

ECEN 403 – Senior Design

System Requirements Report

FireGuard: Smart Fire Alarm with Occupant Detection

Group #
Team 3

Team Members
Moza Al-Mannai
Alreem Alghanem
Aisha Alkhalifa
Shaikha Alsulaiti

Mentor
Dr. Jim Ji

Semester
Fall 2026

Table of Contents

1. Introduction **3**
1.1 Purpose and Scope 3
1.2 Engineering Responsibility Allocation 3
1.3 Change Authority & Control Protocol 3
2. Applicable and Reference Documents **3**
2.1 Regulatory & Engineering Design Standards 3
2.2 Hardware & Component Documentation 3
3. System Requirements **4**
3.1 System Definition and Operational Characteristics 4
3.2 Functional Requirements 4
3.3 Physical Characteristics 4
3.4 Electrical & Electronic Characteristics 5
3.5 Environmental & Operational Requirements 5
4. Support Requirements **5**
4.1 Maintenance & Calibration Protocols 5
4.2 Supply Chain & Laboratory Facilities Support 5
4.3 Interface & Deployment Readiness 5
4.4 Dependencies & Mitigation 5
5. Verification Cross-Reference Matrix **6**
6. References **6**
7. Glossary & Acronyms **7**

1. Introduction

1.1 Purpose and Scope

This Functional System Requirements (FSR) document provides a technical baseline, functional specifications, physical and electrical constraints, and verification criteria for the FireGuard system. FireGuard is an integrated safety system that detects indoor fires and uses millimeter-wave (mmWave) sensing to show emergency responders, in real time, which areas are occupied [3-6, 8, 10, 11, 16]. It covers the relay interface between hardware and software, radar signal processing, wireless communication and the mobile interface [8, 10, 12, 13, 19].

1.2 Engineering Responsibility Allocation

The tasks of development and verification are split up amongst the team members to maximize thorough engineering work:

- **Moza Al-Mannai:** Team Leader & Project Integration; responsible for ConOps, system testing, budget tracking and communication.
- **Alreem Alghanem:** Hardware Engineering Lead, Interfacing relays, wiring mmWave sensors, power distribution, physical assembly.
- **Aisha Alkhalifa:** Requirements & Documentation Lead; defines functional specifications, literature surveys, and compliance documentation.
- **Shaikha Alsulaiti:** Testing & Validation Lead; responsible for coordinating project milestones, verification matrices and system testing protocols.

1.3 Change Authority & Control Protocol

Changes to the system requirements, hardware or software systems must go through the formal Engineering Change Control (ECC) process. A proposed change can only go ahead after a written impact assessment, approval from team leader Moza Al-Mannai and formal acceptance by the academic mentor, Dr. Jim Ji.

2. Applicable and Reference Documents

2.1 Regulatory & Engineering Design Standards

- **Fire Safety Code:** NFPA 72 (National Fire Alarm and Signaling Code), which requires smoke alarms to be interconnected and to have a secondary power backup [19].
- **Wireless Communication:** IEEE 802.11 Wireless Local Area Network (WLAN) standard for secure, packet-based wireless communication [8, 10].
- **Radar Frequency Compliance:** FCC Part 15 / ETSI EN 302 264 – electromagnetic compatibility and radar transmission rules for 60-64 GHz mmWave devices [16].

2.2 Hardware & Component Documentation

- **TI IWR6843ISK-ODS:** Texas Instruments IWR6843ISK-ODS mmWave sensor product documentation [16].
- **TI MMWAVEICBOOST:** Texas Instruments MMWAVEICBOOST carrier card platform documentation [17].
- **Ei Electronics Ei3016:** Ei3016 mains-powered optical smoke alarm product information [19].
- **Ei128RBU Relay Base:** Ei128RBU relay module base product information [20].
- **Samsung Tab A11:** Hardware specifications of the Samsung Galaxy Tab A11 (8.7", 128 GB) [18].

3. System Requirements

3.1 System Definition and Operational Characteristics

FireGuard is a dual-state emergency architecture, that is:

- **Standby State (Normal):** The hardwired smoke detector continuously monitors the environment while the mmWave radar sensors stay completely OFF. The radar only switches on when the alarm is triggered, so no standby power is used and privacy is fully protected [5, 19].
- **Active State (Emergency):** When smoke is detected, the relay in the Ei128RBU base switches the mmWave sensors from OFF to ON. The sensors scan the rooms, capture each occupant's coordinates and send them to the firefighters' Android tablet [16, 18, 20].

3.2 Functional Requirements

- **Fire Triggering:** SYS-FR-01: The system shall activate automatically within 1 second of the primary alarm detecting smoke or fire [19, 20].
- **Occupancy Detection:** SYS-FR-02: The mmWave sensor array shall implement 3D point-cloud processing to acquire a human target detection of statically and moving target [6, 16].
- **Spatial Localization:** SYS-FR-03: The system shall provide spatial localization to 0.12m range resolution between a number of designations within a single floor and between different floors [16].
- **Data Transmission:** SYS-FR-04: Total data transmission latency to the Android interface over Wi-Fi shall be under 2 seconds [8, 10, 12, 18].
- **Dashboard Priority Sorting:** SYS-FR-05: The Android UI shall dynamically place the fire-origin room at the top of the screen, highlighted in bold red [12, 13].

3.3 Physical Characteristics

- **Form Factor:** Sensor nodes shall be no larger than 150 mm x 100 mm x 40 mm so they can be mounted on a standard ceiling [16].
- **Enclosure Material:** The enclosure should be made from heat-resistant ABS/polycarbonate plastic, preferably with a UL 94 V-0 flame rating. A polycarbonate window will be placed in front of the radar antenna so the signal can pass through the enclosure.
- **Radar Coverage:** The sensor antenna array should cover a 120° x 120° overhead field of view [16].

3.4 Electrical & Electronic Characteristics

- **Primary Power:** The smoke alarm runs on 230 V AC (50 Hz) primary power with a 10-year sealed lithium backup battery [19].
- **Relay Isolation:** The Ei128RBU relay isolates the high-voltage side and provides dry-contact switching for the low-voltage sensor circuits [20]. An isolated alarm-status interface will also be used between the relay and the sensor circuit for extra protection.
- **Radar Node Power:** Each mmWave sensor node needs a 5 V DC supply and draws 1.0 A DC when active [16, 17].

3.5 Environmental & Operational Requirements

- **Temperature Resistance:** The smoke alarm operates from -10°C to +40°C [19], and the radar sensor operates from -10°C to +60°C with storage up to +85°C [16].
- **Atmospheric Immunity:** Unaffected by dense smoke, steam, airborne dust or total darkness [5].

4. Support Requirements

4.1 Maintenance & Calibration Protocols

- **Radar Calibration:** mmWave sensor chirp calibration and point-cloud baseline filtering must be done in the laboratory with TI mmWave Studio [16, 17].
- **System Testing:** The alarm test button shall be pressed regularly to confirm that the relay closes and the signal is output [19, 20].

4.2 Supply Chain & Laboratory Facilities Support

- **University Laboratory Resources:** The university lab provides breadboards, wiring, resistors, a power supply and USB cables.
- **Procurement Budget:** The hardware components (TI IWR6843ISK-ODS, MMWAVEICBOOST, Galaxy Tab A11, Ei3016 smoke alarm, and Ei128RBU relay base) will be purchased within the $1000 procurement budget.

4.3 Interface & Deployment Readiness

- **Software Environment:** Software built in Android Studio with Kotlin will be deployed directly to the tablet [12, 13, 18].

4.4 Dependencies & Mitigation

Our project depends of a few things that can cause problems if they don't work the way we planned them to. First is power. The smoke detector needs 230V from the wall, but incase of power shutdowns, it can still work because it has a lithium battery inside [19]. The radar sensors need 5 V, and we will have that from the power supply in the lab when testing.

We also need Wi-Fi to send the data to the tablet. If the connection is slow or drops, the firefighters won't be able to access the information in time. That is why we plan on testing the Wi-Fi early and making sure the delay stays below 2 seconds.

Another issue is shipping. Some of our components are ordered outside of Qatar which may lead to a delay in recievng our components. This is why we are ordering them ahead of time to avoid this delay.

For the radar, we have to use TI's mmWave Studio software. We will install TI's example programs first to make sure everything works and before we build our own setup. Lastly, the app has to work with our Android version on the tablet, so this will be tested beforehand.

5. Verification Cross-Reference Matrix

The matrix below shows each system requirement, and how it will be verified, and whether they are compliant or not:

Req ID	Requirement Description	Verification Method	Compliance Criteria
SYS-FR-01	Alarm relay triggering upon smoke detection	Test & Demonstration	Relay contacts close within <1 second of smoke injection [19, 20]
SYS-FR-02	3D point-cloud human occupant detection	Experimental Test	Detects stationary & moving person in 120° FOV [6, 7, 16]
SYS-FR-03	Spatial localization accuracy (Room/Floor)	Inspection & Analysis	Correctly identifies Room 204 with 0.12m range resolution [16]
SYS-FR-04	Wireless data delivery latency	Measurement Test	End-to-end packet delivery and render under <2 seconds [10, 18]
SYS-FR-05	Dashboard dynamic priority highlighting	Demonstration	Fire-origin room rendered in top red box on Android UI [12, 13]

6. References

[1] "About Automatic Fire Alarm Systems Research," IEEE Xplore. [Online]. Available: https://ieeexplore.ieee.org/abstract/document/5477835

[2] "Real-Time Fire Detection From Video Surveillance Cameras: Where Are We Now?," IEEE Xplore. [Online]. Available: https://ieeexplore.ieee.org/abstract/document/11394755

[3] "Intelligent Smoke Alarm System with Wireless Sensor Network Using ZigBee," Journal of Sensors, vol. 2018, 2018, doi: 10.1155/2018/8235127.

[4] L. White and R. Ajax, "Improved Fire Detection and Alarm Systems," 2025.

[5] "Next-Generation mmWave Wireless Sensing: Foundations, Applications, and Challenges," IEEE Xplore. [Online]. Available: https://ieeexplore.ieee.org/abstract/document/11673190

[6] G. García-Gutiérrez, E. Aparicio-Esteve, J. Ureña, J. M. Villadangos-Carrizo, A. Jiménez-Martín, and J. J. García-Domínguez, "A Practical Case of Monitoring Older Adults Using mmWave Radar and UWB," Sensors, vol. 26, no. 2, Art. no. 681, 2026, doi: 10.3390/s26020681.

[7] Y. Du, R. Nie, L. Ma, C. Xu, Y. Liu, and W. Wang, "Learning 3D Occupancy from Beam Overlap in 2D Rotating mmWave Radar," in Proc. AAAI Conf. Artif. Intell., vol. 40, no. 5, pp. 3714–3722, 2026, doi: 10.1609/aaai.v40i5.37371.

[8] "Wireless Smoke Detector and Fire Alarm System," Int. Res. J. Eng. Technol. (IRJET), 2023.

[9] "Development of a GPS Based Smart Fire Detection using UAV-UGV Coordinated Control," IEEE Xplore. [Online]. Available: https://ieeexplore.ieee.org/abstract/document/11518362

[10] N. Vikram, K. S. Harish, Nihaal MS, Umesh R, and Kumar SA, "A Low Cost Home Automation System Using Wi-Fi Based Wireless Sensor Network Incorporating Internet of Things (IoT)," IEEE, 2017.

[11] W. Xie and H. Huang, "Design and Application of Home Fire Alarm System," 2021.

[12] J. F. DiMarzio, *Beginning Android Programming with Android Studio*. Hoboken, NJ, USA: Wiley, 2016.

[13] D. Jemerov and S. Isakova, *Kotlin in Action*. Shelter Island, NY, USA: Manning, 2017.

[14] "Types of Sensors," GeeksforGeeks.

[15] S. Hall, "Fire Loss in the United States During 2024," National Fire Protection Association (NFPA), Sep. 2025.

[16] Texas Instruments, "IWR6843ISK-ODS: IWR6843 Intelligent mmWave Overhead Detection Sensor (ODS) Antenna Plug-in Module." [Online]. Available: https://www.ti.com/tool/IWR6843ISK-ODS

[17] Texas Instruments, "MMWAVEICBOOST: mmWave Sensors Carrier Card Platform." [Online]. Available: https://www.ti.com/tool/MMWAVEICBOOST

[18] Lulu Hypermarket Qatar, "Samsung Galaxy Tab A11 Wi-Fi Tablet, 8 GB RAM, 128 GB Storage (SM-X133)." [Online]. Available: https://gcc.luluhypermarket.com/en-qa/samsung-a11-wi-fi-tablet-8-gb-ram-128-gb-storage-silver-sm-x133nzsemea/p/2565248

[19] Screwfix, “Aico Ei3016 Mains Interlinked Optical Smoke Alarm (903KJ),” Screwfix.com. [Online]. Available: https://www.screwfix.com/p/aico-ei3016-mains-interlinked-optical-smoke-alarm/903kj (accessed Oct. 21, 2026).

[20] Electricpoint, “Aico Ei128RBU Relay Module Base with Battery Back-up,” Electricpoint.com. [Online]. Available: https://www.electricpoint.com/aico-ei128rbu-relay-module-base-with-battery-back-up.html (accessed Oct. 21, 2026).

7. Glossary & Acronyms

- **AC / DC:** Alternating Current / Direct Current
- **ConOps:** Concept of Operations
- **ECC:** Engineering Change Control
- **FCC / ETSI:** US and European agencies that set radio rules
- **FOV:** Field of View
- **FSR:** Functional System Requirements
- **mmWave:** Millimeter-wave, a radar that uses very high-frequency signals (60–64 GHz)
- **NFPA:** National Fire Protection Association
- **Point cloud:** A set of 3D points the radar creates to show where objects or people are
- **Relay:** A switch that is turned on or off by an electrical signal
- **UI:** User Interface
- **UL 94 V-0:** A flame rating for plastics
- **WLAN:** Wireless Local Area Network