Student Conference Proceedings
Vol 1, No 1, 2025, Article ID 1926, 4 Pages

Student Conference Lübeck

Proceedings Article

Development and Optimization of a Lightweight Drone Prototype with Real-Time Kinematic (RTK) Technology

Noah-Art Leinweber[a,*] · Fabian Domberg[c,*] · Philipp Jan Labod[b]

[a]Student of Robotics and Autonomous Systems, Universität zu Lübeck, Lübeck, Germany
[b]Dronesperhour GmbH, Berlin, Germany
[c]Institute of Electrical Engineering in Medicine, Universität zu Lübeck, Lübeck, Germany
[*]Corresponding author, email: noahart.leinweber@student.uni-luebeck.de; f.domberg@uni-luebeck.de

Received 03 February 2025; Accepted 18 June 2025; Published online 15 July 2025

Abstract

This paper presents the design and optimization of a prototype of a lightweight drone equipped with Real-Time Kinematic (RTK) technology. The prototype weighs less than 250 grams and is designed for high-precision tasks such as surveying and infrastructure inspections. Key components include a 64 MP camera, a high-speed flight controller (FC), and an electronic speed controller (ESC). Constructing such a drone involves effective weight management and material selection, which enabled the integration of RTK technology, thereby achieving centimeter-level accuracy. This accuracy was validated through thorough flight tests and analyzed using Mission Planner software. This work demonstrates the challenges encountered in the design process, the outcomes of the performance evaluation, and the potential industrial applications of the drone.

I. Introduction

The utilization of drones in industrial and commercial applications has undergone exponential growth over the past decade. Of particular note are lightweight drones, which have garnered attention for their capacity to operate in urban environments with less regulatory restrictions as bigger counterparts while maintaining high precision and reliability [1]. These drones have found extensive use in infrastructure inspections, land surveying, and environmental monitoring, owing to their versatility and efficiency [2].
The integration of Real-Time Kinematic (RTK) technology signifies a substantial advancement in drone navigation. RTK is a precise satellite navigation technique used to enhance the accuracy of Global Navigation Satellite System (GNSS) data. It works by utilizing a fixed base station and one or more mobile receivers (rovers). The base station provides real-time corrections for satellite signal errors, enabling the rover to achieve centimeter-level positioning accuracy. This method is widely applied in fields such as land surveying, precision agriculture, and autonomous navigation [3].This means that a drone's position can be determined with a high degree of accuracy in real-time.
The to-be developed prototype named "Eule" is an example of this technological advancement, offering high precision that renders it ideal for complex tasks such as close-proximity inspections and autonomous navigation in challenging environments.

The C0 classification, as defined by the European Union Aviation Safety Agency (EASA), pertains to drones with a maximum take-off mass (MTOM) of less than 250

grams. These drones are primarily intended for low-risk operations within the 'open' category, specifically under category A1, which allows for flights over people but not over assemblies of people [4]. The goal of the developed prototype "Eule" is the C0 classification, which offers an additional advantage, enabling operations in closer proximity to people and structures without the need for extensive licensing.
However, achieving this weight limit while incorporating advanced technologies such as RTK and a high-resolution camera posed significant design challenges. This paper explores the solutions employed to balance weight, performance, and regulatory compliance, showcasing the potential of lightweight drones in professional applications.

II. Methods and Materials

The development of the "Eule" drone was driven by the requirement to balance the integration of advanced technology with stringent weight restrictions. Therefore, a systematic approach was necessitated. This section details the materials, components, and methods employed to achieve the objectives, focusing on hardware selection, software configuration, and iterative design processes.
The main challenge is the integration of state-of-the-art technologies, RTK systems and high-resolution imaging capabilities, while adhering to the 250 gram weight limit. To address this, lightweight materials and optimized configurations were employed to ensure structural integrity and operational efficiency.
The presented methods include hardware integration, weight optimization strategies, and the use of specialized software tools for system calibration and performance evaluation. The integration of these approaches resulted in the development of a prototype capable of performing high-precision tasks while adhering to regulatory requirements.

II.I. Hardware Integration

The "Eule" drone's design involved integrating advanced hardware components while adhering to strict weight constraints. During the design process different components were tested. The components listed below have become established due to various properties such as speed, reliability and weight.

- Flight Controller (FC): The Matek H743 V3 Slim flight controller, operating at 480 MHz, was selected for its high processing speed and compatibility with advanced navigation systems. Furthermore, it can provide great memory capacity. Its capability to execute stabilization algorithms in real time was critical for maintaining flight stability [5].
- RTK module: The RTK module enabled centimeter-level accuracy by using phase measurements of satellite signals, surpassing GPS and differential GPS (DGPS) systems. A lightweight RTK module was chosen, weighing only 7 grams, including the flat-flex-antenna.
- Camera System: A 64 MP autofocus camera, with a 84° DFOV, was integrated to capture high-resolution images essential for industrial applications. The camera was connected to a Linux-based microcontroller for image processing and storage [6].
- Motors and ESCs: High-efficiency motors and electronic speed controllers (ESCs) were chosen to maximize flight time and stability.
- Frame: Carbon-reinforced nylon (PAHT-CF) was used for the frame due to its excellent strength-to-weight ratio. This material provided durability without significantly increasing the drone's weight [7].

II.II. Software Tools

The software ecosystem played a significant role in the drone's development:

- **ArduPilot:** Distinguished by its versatility and status as open-source software, this particular program is utilized for the implementation of advanced flight control and navigation algorithms. Additionally it provides great support for special hardware, needed for highly automated drones. Therefore it is optimal to provide robust support for autonomous operations.
- **Mission Planner:** This software is utilised for the planning and analysis of autonomous flight paths. It provides real-time telemetry data and facilitates the configuration of waypoints and other flight parameters. Furthermore, it provides a useful Graphical User Interface (GUI) to select and tune the parameters needed for tuning and calibration.
- **Picamera2 API:** It has been integrated with the camera module to efficiently handle high-resolution image capture and processing.

II.III. Weight Optimization

In order to comply with the stipulated weight limit of 250 g, the design process was orientated towards the elimination of superfluous connectors and components, including but not limited to redundant wiring and over-sized mounting brackets. In addition, screw-based assemblies were substituted with lightweight clip mechanisms, ensuring a reduction in overall weight. The prototypes were created using an iterative approach in order to identify areas where material could be removed without compromising structural integrity. The design, which is shown in Figure 1 and Figure 2 was perceived sufficient, due to its lightweight, material efficient and grid-reinforced design.

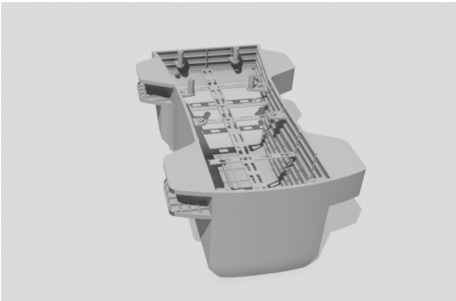

Figure 1: The following illustration depicts the latest revision of the drone casing, including the center frame and battery compartment, from a rear perspective. The model was generated using the 3D modeling software Shapr3D and Autodesk Fusion 360.

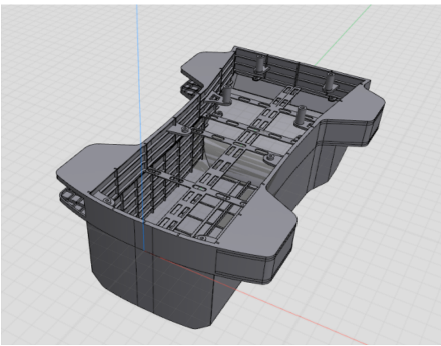

Figure 2: The following screenshot depicts the frame in the editor. The intricate details of the frame and the initiatives undertaken to minimize its weight are readily discernible.

The drone was tested in various environments to evaluate its performance, including autonomous flight tests using Mission Planner software. The software was used to analyze the accuracy of the RTK system and the drone's ability to navigate around obstacles.

Achieving the target weight required meticulous attention to every component. The frame underwent multiple iterations, resulting in a final weight of 35 g, a 36% reduction from initial designs. Screws were replaced with clip mechanisms, and unnecessary connectors on electronic components were removed to save additional weight. Also the stranded wire cables were replaced with ultra-thin solid wires.

III. Results and Discussion

This section presents the results from the development and testing of the "Eule" drone, focusing on its performance, technical capabilities, and potential industrial applications. The results are structured to highlight key aspects of the project, including weight management, flight performance, imaging capabilities, and the implications of the integrated RTK technology.
Through comprehensive testing and evaluation, the drone demonstrated its capacity to meet the requirements of the C0 classification, while achieving centimeter-level accuracy. This level of precision, when combined with the lightweight design, positions the drone as a versatile tool for various high-precision tasks. In the ensuing discussion, the challenges encountered during the developmental process are presented, along with the solutions implemented to address these obstacles.

III.I. Weight Management and Material Selection

The utilization of the material PAHT-CF in the drone's frame proved to be a pivotal factor in attaining the requisite weight reduction while ensuring durability. As demonstrated in Figure 3, this material exhibited superior performance in terms of tensile strength and flexural rigidity when compared to other popular engineering materials like ASA and PETG, despite a slight increase in density [7]. The fabrication of components necessitating a high degree of precision was accomplished through the implementation of resin-based additive manufacturing techniques, utilizing a Formlabs 3D printer. The material selected for this purpose was Tough2000, which has been demonstrated to exhibit an optimal balance between impact strength and stiffness. [8].

		PETG Jetzt einkaufen >	ASA Jetzt kaufen >	PAHT-CF Jetzt einkaufen >
Filament Eigenschaften	**Zähigkeit** Schlagfestigkeit - XY	52,7 kJ/m²	41,0 kJ/m²	57,5 kJ/m²
	Stärke Biegefestigkeit - XY	65 MPa	65 MPa	125 MPa
	Steifigkeit Biegemodul - XY	1670 MPa	1920 MPa	4230 MPa
	Schichthaftung Schlagfestigkeit - Z	13,6 kJ/m²	4,9 kJ/m²	13,3 kJ/m²
	Hitzebeständigkeit HDT, 0,45 MPa	69 °C	100 °C	194 °C
	Gesättigtes Wasser Absorptionsrate 25 °C, 55% RH	0,32%	0,45%	0,88%

Figure 3: A tabular comparison of the physical properties of relevant plastics for the construction of drones using the FDM manufacturing method is presented herewith [7].

III.II. Flight Performance

A series of test flights were conducted to evaluate the drone's flight performance. The focus of these tests was on assessing stability, navigation accuracy and battery efficiency. These tests were conducted in both controlled environments and real-world scenarios. The data collected during these tests was analysed using Mission Planner software.

The RTK module has been demonstrated to have a pivotal role in enhancing the precision of the drone's autonomous flight capabilities. During waypoint navigation, the RTK module exhibited a positional deviation of less than 3 cm, signifying a substantial enhancement over conventional GPS systems, which frequently demonstrate deviations within the meter range. This enhanced precision consequently enabled the drone to perform complex maneuvers around obstacles and execute precise landings, which is critical for industrial applications such as infrastructure inspections and surveying.
During the testing phase, the drone exhibited remarkable stability, even in conditions of moderate wind. The Matek H743 V3 Slim flight controller exhibited high-speed processing capabilities, enabling real-time adjustments to motor speeds and complex filtering to reduce sensor noise. This ensured environmental disturbances were compensated for, thereby maintaining a steady flight path. This capability was particularly beneficial for operations requiring the drone to hover or operate near sensitive structures.
The lightweight design, combined with efficient brushless motors and electronic speed controllers (ESCs), has resulted in a 30% increase in flight time. The motors and the light-weight rotor blades exhibited an optimal balance between thrust and energy consumption, thereby ensuring consistent performance without significant battery drain. This enhanced efficiency enabled the drone to execute extended missions, a crucial specification for industrial operations in remote or expansive environments.

Overall, the drone's flight tests validated the integration of RTK technology and lightweight design principles, demonstrating its suitability for high-precision tasks and extended operational use.

III.III. Imaging System

The 64 MP camera captured high-resolution images, which are critical for infrastructure inspection and surveying. The employment of a large-format sensor, in conjunction with a high Signal-to-Noise Ratio (SNR), enabled the acquisition of pristine images, even under suboptimal conditions such as low-light environments. The ARM-based microcontroller, running a headless version of Debian, ensured efficient multi-threaded processing and transmission of data. Real-time testing validated the system's reliability, even during extended flight durations.

IV. Conclusion

The "Eule" drone prototype demonstrates the capacity for integration of technologies such as RTK and high-resolution imaging within lightweight platforms. By meeting the C0 classification requirements, it offers significant advantages for use in urban and industrial contexts.
Future research could focus on integrating additional sensors for expanded functionalities. The success of this project underscores the growing importance of lightweight drones in precision-demanding industries and paves the way for their broader adoption in diverse applications.

Acknowledgments

The work has been carried out at Dronesperhour GmbH, Berlin and supervised by Prof. Dr. Georg Schildbach, Institute of Electrical Engineering in Medicine, Universität zu Lübeck, Lübeck.
Research funding: The author state no funding involved.

Author's statement

Conflict of interest: Authors state no conflict of interest. AI-based tools, including DeepL, were used in this paper to enhance linguistic accuracy and conciseness.

References

[1] T.-H. Tran and D.-D. Nguyen. Management and regulation of drone operation in urban environment: A case study. *Social Sciences*, 11(10), 2022, doi:10.3390/socsci11100474.

[2] E. U. A. S. A. (EASA), Eu regulations on drones and model aircraft, https://www.easa.europa.eu/, last accessed on 2025-12-01, 2020.

[3] M. Buśko, R. Krzyżek, and P. Hanus. The update of a land survey and height map for design purposes with the use of the rtk gps technology. *Geomatics and Environmental Engineering*, 3:19–31, 2009. URL: https://api.semanticscholar.org/CorpusID:126559536.

[4] European Union Aviation Safety Agency (EASA). (2020). Open category - low risk civil drones. https://www.easa.europa.eu/en/domains/drones-air-mobility/operating-drone/open-category-low-risk-civil-drones, last accessed on 2025-12-01.

[5] Mateksys, H743 slim v3 flight controller technical data, https://www.mateksys.com/?portfolio=h743-slim, last accessed on 2025-12-01, 2024.

[6] Arducam, 64 mp camera module specifications, https://docs.arducam.com/Raspberry-Pi-Camera/Native-camera/64MP-OV64A40/, last accessed on 2025-12-01, 2024.

[7] B. Lab, Bambu filament leitfaden, https://bambulab.com/de-de/filament-guide, last accessed on 2025-12-01, 2024.

[8] Formlabs, Tough 2000 resin, https://formlabs.com/de/shop/materials/tough-2000-resin/, last accessed on 2025-12-01, 2025.

10.18416/SCP.2025.1926