthomosaics, 3D models, and detailed DSMs for better planning and visualization

Competitive Advantage

Adopting modern workflows demonstrates technical capability and offers a significant advantage in a competitive market.

Conclusion: A Practical Path to Modernization

This research successfully demonstrated that RTK-enabled UAVs, when properly integrated with traditional surveying methods for control and validation, provide a robust solution for high-accuracy mapping. The findings show that surveyors are not facing a choice between old and new, but an opportunity to combine them.

Key Takeaways:

- UAVs extend the surveyor's capabilities, enabling efficient large-area mapping.
- Traditional methods, particularly GNSS static surveys for GCPs, remain indispensable for ensuring data quality and accuracy. accuracy.
- The synergy between the two creates a workflow that is greater than the sum of its parts: fast, comprehensive, and reliable.
- This integrated model is directly applicable and beneficial for the surveying community in Papua New Guinea.

Keywords & Acknowledgements

Keywords

RTK UAV Integration, Traditional Surveying Methods, GNSS Static Survey, Data Validation, Surveying Evolution, Photogrammetry, Digital Surface Model (DSM), PNG94, CORS

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Thank You & Questions

Thank you for your attention. We welcome any questions regarding our research, methodology, or findings.

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