# Aerohack Design Dexterity Challenge: Bird Deterrence System

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# Problem Statement

A Drone is being used to deliver medicines in a hilly region with flight distance of 10 kms to destination. Unfortunately, the Drone is prone to attack by birds of prey such as Eagle, Crow etc. at around 5 kms from origin.

**Design** a system for Drone to deter the bird attacks and to safely traverse the remaining distance to destination to deliver the medicines. Cost of the system should not exceed Rs. 50000/- and weight of the proposed deterrence system should not exceed 1.5 kg.

- **Note:** The hilly area is prone to drizzles and wind gust.

# My Perception of the Problem

• Bird strikes are a major safety concern, capable of causing catastrophic failure.
• A single, static deterrence method is often ineffective long-term due to bird habituation.
• A successful solution requires a dynamic, multi-layered approach that is both intelligent and adaptable.

**My Guiding Principles:**

• **Proactive & Reactive:** Detect threats early and respond instantly to close-proximity attacks.

• **Intelligent:** Differentiate between real threats and environmental noise to avoid energy-wasting false positives.

• **Efficient:** Operate within the given weight and cost constraints, while maximizing battery life.

# Solution

• A Hybrid, Dual-Mode bird deterrence system for autonomous drones.

• **Detection:** Combines high-precision YOLO-based computer vision for long-range threats with low-power PIR sensors for close-range proximity.

• **Deterrence:** A layered defense with an "**acoustic bubble**" of piezo buzzers and a targeted,  LRAD-inspired directional speaker on a servo.

• **Control:** A state-based logic system on an ESP32 like microcontroller/potentially even could switch to 555 timers etc. to make system more cost feasible ensuring an intelligent and efficient response.

•The system is a modular and self-contained unit, designed to be lightweight, cost-effective, and robust.

**Fig.** Hybrid bird deterrence module with YOLO and PIR detection, piezo buzzers, directional speaker, and ESP32 control.

# System Architecture

The proposed system is built on a **Sense -> Think -> Act** architecture, ensuring a clear and robust control flow.

**<u>Sense (Inputs):</u>**

•**YOLO (Camera/esp32cam):** High-precision visual detection.

•**PIR Sensors:** Low-power proximity detection.

•**Push Button & Potentiometer:** Manual controls.

**<u>Think (Control Unit):</u>**

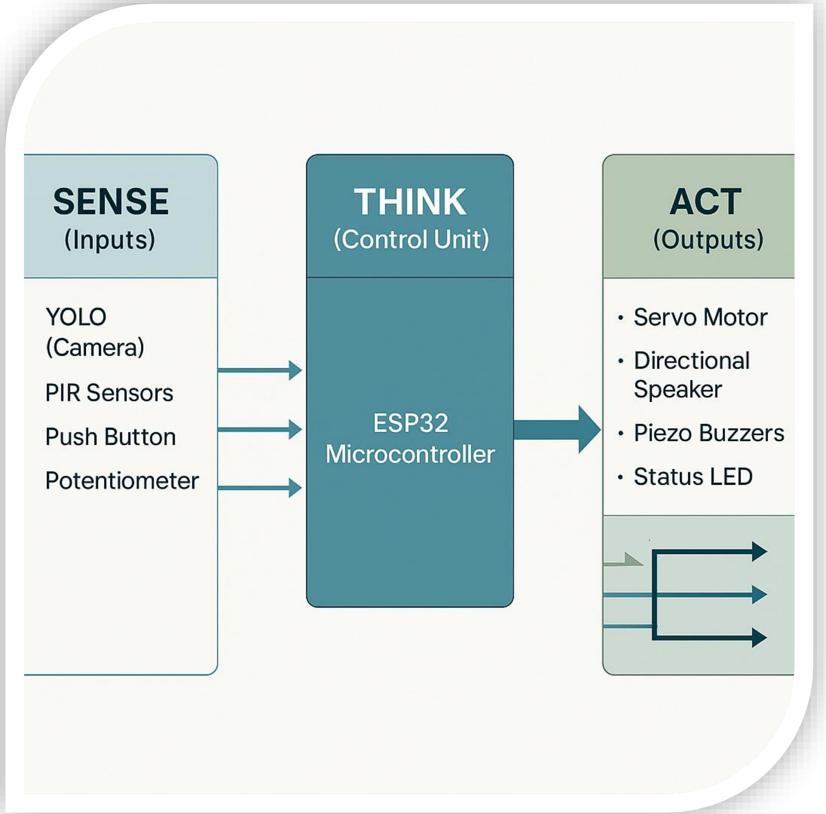
•**ESP32 Microcontroller:** The brain that processes sensor data and makes real-time decisions.

**<u>Act (Outputs):</u>**

•**Servo Motor & Directional Speaker:** Targeted deterrence (our USP).

•**Piezo Buzzers:** Omnidirectional emergency deterrence.

•**Status LED:** Visual feedback.




This modular design allows for intelligent, energy-efficient responses to threats.

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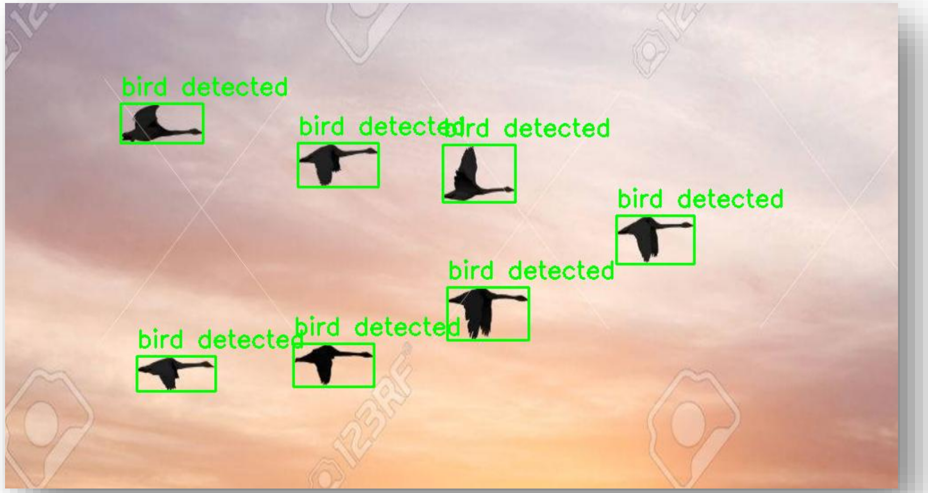
# Dual-Mode Detection: An Integrated Approach

**<u>Long-Range Detection (Camera + YOLOv5):</u>**

• Detects birds early with bounding box + angle for precise targeting.
• Custom-trained model improves accuracy and species recognition.
• Runs in real-time on **ESP32-CAM**.
• Pretrained YOLOv5 offers strong baseline while custom-trained model improves accuracy and species detection.




**<u>Close-Range Detection (PIR + Mic/Photo):</u>**

•Detects heat/motion for blind-spot coverage.
•Low-power trigger for fast response.

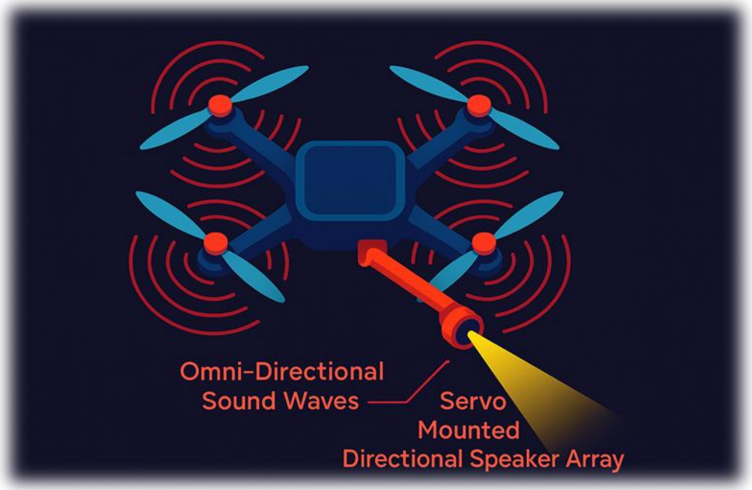
# Hybrid Deterrence Mechanism: USP

- The system uses a layered, intelligent deterrence approach, not a single one-size-fits-all solution.
- **Close-Range Defense:** Omnidirectional piezo buzzers create an immediate acoustic bubble around the drone.
- **Long-Range Defense:** A servo-mounted, LRAD-inspired directional speaker fires a focused sound beam at the threat.
- This hybrid approach is more effective, energy-efficient, and less prone to bird habituation.

# Deterrence I: Omni-Directional Buzzers

- **Component:** Four piezo buzzers mounted on the drone body.
- **Activation:** Triggered by a confirmed threat within close proximity (e.g., <2 meters, via PIR or YOLO bounding box size).
- **Effect:** Emit loud, irritating, omnidirectional sound signals (2-5 kHz) to startle and disorient birds.
- **Advantage:** Provides an immediate, 360-degree defense without the need for precise aiming, perfect for last-minute or surprise attacks.

# Deterrence II: LRAD-inspired Directional Speaker




**<u>Component:</u>**

**Speaker array** mounted on a **servo motor** for precise aiming.

**<u>Activation:</u>**

Triggered when a bird is detected **at range** (via YOLO), enabling **proactive deterrence**.

**<u>Functionality:</u>**

- Emits a **focused sound beam** (2–10 kHz sweep or 25–30 kHz ultrasonic burst).
- Can create **destructive interference patterns** to disorient birds without harming them.

**<u>Advantages:</u>**

**Targeted:** Aims sound only at the threat which **minimizes noise pollution**.

**Energy Efficient:** Activates and rotates **only when needed**.

**Proactive:** Repels birds **before** they breach the drone's safety zone.

# Simulation & Validation

To validate the concepts, I used a multi-platform simulation approach.

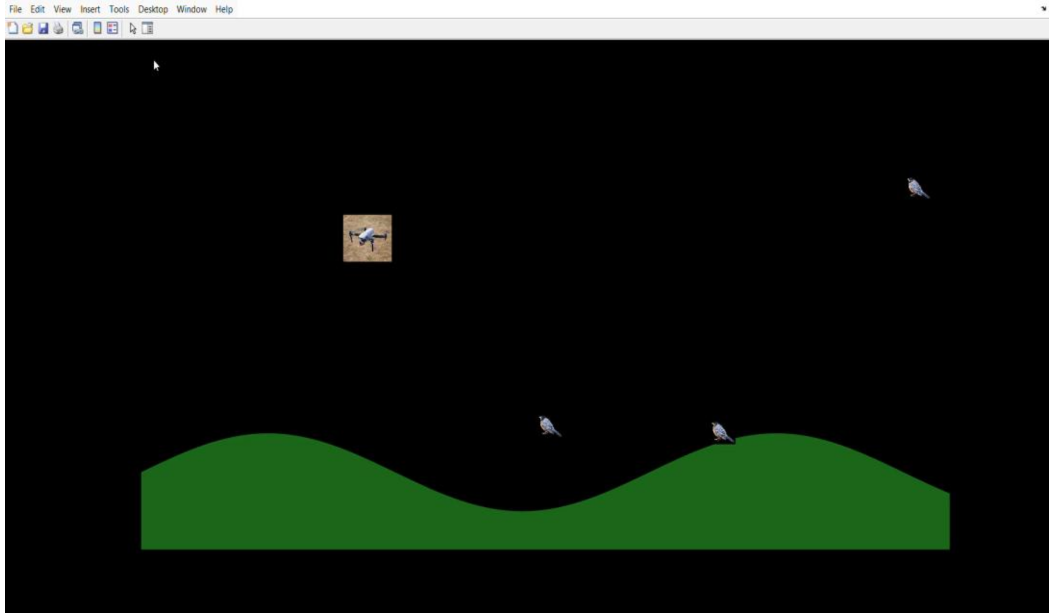
• **MATLAB:** A physics-based simulation of drone, terrain, and bird interaction to visualize the system's behavior.

• **Interactive Website:** A web-based application to demonstrate the servo-aiming and hybrid deterrence in real time.

• **Tinkercad:** A hardware-in-the-loop simulation to test the basic circuit logic with real-world components (Arduino, PIR, Servo, Buzzers).

*(All simulation files are included in the submitted ZIP folder.)*

# Simulation I: MATLAB Model



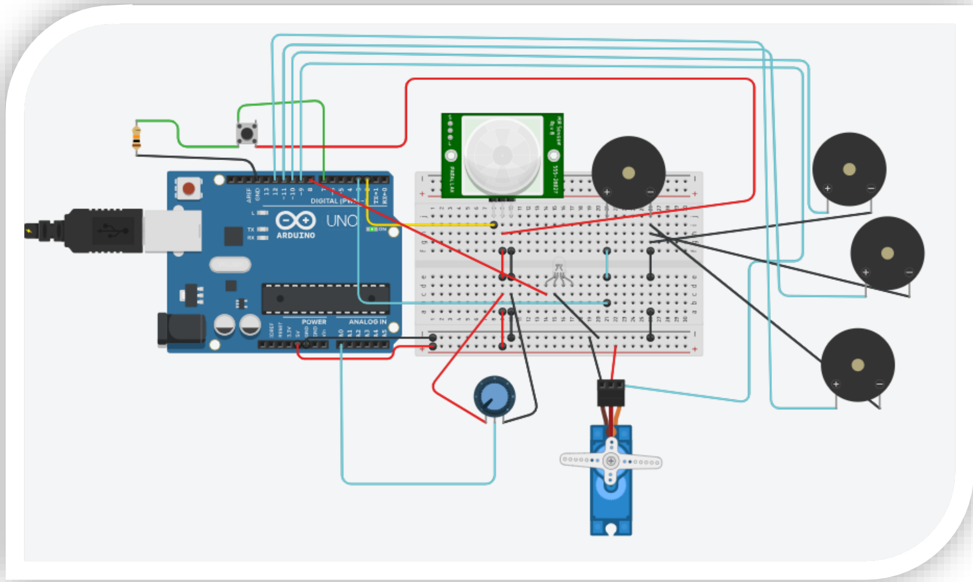

- **Objective:** Visually demonstrate the drone navigating terrain, detecting birds, and activating deterrence.
- **Scenario:** A drone flies a path while birds enter its airspace.
- **Visual Logic:** A red line simulates the LRAD beam targeting a distant bird.
- Cyan circles simulate omnidirectional sound waves from the buzzers for close-range threats.
- Birds "**flee**" when hit by the deterrence beam.

# Simulation II: Interactive Web Demo


- **Objective:** Provide a dynamic and interactive demonstration of the system's core logic.
- **Functionality:**

- A drone model with a servo arm is displayed.
- The user clicks anywhere on the screen to simulate a bird's position.
- The servo arm instantly rotates to point at the clicked location.
- A red sound ray simulates the directional speaker.
- Buzzers flash based on proximity (closer → brighter).

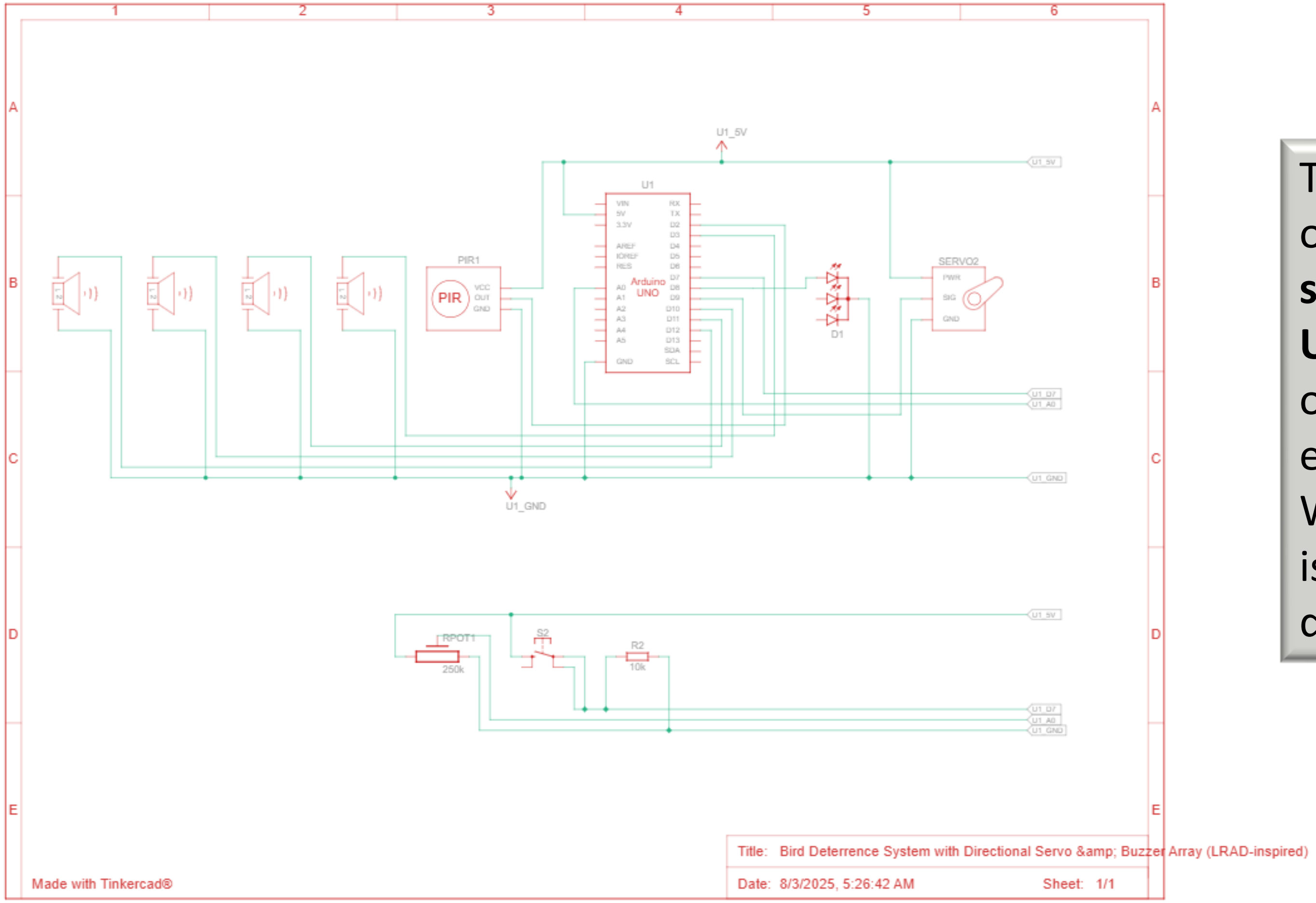
# Simulation III: Tinkercad Hardware Prototype




- **Objective:** Validate circuit logic and component integration before physical assembly.
- **Components:** Arduino Uno, PIR Sensor, Push Button, Potentiometer, Servo Motor, Buzzers, LED.
- **Logic:** The Arduino code reads input from the PIR sensor and push button , A potentiometer controls servo angle, while buzzers and LED activate upon detection.
- The push button in the circuit acts as the output from YOLO model

**Note:** Arduino Uno is used for simplicity in simulation, but real-world deployment could explore more advanced microcontrollers like ESP32 for wireless control and compact integration.

# Simulation III: Tinkercad Hardware Prototype




This **circuit schematic** illustrates the integration of a **PIR sensor**, **push button**, **potentiometer**, **servo motor**, **buzzers**, and **LED** with the **Arduino Uno**. Inputs control the system's behavior, while outputs respond to detection events. The setup enables quick validation of the deterrence logic. While Arduino is used for simulation, the design is adaptable to **ESP32** for real-world deployment.

# System Build: Materials & Fabrication

- **Drone Frame:** A F450 quadcopter frame with carbon fiber arms provides a lightweight and durable base.
- **Electronics:** A custom Printed Circuit Board (PCB) replaces the prototype's breadboard for compactness and reliability.
- **Microcontroller:** An ESP32 or ESP-CAM handles the YOLO algorithm and control logic, offering powerful, real-time processing.
- **Deterrence Housing:** A 3D printed ABS plastic enclosure houses the LRAD-inspired directional speaker, balancing acoustic rigidity with minimal weight.

# Weight & Cost Analysis

| Component | Estimated Weight |
|---|---|
| ESP32-CAM Module | ~ 50 g |
| PIR Sensors (x2) | ~ 20 g |
| Piezo Buzzers (x4) | ~ 40 g |
| Micro Servo Motor | ~ 10 g |
| Directional Speaker & Amplifier | ~ 100 g |
| Custom PCB & Wiring | ~ 50 g |
| 3D Printed Housing (ABS) | ~ 150 g |
| LiPo Battery (for payload) | ~ 200 g |
| Total Estimated Weight | ~ 620 g (≈ 0.62 kg) |

| Component | Estimated Cost |
|---|---|
| ESP32-CAM Module | ~ Rs. 1,000 |
| PIR Sensors (x2) | ~ Rs. 300 |
| Piezo Buzzers (x4) | ~ Rs. 400 |
| Micro Servo Motor | ~ Rs. 500 |
| Directional Speaker & Amplifier | ~ Rs. 1,500 |
| Custom PCB Fabrication | ~ Rs. 2,000 |
| 3D Printing & Materials | ~ Rs. 1,000 |
| LiPo Battery | ~ Rs. 2,000 |
| Miscellaneous components | ~ Rs. 500 |
| Total Estimated Cost | ~ Rs. 9,200 |

The total estimated weight of the complete deterrence system is approximately 0.62 kg, which is well below the 1.5 kg constraint.
Concurrently, the total estimated cost is around Rs. 9,200, which is a small fraction of the Rs. 50,000 budget.
These findings demonstrate that the proposed solution is not only technically sound and effective, but also highly feasible and fully compliant with all specified weight and cost requirements.

# Conclusion

- The proposed system is a robust and intelligent solution to the problem of drone bird strikes.
- The hybrid detection and deterrence approach ensures reliability and effectiveness against various threats.
- Leveraging readily available and cost-effective components, the design meets and exceeds all project constraints.
- Modular architecture allows for easy integration into existing drone platforms, making it a highly practical solution.

# Future Scope & Enhancements

• **Advanced Sensor Fusion:** Further integration of a microphone array could enable audio-based bird detection and localization, which would supplement the existing vision and motion data.

• **Bio-Acoustic Deterrence:** The system could be enhanced by developing a library of dynamic, bio-acoustic tones and distress calls, which would make the deterrent more effective and prevent bird habituation.

• **Predictive Analytics:** Implementing an on-board machine learning model could allow the system to analyze and predict bird flight patterns, enabling a shift from reactive deterrence to a proactive one.

• **Increased Durability:** The entire system could be made more robust for diverse environments by designing a fully weather-sealed and wind-resistant housing.

# References

**[1]** R. Yauri, E. Campos, R. Yalico, and V. Gamero, "Development of an Electronic Bird Repellent System using Sound Emission," WSEAS TRANSACTIONS on SYSTEMS and CONTROL, vol. 18, 2023, doi: 10.37394/23203.2023.18.14.

**[2]** Prof Raghu Tilak Reddy M, K. K. S, S. C. M, N. G. S, and M. B, "BIRD REPELLER AND DETERRENT SYSTEM," International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES), vol. 5, no. 05, 2019.

**[3]** H. T. Vo, N. N. Thien, and K. C. Mui, "Bird Detection and Species Classification: Using YOLOv5 and Deep Transfer Learning Models," IJACSA-International Journal of Advanced Computer Science and Applications, vol. 14, no. 7, 2023.

**[4]** Semco Maritime. Bird Deterrent System. [Online]. Available: https://www.semcomaritime.com/bird-deterrent-system [Accessed Aug. 3, 2025].