GUNSHOT DETECTION SYSTEM

TRANSFORMING NOISE INTO TACTICAL INTELLIGENCE

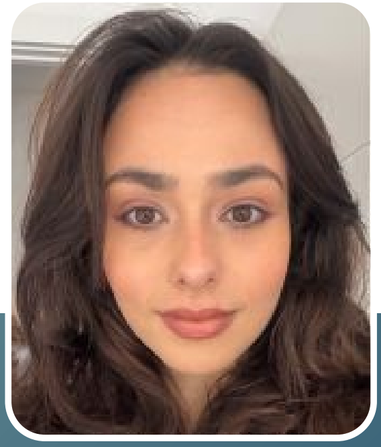
Meet Our Team

Rui Martins

- Hardware development
- Real world tests
- System integration
- Lab tests

Francisco Saramago

- Software development
- Problem Analysis
- Real world tests
- Lab tests
- Pitch deck

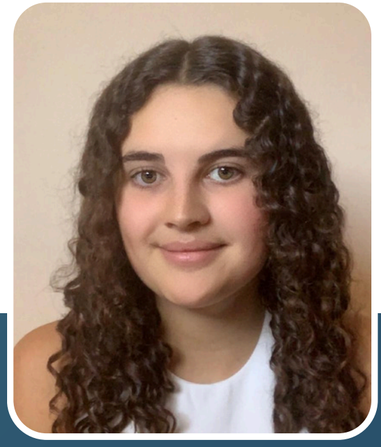


Eva Oliveira

- User interface
- WebSite/Blog
- Poster
- ElectroDay Stand
- Logistics

Francisco Costa

- Hardware development
- WebSite/Blog
- Video production
- Lab tests



Joana Rodrigues

- User interface
- WebSite/Blog
- Poster
- ElectroDay Stand
- Logistics

Miguel Matias

- Software
- Communication and management
- System integration
- Real world tests

Partners

ACADEMIA DA FORÇA AÉREA

A prestigious military academy dedicated to training and developing highly skilled officers for the Portuguese Air Force. Through rigorous academic and technical programs, AFA fosters excellence in aeronautical sciences, leadership, and defense innovation.

INSTITUTO SUPERIOR TÉCNICO

Portugal’s leading engineering school, renowned for its cutting-edge research and innovation in science and technology. IST provides a robust academic environment, equipping students with the knowledge and expertise to tackle real-world challenges in various engineering disciplines.

Advisors and Mentor

01

Scientific Advisor

Prof. Luís Caldas

Instituto Superior Técnico

02

Scientific Co-Advisor

Prof. João Pedro Gomes

Instituto Superior Técnico

03

Coordinator

Prof. Luís Caldas Oliveira

Instituto Superior Técnico

04

Mentor

CAP PA-OFI Sara Carvalho

Academia da Força Aérea

GUNSHOT DETECTION SYSTEM

Problem definition

01

Problem Definition

Identifying the direction of incoming gunfire can sometimes be challenging. A system capable of accurately estimating the direction of hostile fire and weapon types could prove useful in battle conditions. It could lead to:

- Increased survival rates.
- Better efficiency of operations.
- Protection of deployed teams.

Our Mission

02

Mission

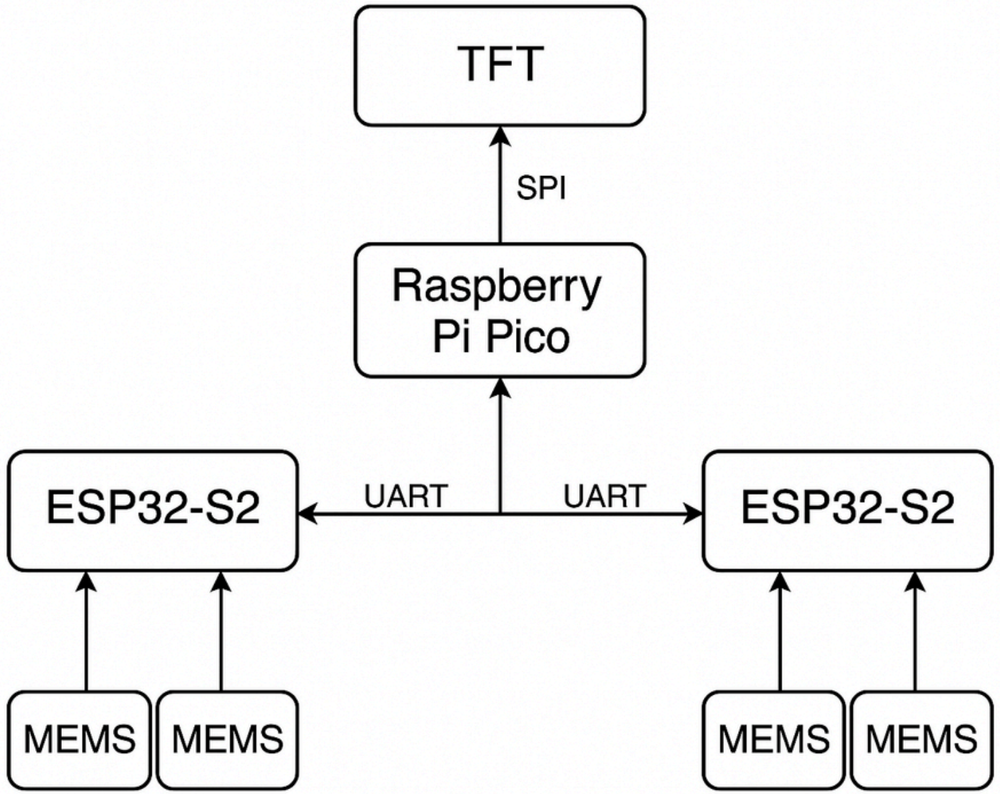
Providing armed forces and tactical intervention teams with increased situational awareness, with the purpose of preventing personnel casualties caused by hard-to-identify gunshot sounds in hostile conditions, by giving them a technological advantage.

GUNSHOT DETECTION SYSTEM

SO HOW DOES IT WORK?

The main pilars of our prototype are:

- 2 ESP32-S2 units with 2 microphones each
- Direction detection based on sound timing (TDOA)
- Communication via UART to Raspberry Pi Pico
- Final direction displayed on TFT screen

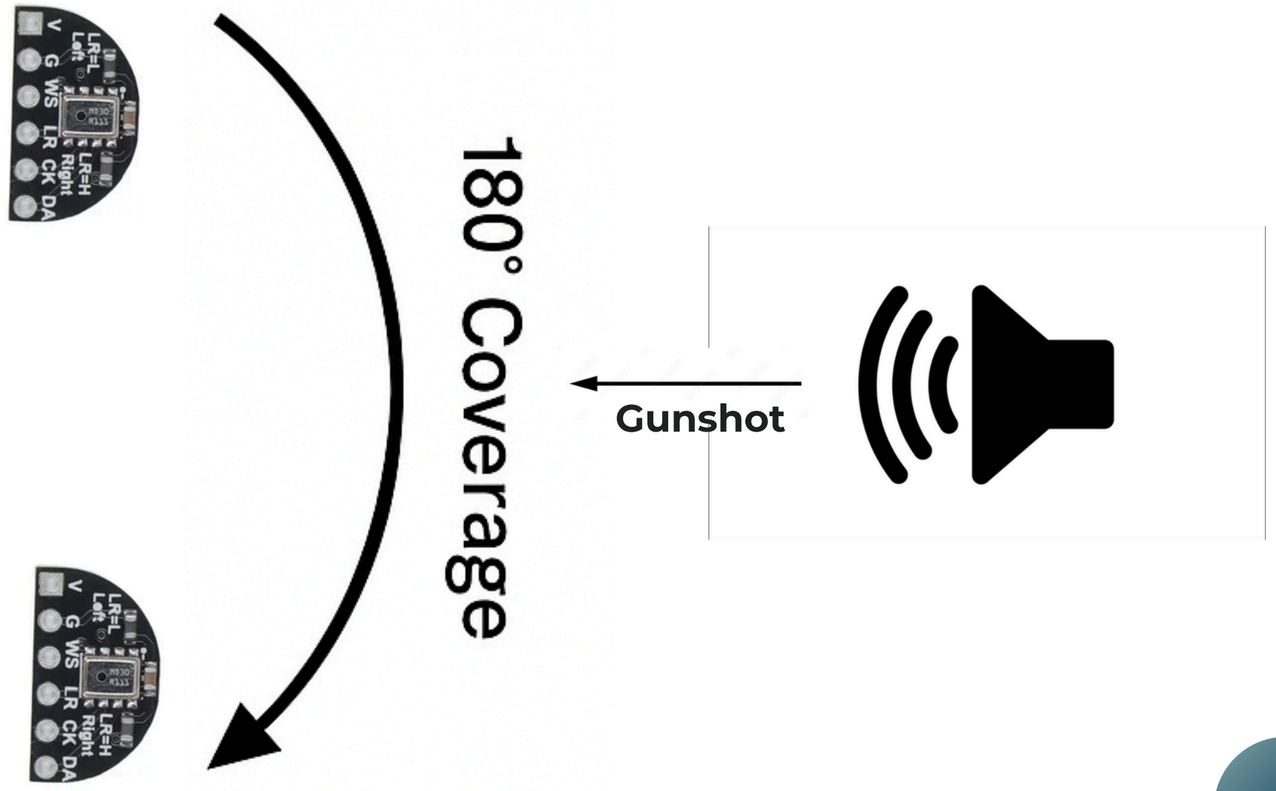


GUNSHOT DETECTION SYSTEM

SO HOW DOES IT WORK?

How Direction Detection Works:

- Cross-correlation determines the time offset
- TDOA → angle calculation over 180°
- Each ESP covers a different quadrant (e.g. 0–180°, 180–360°)

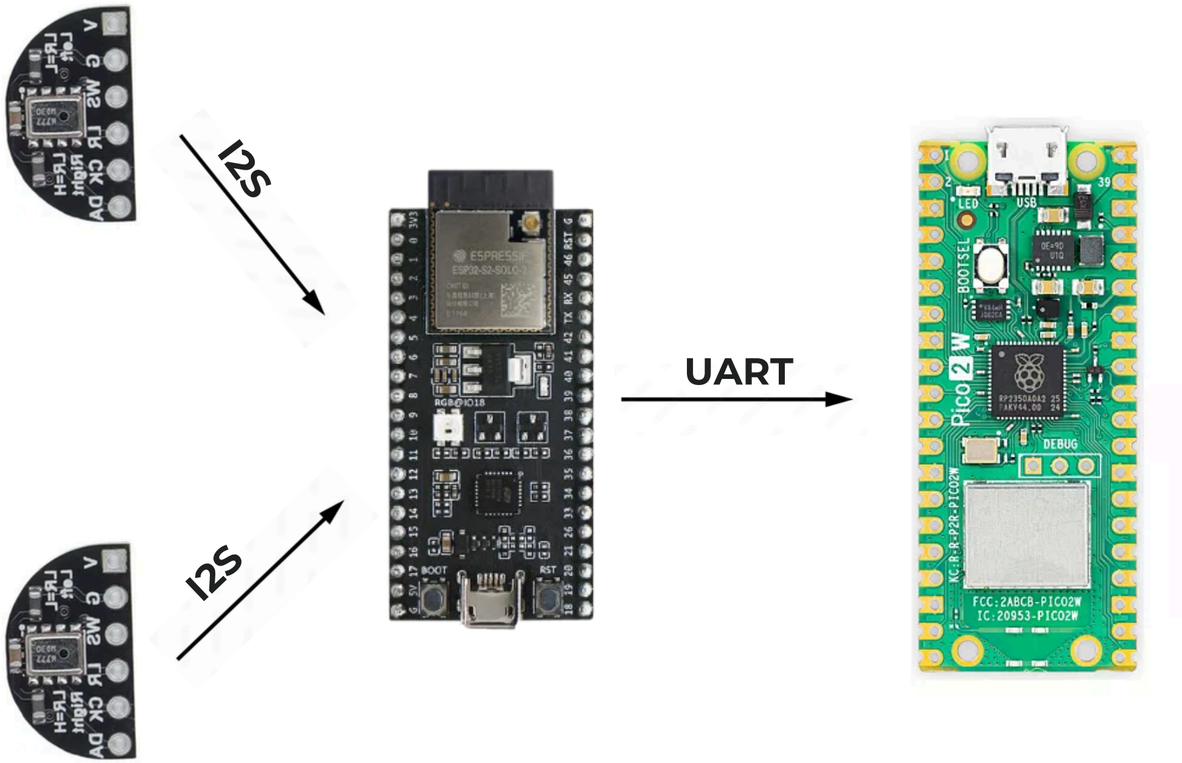


GUNSHOT DETECTION SYSTEM

SO HOW DOES IT WORK?

Data Communication:

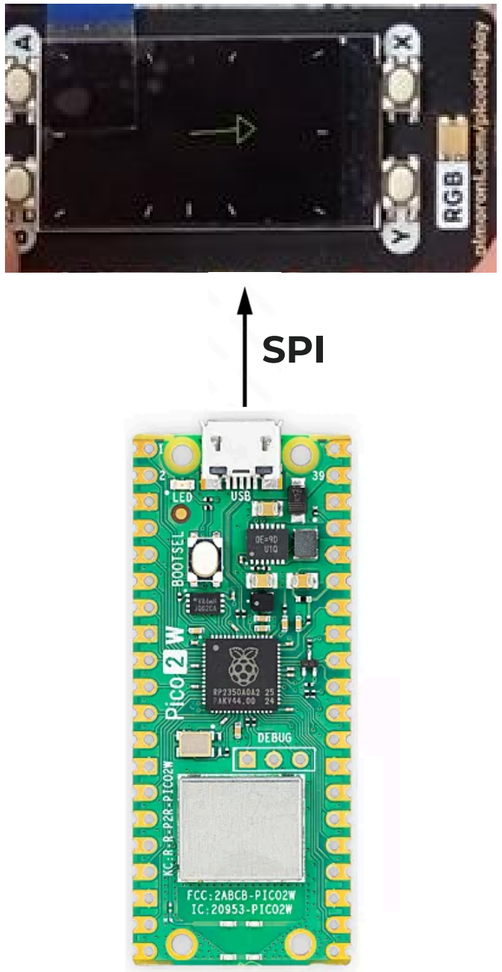
- ESP32-S2 → UART → Pico
- Example message: esp1,-12.2,118.0



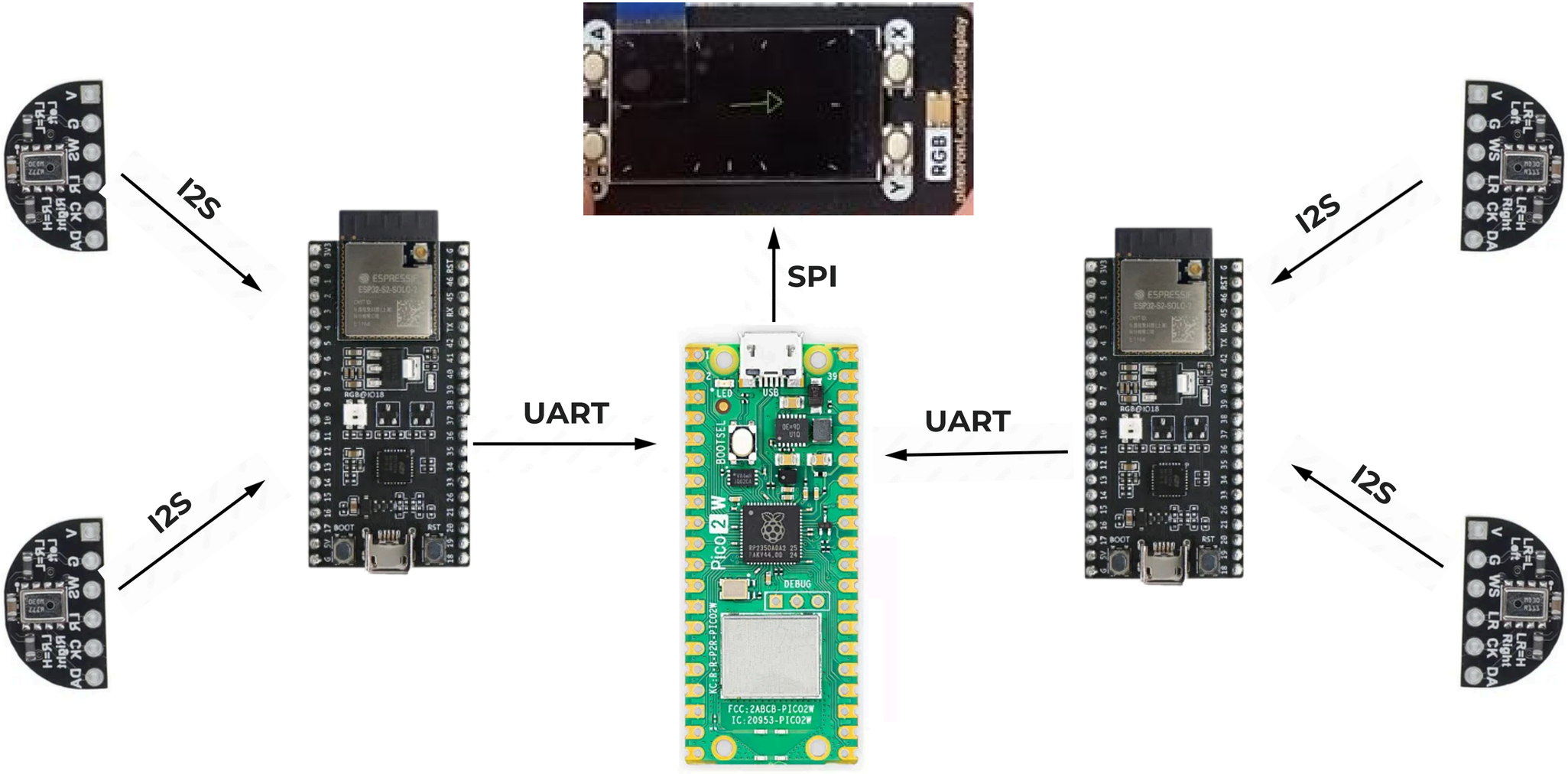
SO HOW DOES IT WORK?

Display Logic:

- Pico selects the strongest signal
- Displays arrow on TFT
- Communication through SPI



FULL SETUP


I2S
I2S
UART
SPI
UART
I2S
I2S
RGB
LED
USB
BOOTSEL
DEBUG
BOOT
RST
RGB@IO18
ESPRESSIF
ESP32-S2-SOLO-2
Pico 2 W
FCC:2ABCB-PICO2W
IC:20953-PICO2W

GUNSHOT DETECTION SYSTEM

WHO BENEFITS FROM OUR SYSTEM?

Military Personnel → The primary use case is battlefield awareness and soldier protection.

Police Forces → Can be deployed to protect events, compounds, or high-value assets.

Secret Service Agents → Helps secure VIP perimeters and react faster in crisis scenarios

Private Security Agencies → Enables rapid localization of gunfire in urban or high-risk patrol environments.

GUNSHOT DETECTION SYSTEM

COMPETITORS AND PREVIOUS WORK

The EARS Gunshot Localization system by QinetiQ:

Provides real-time, accurate detection of gunfire, with flexible deployment on vehicles, fixed sites, and wearable units.

GUNSHOT DETECTION SYSTEM

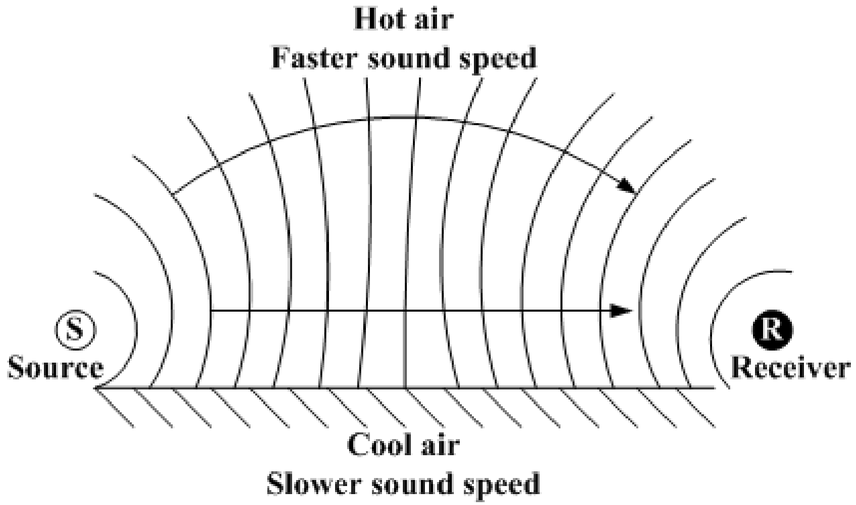
KEY TECHNICAL CHALLENGES

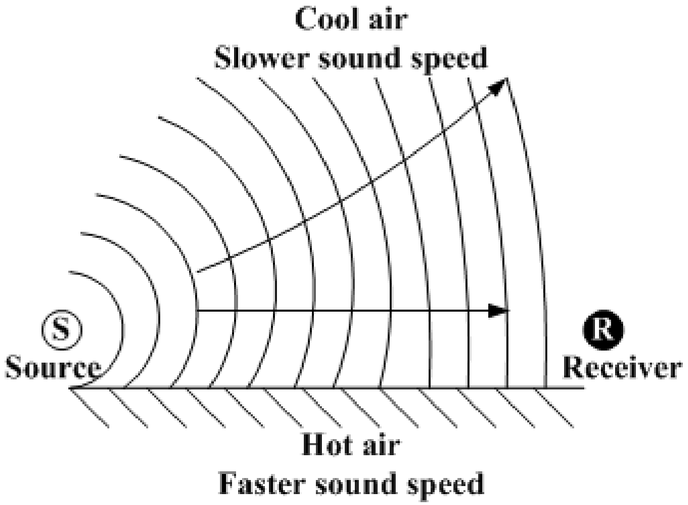
Environmental Interference

Weather and terrain can distort sound waves, leading to false positives or delayed detection if not properly filtered or corrected for.

Real-Time Processing vs Accuracy

The system needs to respond quickly in the field, but increasing processing speed can reduce precision, requiring a careful balance between speed and reliability.

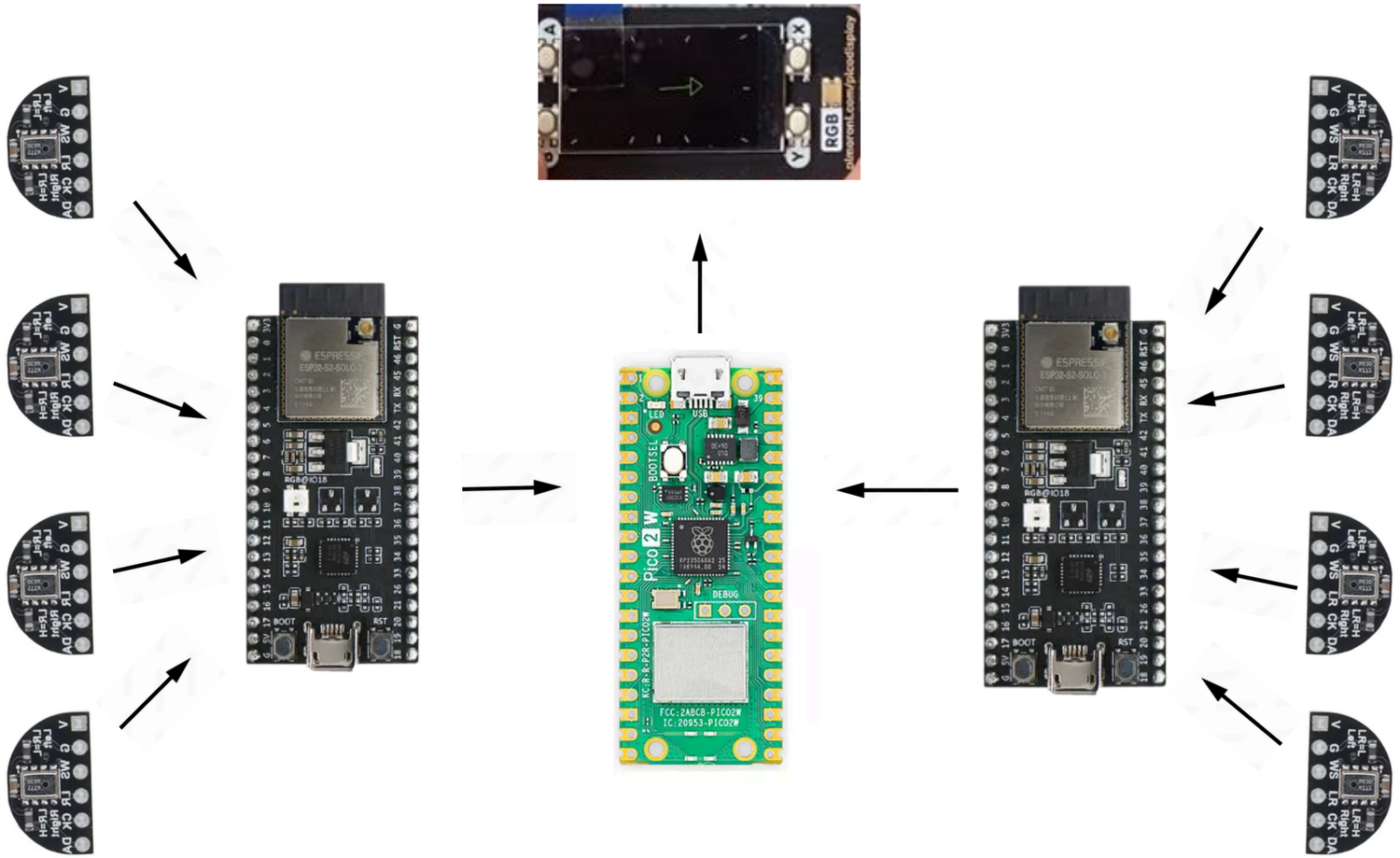




DESIGN EVOLUTION

Initial Plan:

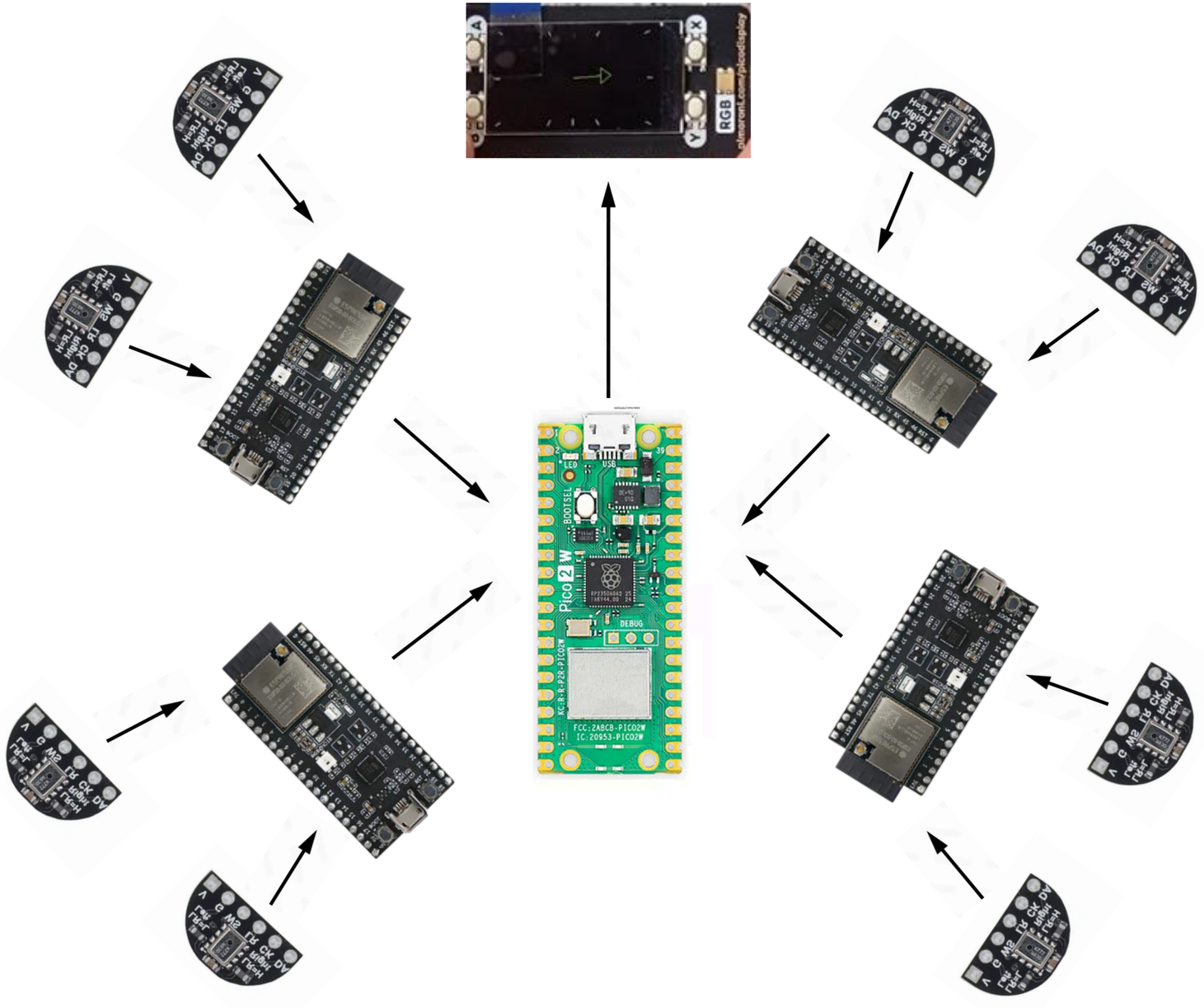
- We thought our ESP32-S2 had 2 I²S ports and planned to connect 4 microphones per board.
- Reality: Only 1 I²S interface — so only 2 microphones supported per ESP.
- Result: Switched to 2 MEMS per board, 180° each.



DESIGN EVOLUTION

Second Plan:

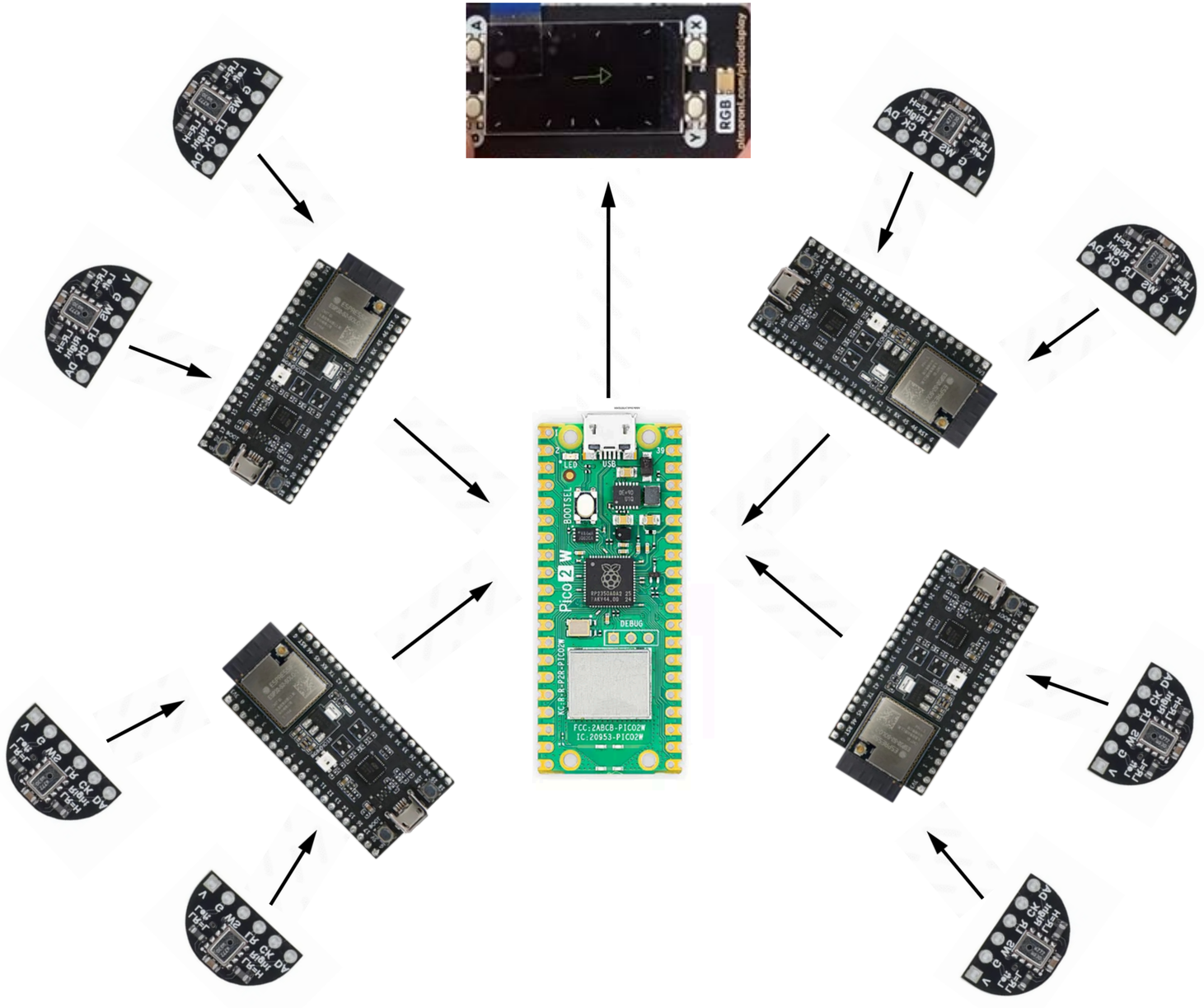
- We wanted to use 4 ESPs (1 per 90°) and send data over Wi-Fi to the Pico.
- Reality: Wi-Fi isn't always reliable in battlefield scenarios.
- Result: Abandoned wireless and needed a wired solution.



DESIGN EVOLUTION

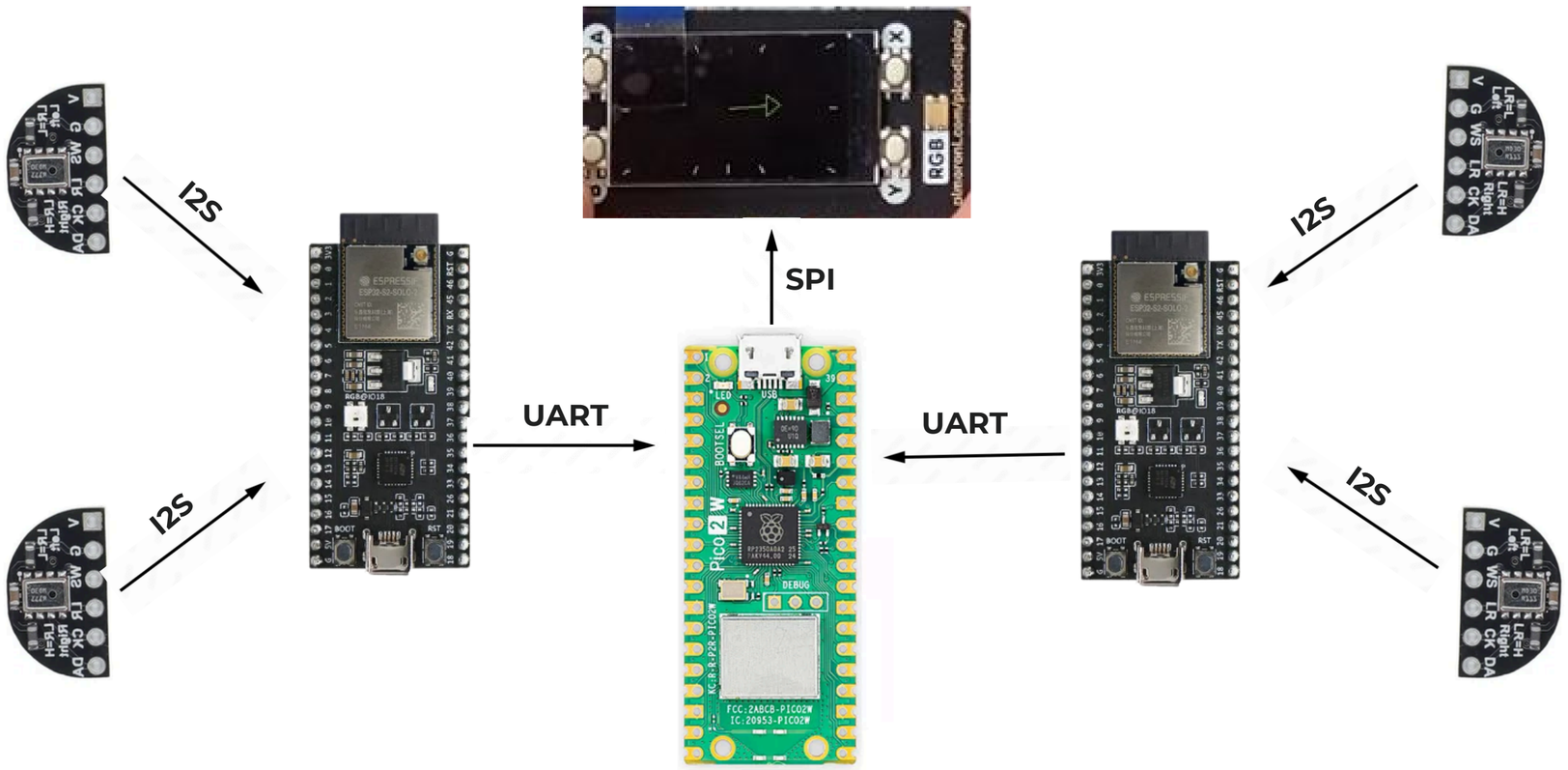
Third Plan:

- We tried sending data over UART instead.
- Challenge: Pico has only 2 UART ports.
- Tried: Software UART (bit-banging), but performance was unstable



FULL SETUP

- 2 ESPs with 2 microphones each (180° coverage).
- Communication via UART.
- Direction + amplitude sent to Pico → shown on TFT.
- Result: Simpler, more robust, and still accurate enough.

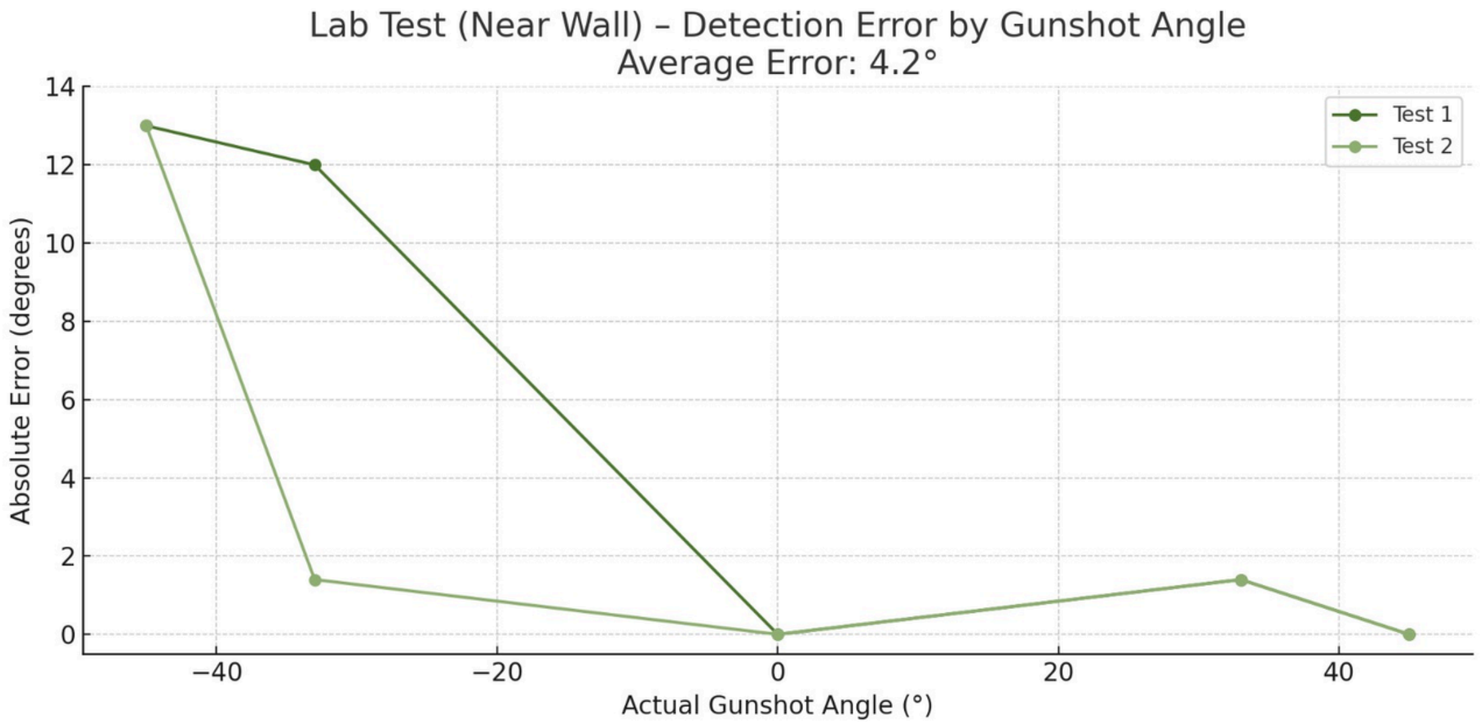


GUNSHOT DETECTION SYSTEM

TESTING IN THE FIELD

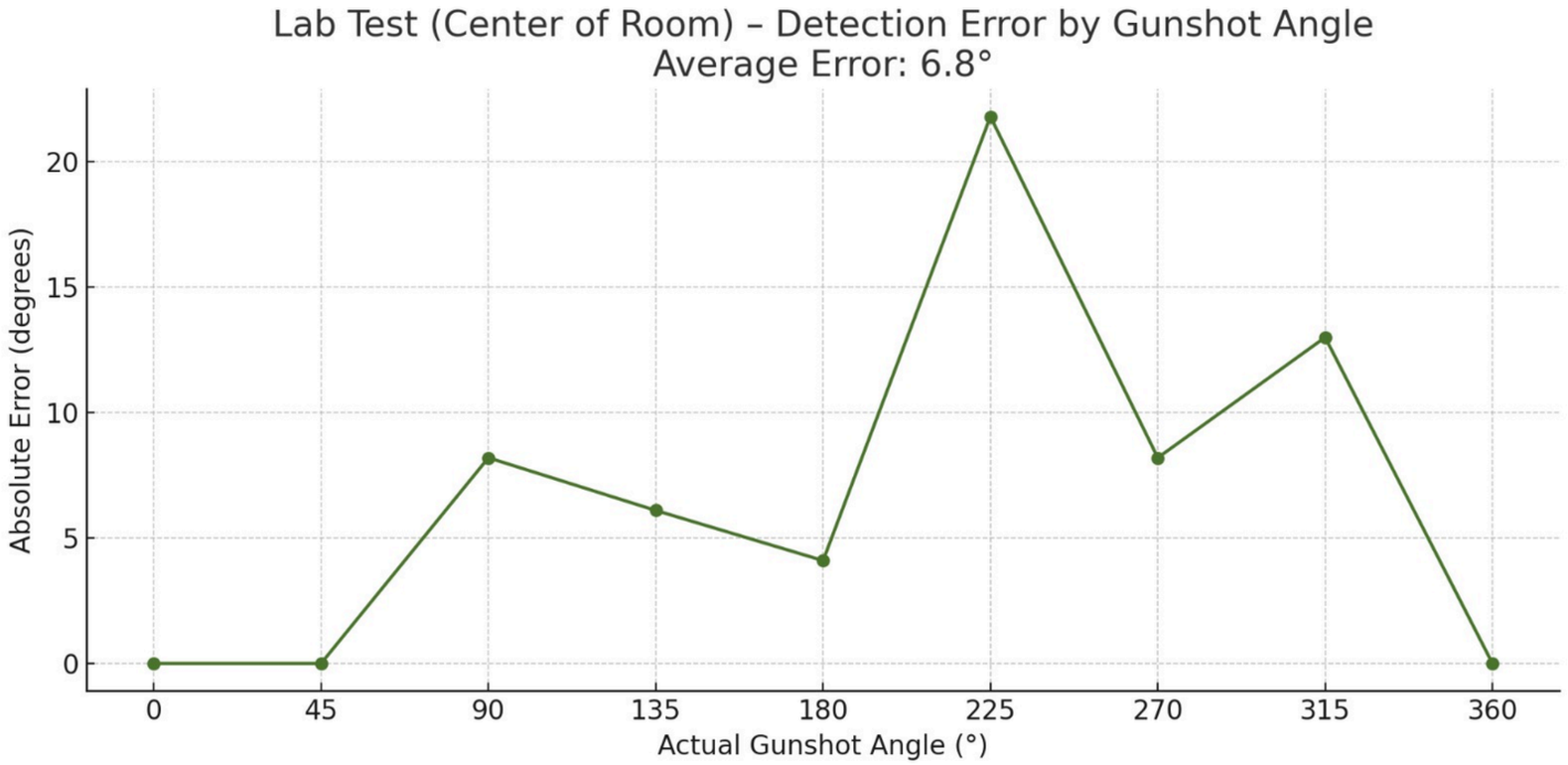
GUNSHOT DETECTION SYSTEM

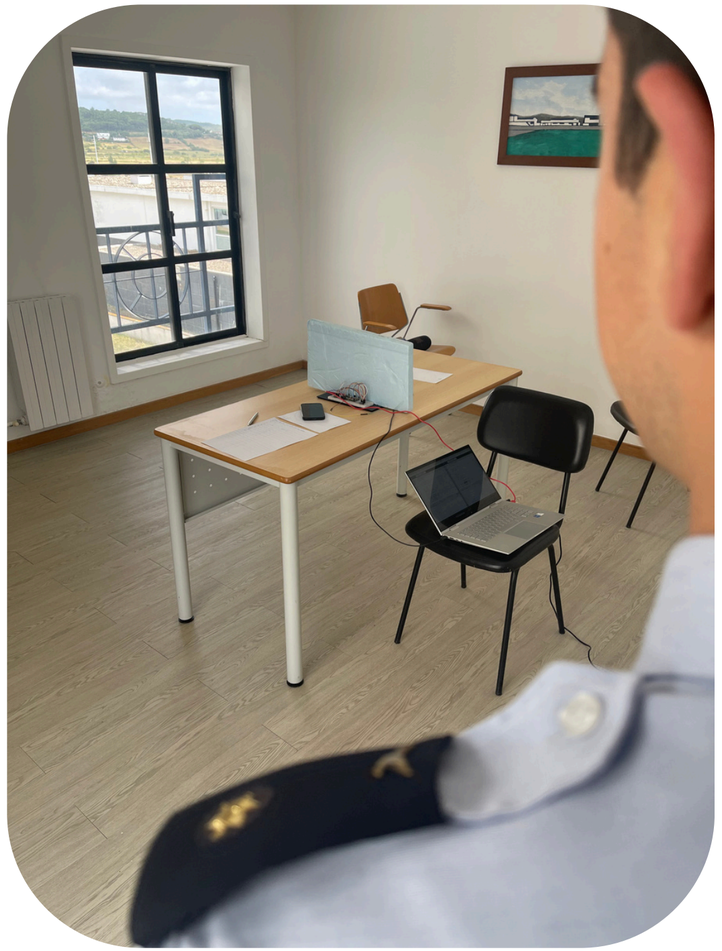
LAB TESTING WITH THE DEVICE NEXT TO THE WALL



GUNSHOT DETECTION SYSTEM

LAB TESTING WITH THE DEVICE IN THE CENTER OF THE ROOM





GUNSHOT DETECTION SYSTEM

WHY CHOOSE OUR GUNSHOT DIRECTION SYSTEM?

Fast & Tactical

Provides immediate direction feedback in high-stakes scenarios

Affordable

Built with low-cost hardware. Entire system under 93,5 €

Precise

Testing showed error under 15°

FUTURE WORK

Make it smaller and lighter

Reducing the device's bulk and weight will improve portability

Increase resistance to damage

Protecting the system against gunshots or other impacts is essential

THANK YOU

VIDEO

WEBSITE

POSTER