2HAD-RAD: Portable Life Detection Radar

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CHAPTER 2 – PROJECT DESCRIPTION

2.1 PROJECT BACKGROUND AND MOTIVATION

In the aftermath of disasters such as earthquakes, structural collapses, or fires, the most critical priority is locating and rescuing survivors as quickly as possible. Traditional search and rescue techniques rely heavily on human senses, trained canines, and thermal imaging systems. While these tools have saved countless lives, they each present significant limitations. Canine units require extensive training and can experience fatigue or environmental disorientation, while thermal cameras alone are less effective in smoke-filled spaces, under debris, or when heat signatures are blocked. Similarly, acoustic detection techniques may fail in noisy post-distortion environments. These constraints underline the need for advanced, multimodal technologies that can complement conventional tools and improve the speed, reliability, and safety of rescue operations.

Recent advances in sensing technologies have enabled the development of compact, low power devices capable of detecting human presence and activity in challenging environments. Radar based sensing is particularly promising for search and rescue applications because it is unaffected by lighting conditions, operates effectively in smoke or dust, and offers the capability to detect micro-motions associated with life functions, such as chest movement from breathing. However, radar is not always sufficient, as complex environments and clutter can obscure signals or cause false positives. To address these challenges, integrating radar with complementary sensing methods can significantly enhance the detection of confidence and situational awareness.

This project proposes a handheld, multi-sensor human detection device that fuses data from radar, ultra-wideband (UWB), infrared (IR), inertial and barometric sensors, and a seismic sensing subsystem. Each sensing modality provides a distinct type of information that enhances the reliability and robustness of human detection. Radar serves as the primary detection mechanism, while UWB aids in localization and ranging. IR provides thermal contrast in accessible scenarios, and barometric data supports altitude estimation indoors or underground. The addition of seismic sensing allows the system to detect low frequency vibrations from footsteps, tapping, or shifting debris, even when line-of-sight is not available. Depending on mission requirements, the seismic capability can be implemented using a low noise MEMS accelerometer integrated into the handheld unit or a dedicated geophone module connected externally for higher sensitivity.

By integrating these sensing technologies into a single, portable system and applying advanced digital signal processing (DSP) and sensor fusion techniques, this project aims to enhance human detection in complex rescue scenarios. The system is designed to function primarily in line-of-sight conditions but includes a stretch goal of achieving limited through material detection, expanding its utility in real-world emergency response operations. Ultimately, this approach seeks to support first responders with a tool that is faster, more reliable, and more versatile than current solutions.

2.2 PROJECT FUNCTION

The proposed system is a handheld, battery powered device designed to support first responders in locating survivors during disasters such as earthquakes, building collapses, or fires. The device integrates multiple sensing modalities such as a millimeter-wave radar, ultra-wideband (UWB), seismic sensing, infrared (IR), and an inertial navigation system (INS) with barometric sensing, to provide complementary data that improves detection accuracy and situational awareness.

The radar subsystem is the primary detection mechanism, capable of capturing micro-motions associated with human activity. High frequency radar signals penetrate smoke and airborne debris and reflect moving targets, allowing the system to detect subtle motions such as breathing. The signal returned undergoes analog signal conditioning and digitization before being processed with digital signal processing (DSP) algorithms to extract motion patterns and reduce environmental noise and clutter. The UWB subsystem enhances the radar by providing precise ranging and localization capabilities. UWB signals enable accurate distance measurements and tracking of movement, improving spatial awareness in both indoor and outdoor environments. This is particularly valuable in collapsed structures or underground areas where GPS signals are unavailable. The seismic sensing subsystem further enhances detection by capturing low frequency vibrations transmitted by structural materials. Movements such as footsteps, tapping, or shifting debris generate seismic waves that can reveal human activity even when visual and radar line-of-sight are obstructed. This subsystem can be implemented in two ways: using a low-noise MEMS accelerometer integrated into the main PCB to act as a seismic-proxy channel through DSP filtering, or through a separate geophone module with its own analog front end (AFE) and high resolution ADC, connected to the main device via a shielded digital interface. The geophone configuration offers higher sensitivity and better low frequency performance, while the MEMS approach enables compact, fully integrated operation with advanced signal processing techniques.

The IR subsystem provides thermal imaging data to highlight human presence where line-of-sight is available. Unlike radar, which operates independently of light and temperature, IR sensing utilizes temperature contrast to confirm the presence and approximate location of a human target, particularly in smoke-filled or visually obstructed environments. The INS and barometric subsystems add spatial context by tracking the device's movement and altitude changes, enabling responders to maintain positional awareness as they navigate multi-story buildings or subterranean environments. When paired with a global navigation satellite system (GNSS) receiver, the system can further improve positional accuracy by referencing absolute geographic coordinates when satellite signals are available.

Sensor data is fused in real time within the microcontroller unit (MCU), which runs DSP pipelines, sensor calibration routines, and data fusion algorithms such as Mahony or Madgwick filters for attitude estimation, and extended Kalman filters (EKF) for pose estimation and sensor integration. The device assigns confidence scores to detections by cross validating radar, seismic, thermal, and ranging data, reducing false positives, and improving detection reliability.

A user interface (UI) on the handheld device displays detection confidence, relative location, and activity levels, while a companion Android application communicates over Bluetooth Low Energy (BLE) to visualize detections and mark victim locations on a map. This connectivity enables rapid sharing of situational data among rescue teams. The device is powered by a rechargeable battery system, ensuring portability and continuous operation in field conditions.

While the primary objective is accurate line-of-sight detection, the system is designed with scalability in mind. Future iterations will explore through material detection, extending the device's effectiveness to scenarios involving drywall, wood, or light rubble. By uniting multiple sensing technologies into a single platform, this project aims to provide first responders with a powerful, field deployable tool that enhances search and rescue operations in time-critical environments.

2.3 Current Commercial Technologies and Existing Projects

2.3.1 Portable Sign of Life Identifier (Department of Homeland Security)

The *Portable Signs of Life Identifier* was a research effort funded by the Department of Homeland Security (DHS) focusing on evaluating compact and portable tools that could detect subtle respiration and heartbeat signals through walls or rubble [7]. The project explored radar and acoustic sensing methods capable of identifying minor chest movements caused by breathing or cardiac activity. The study emphasized portability, rapid deployment, and resilience to environmental interference, aligning closely with the design objectives of the 2HAD-RAD system.

While the DHS report demonstrated that the radar is capable of successfully detecting vital signs using Doppler radar, it also discussed limitations of the system such as the high-power demand, environmental noise, and false positives triggered by non-human motion. The 2HAD-RAD project builds on these findings by leveraging more power efficient embedded radar hardware, modern signal processing techniques, and a multi sensor approach to reduce false detections. By integrating radar data with infrared and inertial sensors, the system aims to confirm that detected motion correlates with human body temperature, thus improving detection confidence in cluttered environments.

2.3.2. Detection of Presence of Life Through Walls (DHS Research Report)

The DHS publication *Detection of Presence of Life Through Walls* expanded on earlier work by analyzing prototypes based on radar in urban search and rescue scenarios [8]. These prototypes used continuous wave (CW) and pulse-based radar to detect motion and vital signs through common building materials. The study highlighted several engineering requirements critical for field deployment, minimizing false alarms, maximizing detection range, and ensuring regulatory compliance with FCC standards.

Drawing from these insights, 2HAD-RAD explores ultra-wideband (UWB) radar as the preferred sensing technology. UWB transmits extremely short electromagnetic pulses across a wide frequency band, offering high spatial resolution and the ability to penetrate most nonmetallic materials [9]. This makes it ideal for locating survivors in collapsed structures or obscured environments. Whereas earlier DHS prototypes were bulky and power intensive, the 2HAD-RAD system integrates a compact radar front end with an ESP32-WROOM microcontroller, enabling local processing, reduced power draw, and improved portability. This shift from research grade instrumentation to a fully embedded system supports field ready use while maintaining technical rigor.

2.3.3 Integration of Multi Sensor Detection Technologies

Multiple academic and industrial studies have explored multi modal life detection by combining radar with other sensing domains such as infrared (IR), acoustic, and seismic detection [10]. Multi sensor fusion improves detection reliability by verifying that observed movement correlates with a valid heat or vibration signature. The *2HAD-RAD* system adopts a similar sensor fusion strategy, merging radar data with IR temperature readings and barometric or inertial feedback. This approach enhances both accuracy and interpretability, ensuring that life detection outputs are based on multiple physical indicators rather than radar reflections alone.

Unlike earlier systems relying only on radar, which required external computers for visualization, *2HAD-RAD* integrates a dedicated LCD interface to display immediate feedback such as “Human Detected” or “Area Cleared”. The system’s design philosophy prioritizes speed, portability and user clarity, which are essential in high stress and time sensitive emergency operations. The inclusion real time signal filtering and sensor fusion to differentiate human activity from background motion further improves performance by distinguishing human respiration from background motion, offering a modernized and efficient evolution of earlier prototypes.

2.3.4 Commercial Through Wall Radar Systems: Camero Xaver and Vayyar Imaging

Several commercial radar solutions demonstrate the capabilities of current industry technology. The *Camero Xaver 100* and *400* series, developed in Israel, are professional grade through wall imaging radars that use UWB impulse radar to detect movement and breathing through concrete and other solid barriers [11]. These systems offer high accuracy and real time visualization but are limited by large form factors, high cost, and significant power consumption, making them impractical for compact or battery-operated systems.

Similarly, *Vayyar Imaging* produces radar on chip modules based on frequency modulated continuous wave (FMCW) and UWB techniques that provide 3D imaging and real time presence detection [12]. While Vayyar modules are smaller than the Xaver systems, they rely on proprietary signal processing and high-speed computing, increasing integration complexity for lightweight embedded designs.

By integrating a compact radar module with thermal and inertial sensors on a single custom PCB, the *2HAD-RAD* system delivers the same core capabilities as large commercial life-detection platforms, such as identifying human presence through barriers, but in a far smaller and more power efficient design. Its lightweight, affordable cost architecture makes it well suited for search and rescue kits, field testing, and educational applications, bridging the gap between complex commercial systems and practical embedded solutions.

2.3.5 Infrared Assisted Radar Concepts

Recent academic research has explored combining radar with infrared thermography to enhance detection accuracy, particularly in environments with high clutter or minimal motion [13], [14]. These hybrid systems use radar to detect movement and IR sensors to verify heat signatures corresponding to living organisms. Studies have shown that thermal data can significantly reduce false positives caused by moving objects such as fans, machinery, or debris.

The *2HAD-RAD* project adopts this hybrid principle by incorporating an IR temperature sensor (MLX90640) alongside the radar subsystem. The IR module provides contactless temperature verification, confirming that detected motion corresponds to human body heat (typically 30 - 40 °C). This design choice improves performance in both open and obstructed fields of vision, while maintaining a compact and portable size. By integrating IR, radar, and inertial data within a unified embedded framework, *2HAD-RAD* effectively combines vital sign detection, thermal validation, and environmental context for higher reliability than single sensor designs.

Summary

Both government and commercial studies confirm that detecting human life through walls is achievable but technically complex. Early DHS projects proved radar could measure vital signs, while also revealing the challenges of interference and high-power use. Meanwhile, modern commercial systems like *Camero Xaver* and *Vayyar Imaging* demonstrate impressive capability but remain expensive and bulky.

The *2HAD-RAD* project takes these lessons a step further by merging radar, infrared, and inertial sensing into a compact embedded design. It delivers a handheld, low power, and affordable life detection system that’s both practical and field ready. This multi sensor approach not only enhances accuracy but also makes the technology more accessible to academic researchers and first responders, representing a meaningful step toward the next generation of rapid, portable life detection devices.

2.4 PROJECT OBJECTIVES AND GOALS

The objective of 2HAD-RAD is to design and build a portable, integrated multi-sensor device that assists rescuers in detecting and localizing human presence during emergency and disaster response. Radar serves as the primary sensing modality, supported by complementary technologies such as UWB, seismic, infrared, and inertial/barometric sensing. Research and manufacturer demonstrations have shown that radar can detect subtle life signs, such as breathing or even heartbeat, though this project emphasizes broader line-of-sight detection, with limited through-material capability considered as a stretch goal. The device combines sensor fusion, modern signal processing into a unified system, delivering rapid and reliable feedback in real time under field conditions.

2.4.1 GOALS

- Basic:
  - Integrate a commercial radar module to detect motion and respirations detection in open space.
  - Interface and condition the output from a seismic sensor/geophone to capture vibrations through materials.
  - Confirm human presence by detecting body heat signatures using an infrared sensor.
  - Provide relative location and orientation tracking using an INS with barometric feedback.
  - Display detection results on an LCD interface providing immediate visual feedback.
  - Power the entire device with a rechargeable battery subsystem that ensures stable operation.
- Advanced:
  - Maintain performance in smoke-filled or cluttered environments.
  - Improve relative location tracking precision by using GNSS.
  - Extend radar detection by integrating a UWB sensor for sensor fusion.
  - Optimize the power delivery for extended operational runtime.
  - Enhance LCD readability with clear formatting and detection indicators.
  - Transmit data from a detection device to an android mobile application.
- Stretch:
  - Extend radar detection for stationary human targets in open-air testing.
  - Incorporate a machine learning Layer to improve classification accuracy,
  - Demonstrate detection capability through common building materials.
  - Add user-adjustable controls to the UI to modify radar sensitivity, detection modes, and display a simplified thermal heat map.
  - Enhance data transmission to the Android application in real-time and include positional mapping.

- Integrate a battery monitoring subsystem that displays voltage, charge percentage, and estimated runtime on the LCD.
- Incorporate a hazard awareness layer that flags potential risks using fused sensor data.

2.4.2 OBJECTIVES

- Basic:
  - Demonstrate radar-based detection of a human subject within a line-of-sight range of at least 2 meters.
  - Confirm human presence using an infrared temperature sensor under line-of-sight conditions at distances up to 1 meter.
  - Provide relative location using INS and barometric sensing with an accuracy of ≤ 2 meters.
  - Display detection feedback on an LCD interface within 5 seconds of confirmed detection.
  - Add a red LED to indicate when a human is detected in less than 1 second.
  - Incorporate buttons to mark the location of a victim, clear/reset, and power the device.
  - Operate the complete device on a rechargeable subsystem for at least 2 hours of continuous use.
  - Detect ground vibrations (e.g., knocks or footsteps) within a 2-meter radius using a seismic sensor.
- Advanced:
  - Demonstrate consistent radar detection performance in cluttered or noisy environments and maintain ≥ 90% detection accuracy.
  - Improve fused localization accuracy within ≤ 1 meter when GNSS data is fused with INS outdoors.
  - Extend radar detection by fusing UWB data to detect stationary targets beyond 3 meters.
  - Enhance LCD readability in field conditions to ≥ 90% legibility under ambient light with clear indicator labels.
  - Transmit data from the handheld device to an android mobile application through BLE within 5 seconds.
  - Improve operational runtime by at least 25% compared to baseline while maintaining ≤ 10 W power draw.
- Stretch:
  - Demonstrate detection of human presence through 1 inch of drywall material in controlled indoor tests with ≥ 80% accuracy.
  - Incorporate a hazard awareness layer that flags 3 potential risks using fused sensor data with ≥ 80% detection accuracy.
  - Add user adjustable controls to UI for radar sensitivity, detection modes, and heat map visualization and update display within 5 seconds of adjustment.
  - Add real-time battery monitoring to charge percentage and estimated runtime on the UI.

- Enhance android application with real-time positional mapping with ≤ 2 second latency.

2.5 REQUIREMENT SPECIFICATIONS

Parameter	Description	Target Value
Radar detection range	Detect a human subject in LOS	≥ 2 m (LOS)
Detection accuracy	Overall detection performance for radar, IR, and seismic sensing.	≥ 90%
Average system power	Average electrical power during continuous scanning	≤ 10 W
Battery life	Continuous operation time on rechargeable battery during scans.	≥ 2 hours
UI response	Time for LCD and buzzer/LEDs to respond after confirmed detection.	≤ 5 second
Infrared detection	Confirm human presence by detecting body heat signatures.	within ≤ 1m LOS
Location	Track victims' location when detected using INS, GNSS (when applicable) and barometer.	≤ 2 m

Figure 1: Overall System Specifications

Component	Parameter	Description	Target Value
Radar module	Integration latency	Time from RF transmission to usable baseband output	≤ 200 ms
Radar module	Detection range	Detect human motion under LOS conditions	≥ 2 m
IR sensor	Human heat confirmation	Detect knocks/footsteps through materials	≤ 1 m
IR sensor	Interface and conditioning	Digital bus, add small series resistors for edge damping.	I2C/SPI with 22-47Ω series, proper decoupling
Seismic/Geophone	Passband	Band limit human knocks/footsteps	0.5-60 Hz (≥ 2nd order HPF and ≥ 2nd order LPF)
Seismic/Geophone	Gain	Selectable amplification to lift signal above ADC noise	x10 - x40
Seismic/Geophone	Anti-alias filter	Final LPF ahead of ADC for sampling margin.	80-100 Hz cutoff, assuming fs ≅ 500 S/s
Seismic/Geophone	Input protection	Prevent AFE from ESD/inductive spikes	TVS at connector and 100-330Ω series/lead with back-to-back diodes and diodes to Vref.
Seismic/Geophone	Post-conditioning noise	Noise at AFE output with sensor quiet	≤ 25 mV RMS
Seismic/Geophone	Natural frequency	Mechanical resonance of element	4.5 -10 Hz
Seismic/Geophone	Coil resistance	DC resistance of pickup coil	about 375Ω
Seismic/Geophone	Sensitivity	Open-circuit sensitivity to velocity	≅ 28.8 V/(m/s)
ADC (seismic path)	Resolution and rate	Digitize conditioned geophone output	≥ 12-bit, ≥ 500 samples/s
INS with barometer	Relative localization	Dead reckoned displacement over short paths	≤ 2m error over 10 m
GNSS (advanced)	Fusion anchor	Absolute position when available	≤ 1 m

UWB (advanced)	Ranging precision	Sensor fusion with radar to extend range	≥ 3 meters
LCD	Feedback latency	Time from confirmed detection to display	≤ 5 s
LED	Turn on latency	Visual alert	≤ 1s
Wireless	Telemetry latency	From detection device to mobile application	≤ 5 s
MCU	Logic and supply	Core voltage and primary input/output for links and wireless	3.3 V, processor class at least 240 MHz
MCU	Interfaces	Serial links for INS, IR sensor, barometer, ranging for radio and telemetry.	at least 2 universal asynchronous receiver-transmitter links, 1 I2C and 1 SPI interface bus
MCU	Processing/signal processing	Filtering, detection logic, sensor fusion, and UI updates	Display update within 5 s and LED within 1 s

Figure 2: Component Specifications

2.6 RELATED STANDARDS

Our team anticipates conforming to the following national and/or international standards:

- FCC Part 15: including but not limited to subparts A, B, C and F
- IEEE 802.15.4: UWB communications standard
- IEC 62133 / UL 2054: Li-ion battery safety
- ETSI EN 305 550: European equivalent to FCC Part 15 to cover 57-64 GHz short-range devices
- ESTI EN 302 065: Covers 3.1 - 10.6 GHz band.
- USB-IF USC Type-C and Power Delivery standards
- IEC 62368-1/UL 60950 for DC input safety
- IEEE 52-2019: Standard letter designations for radar-frequency bands
- IEC 62366: Application of using engineering for medical devices.
- API 35 for new android applications
- Build OWASP MASVS (Mobile application security verification standard)
- Follow WCAG 2.1 level AA

2.7 PROJECT BLOCK DIAGRAM

Figure 3 illustrates the signal flow and major subsystems of the proposed handheld human detection device. The design integrates radar, UWB, IR, inertial and barometric sensors, and seismic sensing into a unified system, all managed by a central MCU. The figure represents a single PCB implementation where sensing, processing, user interface, and power management are consolidated into a compact and portable platform.

At the core of the system is the TI IWR6843AOP radar module, which transmits and receives a 60 GHz frequency modulated continuous wave (FMCW) chirp. Reflected signals return as baseband I/Q data, which pass through an analog to digital converter (ADC), a hardware accelerator, and a C674x DSP core for low level signal processing. The radar has the capability of detecting human micro-motions such as breathing or small body movements, even in environments with low visibility caused by dust, smoke, or debris. Radar outputs are then sent to the ARM R4F control core and passed to the MCU for higher level processing, fusion, and decision making.

The sensors subsystem complements the radar by integrating additional modalities that improve detection accuracy and situational awareness. To expand the radar's sensing capabilities and strengthen overall system performance, the device incorporates an UWB subsystem, which is specifically chosen for its ability to complement radar data by improving ranging precision and providing additional spatial information. Previous research and industry solutions have demonstrated that combining UWB with radar improves localization and reduces uncertainty in complex environments. In this project, UWB measurements will help refine detection zones and can aid in limited through material sensing, extending the radar's effectiveness in cluttered or partially obstructed scenarios. The IR sensor provides thermal contrast, confirming the presence of humans when line-of-sight is available and highlighting heat signatures even in visually obstructed environments. The INS, combined with a barometric pressure sensor, enables inertial navigation by tracking device orientation, motion, and elevation changes, critical for maintaining positional awareness in multi-story buildings or underground areas.

A key feature of this design is the inclusion of a seismic sensing path, which can be implemented through one of two configurations. In the first configuration, a low-noise MEMS accelerometer is mounted directly on the main PCB, allowing it to act as a seismic-proxy channel. Through DSP, the accelerometer data is filtered to remove gravity and high frequency noise, isolating the low frequency vibrations produced by footsteps, tapping, or shifting debris. In the second configuration, a dedicated geophone sensor module is deployed as an external accessory. This module contains its own AFE for signal amplification, damping, and anti-aliasing, followed by a high-resolution ADC for digitization. The processed seismic data is then transmitted back to the main PCB over a shielded SPI or UART interface. The geophone option offers superior sensitivity to very low frequency signals and is ideal when the device can be placed in direct contact with the ground.

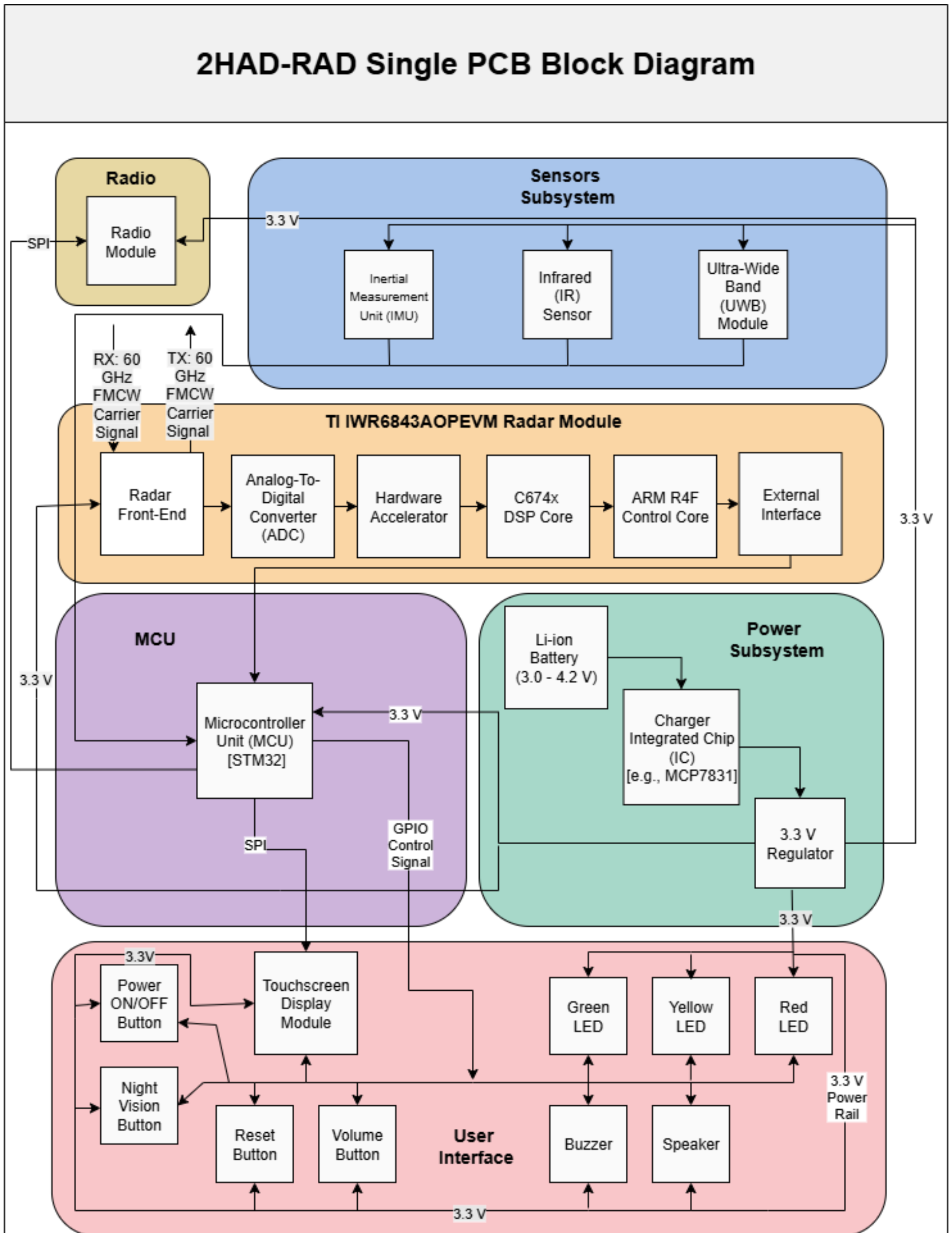
All sensor data converge at the MCU, which serves as the central processing hub. The MCU performs multiple roles: it coordinates data acquisition from each sensor, applies DSP algorithms and filtering, and executes sensor-fusion logic to combine inputs into a unified detection decision. Algorithms such as Mahony or Madgwick filters are used for attitude estimation, while extended Kalman filters (EKF) may be implemented for fusing IMU, UWB, and barometric data into a coherent position estimate. Detection of confidence scores is generated by cross validating radar, seismic, thermal, and ranging data to reduce false positives and improve decision reliability.

The user interface subsystem provides intuitive feedback to the operator. A display presents key metrics such as detection of confidence, relative location, and sensor activity. LEDs and a buzzer provide quick visual and audible alerts when potential human presence is detected. Additionally, BLE connectivity links the device to an Android application, which visualizes detection data, marks victim locations, and enables rapid communication among response teams.

The power subsystem is built around a rechargeable lithium-ion battery, supplying regulated 3.3 V power to all modules through a buck converter and low noise linear regulators. The power circuit includes charging management and protection features to ensure safe and continuous operation in the field.

Finally, the division of labor table shows how subsystem responsibilities are distributed among team members according to their expertise. This structure allows specialized focus on radar processing, sensor integration, power delivery, user interface design, and communication modules, while enabling collaborative development and integration of the full system.

Figure 4 (software block diagram) further illustrates the flow of information within the device. The MCU centralizes data from all sensing subsystems and processes it through layers of filtering, calibration, and fusion. LED indicators respond to radar detection results, seismic event flags, and combined sensor confidence outputs. Meanwhile, localization and movement data from the INS, UWB, and barometric sensors feed into the mapping interface, which updates the user's display and Android application in real time. Together, these hardware and software layers enable a coordinated, multi-modal detection system designed to improve the speed, accuracy, and reliability of search and rescue operations.



Division of Labor

Subsystem	Primary Lead	Secondary Support
Power Subsystem	Bailey Hitt (EE)	Shannon Hankinson (EE)
Sensors Subsystem	Ryan Andersen (EE)	Bailey Hitt (EE)
Radar Module	Shannon Hankinson (EE)	Ryan Andersen (EE)
MCU	Joshua D'Souza (CpE)	Bailey Hitt (EE)
User Interface	Joshua D'Souza (CpE)	Ryan Andersen (EE)
Radio	Shannon Hankinson (EE)	Ryan Andersen (EE)

Figure 3: Hardware Block Diagram for 2HAD-RAD

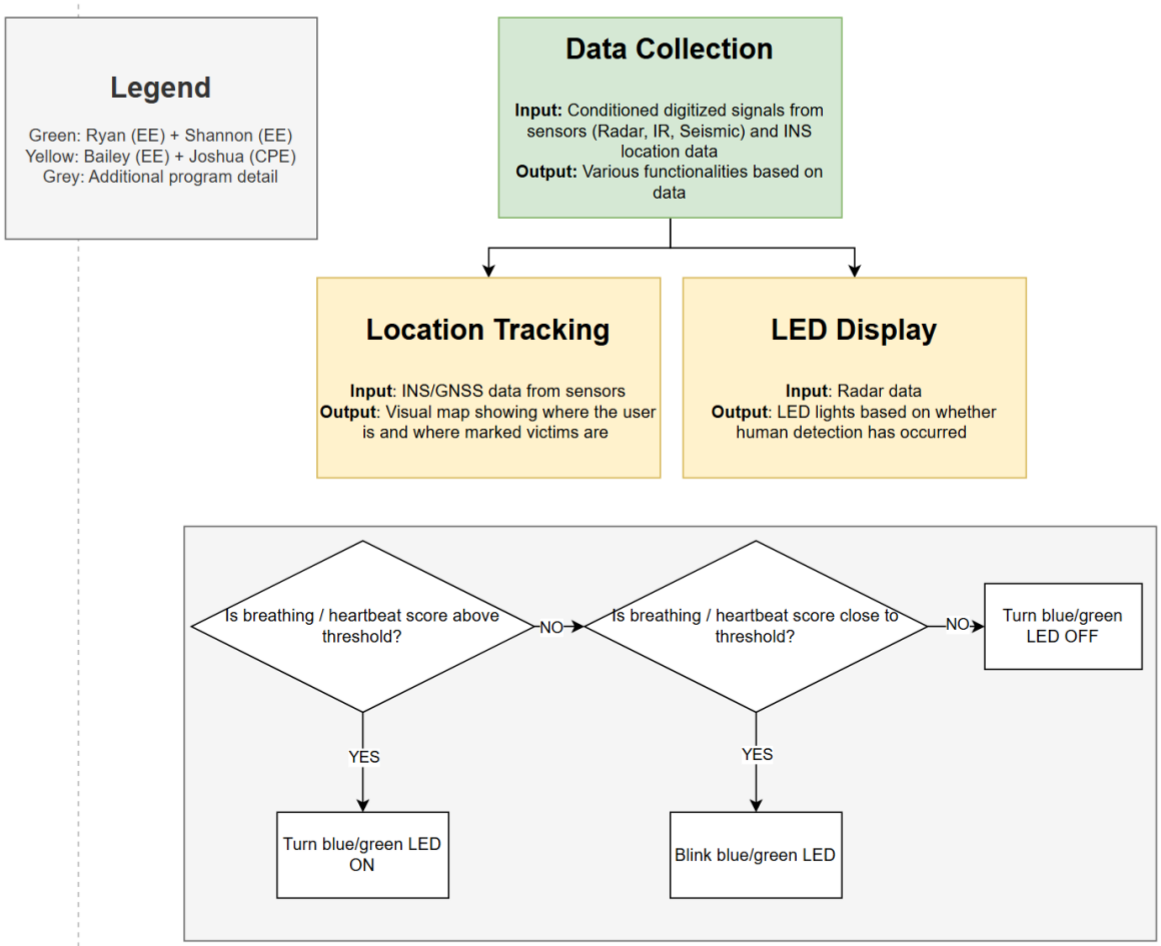


Figure 4: Software Block Diagram for 2HAD-RAD

2.8 HOUSE OF QUALITY

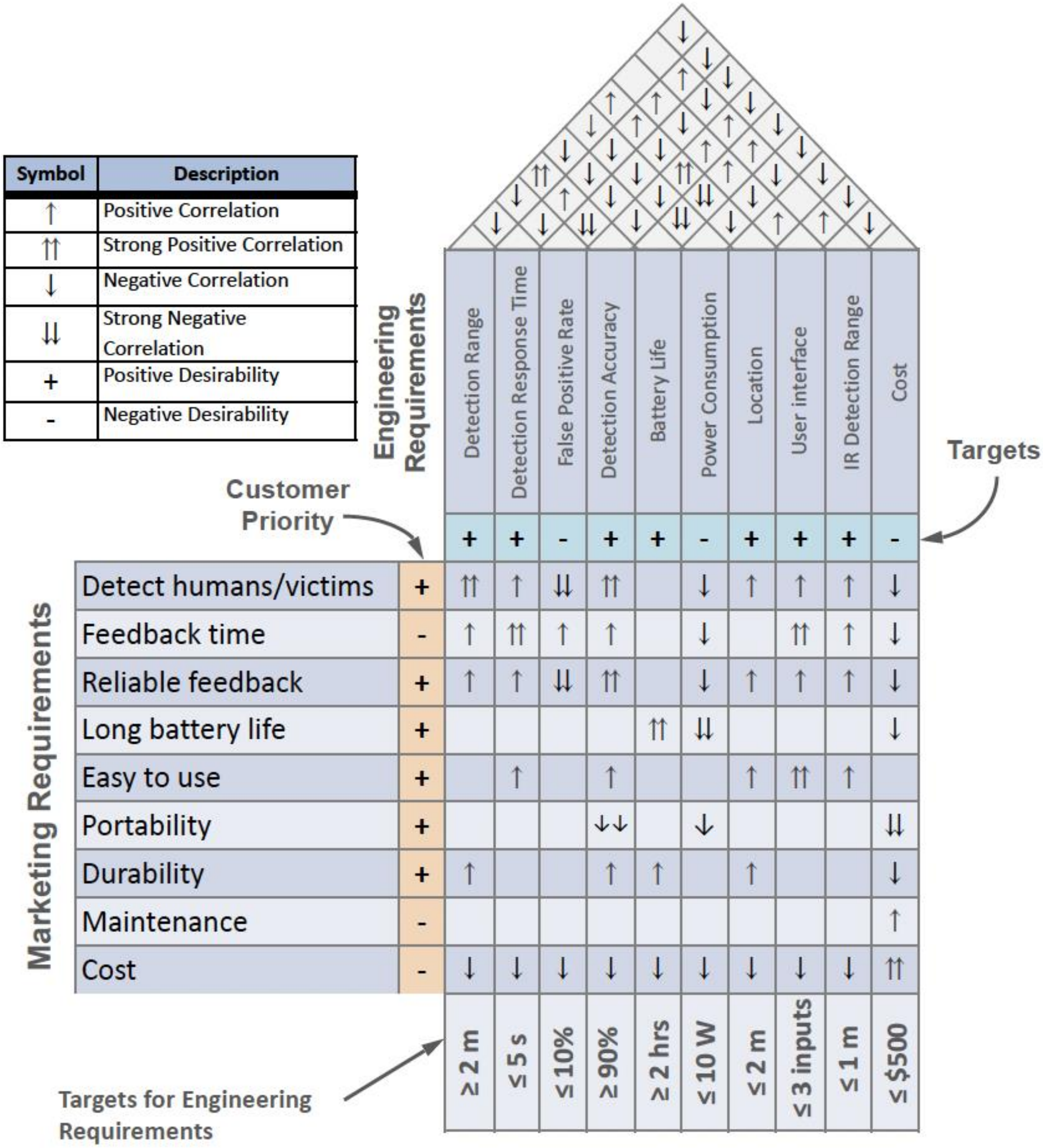


Figure 5: House of Quality

2.9 PROJECT BUDGET AND FINANCING

Our team will self-fund this project, so it is in our best interest to keep the total budget as conservative as possible. Here is the estimated total bill of materials (BOM) as can be foreseen currently:

Item	Quantity	Unit Cost (USD)	Total Cost (USD)
Radar Front-End Module	1	$200.00	$200.00
Custom PCB Components	1	$75.00	$75.00
Microcontroller / Processing Unit	1	$75.00	$75.00
Battery Pack	1	$40.00	$40.00
Battery Charger & Regulator Circuit	1	$20.00	$20.00
User Interface	1	$30.00	$30.00
Enclosure	1	$40.00	$40.00
Miscellaneous	1	$20.00	$20.00
Total Estimated Cost			$500.00

Figure 6: Bill of Materials

2.10 INITIAL PROJECT MILESTONES

Our team formed in the Spring semester of 2025 when we began brainstorming. However, our serious efforts did not begin until the start of the Fall semester of 2025. Therefore, the timeline begins at the start of the Fall 2025 semester.

Item	Start Date	Anticipated End Date	Duration
Project Brainstorming	8/19/2025	8/26/2025	0 Weeks
Project Scope Finalized	8/26/2025	9/6/2025	1 Week
Individual Research	8/26/2025	9/6/2025	2 Weeks
Initial Project Proposal	8/26/2025	9/6/2025	1.5 Weeks
30-Page Milestone	9/6/2025	9/27/2025	3 Weeks
60-Page Milestone	9/27/2025	10/17/2025	3 Weeks
90-Page Milestone	10/17/2025	11/7/2025	3 Weeks
120-Page Milestone	11/7/2025	11/25/2025	3 Weeks
Final Draft	11/25/2025	12/3/2025	1 Week

Figure 7: Senior Design I Project Documentation Timeline

Item	Start Date	Anticipated End Date	Duration
Individual System Design	9/5/2025	10/2/2025	4 Weeks
Individual System Testing	10/2/2025	10/30/2025	4 Weeks
Breadboard Prototyping	10/30/2025	11/21/2025	3 Weeks
PCB Design/Ordering	11/21/2025	12/12/2025	3 Weeks

Figure 8: Senior Design I Project Design Timeline

Item	Start Date	Anticipated End Date	Duration
PCB Testing	1/9/2026	1/23/2026	2 Weeks
System Integration/Testing	1/23/2026	2/16/2026	4 Weeks
Practice Project Demo	2/16/2026	2/27/2026	2 Weeks
Finalize Documentation	2/27/2026	3/13/2026	2 Weeks
Practice Final Presentation	3/13/2026	3/20/2026	1 Week
Final Presentation	TBD	TBD	TBD

Figure 9: Senior Design II Project Design Timeline

2.11 PROTOTYPE

To envision what our final project will look like, we rendered a blueprint of the physical model and a prototype for the user interface. To ensure portability and ease of use in the field, the physical model was designed to resemble a tablet, the size and shape of a kindle. The device features a power/reset button, status LED indicators and a USB-C power port. This design allows for reliable use by first responders in low visibility environments.

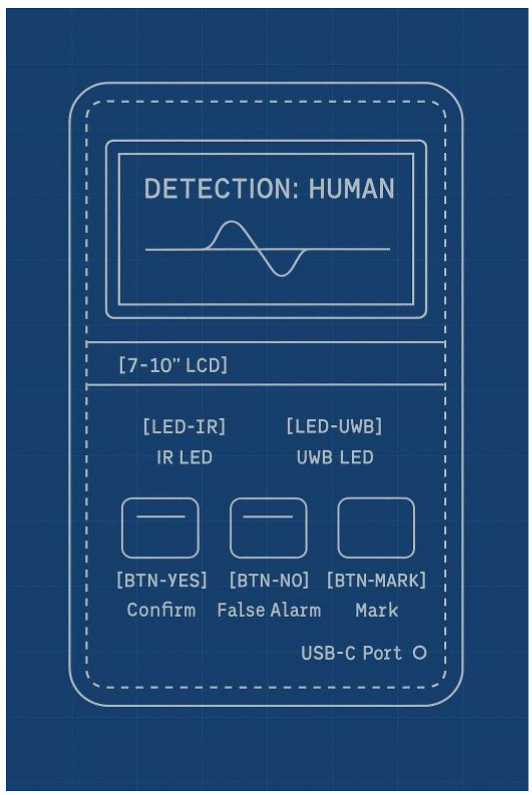


Figure 10: Portable Life Detector Prototype Blueprint

Furthermore, the prototype illustration for the user interface can be seen in the figure below. The interface highlights real time alters, thermal detection overlays and mapping functions to provide rescuers with immediate and actionable information.

Figure 11: Real Time User Interface Illustration

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