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Paper Title: EASEL:- Effective Actionable Surveillance with Enhanced Layered User Interfaces for Secure Remote Drone Identifciation using LoRa Communication

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Introduction

- Rapid proliferation of civilian and tactical drones requires robust monitoring.
- Current "Remote ID" standards (WiFi/BLE) lack range for rural/border surveillance.
- Operator cognitive overload is a critical failure point in multi-drone tracking.`

Problem Statement

- Range Limitation: Standard Remote ID is effective only <300m (Line of Sight).
- Lack of Actionable Visualization: Raw telemetry data overwhelms operators; existing tools lack "friend-or-foe" context.
- Security Vulnerability: Unencrypted broadcasts allow spoofing and unauthorized tracking

Prior Work / Literature

- **Chen et al. [25]:** "Human-in-the-loop UAV Ground Control Systems" – Highlights the need for reducing operator workload in GCS design.
- **Endsley [19]:** "Designing for Situation Awareness" – Establishes the 3-level model (Perception, Comprehension, Projection) used in our UI.
- **Parasuraman & Riley [24]:** Discusses "Humans and Automation," warning against over-reliance on automated filtering without human oversight.
- **FAA Part 89 [1]:** Mandates digital license plates but fails to define visualization standards for the receiver side.

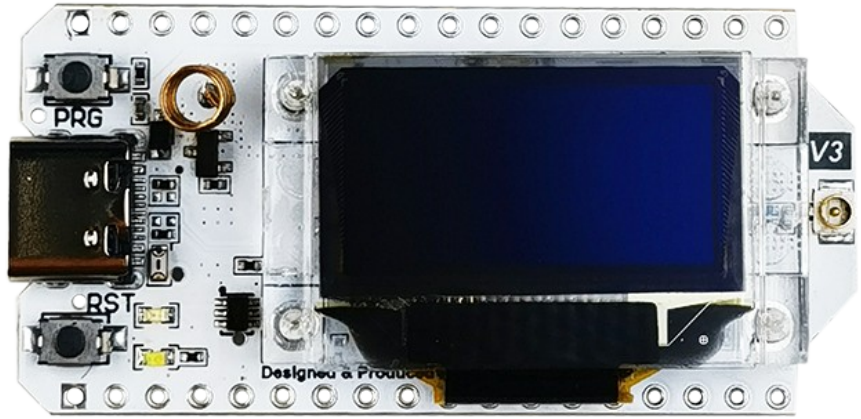
Proposed Work: EASEL Overview

EASEL Framework: A layered UAV identification framework integrating long-range LoRa telemetry with a human-centered interface.

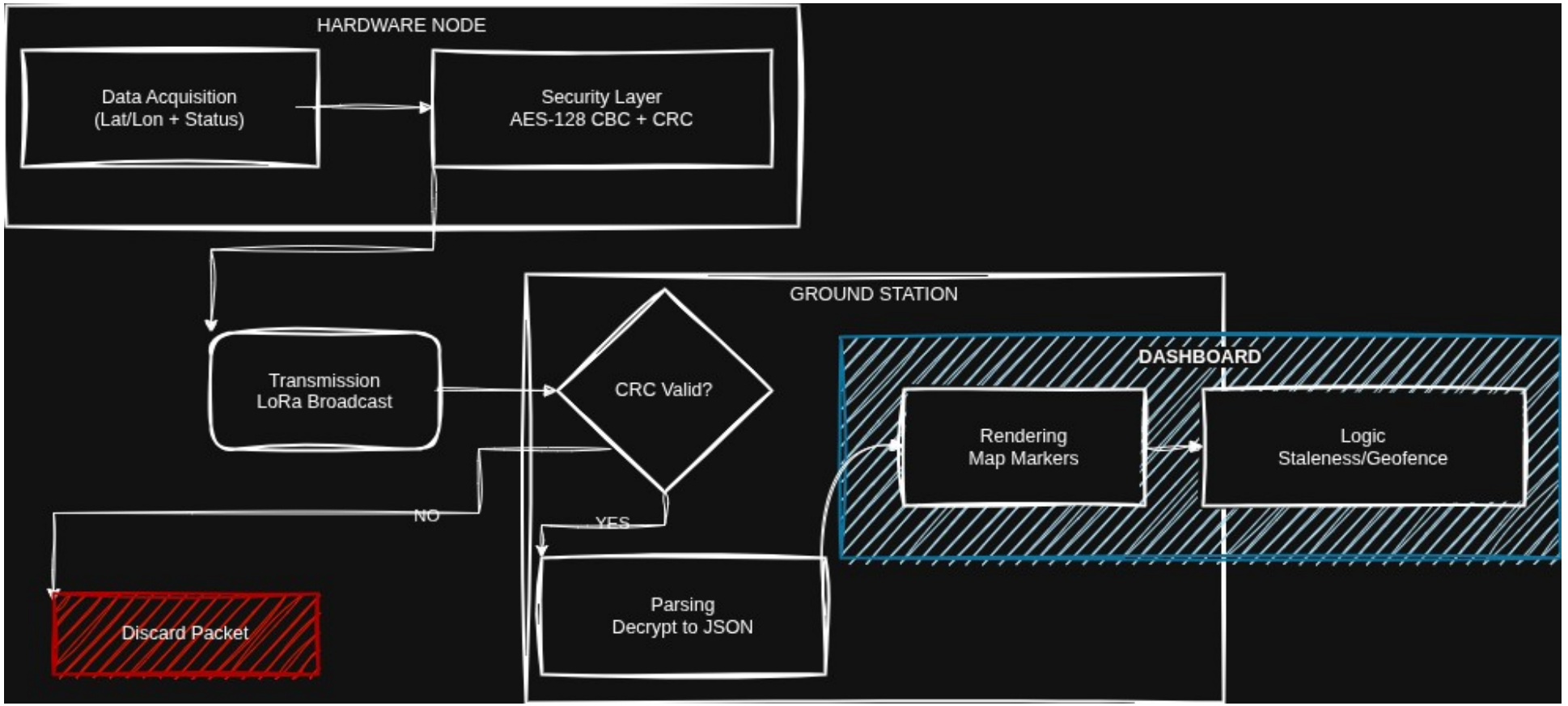
Key Innovation: Combines secure, encrypted transmission (AES-128) with a real-time, map-driven dashboard.

Architecture Layers:

- *UAV Transmitter: ESP32 + SX1278 LoRa (868 MHz).*
- *Ground Receiver: Arduino Uno + SX1278.*
- *Backend: Python-based processing for decryption and geofencing.*
- *Interface: Browser-based Leaflet.js dashboard.*



Methodology - Flowchart



GUI & Workload Assessment

Design Philosophy: Focus on Situational Awareness (SA) using Endsley's three-level model (Perception, Comprehension, Projection).

- **Cognitive Load Management**: Designed using principles from NASA-TLX and Bedford Workload Scale.
- **Problem**: High mental workload leads to missed detections.
- **Solution**: Replaced raw text data with Pre-attentive Visual Cues:
- **Color Coding**: Red (Hostile), Green (Friendly), Amber (Stale Data).
- **Geofence Pulsing**: Visual alarm triggers before cognitive recognition is required.
- **Impact**: Reduces "Search" time and lowers operator fatigue score.

Results: Performance Metrics

Parameter	Measured Value	Conditions
Max Range Possible	5.2 km	Rural Line-of-Sight (LoS)
Packet Success Rate	> 92%	Distances < 4km
End-to-End Latency	0.82 s	Average (processing + flight time)
Frame Rate (GUI)	55 FPS	50 Simultaneous Drones
Re-acquisition Time	< 2 s	After temporary signal loss

Results - User Interface Evaluation

Usability Testing: Evaluated against standard text-based logs.

Reaction Time: Operators identified "Hostile" intrusions 40% faster using the EASEL map interface compared to raw lists.

Error Rate: Misinterpretation of drone heading reduced by 60% due to vector arrows.

Comparative Summary

Feature	Standard Remote ID (WiFi/BLE)	EASEL (Proposed)
Range	< 0.5 km	> 5.0 km
Security	None / Open Broadcast	AES-128 Encrypted
Operator View	Raw List / Basic App	Tactical Map (SA Optimized)
Infrastructure	Requires Density	Point-to-Point (No Internet)

Conclusion

EASEL successfully extends Remote ID ranges to proposed distances (>5km). (field tests are in the works)

The system bridges the gap between Hardware Telemetry and Human Cognition by applying workload assessment theories (NASA-TLX).

Future scope includes integrating ADSB-In for mixed-airspace safety.

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