Delhi Technological University

Team UGV–DTU

System Design and Development Report

(SDDR - ISDC 2026)

Team UGV-DTU

Project: Valkyrie

Team Lead: Vedant Singh

Submitted To

International Space Drone Challenge (ISDC) 2026

Space Robotics Society (SPROS)

1 Conduct of Design Process, Team Identification, and Team Organization

1.1 Introduction

Team UGV–DTU is representing Delhi Technological University in the International Space Drone Challenge 2026. The team brings together students from multiple engineering branches who collaborate on aerial robotics, embedded systems, and mission-oriented design. This year's drone, **Valkyrie**, is named to reflect precision and resilience qualities essential for Martian analogue operations.

The team's background in competitive robotics and system integration supports the development of a stable, pilot-controlled aerial platform capable of scientific data collection and mission execution. Through this project, the team aims to advance DTU's presence in space-robotics competitions while expanding research culture and technical outreach within the university.

1.2 Organization

Team UGV–DTU follows a compact leadership structure where the Captain, Vice-Captain, and Team Manager come from three different engineering departments, ensuring that all major decisions reflect mechanical, electronics, and software perspectives. The team operates with four specialised departments that manage development and coordination across nearly thirty members from both engineering and non-engineering backgrounds.

- **Mechanical Department**: Airframe, structural design, load mapping, and stability.
- **Electronics and Power Department**: Power distribution, sensors, communication hardware, and flight electronics.
- **Software Department**: Companion computing, telemetry, ground control tools, image and data processing.
- **Corporate Department**: Documentation, outreach, sponsorships, logistics, and science research support.

This structure keeps subsystem responsibilities clear while enabling efficient cross-team integration and faster decision-making during the development cycle.

Name	Position	Major/Year	Subsystem
Vedant Singh	Captain	ME/3rd	Software
Yuvraj Gupta	Vice-Captain	EE/3rd	Mechanical
Akshat Rajwansh	Team Manager	ME/3rd	Electronics
Gatik Gupta	Electronics Head	AE/3rd	Electronics
Hriday Goel	Mechanical Head	ENE/3rd	Mechanical
Daksh Panchal	Software Head	CSE/2nd	Software
Narayan Mishra	Corporate Head	ENE/2nd	Corporate
Archit Shukla	Electronics Co-head	ECE/2nd	Electronics
Aryan Sharma	Electronics Co-head	ECE/2nd	Electronics

Table 1: Core Organizational Structure and Subsystem Roles

1.3 Project Planning

Valkyrie's development follows a phase-wise project plan designed to keep all subsystems synchronized through overlapping work cycles and weekly integration reviews. This ensures continuous progress and avoids bottlenecks.

This plan allows subsystems to advance in parallel while maintaining system-level alignment throughout the development cycle.

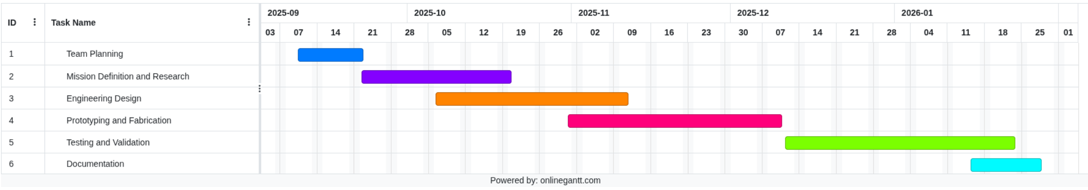

Figure 1: Project implementation timeline.

1.4 Team Recruitment Process

Team UGV–DTU recruits only first- and second-year students to maintain continuity and ensure long-term contribution. The cycle begins with a PR announcement across campus, followed by a three-stage selection process.

Candidates first attempt a 20-minute online aptitude test that evaluates logical reasoning and basic problem-solving. Shortlisted students then participate in a day-long departmental test involving practical, high-difficulty tasks designed to assess real engineering intuition beyond what generic tools or AI can solve.

Final candidates undergo an interview conducted by at least two council members, assessing subsystem knowledge, communication skills, and teamwork behaviour. This process ensures that selected members are technically capable and aligned with the collaborative culture required for ISDC development.

1.5 Initial Budget and Fundraising Strategy

Every year UGV–DTU receives an annual allocation of *(INR)*8,00,000 from the university, of which *(INR)*5,00,000 is mandated for fabrication and development, while *(INR)*3,00,000 is reserved for logistics, registration fees, and travel.

Traditionally, the team focuses on building Unmanned Ground Vehicles (UGVs) for the IGVC competition in the USA. However, beginning this session, the team has expanded into SPROS competitions, starting with ISDC and planning future participation in the International Rover Challenge (IRC). To support this expansion, the team internally allocated *(INR)*1,25,000 from the fabrication budget and *(INR)*75,000 from the logistics and registration budget specifically for the ISDC drone project.

The Corporate department actively approaches potential sponsors to reduce development costs and strengthen industry connections. In previous years, the team secured in-kind sponsorships from SolidWorks, Ansys, and MathWorks, which provided licenses and design tools essential for UGV development.

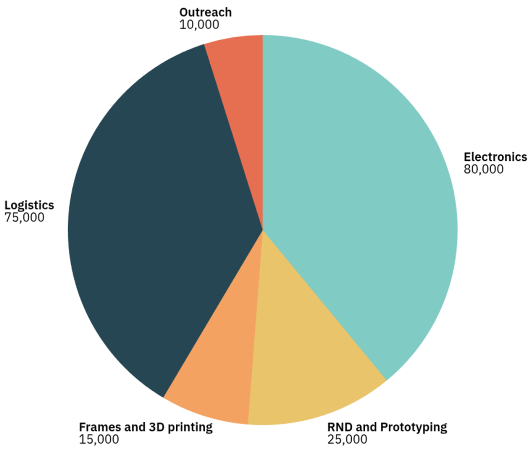

Figure 2: Fund Distribution

For outreach-linked collaborations, the team has initiated partnerships with Jindal Steels, Times of India, and Skilligen for workshop activities. For technical sponsorships, discussions are underway with Onshape, Siemens, and PCB Power for software and hardware support. The team has also successfully secured an in-kind sponsorship from Blue Robotics, which now provides exclusive discounts on components purchased through their platform. This combination of institutional support and external sponsorships ensures that the project remains financially sustainable throughout the development cycle.

1.6 Current Progress

The development of Valkyrie is underway across all four departments. The electronics team is currently integrating the companion computer with the Pixhawk and validating the environmental sensor suite through bench and field tests. The software team is training and evaluating machine-learning models for sensor calibration, developing the custom Mission Planner interface, and refining MAVProxy-based communication tools. On the mechanical side, the team is iterating multiple gripper concepts for missions and analysing drone aerodynamics under varied loading and wind conditions. The corporate department manages logistics, documentation, and workshop coordination while actively conducting outreach activities to promote robotics and space-science awareness.

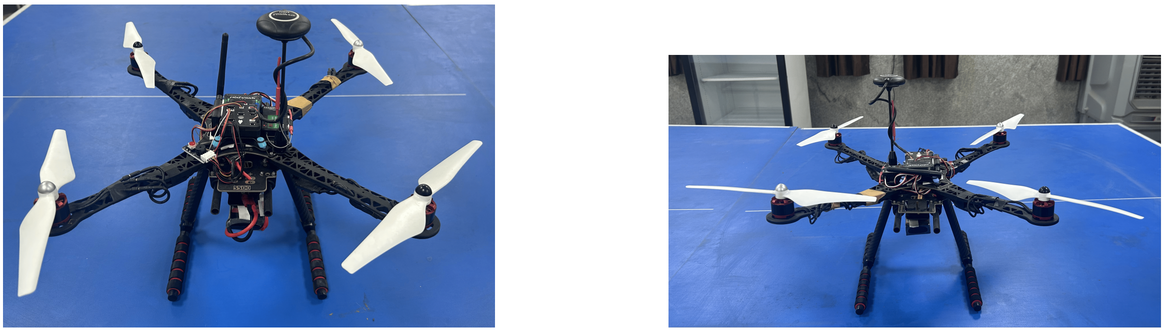

Figure 3: Current Progress of Valkyrie

1.7 Educational & Public Outreach

The team has prepared a structured outreach plan for November 2025 to January 2026 to increase visibility for UGV–DTU, promote ISDC, and engage students in STEM fields. In the first week of November, the team also participated in a university Open House event where Valkyrie was showcased to students from classes 9 to 12. The session covered the fundamentals of drone design, the importance of robotics, and the team's current progress for ISDC, helping inspire young students toward engineering and space robotics.

In the first week of January, the team will conduct a workshop in collaboration with Jindal Steels, Times of India, and Earthday.org focused on climate change, responsible technology development, and how robotics and aerial systems can support environmental monitoring. A second workshop, planned with Skilligen, will introduce school and undergraduate students to cybersecurity in robots, rovers, and drones, highlighting secure communication and safe control-system practices.

Alongside these events, the team is executing a two-month social media plan featuring subsystem updates, testing highlights, educational posts, and ISDC-related content. The official team website also includes a dedicated ISDC section containing development logs, design updates, and documentation for Valkyrie. Proprietary innovations are withheld, but all essential project information and outreach activities are shared publicly in accordance with competition expectations.

2 System Architecture of the Drone

2.1 Overview

Valkyrie is designed around a layered architecture that separates flight-critical control from high-level sensing and computation. The Pixhawk 2.4.8 flight controller manages all stabilization, IMU fusion, motor mixing, GPS-assisted positioning, and safety routines. A Raspberry Pi acts as the companion computer responsible for environmental sensing, imaging, data packaging, and telemetry extension without holding any flight authority. This separation ensures reliability, manual-control compliance, and modular development across subsystems.

2.2 Mechanical, Power, and Electronic Identification

The drone is built on the S500 carbon-fiber frame, equipped with four 920KV motors driven by 30A BLHeli ESCs and powered through a 4S 10000 mAh Li-Po battery. Power is distributed via an XT60-based PDB, with regulated 5 V rails supplied to avionics through a UBEC and the Pixhawk power module. The Raspberry Pi, Pixhawk, environmental sensors, and imaging payload operate on isolated regulated rails to minimize electrical noise from propulsion.

Component	**Specification**	**Qty**	**Price (Rupees)**
Pixhawk Flight Controller Set	2.4.8	1	15,000
Raspberry Pi	Model 4 (4GB)	1	7,000
SiK Telemetry	433MHz (pair)	1	7,500
FS-i6s/ia-10b TX/RX	10-channels, 2.4GHz	1	7000
Brushless Motors	920KV	4	3,500
ESCs	30A BLHeli	4	2,800
Propellers	9045	4	1,000
LiPo Battery	4S 10000 mAh	1	5,400
GPS Module	Ublox NEO-M8N	1	2,500
PDB	XT60 Input, 6 Rails	1	1100
Arducam Camera	64MP Autofocus	1	8,500
Environmental Sensors	SHT45, BME688, Optical dust sensor	1 set	6,000
FPV System	RunCam + TX800 VTX + ROTG01 PRO VRX	1	9,500
Drone Frame	S500	1	3,200
Total Cost			**80,000**

2.3 Electronic and Power Architecture

The Li-Po battery feeds the PDB, which supplies unregulated VBAT to ESCs and isolated regulated rails to the Pixhawk and Raspberry Pi. The Pixhawk handles all flight-critical functions; ESCs interface through MAIN OUT ports, and the FS-i6s receiver connects to RC_IN to preserve manual override. GPS, compass, and telemetry modules connect via dedicated ports (GPS, I2C, TELEM1).

The Raspberry Pi communicates with the Pixhawk over UART through TELEM2 using MAVLink, forwarding environmental sensor data and managing camera control. The FPV subsystem operates independently, with the RunCam Phoenix 2 Micro sending analog video to the TX800 VTX and received by a 5.8GHz VRX at the base station.

2.4 Subsystem Descriptions

2.4.1 Controller and Propulsion System

The Pixhawk 2.4.8 executes stabilization, IMU fusion, failsafe logic, geofence handling, low-voltage descent, and RC-loss behavior. It enforces manual-control-only operation under ISDC rules, giving highest priority to the Spotter Pilot's FS-i6s transmitter. Our 920KV motors paired with 9045 props provide adequate thrust, with 30A ESCs offering smooth throttle response and overcurrent protection.

2.4.2 Environmental Sensing

Sensors connected to the Raspberry Pi measure temperature, humidity, VOCs, CO_2-equivalent, gas composition, and particulate levels. The Pi aggregates these readings and transmits them as MAVLink payload messages for the ground station.

2.4.3 Imaging Payload

The 64MP Arducam AF camera is managed by the Raspberry Pi, which supports autofocus, controlled orientation (if a gimbal is present), and high-resolution captures for Science Mission documentation.

2.4.4 FPV Navigation

A low-latency analog FPV feed assists the base-station pilot during manual navigation. The FPV stream is completely independent of telemetry and command channels.

2.4.5 Safety Provisions

Safety systems include an FS-i6s hardware kill-switch, Pixhawk-managed failsafes, ESC thermal protection, and prop-guarded indoor testing. Manual-control priority is enforced at all times, with immediate override capability for the Spotter Pilot.

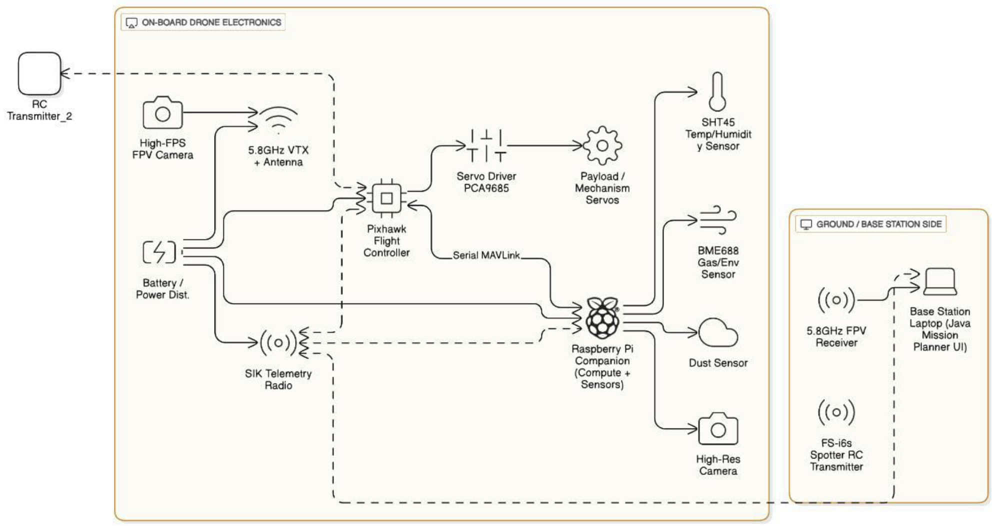

Figure 4: Drone avionics layout.

2.5 Software Architecture and Ground Control Interface

2.5.1 Overview

The drone's software architecture is built on three principles: strict manual-control compliance, modular/scalable design, and robustness under RF and sensor uncertainty. It preserves full human pilot authority while providing computational assistance for mission efficiency. The system integrates Pixhawk flight control, a Raspberry Pi companion computer, and a custom Java ground station within a framework that prohibits autonomous navigation but enhances pilot effectiveness.

2.5.2 Flight Control Layer (Pixhawk)

Pixhawk manages stabilization, mixing, and motor control while receiving dual RC inputs from the spotter and base-station pilots. Operating in only STABILIZE and ALTHOLD, it enforces no-autonomy rules by processing only manual input. Priority logic ensures the spotter's RC commands always override base-station inputs, while a failsafe landing triggers if both links drop. Key parameters include RC_OVERRIDE_ENABLE (spotter priority) and FS_THR_ENABLE (loss-link safety).

2.5.3 Companion Computer Layer (Raspberry Pi)

The Raspberry Pi provides sensor processing, imaging, and communication management with zero pilot authority. MAVProxy bridges Pixhawk–base station communication and monitors link quality. Sensor pipelines use ML-calibrated atmospheric data algorithms (temperature, humidity, pressure) with autoencoder-based noise reduction. The imaging system handles dual-camera operation: high-FPS FPV streaming and high-resolution scientific capture, with chunked transmission protocols enables reliable large-file transfer despite MAVLink bandwidth limits.

2.5.4 Base Station Layer (Java Mission Planner)

A custom Java ground control station replaces standard planners, offering mission-specific interfaces. It displays link health, ML-corrected environmental data, authority transition prompts, GNSS mapping with live tracking, and full camera-control tools. All UI elements prioritize fast decision-making within the 15-minute mission duration.

2.5.5 Science Strategy

Our science strategy employs an integrated data pipeline that streams live environmental sensor readings alongside real-time video to the base station, enabling immediate correlation of visual and quantitative data for rapid identification of scientific targets and informed capture of high-resolution imagery during flight.

2.5.6 Dual-Pilot System Design

The software implements a redundant dual-pilot structure with three control paths. Pilot A manages the FPV/base-station control, while Pilot B (spotter) provides VLOS oversight with instant emergency takeover. Authority hierarchy is Spotter, Base, Pi, Failsafe, respectively with soft-lock transitions to prevent abrupt changes. Additional safety features include conflict-input detection, stick-pattern–based pilot-overload prediction, RF-fade forecasting, and flight-envelope protection during handovers.

2.6 Communication Pathways

The communication architecture employs dual RF channels with MAVLink telemetry for bidirectional control and data exchange, plus separate analog video for low-latency FPV streaming. The system operates in unlicensed frequency bands with dynamic channel selection to handle congested RF environments. Multi-layer error handling includes per-chunk CRC32 verification, file-level SHA256 integrity checks, and adaptive retransmission strategies that ensure reliable operation despite interference.

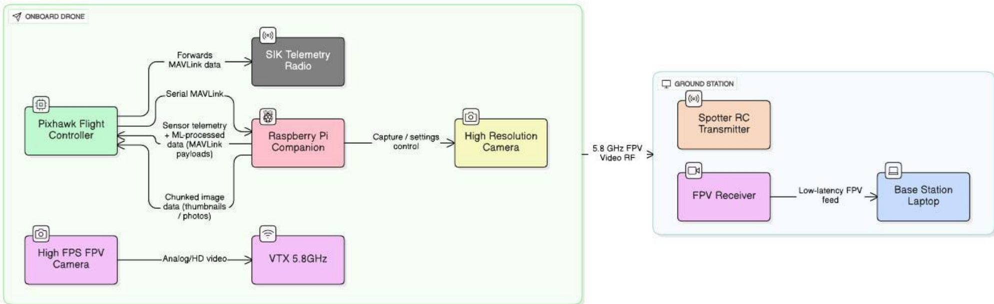

Figure 5: Communication link diagram

2.6.1 Data Integrity and Loss Prevention

Robust data management employs chunked transfer protocols with selective repeat ARQ and sliding window mechanisms for reliable file transmission. The system adapts chunk sizes based on real-time RF health assessment and implements forward error correction readiness for challenging link conditions. All mission-critical data undergoes comprehensive integrity verification before being presented to pilots or included in post-mission analysis.

2.6.2 Machine Learning Modules

Machine learning enhances system capabilities without violating manual-control constraints. ADC ML calibration uses regression models with environmental embedding for accurate sensor readings. Pilot behavior classification detects confusion or overload patterns from stick input analysis. RF health prediction forecasts link degradation using RSSI slope analysis, while visual triggers identify areas of interest and capture-worthy scenes for documentation.

2.6.3 Mapping and Science Capabilities

The software supports comprehensive mapping through photogrammetry processing with PPK geotagging for precise positioning. Onboard depth estimation utilizes stereo and monocular algorithms for terrain analysis, while real-time mosaic preview generates pseudo-orthomap composites from thumbnail stitching. These capabilities directly support Science Mission requirements for terrain documentation and Technology Mission vicinity surveying.

2.6.4 Mission Safety Logic

A hierarchical failsafe system ensures safe operation under all conditions. Spotter RC failure triggers base station override activation, while dual RC loss initiates automated landing procedures. Altitude boundary violations force AltHold mode stabilization, and IMU divergence detection freezes companion computer interventions. All safety transitions are logged for post-mission analysis and compliance verification.

2.6.5 Logging and Post-Mission Tools

Comprehensive data logging captures MAVLink telemetry, sensor outputs, camera metadata, and pilot arbitration timelines. Base station records maintain complete mission reconstruction capabilities for PIMA reporting and failure analysis.

The organized data structure enables rapid compilation of post-mission presentations within the 15-minute preparation window, directly supporting competition requirements for both Science and Technology mission deliverables.

2.7 Mechanical Design and Structural Considerations

2.7.1 Airframe

The mechanical design is based on the S500 composite airframe, which provides a stable, modular, and lightweight platform for mission-critical payloads. Its high stiffness and wide center plates allow for the secure mounting of additional hardware without compromising structural integrity. The frame performs reliably under dynamic thrust loads and offers sufficient space for the integrated payload module. The arm geometry ensures a uniform thrust distribution, minimizes vibration, and improves overall stability during aggressive maneuvers.

2.7.2 Camera and Gripper Mounting Module

A compact front-mounted actuation module integrates both the Arducam mount and the lightweight gripper into a single assembly. The camera is supported on a minimal two-axis servo mount that provides controlled pitch and yaw rotation for stable visual feedback during navigation and target acquisition. Beneath the same structure, a PLA-based gripper is mounted, featuring a servo-driven rotating linkage with a guided sliding tray, as shown in the CAD model. The mechanism uses a horn-and-pivot arrangement to convert servo rotation into linear gripping motion, allowing reliable handling of small, low-weight payloads. The entire module is designed to be lightweight, modular, and easily serviceable, while being mounted close to the drone's centerline to minimize forward Centre of gravity shift and avoid introducing significant imbalance.

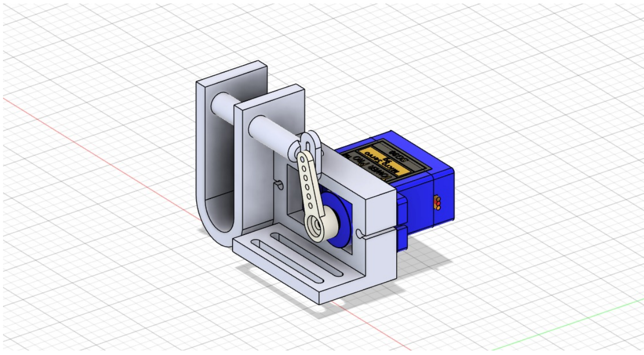

Figure 6: Gripper CAD Model

The servo-actuated release mechanism secures the atmospheric sensor in a retention tray during flight. Upon command from the base station, the servo rotates to unlock the gate, allowing the payload to descend under gravity to the designated deployment zone with minimal impact and precise accuracy.

2.7.3 Landing Gear

The extended landing legs provide sufficient clearance for the gimbal and protect the camera assembly during takeoff and landing. Rubber dampers help reduce impact loads.

2.7.4 Payload and Electronics Mounting

The flight controller, companion computer, and supporting electronics are mounted on the top and middle plates using vibration isolation stands. This arrangement protects sensitive components from motor-induced oscillations and ensures consistent sensor readings. The wiring channels and mounting points on the S500 frame allow a clean routing of the servo cables connected to the front module.

3 Testing and Validation Strategy

The initial testing unfolded as a structured sequence, beginning with full hardware verification, while later stages continue to progress. ESC–motor pairs were actively calibrated and monitored for current draw, sensors were continuously bench marked against reference instruments, and GPS modules were observed in real time for lock stability under open-sky conditions, confirming the electronics stage as largely complete.

Communication software testing then moved into focus, where the Raspberry Pi–Pixhawk UART link sustained ongoing data-rate and reliability checks while protocols continue to be refined. Controlled indoor flights followed, using prop guards and tethering lines while hover stability was evaluated, PID parameters were tuned on the fly, and sensor noise behavior was tracked under fluctuating prop-wash. With stable indoor performance achieved, the drone began transitioning into structured outdoor field tests mirroring ISDC operating conditions. These include live waypoint navigation trials, fluid dual-pilot authority switching, rapid kill-switch responsiveness checks, and camera performance evaluation under varied lighting.

Communication pathways are still undergoing range and interference tests using the 433MHz SiK telemetry system, while the 5.8GHz FPV link is monitored for latency, clarity, and dropout resistance. Full mission simulations will proceed next to replicate atmospheric sampling, mock data-collection runs, and the complete post-mission presentation workflow.

4 Dual Pilot Protocol and Safety Workflow

4.1 Role Separation

The drone operates under the ISDC-mandated dual-pilot structure. Pilot A at the base station controls the drone through FPV using the ground-station interface, while Pilot B (Spotter) maintains visual line-of-sight with an FS-i6s transmitter. The spotter holds the highest authority link to ensure immediate intervention whenever flight safety is at risk.

4.2 Control Authority Transfer

Authority transfers follow a simple and deterministic workflow. If the spotter identifies unsafe behaviour such as instability, drift, or potential collision they announce an override attempt and activate the mapped switch on the FS-i6s controller. Pixhawk prioritizes this RC input above all other control paths, enabling the spotter to instantly stabilize or redirect the drone. Once the situation is resolved, control may be returned to the base-station pilot in a coordinated manner.

4.3 Emergency Landing Protocol

Under critical conditions, the spotter executes an emergency landing by reducing throttle, levelling the altitude, and guiding the drone to a safe touchdown. A dedicated hardware kill-switch is available at all times to immediately cut motor power if the drone poses a hazard to the pilots, observers, or surroundings.

4.4 Verification and Reliability

The dual-pilot workflow was validated through repeated outdoor tests to ensure zero-delay takeover, conflict-free RC input handling, and stable transitions during dynamic maneuvers. These tests confirm that manual-control priority is preserved at all times, fulfilling both ISDC safety requirements and team-level operational standards.