Drone Design

Currently the hardware or software of the drone does not exist, however preliminary ideas have been formulated. This should sereve as a good baseline for what the drone needs to include, how it communicated and what safety features it should include.

Drone Subsystem Architecture

The drone is a custom-built, high-performance four rotor platform optimized for autonomous indoor navigation within a 10 x 10 x 4m netted flight cage. It features a decoupled, two-tier processing architecture: a dedicated Flight Controller (FC) handles real-time attitude estimation and low-level flight stability, while an onboard Companion Computer executes high-level vision processing, obstacle avoidance, and mission state machines.

System Specifications

Parameter	**Specification**	**Engineering Note**
Total Mass	1.95 kg	All-Up Weight (AUW) including 6S 4500mAh LiPo & Jetson Nano.
Hover Power	380 W	Average draw during steady hover, including onboard compute payload.
Max Power	920 W	Peak current draw during emergency maneuvers / dynamic correction.
Power Source	6S 4500 mAh LiPo	Sized to complete the 3-mission task cycle within the 30-min window.
Primary Link	5.8 GHz (Wi-Fi)	IEEE 802.11 compliant link for high-throughput video & telemetry.
Safety Link	2.4 GHz	Low-latency RadioMaster ExpressLRS manual safety link.

Hardware Integration & Component Breakdown

The hardware selection prioritizes structural rigidity, vibration isolation, and indoor localization reliability without reliance on satellite positioning.

- **Carbon Fiber Frame:** Built on a 7-inch carbon fiber racing frame selected for high torsional stiffness and ample top/bottom deck area to accommodate the companion computer, power distribution, and downward-facing optical sensors.
- **Propulsion System:** Driven by four 1350 Kv brushless motors paired with 7-inch dual-blade propellers. This combination balances high thrust-to-weight ratio with electrical efficiency during steady hovering.
- **Enclosure & Sensor Mounts:** A custom 3D-printed housing protects sensitive core electronics from mechanical impacts and provides a rigid down-facing mount for the primary visual landing camera.
- **Flight Control Stack:** Uses a T-Motor Velox F7 SE Flight Controller combined with a V70A SE 4-in-1 ESC. The F7 FC is flashed with open-source PX4 or ArduPilot firmware to support MAVLink offboard commands.
- **Indoor Positioning Sensors:** Equipped with a Mateksys Optical Flow & LiDAR sensor package. This provides real-time ground velocity tracking and precise altitude measurement to replace GPS in enclosed, signal-degraded environments.
- **Companion Computer & Vision Sensor:** An onboard NVIDIA Jetson Nano processes high-level autonomy algorithms. It interfaces with a **Global Shutter USB camera** targeting ArUco markers.

Software & Autonomy Architecture

The high-level autonomy suite is developed and executed within **MATLAB/Simulink**.

- **Vision Processing Pipeline:** A dedicated Simulink model performs real-time image processing in two stages:
  1. *Target Probe Detection:* Color-space thresholding (HSV) tuned specifically for yellow-green probe identification.
  2. *Landing & Alignment:* ArUco tag identification libraries compute relative 3D pose vectors for accurate landing alignment.
- **Telemetry & Offboard Communications:** High-level trajectory setpoints and real-time state estimates are streamed over MAVLink protocol via a 5.8 GHz Wi-Fi bridge.

Design Rationale: Global Shutter vs. Rolling Shutter in Indoor Vision:

Standard CMOS cameras use rolling shutters that expose pixels line-by-line. Under high drone vibration or swift pitch/roll maneuvers, this introduces severe image warping ("jello effect"), causing ArUco marker detection algorithms to fail or miscalculate target distance.

Integrating a **Global Shutter camera** captures the entire sensor plane simultaneously. This eliminates rolling-shutter distortion during motion, ensuring solid target tracking and accurate 3D pose estimation even during aggressive flight corrections.

Safety & Fail-Safe Architecture

To guarantee total flight control and satisfy safety protocols within the cage environment, the drone incorporates a triple-redundant fail-safe architecture.

- **Manual RC Override (Primary Safety):** A dedicated physical switch assigned on the pilot’s RadioMaster Boxer transmitter immediately revokes offboard MATLAB control, returning raw flight control to the operator.
- **Hard-Coded 3D Geofence (Boundary Protection):** A cylindrical 3D geofence is defined directly inside the FC firmware, preventing the drone from drifting into the cage netting regardless of automated setpoint commands.
- **GCS E-Stop (Ground Control Safety):** The MATLAB/Simulink operator dashboard features an emergency software kill-switch that transmits an instant motor-disarm instruction.

Signal Loss Procedure (Link-Loss Recovery):

If the primary 5.8 GHz Wi-Fi data link or 2.4 GHz ExpressLRS control link experiences a complete disconnect, the F7 FC and T-Motor ESCs bypass state-estimation and execute an immediate, autonomous **Land-In-Place** sequence. The FC maintains attitude lock while decreasing throttle at a fixed, controlled descent rate to land vertically without drifting.

Revision #2
Created 2026-07-31 16:12:18 UTC by Ludwig Franz Kumpf
Updated 2026-07-31 16:20:40 UTC by Ludwig Franz Kumpf