Search & Rescue Swarm Drone System

Master System Architecture Specification v1.1 (Complete & Aligned)

This document consolidates the Electronics Stack, Perception Architecture, and Mesh Communications Architecture into a single aligned system specification. It preserves all previously defined cost sections, processor separation, and mission philosophy.

1. Mission Overview

Deploy 1–12 cooperative 150 g class drones for indoor search & rescue and hazard (IED-like) detection. Each drone maps rooms, identifies people and objects, shares small structured map updates over mesh, and maintains a long-range pilot link.

2. Electronics Stack (150 g Class)

System Architecture Overview:

• STM32H7 – Flight control, stabilization, navigation, motor control, failsafe

• STM32N6 – Camera + LiDAR processing, AI inference, object detection, semantic mapping

• STM32WL – Sub-GHz mesh radio for building/tunnel communication

• 900 MHz long-range radio – Pilot command, telemetry, emergency control link

• Camera – OV2640 low-weight JPEG camera (~1 MP)

• LiDAR – ST 3D ToF 54×42 depth sensor

Data Flow:

Camera + LiDAR → STM32N6 → detections/map updates → STM32H7 → mesh radio (STM32WL)

STM32H7 ↔ 900 MHz control radio for operator link and failsafe

Design Principle: Flight controller remains deterministic and isolated. All AI and perception tasks execute on STM32N6.

3. Perception Architecture

3.1 Primary Mode – Real-Time RGB Detection
Sensor: OV2640 (~1 MP JPEG camera)

Model: YOLOv8n INT8 (TFLite)

Input to model: 256×256 RGB
Target inference: 20–30 FPS

Pipeline on STM32N6:
1. Capture 1 MP frame
2. Downscale/crop to 256×256
3. Normalize and quantize to INT8
4. Run inference on Neural-ART NPU
5. Apply confidence threshold (≥ 0.5)
6. Select highest-confidence detection
7. Output format: label confidence%

3.2 Fallback Mode – LiDAR-Only Detection
Sensor: ST 3D ToF 54×42 depth grid (~2,268 pixels)
Depth[y][x] $\rightarrow$ distance (mm)

Activated when lighting insufficient or RGB confidence unstable.

Model: Tiny INT8 TFLite CNN
Input: 54×42×1
Initial geometric classes:
• person_like_blob
• doorway_opening
• wall_plane
• obstacle_blob
• empty_open

Mode switching handled locally on STM32N6 and transparent to STM32H7.

4. Training Strategy (Teacher–Student)
There are no pretrained semantic models for 54×42 depth grids.

Training Process:
1. Collect synchronized RGB + LiDAR frames
2. Run YOLOv8n on RGB
3. Accept detections with confidence ≥ 0.8
4. Align camera detections with LiDAR grid
5. Train tiny CNN to predict labels from depth only

Recommended initial dataset: ~10,000 synchronized frames.

5. Mesh Communications Architecture
Phase 1 uses only 900 MHz XBee-class mesh radio (STM32WL).

Realistic constraints:
- Effective throughput ≈ 100 kbps
- Per-hop latency 20–80 ms
- Packet loss 1–15%
- Max payload ≈ 200 bytes

Store-and-forward model. Drones relay data hop-by-hop.
Structured data only (no video streaming).

Priority Model:
Highest – mission commands, hazard detections
Medium – map updates
Lower – LiDAR keyframes, diagnostics

Redundancy Principle: Multiple drones intentionally maintain overlapping map data so mission information survives loss of individual units.

6. Initial Development Hardware (Low Quantity Estimates)

STM32H7 dev board: $30–60

STM32N6 Discovery kit: $120–180

STM32WL Nucleo board: $40–60

RFD900x-class control radio pair: $180–260

OV2640 camera module: $6–12

ST 3D ToF LiDAR: $25–60

Starter budget estimate: ~$500–900 total for early prototyping.

7. Production Direction (Approximate Volume Pricing)

STM32H7 MCU: $8–18

STM32N6 MCU: $12–30

STM32WL radio module: $5–15

900 MHz control radio OEM: $50–130

OV2640 camera: $2.5–7

3D ToF LiDAR: $12–35

Electronics BOM estimate:

• Early builds: ~$200–350 per drone

• 1k+ units: ~$100–180 per drone