Creating an Effective Flight Route Plan for Drone Photogrammetry Survey Using Mission Planner

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Abstract: Aerial photogrammetry has been around long before Unmanned Aerial Vehicle (UAV) and more specifically the drones. Drone photogrammetry has made the accurate creation of 2D maps and 3D models of physical landscapes faster and less expensive, putting it within reach of the budgets of many more users and organizations. It has emerged as a powerful tool for capturing high-resolution aerial imagery to create accurate maps and detailed models. To ensure that the resolution and data density of the output files are adequate, drones must fly based on a previously planned scheme, and then take pictures at specified distances or intervals along the route with predefined overlaps. The photos taken in this way will be suitable for creating maps and models. This study aims to use Mission Planner oftware (MPS) version 1.3.82 to plan and create an effective flight route for drone photogrammetry survey over the vast land of the Federal Polytechnic Nasarawa, Tammah campus. The methodology utilizes thirty-one (31) drone payload of passive optical sensors (RGB photogrammetry cameras) available in MPS. The study used properties of ten different RGB cameras with 500m altitude, 80% and 70% for forward and sideward overlap respectively. Results showed that camera "Canon EOS 5D Mark II" produces the most efficient flight mission plan with 54 photographs, 7 number of strips, 40.00 seconds stop spots and flight time of 1:03:57 hours. The integration of systematic planning methodologies with advanced software tools like Mission Planner enables the creation of highly effective flight route plans that deliver survey-grade photogrammetric products.

Keywords: *Flight Route Planning, Drone Photogrammetry Survey, Mission Planner, Unmanned Aerial Vehicle, Aerial Photogrammetry.*

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I. INTRODUCTION

In its simplest form, photogrammetry is the science of using photographs usually assembled to make maps and to take measurements through visual inspection or the use of software (Ey-Chmielewska et. al., 2015). Photographs can be collected from ground-based platforms, planes, satellites, or drones, and the type of camera used can range from a traditional Red-Green-Blue (RGB) camera to a Light Detection and Ranging (LiDAR) camera (Panda et. al., 2016). The deployment of UAV for mapping purposes has become very competitive over the years. So many platforms have been equipped with sophisticated imaging and navigation instruments which together constitute various photogrammetric tools (Colomina and Molina, 2014). Effective drone photogrammetry requires systematic flight planning with optimal overlap, terrain-aware altitude control, and precise imaging geometry. Mission Planner enables automated waypoint generation, camera triggering, and safety protocols essential for survey-grade 2D/3D mapping products. Pepe et. al., (2018) observed that a detailed planning of a flight mission is a fundamental prerequisite for a successful acquisition of airborne data sets. The most significant factor to consider when creating an effective route flight plan for photogrammetry survey is safety. The civil aviation institutions of many countries are working on defining proper rules and regulations to guide the safety of UAV operations (EASA European Aviation Safety Agency, 2015). The intended goal is to have a regulatory system that is same all over the countries. One of the common challenges is to keep a direct line of sight between the operator and the UAV without artificial enhancements of vision, example Binoculars view. The accuracy of outputs such as orthomosaics, digital elevation models (DEMs), and 3D reconstructions is critically dependent on effective mission planning. Flying Drone (UAV) in challenging terrain or places, such as hilly or mountains, requires to extend flight planning beyond the common features of 2D zone calibration and ground sampling distance (GSD) assessment and overlap criteria. But by combining real 3D zone into mission planning with inclusion of some advanced features, hence the proposed tool will facilitate the process of mission planning (Pix4D, 2023). With the availability of terrain model globally, individual user can customise digital elevation models of high resolution to

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improve the planning of photo positions with respect to area coverage, overlaps and resolution. Thus, reduced the problems of having areas not covered is addressed. Furthermore, since the UAV is equipped with GPS for accurate determination of location and features then, GPS signal quality reception can be evaluated within the UAV for a specific time and area in order to determine the best time for performing the photogrammetry survey (Aerotas, 2023). Drone photogrammetry has emerged as a transformative technology for creating high-resolution 2D orthomosaics, 3D points clouds, and digital surface models (DSMs) across diverse applications including surveying, construction monitoring, archaeology, and environmental assessment (Jiang et al., 2021). The technology relies on the principle of stereo photogrammetry, where overlapping images captured from different viewpoints are processed to reconstruct three-dimensional geometry and generate accurate spatial products. The quality and accuracy of photogrammetric outputs are fundamentally determined by the flight mission design, making effective flight planning critical for successful surveys (Zacc, 2025). Poor planning can result in insufficient image overlap, inconsistent ground sampling distance (GSD), data gaps, and ultimately, failed reconstructions or inaccurate measurements. This paper presents a comprehensive study on creating effective flight route planning for drone-based photogrammetry surveying using mission planner software (MPS) for Federal Polytechnic Nasarawa.

II. MATERIALS AND METHODS

➢ *Study Area*

The study was conducted utilizing the extensive perimeter plan of the Federal Polytechnic Nasarawa, situated in the Nasarawa local government area of Nasarawa State, Nigeria. The total area of the study site encompasses 21,454,915 m² (approximately 2,145.49 hectares). The geographical coordinates of the area are delineated by latitudes ranging from 8°33′N to 8°37′N and longitudes from 7°41′E to 7°45′E, as illustrated in Figure 1.

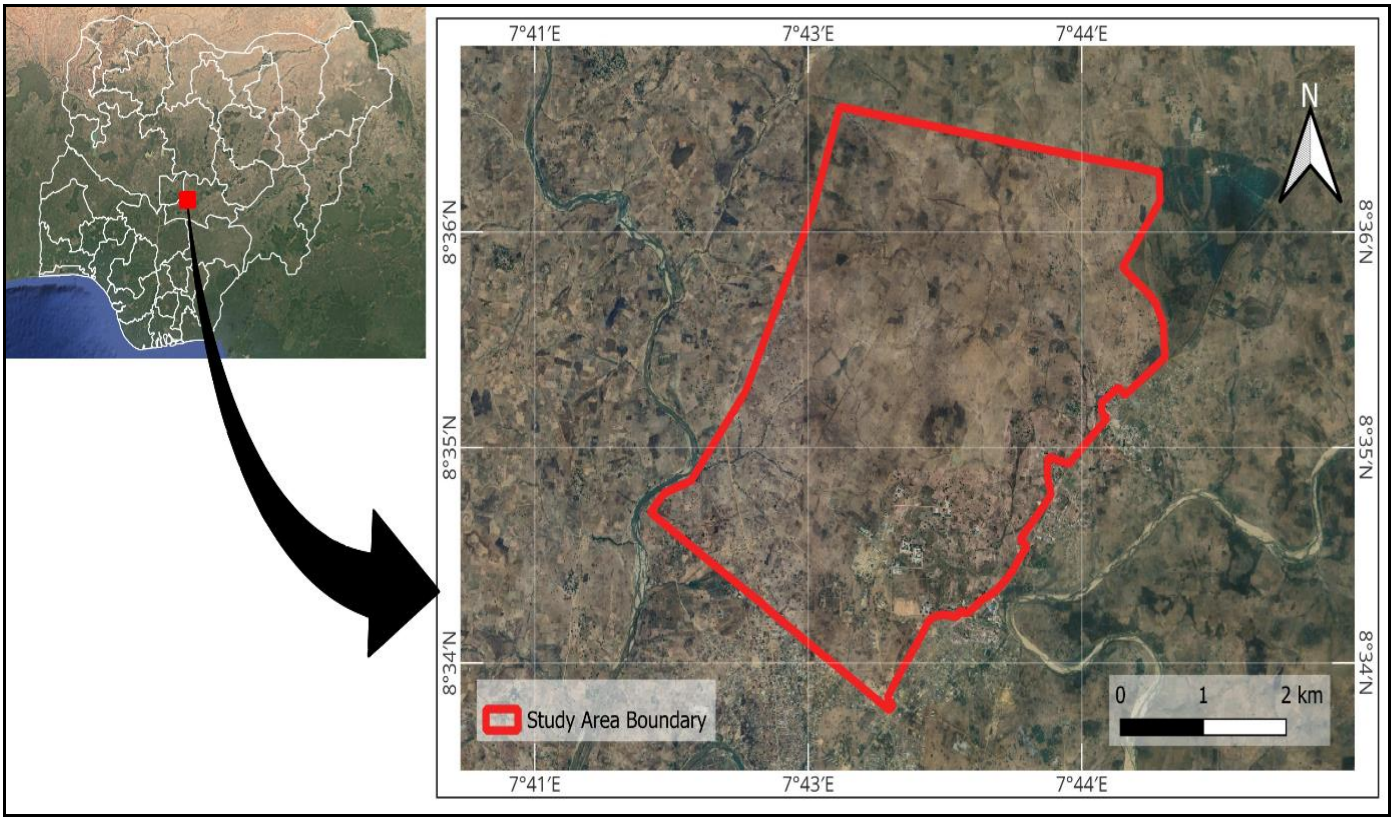

Fig 1 Map of the Study Area

➢ *Mission Planner Overview*

ArduPilot Development Team (2024), defined Mission Planner as an open-source ground control station software developed for the ArduPilot autopilot system, widely used for planning and executing autonomous drone missions. It provides comprehensive tools for waypoint navigation, camera control, telemetry monitoring, and post-flight analysis. MPS (Figure 2) offer grid/polygon auto-generation, corridor modes, overlap and side lap settings, DEM-based terrain following, and real-time mission simulations. For photogrammetry applications, Mission Planner offers specific features including:

- Automated grid pattern generation for area coverage
- Terrain-following capabilities using digital elevation models
- Camera trigger control based on distance or time intervals
- Real-time mission monitoring and adjustment capabilities
- Integration with various drone platforms and camera systems

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Fig 2 Mission Planner Software Interface

➢ *Photogrammetric Flight Planning Fundamentals*

Photogrammetric mission planning can be defined as the planning process of the project locations to fly (waypoints) and the UAV actions to. taking a picture, over a time period. The planning is often connected to the mission control but in principle can be separated from the mission planners. The planning part for all UAV's are similar to other vehicle developed over decades as the mapping evolved from analogue to the digital ages and technological advancement, see (Leica, 2012) for planes or (Schaer & Skaloud, 2007) for close-range helicopter mapping. Hence, the mission planners can be real-time connected to the UAV and serve as complementary to offline planning. Some mission planning tools support also systematic repetitions of Aerial photogrammetry survey flight for situation awareness or research purposes. When an individual plans a mapping mission, the success derived may depend on many factors. A planning algorithm must also provide feasible and flyable optimal trajectory that connects each waypoint (Zhang, 2024). These criteria are related to all the mapping needs. Core planning parameters include overlap (forward and side), ground sampling distance (GSD), camera orientation, flight speed, and triggering methods. For general mapping, most guidelines recommend ~75% forward overlap and ~60–70% side lap. Higher overlap (~80–85%) is advised for complex terrain, vegetated areas, or 3D modelling. Flight altitude is chosen to meet target GSD while considering regulatory limits (often 120m above ground level (AGL)). Camera settings must avoid motion blur, with shutter speeds synchronized to UAV speed and trigger intervals.

III. RESULTS AND DISCUSSION

➢ *Creating a Flight Plan with MPS*

Creating a flight plan in Mission Planner Software (MPS) involves several key steps to ensure a safe and successful autonomous flight. The process is intuitive and allows for precise control over the drone's route and actions. To commence the flight planning process, the MPS must be initiated. Once the software is active, navigate to the "Plan" tab to access the mission planning interface. Within this tab, the appropriate drone camera type should be selected to ensure that flight parameters are calibrated correctly for the specific sensor. The next step involves defining the survey area. This is accomplished by loading the shapefile that outlines the precise boundaries of the polytechnic's land (Figure 3). This action establishes the operational area for the drone's mission. Following the area definition, crucial mission parameters are established. The flight altitude, or desired ground sample distance (GSD), must be set to achieve the required image resolution. Furthermore, the image overlap is meticulously configured to ensure comprehensive data collection. Specifically, a forward overlap of 80% and a side overlap of 70% were designated. Finally, the flight speed is adjusted to a conservative 12 m/s (Figure 4). This speed is selected to be slow enough to prevent motion blur and guarantee high-quality imagery from most camera types, thereby ensuring the integrity of the captured data. The home position is the drone's starting point in green colour pin and is crucial for navigation. It's automatically set to the location of the drone when it is armed, but for planning purposes, it was manually set it on the map by right-clicking on the desired home location on the map and selecting "Set Home Alt." This is typically your take-off point. After defining all waypoints and their parameters, the process is repeated for other cameras for the entire flight plan on the map. An auto waypoint generated using 'survey grid' method for AeroHawk_8MP camera is shown in Figure 4.

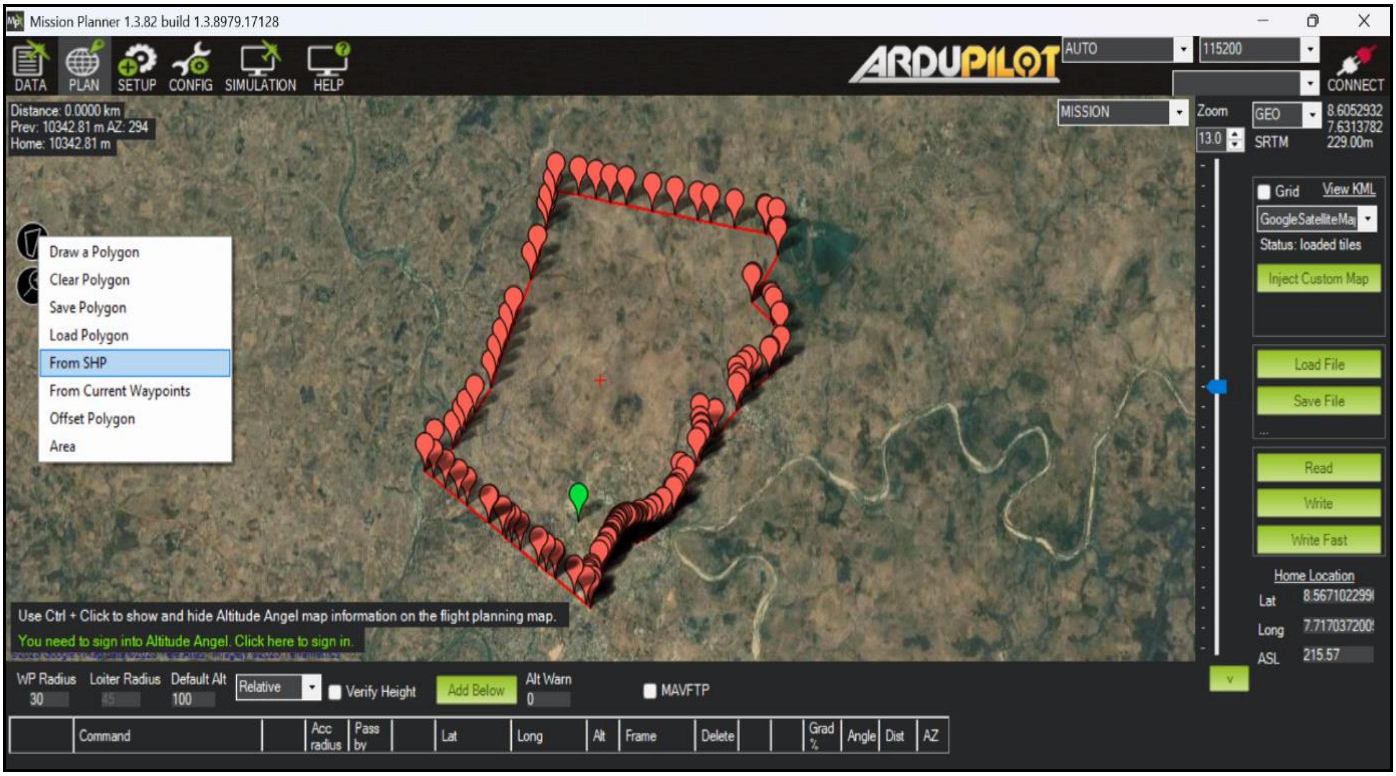

Fig 3 Shapefile of Study Area Loaded into MPS

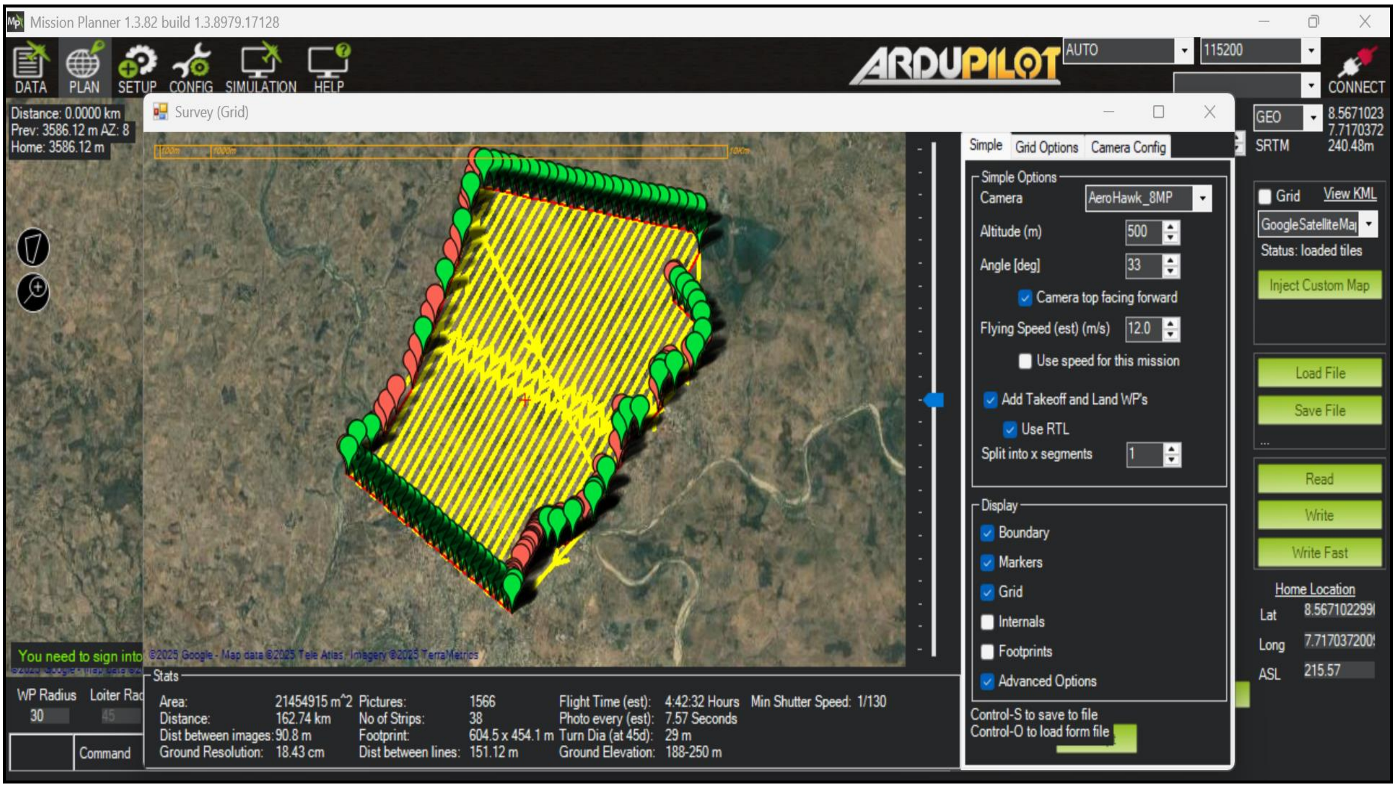

Fig 4 Flight Waypoints and Parameters Based AeroHawk_8MP Camera

➢ *Camera Payload Configurations in MPS*

The study utilized MPS version 1.3.82, which provides thirty-one default camera configurations. It is also possible to upload additional camera settings that are not pre-installed in the software, allowing for customization and integration of new or unsupported cameras. Using the same flight settings, table 1 summaries the statistics of each camera.

The Canon EOS 5D Mark II ("Canon 5D Mk2" as indicated on MPS) features a full-frame digital single-lens reflex (DSLR) with a 21.1MP CMOS sensor, DIGIC 4 image processor, and Full HD video capabilities. Its flight plan statistics for this study are listed on row number thirteen in Table 1 was observed to have provided the most efficient flight plan setting statistics for the study area (Figure 5). Important specifications of the camera are presented in Tabel 2.

Fig 5 Excellent Camera Configuration Type for the Study Area

Table 1 Summary of MPV Camera Statistics for the Study Area

S/N	Camera	Area (m²)	Distance	Dist between images	Ground Resolution	Pictures	No of Strips	Footprint	Dist between Lines	Flight Time (est)	Photo every (est)	Turn Dia (at 45d)	Ground Elevation	Min Shutter Speed
1	Nikon aw 100	21454915	159.44 km	92.4 m	13.37 cm	1508	36	616 x 462 m	154 m	4:36:48 Hours	7.70 Seconds	29 m	187-251 m	1/179
2	Canon SX230 HS	21454915	159.44 km	92.4 m	15.40 cm	1508	36	616 x 462 m	154 m	4:36:48 Hours	7.70 Seconds	29 m	187-251 m	1/155
3	Samsung s860	21454915	207.16 km	68.1 m	13.91 cm	2756	50	457.1 x 340.5 m	114.29 m	5:59:39 Hours	5.67 Seconds	29 m	187-251 m	1/172
4	Canon SX260-SX28	21454915	146.11 km	101.1 m	16.85 cm	1231	35	685.6 x 505.6 m	171.39 m	4:13:39 Hours	8.43 Seconds	29 m	187-250 m	1/142
5	NexS 25mm	21454915	203.14 km	62.4 m	10.21 cm	2936	49	468 x 312 m	117 m	5:52:41 Hours	5.20 Seconds	29 m	188-250 m	1/235
6	NexS 16mm	21454915	136.31 km	97.5 m	15.95 cm	1196	32	731.3 x 487.5 m	182.81 m	3:56:39 Hours	8.12 Seconds	29 m	188-250 m	1/150
7	Nex7 16mm	21454915	385.74 km	97.5 m	12.19 cm	10145	96	734.4 x 487.5 m	183.59 m	11:09:41 Hours	8.12 Seconds	29 m	186-251 m	1/196
8	Canon S110-S120	21454915	135.62 km	109.6 m	18.27 cm	1063	31	730.8 x 548.1 m	182.69 m	3:55:28 Hours	9.13 Seconds	29 m	187-251 m	1/131
9	Canon ELPH 520HS	21454915	129.9 km	113.7 m	20.79 cm	977	29	771.3x 568.8 m	192.81 m	3:45:32 Hours	9.48 Seconds	29 m	187-250 m	1/115
10	Canon ELPH 330HS	21454915	136.79 km	105.8 m	19.34 cm	1136	31	717.4 x 529.1 m	179.36 m	3:57:29 Hours	8.82 Seconds	29 m	188-250 m	1/124
11	Canon ELPH 115-13	21454915	159.72 km	91 m	14.81 cm	1526	36	617 x 455 m	154.25 m	4:37:17 Hours	7.58 Seconds	29 m	187-251 m	1/162
12	Canon A2300-A2400	21454915	159.72 km	91 m	13.17 cm	1526	36	617 x 455 m	154.25 m	4:37:17 Hours	7.58 Seconds	29 m	187-251 m	1/182
13	Canon 50 Mk2	21454915	36.84 km	480 m	64.10 cm	54	7	3600 x 2400 m	900 m	1:03:57 Hours	40.00 Seconds	29 m	189-245 m	1/37
14	NX1000	21454915	574.09 km	78.5 m	10.76 cm	23392	146	587.5 x 392.5 m	146.88 m	16:36:41 Hours	6.54 Seconds	29 m	186-252 m	1/223
15	FIREFLY 6S	21454915	100.28 km	156.9 m	26.14 cm	530	20	1039.5 x 784.3 m	259.88 m	2:54:06 Hours	13.07 Seconds	29 m	191-251 m	1/91
16	Sony A6000	21454915	167 09 km	78 m	9.75 cm	1876	39	587.5 x 390 m	146.88 m	4:50:05 Hours	6.50 Seconds	29 m	187-250 m	1/246
17	Sony A7R	21454915	1027.76 kn	85.7 m	8.72 cm	77869	263	641.1 x 428.6 m	160.27 m	29:44:19 Hours	7.14 Seconds	29 m	186-252 m	1/275
18	Parrot Sequoia Mon	21454915	162.85 km	90.5 m	47.11 cm	1575	37	603 x 452.3 m	150.75 m	4:42:44 Hours	7.54 Seconds	29 m	187-250 m	1/50
19	Parrot Sequoia RGB	21454915	155.9 km	94.9 m	13.73 cm	1427	36	632.2 x 474.4 m	158.04 m	4:30:40 Hours	7.91 Seconds	29 m	188-250 m	1/174
20	Canon S120	21454915	162.41 km	109.6 m	18.27 cm	1656	35	730.8 x 548.1 m	182.69 m	4:41:58 Hours	9.13 Seconds	29 m	188-251 m	1/131
21	WX 500	21454915	132 85 km	111 m	17.00 cm	1022	30	752.4 x 554.9 m	188.11 m	3:50:39 Hours	9.25 Seconds	29 m	188-251 m	1/141
22	RedEdge	21454915	216.85 km	65.5 m	34.09 cm	3002	52	436.4 x 327.3 m	109.09 m	6:16:28 Hours	545 Seconds	29 m	187-251 m	1/70
23	FLIR Vue 336 6.8mm	21454915	225.33 km	64 m	125.00 cm	3187	53	420 x 320 m	105 m	6:31:12 Hours	5.33 Seconds	29 m	187-250 m	1/19
24	FLIR Vuc 336 9mm	21454915	296 62 km	48.4 m	94.44 cm	5594	72	317.3 x 241.8 m	79.33 m	8:34:57 Hours	4.03 Seconds	29 m	187-252 m	1/25
25	FLIR Vue 336 13mm	21454915	414.86 km	33.5 m	65.38 cm	11674	102	219.7 x 167.4 m	54.92 m	12:00:15 Hours	2.79 Seconds	29 m	187-251 m	1/36
26	FLIR Vue 640 9mm	21454915	162.74 km	96.7 m	94.44 cm	1473	38	604.4 x 483.6 m	151.11 m	4:42:32 Hours	8.06 Seconds	29 m	187-250 m	1/25
27	FLIR Vue 640 13mm	21454915	224 65 km	67 m	65.38 cm	3064	53	418.5 x 334.8 m	104.62 m	6:30:01 Hours	5.58 Seconds	29 m	187-251 m	1/36
28	FLIR Vue 640 19mm	21454915	551.99 km	45.8 m	44.74 cm	22023	139	286.3 x 229.1 m	71.58 m	15:58:18 Hours	3.82 Seconds	29 m	187-252 m	1/53
29	GoPro Hero 4 Black	21454915	87.1 km	185.4 m	30.89 cm	370	18	1254.1 x 926.8 m	313.52 m	2:31:13 Hours	15.45 Seconds	29 m	189-250 m	1/77
30	Sony a7R2	21454915	159.44 km	92.4 m	13.37 cm	1508	36	616 x 462 m	154 m	4:36:48 Hours	7.70 Seconds	29 m	187-251 m	1/179
31	AeroHawk_8MP	21454915	162.74 km	90.8 m	18.43 cm	1566	38	604.5 x 454.1 m	151.12 m	4:42:32 Hours	7.57 Seconds	29 m	188-250 m	1/130

(Source: Exploring MPS by Authors)

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Table 2 Specifications of a "Canon 5D Mark II" Camera (Yang et al., 2014)

Characteristics	**Description**
Camera type	Digital* single-lens reflex
Sensor type	CMOS
Sensing area	36 x 24 nim
Pixel array	2784 x 1856* 3861 x 2574 or 5616 x 3744
Image type	RAW (14-bit) + JPEG
Image size	10 *8 + 24 MB, 14 *8 + 3*6 MB or 25 *8 + 6.1 MB
Shooting speed	Max 3.9 shots/s
Display	3-in TFT color LCD
Recording media	Type I or IICF card
ISO speed	100-6400
Shutter speed	1/8000 to 30 s
Dimensions	152 x 113.5 x 75 mm
Weight	S l O g
Operating temperature	0-40 °C

- *Analysis of Flight Altitude and Terrain*

As depicted in Figure 6(c), flight altitude did not pose a significant challenge due to the relatively flat topography of the study area and the absence of high-rise artificial structures. The flight path, shown in red, maintained a safe clearance from the terrain surface even at an altitude of 120m. As anticipated, the flight duration was substantially influenced by altitude. With the mission plan set at an altitude of 120m, it was estimated to take 1:03:57 hours, whereas the mission at 500m required a total flight time of 3:20:29 hours. This finding underscores the direct correlation between increased flight altitude and a corresponding increase in mission duration.

Conversely, a direct inverse relationship exists between flight altitude and the logistical parameters of a mission. Specifically, a lower operational altitude necessitates a greater number of flight routes, which, in turn, leads to an increased quantity of captured images and a higher density of waypoints Figure 6(a) and 6(b). Equally, at higher altitudes, these metrics are significantly reduced. The careful consideration of these variables is fundamental for selecting an appropriate drone platform capable of fulfilling mission requirements or for developing a tactical plan to effectively utilize available assets by splitting the study area into segments. This analysis confirms that meticulous flight route planning is a critical precursor to the successful execution of any drone photogrammetry project.

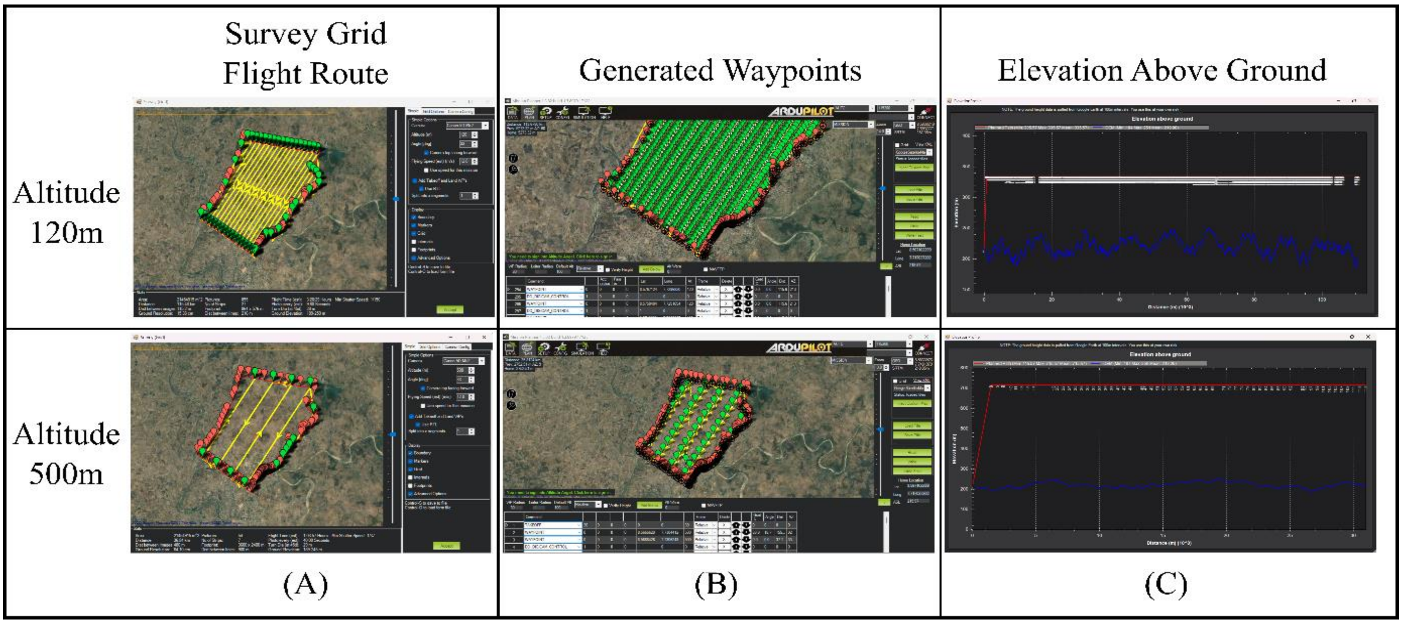

Fig 6 Comparison of Flight Plan Settings at the Altitudes of 120m and 500m. (a) the Survey Grid Flight Pathway, (b) the Generated Waypoints and (c) the Elevation Above Ground for Each Altitude.

IV. CONCLUSION

This study successfully demonstrated a systematic and effective methodology for creating drone flight mission plans and selecting an optimal camera for photogrammetric surveys over extensive land areas of the Federal Polytechnic Nasarawa campus. The findings from our comparative analysis of available camera options in MPS indicate that the Canon EOS M50 Mark II is the most suitable choice for the defined study area and flight specifications. Furthermore, this research has

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established a comprehensive framework that extends beyond mere camera selection. The developed template provides a robust basis for determining not only the most appropriate camera for a given photogrammetry mission but also for calculating the required flight time. This, in turn, facilitates the selection of a drone with the necessary battery capacity to ensure mission completion. The methodology outlined in this study can thus serve as a valuable guide for future aerial photogrammetry projects, ensuring efficiency and accuracy in data acquisition.

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