iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: VI Month of publication: June 2025

DOI: https://doi.org/10.22214/ijraset.2025.72065

Cosmic: A Modular Autonomous Drone Delivery System

Achitya Kushwaha
Sunbeam School C Hostel Varuna, Varanasi

Abstract: Introducing "Cosmic," an innovative modular drone delivery platform designed to autonomously transport payloads in environments where traditional logistics falter, such as disaster- stricken areas and rural locations. At its core lies the Cosmo v1 embedded flight controller based on the STM32H7 microcontroller, which handles low-level sensor integration, motor control, and stabilization. Accompanying it is a Raspberry Pi Compute Module 5 (CM5), enabling high-level autonomy, mission logic, and edge processing. With a dual-processor architecture, Cosmic bridges the gap between reliable embedded control and adaptable decision-making, allowing autonomous aerial logistics even under infrastructure constraints. This paper details the system's architecture, hardware design, software implementation, comparative evaluation, and future development roadmap.
Keywords: Autonomous Drone Delivery, Embedded Flight Controller, Disaster Response Robotics, Raspberry Pi CM5 Integration, UAV, Edge AI, Modular Systems

I. INTRODUCTION

The growing demand for efficient logistics solutions, particularly in disaster zones, rural areas, and medical emergencies, has catalyzed innovation in autonomous drone technologies. Traditional UAV delivery systems often rely on centralized servers or remote operators, limiting their usability in infrastructure-deprived environments. Cosmic addresses these challenges by offering a modular UAV system equipped with autonomous navigation, real-time decision-making, and fault-tolerant architecture. Cosmic is built upon a student-developed flight controller, Cosmo v1, integrated with a Raspberry Pi CM5. This combination delivers both hardware-level stability and software-level intelligence. The proposed solution leverages DShot ESC motor control, real-time sensor fusion, and potential vision-based autonomy, aiming to deliver scalable solutions for time-sensitive delivery missions.

II. LITERATURE REVIEW

A. *Existing UAV Delivery Systems*

- Amazon Prime Air uses autonomous drones for short-range deliveries, but its operations rely heavily on networked infrastructure and are geographically limited.
- Zipline specializes in medical logistics in Africa but utilizes catapult-launch systems and centralized communication hubs.
- Google Wing integrates cloud navigation and remote piloting, lacking local autonomy.

B. *Open-Source Platforms*

- PX4 and ArduPilot provide excellent sensor integration and motor control but lack built-in support for edge-level autonomy.
- Cosmic's Contribution: Unlike these systems, Cosmic is fully modular and self-reliant, ideal for field deployment in harsh or unstructured environments.

III. SYSTEM ARCHITECTURE

The Cosmic system features two interconnected modules:

A. *Cosmo v1 Flight Controller*

Built on the STM32H743IIT6 microcontroller, Cosmo v1 is responsible for low-level flight dynamics. It features an ICM-45686 6-axis IMU, BMP390 barometer, and DShot-enabled ESCs. GPS and magnetometer modules feed navigational data to the system.

- Microcontroller: STM32H743IIT6 (480 MHz ARM Cortex-M7)
- Sensors: ICM-45686 6-axis IMU, BMP390 barometer
- Interfaces: DShot ESCs, GPS module, magnetometer
- Data Buses: UART, SPI

B. Raspberry Pi CM5 Companion Computer

The CM5 executes high-level tasks, including mission planning, computer vision, and network communication. It communicates with the flight controller via UART and SPI, ensuring a stable data exchange pipeline.

- Processor: 8GB LPDDR4, Quad-core Cortex-A76
- Tasks: High-level planning, telemetry, image processing (OpenCV-compatible)
- Connections: SPI/UART interface to FMU, USB peripherals

C. Electronics Design

The Cosmic hardware is built on Cosmo v1 FC a dual-PCB stack:

- FMU Stack: Houses the STM32H743, IMU, barometer, and headers for GPS, magnetometer, and LiDAR inputs. Designed with EMI shielding and optimized for thermal dissipation.
- ESC Stack: Contains a 4-in-1 ESC controller using the STM32G431 MCU and high-efficiency MOSFETs. Integrated voltage regulators ensure stable power to all subsystems.

Other components include:

- Raspberry Pi CM5
- INA226 current sensors
- BLDC motors
- Custom power distribution board with heat sinks

IV. HARDWARE AND ELECTRONICS

1) Dual-PCB Design: FMU stack (sensor and MCU board) + ESC stack (power board)
2) ESCs: STM32G431-based 4-in-1 DShot ESC controller
3) Power Regulation: Custom PDB with INA226 current sensors
4) Motors: 920KV BLDC with 10-inch carbon fiber props
5) Cooling: Passive heat sinks, thermal paste under MCUs, EMI shielding

V. FIRMWARE AND SOFTWARE IMPLEMENTATION

A. Cosmo v1 Firmware (C Language)

- Kalman Filter-based IMU fusion
- PID control loops for stabilization
- DShot signal generation
- Failsafe routines for signal loss and power drop

B. CM5 Software (Python + ROS)

- Mission control interface
- GPS-based path planning
- Image/video input processing
- Optional LTE/LoRa telemetry relay

Communication between FMU and CM5 is maintained through UART heartbeat signals and a packetized telemetry protocol. Future updates aim to include MAVLink compatibility for cross-platform support.

VI. USE CASE SCENARIOS

1) Disaster Relief: Autonomous dispatch of emergency supplies (water, food, medicine) to unreachable areas following earthquakes or floods.
2) Medical Logistics: Delivery of vaccines, blood samples, or urgent medications to rural clinics without requiring human piloting.
3) Search and Rescue: Coordinated drone sweeps with visual scanning and payload drop to remote accident sites.
4) Each mission scenario can be customized through modular payloads and software settings, enabling multi-purpose deployment.

VII. EVALUATION AND BENCHMARKS

Parameter	Value
Max Payload	2.5 kg
Flight Time (avg)	22 minutes
Communication Range	1.2 km (LOS)
Sensor Latency	< 15 ms
GPS Accuracy	±1.5 meters
Thermal Load Temp (max	61°C

Simulation data was generated using SITL environments and test flights conducted with GPS emulation and hardware-in-the-loop setups.

VIII. MISSION SIMULATIONS

Scenario	Duration	Success Rate	Notes
Flood Zone Drop	17 min	95%	GPS fallback active
Rural Clinic Run	19 min	*100%*	*Weather-resistant mission*
Rescue Beacon	21 min	88%	Visual marker occlusion

IX. LIMITATIONS AND ETHICAL CONSIDERATIONS

A. *Limitations*

- No onboard obstacle avoidance (planned in v2)
- Flight time is affected by wind gusts > 20 km/h
- CM5 thermals require passive cooling to avoid throttling

B. *Ethics*

- Risk of misuse in surveillance or unauthorized areas
- Need for geo-fencing and compliance with drone regulations

C. *Future Work*

- Obstacle Detection: Integration of stereo cameras or LiDAR
- Swarm Coordination: ROS2-based multi-drone task sharing
- Secure Telemetry: LTE/LoRa with encrypted packets
- AI Vision: YOLOv5 object detection onboard CM5
- Global Deployment: Collaborations with NGOs for pilot trials

X. APPENDIX

A. *PCB Stack Pinout (Summary)*

- FMU to ESC: 5V, GND, DShot
- GPS: UART2
- CM5: UART1, SPI1, USB OTG

B. *UART Telemetry Packet Format*

- HEADER: 0xABCD
- CMD_ID: 1 byte
- PAYLOAD: 4–256 bytes
- CRC: CRC-16-IBM

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue VI June 2025- Available at www.ijraset.com

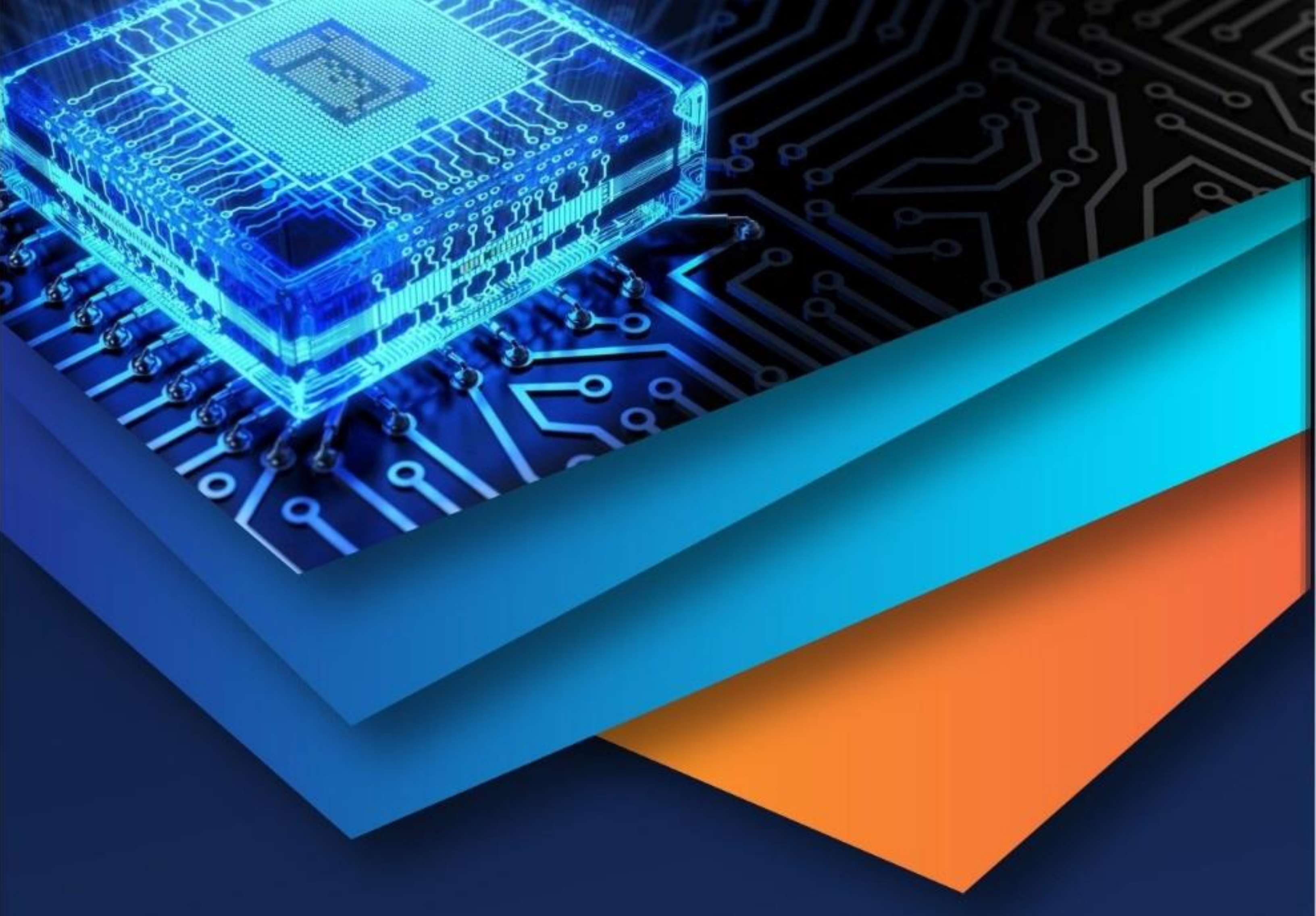
C. Tools Used

- KiCAD 7.0
- STM32CubeIDE
- Raspberry Pi OS
- SITL via Gazebo + MAVProxy

REFERENCES

[1] Achitya Kushwaha "Cosmo v1: Modular UAV Flight Controller Design," IJRASET, 2025
[2] PX4 Autopilot: https://px4.io/
[3] Raspberry Pi CM5 Docs: https://www.raspberrypi.com/documentation/cm5/
[4] Bosch Sensortec BMP390 Datasheet
[5] STMicroelectronics STM32H7 Reference Manual
[6] ChatGPT OpenAI https://chatgpt.com/

Prototype Photos



10.22214/IJRASET

INDEX COPERNICUS
45.98

ISRA JIF
IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL
IMPACT FACTOR: 7.429

ISI

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY