📘 PRODUCT REQUIREMENTS DOCUMENT (PRD)

Elderly Care Smart Wearable – Hardware & Sensor Specifications

1. System Overview

The proposed solution is a **wrist-worn IoT-based elderly care wearable** designed to ensure **safety, health monitoring, and emergency responsiveness** for senior citizens. The system integrates **vital health sensors, motion/fall detection, and location tracking** into a **single wearable device**, supported by a mobile/cloud platform for caregivers and family members.

The hardware architecture prioritizes:

- Non-invasive sensing
- Elderly-friendly comfort
- Low power consumption
- Reliable emergency detection
- Real-time monitoring and alerts

---

2. Selected Core Hardware Components

Component	Model	Specification	Cost (₹)	Rationale
Microcontroller	ESP32 (or ESP32-C3)	Dual-core, Wi-Fi + BLE, 3.3V, 240MHz	350-600	Master controller; handles all sensors + communication
Motion Sensor	MPU6050	6-axis IMU (Accel + Gyro), I^2C, 3.3-5V	250-450	Fall detection; activity tracking; sleep monitoring
Heart Rate & SpO_2	MAX30102	PPG optical sensor, I^2C, 1.8-3.3V	350-650	HR monitoring; blood oxygen; stress via HRV
GPS Module	L76K	Ultra-low power, UART/I^2C, 3.3V	2,000-3,000	Outdoor location; geofencing; emergency dispatch
Battery	Li-Po 3.7V 500-1000mAh	Rechargeable, with BMS, compact	400-800	Wearable-compatible; 1-2 day battery life
Buzzer/Alert	Passive Buzzer 3V	Alarm notifications	30-100	Emergency alerts; reminders
Button	Tactile Push Button	Large (8mm), easy press	20-50	SOS trigger; elderly-friendly

USB Charging	Micro USB Module	5V charging port	200-300	Easy daily charging
Enclosure Material	Medical-grade Silicone	Platinum-cured, biocompatible	200-400	Safe for elderly skin; washable; durable
Sensors PCB + Wiring	Custom PCB + connectors	Multi-layer PCB design	4000-8000	Integration & reliability (if required)

📊 **TABLE: Sensor Accuracy & Performance Metrics**

Sensor	Parameter Measured	Measurement Accuracy	Operating Conditions	Accuracy Notes (Elderly Context)
MAX30102	**Heart Rate (BPM)**	**±2–3 BPM**	**Normal resting state**	**Accuracy may reduce with excessive motion**
	SpO_2 (%)	**±2% (70–100%)**	**Proper skin contact**	**Cold skin or poor circulation may affect reading**
MPU6050	**Fall Detection**	**~90–95% detection accuracy**	**Algorithm-based**	**Accuracy improves using multi-axis validation**
	Activity Detection	**~92%**	**Continuous motion tracking**	**Tunable thresholds for elderly movement**
L76K GPS	**Location (Outdoor)**	**±2.5–5 meters**	**Clear sky view**	**Best during emergencies outdoors**
	Location (Indoor)	**±10–30 meters**	**Limited satellite access**	**Uses last known location fallback**
ESP32 + BLE	**Data Transmission**	**>99% packet success**	**Within BLE range**	**Depends on smartphone proximity**
System-Level	**Emergency Detection**	**~90–93% overall**	**Combined sensors**	**Reduced false alerts using sensor fusion**

📊 Accuracy Improvement Techniques

Issue	Impact on Accuracy	Mitigation
Motion artifacts	**HR & SpO_2 noise**	**MPU6050-based motion filtering**
Poor skin contact	**Low SpO_2 accuracy**	**Adjustable strap design**
False fall alerts	**Unwanted SOS**	**Multi-stage fall logic**
Indoor GPS drift	**Location error**	**Last known location + time stamp**

2.1 MAX30102 – Heart Rate & SpO_2 Sensor

Component Name

MAX30102 Optical Heart Rate & Pulse Oximeter Sensor

Category

Health & Bio-Sensing Sensor

Description

The MAX30102 is an **integrated optical biosensor** designed to measure **heart rate (BPM)** and **blood oxygen saturation (SpO_2)** using **photoplethysmography (PPG)**. It uses **red and infrared LEDs** along with a photodetector to analyze blood volume changes beneath the skin.

Parameters Measured

- Heart Rate (BPM)
- Blood Oxygen Saturation (SpO_2)
- Heart Rate Variability (HRV – derived)

Working Principle

1. LEDs emit red and infrared light into the skin
2. Blood absorbs light differently depending on oxygen level
3. Reflected light is detected by photodiode
4. Signal processing calculates heart rate and SpO_2

Placement

- Wrist (underside of band, skin-contact area)

Typical Cost

₹350 – ₹650

Why Selected

- Elders commonly suffer from **cardiac and respiratory issues**
- Continuous monitoring enables **early detection of emergencies**
- Non-invasive and painless
- Single sensor provides **multiple health parameters**
- Low power consumption – ideal for wearables

Health & Safety

- No radiation
- No electrical current injected into the body
- Safe for continuous, long-term elderly use

2.2 MPU6050 – Accelerometer & Gyroscope (Fall Detection)

Component Name

MPU6050 – 6-Axis IMU Sensor

Category

Motion & Activity Sensor

Description

The MPU6050 is a **6-axis Inertial Measurement Unit (IMU)** combining a **3-axis accelerometer** and **3-axis gyroscope** for detecting motion, orientation, and sudden impacts.

Parameters Measured

- Linear acceleration (X, Y, Z)
- Angular velocity
- Orientation change

Working Principle

- MEMS-based sensors detect changes in motion and rotation
- Sudden acceleration followed by inactivity indicates a fall

- Motion patterns analyzed via threshold-based algorithms

Placement

- Inside wrist band or pendant

Typical Cost (India)

₹250 – ₹450

Why Selected

- **Mandatory sensor for fall detection**
- Enables **automatic SOS triggering** without user interaction
- Supports activity tracking and sleep monitoring
- Very low power and compact size

Health & Safety

- No skin exposure
- No radiation
- Completely passive sensor

2.3 L76K – GPS Location Tracking Module

Component Name

Quectel L76K GPS Module

Category

Location & Safety Sensor

Description

L76K is an **ultra-low-power GPS module** optimized for **wearable and battery-powered IoT devices**, providing real-time outdoor location tracking.

Parameters Measured

- Latitude
- Longitude
- Speed
- Time

Working Principle

1. Receives signals from GPS satellites
2. Calculates distance using signal travel time
3. Uses trilateration to determine location
4. Location data sent to controller via UART/I^2C

Placement

- Inside wearable enclosure with antenna exposure

Typical Cost

₹2,000 – ₹3,000

Why Selected

- Essential for **emergency location sharing**
- Supports **geofencing for wandering detection**
- Optimized for **low power consumption**
- Better suited for wearables than traditional GPS modules

Health & Safety

- Passive receiver only
- Does not emit harmful radiation
- Safe for continuous elderly use

2.4 ESP32 – Microcontroller Unit (MCU)

Component Name

ESP32 (ESP32 / ESP32-C3 Variant)

Category

Main Processing & Communication Unit

Description

ESP32 is a **low-power, high-performance IoT microcontroller** with built-in **Wi-Fi and Bluetooth Low Energy (BLE)** capabilities.
It acts as the **central controller**, processing sensor data and transmitting alerts to mobile/cloud platforms.

Key Responsibilities

- Sensor data acquisition (MAX30102, MPU6050, L76K)
- Fall detection logic
- Emergency alert triggering
- BLE communication with smartphone
- Wi-Fi communication with cloud (optional)

Interfaces Used

- I^2C → MAX30102, MPU6050
- UART / I^2C → L76K GPS
- BLE → Smartphone app
- Wi-Fi → Cloud server

Typical Cost

₹350 – ₹600

Why Selected

- Supports **multiple sensors simultaneously**
- BLE is ideal for wearable-to-phone communication
- Sufficient processing power for real-time monitoring
- Large ecosystem and development support
- Deep sleep modes enable long battery life

2.5 Li-Po Battery (500–1000 mAh)

Component Name

Rechargeable Lithium Polymer Battery

Category

Power Source

Description

A compact, lightweight **rechargeable Li-Po battery** used to power the wearable device.

Capacity Options

- 500 mAh (smaller, lighter)
- 1000 mAh (longer battery life)

Expected Battery Life

- 24–72 hours depending on GPS usage and sampling rate

Table: Battery Usage Estimation

Component	Power Mode	Approx Consumption
ESP32	BLE active	~40 mA
MAX30102	Sampling	~1–2 mA
MPU6050	Always on	~3–5 mA
GPS	Active tracking	~25–30 mA
Total	—	~70–80 mA

Why Selected

- High energy density
- Lightweight and wearable-friendly
- Rechargeable via USB
- Commonly used in medical wearables

Safety Considerations

- Overcharge & short-circuit protection required
- Proper enclosure ventilation
- Certified battery recommended

---

3. System-Level Justification

Why This Sensor Combination Was Chosen

- **MAX30102** → Core health monitoring (HR, SpO_2, stress indicators)
- **MPU6050** → Automatic fall detection (critical for elderly safety)
- **L76K GPS** → Emergency location tracking & geofencing
- **ESP32** → Reliable processing & communication
- **Li-Po Battery** → Portable and wearable-friendly power

This combination achieves:

- Essential elderly health monitoring
- Automatic emergency response
- Low cost
- Non-invasive and safe operation
- Scalability for future upgrades

Sensor Summary Table :

📊 Table 1: Sensor Selection Overview

Sensor	**Parameter Measured**	**Use Case**	**Power Consum-ption**	**Reason for Selection**
MAX30102	Heart Rate, SpO_2	Cardiac & respiratory monitoring	Low	Non-invasive, multi-vital sensor
MPU6050	Acceleration, Rotation	Fall detection	Very Low	Reliable fall detection
L76K GPS	Location	Emergency tracking	Medium	Accurate, low-power GPS
ESP32	Data processing, BLE/Wi-Fi	Central control	Low	IoT-ready MCU

📊 TABLE 2: Elderly Safety & Health Impact Table (HIGHLY RECOMMENDED)

Table: Health Safety Assessment of Sensors

Sensor	**Skin Contact**	**Radiation**	**Long-Term Use Risk**	**Elder-Safe**	**Explanation**
MAX30102	Yes	No	None	✓ Yes	Uses harmless LED light
MPU6050	No	No	None	✓ Yes	Passive MEMS sensor
L76K GPS	No	No	None	✓ Yes	Passive receiver only

ESP32 (BLE)	No	Very Low RF	Negligible	✓ Yes	BLE within global safety limits

ENCLOSING: -

ElderCare Smart Health Wristband: -

Design and develop a **comfortable, safe, and reliable wearable health monitoring wristband for elderly users**. The product prioritizes **skin safety, long-term comfort, accurate sensor contact, and ease of daily use**, while integrating health and location monitoring electronics.

Materials Selection (Wearability & Safety Focus)

1. Medical-Grade Silicone (Platinum-Cured)

Alias / Other Names

- Platinum-cured silicone
- Medical silicone rubber
- Implant-grade silicone (material class)

Description
Soft elastomeric band made from **medical-grade platinum-cured silicone rubber**, known for biocompatibility and extremely low chemical leachables.

Why It Is Suitable for Elderly Users

- **Hypoallergenic**: Very low risk of skin reactions; significantly safer than low-grade silicone or latex.
- **Soft & Flexible**: Gentle on thin, fragile, or aging skin; minimizes pressure points.
- **Waterproof & Washable**: Allows daily cleaning; reduces hygiene-related skin problems.
- **Durable & Stretchable**: Suitable for continuous daily wear and light physical activity.
- **Sensor-Friendly**: Maintains consistent skin contact, improving accuracy of optical (PPG) sensors.

Drawbacks / Considerations

- Very rare silicone allergies may still exist.
- Poor ventilation may trap sweat, increasing risk of skin maceration or fungal growth if not designed properly.

Design Guidelines

- Use **perforated or breathable strap patterns** for airflow.

- Ensure **rounded edges and soft inner surface finish** to prevent chafing.
- Provide **replaceable or quick-swap bands** for hygiene.
- Use **316L stainless steel or titanium** for pins/clasps (avoid nickel plating).
- Avoid adhesives or glues in direct skin contact.

Cleaning & Maintenance

- Wash daily with mild soap and water.
- Dry thoroughly before wearing.
- Avoid alcohol wipes on broken or sensitive skin.

Approximate Use Case
Primary recommendation for **daily wear, sleep tracking, shower-safe use, and long-term elderly monitoring**.

2. Hypoallergenic Coatings / Barrier Layers

Alias / Other Names

- Parylene coating
- PTFE (Teflon) coating
- Biocompatible barrier coating

Description
Ultra-thin protective coatings applied to metal or polymer surfaces to reduce skin irritation and allergen exposure.

Why Considered

- Reduces metal ion leaching.
- Minimizes friction and skin abrasion.
- Improves long-term comfort at contact points.

Drawbacks

- Coating wear over time.
- Incorrect application may trap moisture.

Recommended Use Case
Best suited for **metal clasps, pins, and sensor housings**, not entire straps.

Approximate Wristband Size Specifications

Component	Approximate Size
Strap width	20–22 mm
Strap thickness	2.5–3 mm
Adjustable wrist range	140–220 mm
Ventilation holes	3–4 mm diameter
Clasp width	18–20 mm

Electronics Module Size (Approximate)

Module	Approximate Dimensions
Main housing length	40–45 mm
Main housing width	20–25 mm
Housing thickness	10–13 mm
Sensor window (PPG)	10–12 mm diameter

Final Product Size (Assembled)

Parameter	Approximate Value
Total length (including strap)	140–200 mm
Band width	20–25 mm
Max thickness (sensor area)	≤14 mm
Target weight	30–45 grams

6. Safety & Compliance Requirements

- ISO 10993 (Biocompatibility)
- Hypoallergenic materials only
- No exposed sharp edges
- Electrical isolation between sensors and skin
- Secure enclosure (IP65 or higher recommended)

7. Final Material Recommendation

Primary Strap Material: Platinum-cured medical-grade silicone
Metal Components: 316L stainless steel or titanium with hypoallergenic coating

📊 **TABLE 3: Disability Coverage Table**

Table: Support for Different Elderly Conditions

Elderly Condition	Supported?	How System Helps
Weak Mobility	✓ Yes	Fall detection + SOS
Memory Loss	✓ Yes	Automatic alerts
Cardiac Issues	✓ Yes	HR & SpO_2 monitoring
Living Alone	✓ Yes	GPS + family alerts
Speech Disability	✓ Yes	Automatic sensing (no voice needed)
Visual Impairment	✓ Yes	No screen dependency
Wheelchair User	✓ Yes	Fall logic adjustable

📊 **TABLE 4: Risk & Limitation Table**

Limitation	Risk	Mitigation
Indoor GPS inaccuracy	Wrong location	Use last known location
False fall detection	False SOS	Multi-parameter validation
Battery drain	Device shutdown	Power optimization
Skin tone variation	HR accuracy	Calibration algorithm

Failure & Safety Considerations: -

The elderly care wearable is designed with **fail-safe mechanisms** to ensure **user safety, system reliability, and comfort**, even under abnormal or failure conditions. Each possible failure scenario is addressed at both **hardware and system levels**.

1 Device Not Worn (Non-Compliance Detection)

Problem:
Elderly users may forget to wear the device, remove it due to discomfort, or be unable to wear it because of disability.

Detection Method:

- **MAX30102 signal loss** (no pulse detected)
- **MPU6050 inactivity** (no micro-movements)
- Sudden drop in skin-contact readings

System Response:

- Marks device status as *"Not Worn"*
- Sends notification to family/caregiver app
- Temporarily disables fall detection to prevent false alerts

Safety Justification:

- Prevents false emergency triggers
- Encourages consistent usage without forcing compliance

2 Battery Drain / Power Failure

Problem:
Low battery may stop monitoring during emergencies.

Detection Method:

- ESP32 continuously monitors battery voltage via ADC
- Battery level thresholds:
    - Warning: <20%
    - Critical: <10%

System Response:

- Sends low-battery alert to caregivers
- Enters **low-power mode** (disables GPS first)
- Reserves power for **SOS & BLE communication**

Safety Justification:

- Ensures emergency alerts remain functional
- Prevents sudden device shutdown

3 Sensor Failure or Malfunction

Problem:
Sensors may give invalid readings due to aging, sweat, misplacement, or hardware fault.

Detection Method:

- Out-of-range or constant sensor values
- Internal self-test checks during boot
- Cross-validation between sensors (e.g., motion vs HR)

System Response:

- Flags sensor as *"Faulty"*
- Notifies family/caregiver
- Continues partial operation using remaining sensors

Safety Justification:

- Avoids misleading health data
- Maintains partial functionality instead of total failure

4 False Positives (False Fall / Emergency Alerts)

Problem:
Sudden hand movements or object drops may trigger false SOS alerts.

Mitigation Strategy:

- Multi-stage fall detection:
    1. Sudden acceleration (MPU6050)
    2. Orientation change
    3. Post-fall inactivity
- Time-based confirmation window (5–10 seconds)

System Response:

- Provides brief cancellation window (auto or via caregiver)
- Confirms emergency only if conditions persist

Safety Justification:

- Reduces caregiver fatigue
- Prevents unnecessary panic
- Improves trust in system alerts

5 Overheating or User Discomfort

Problem:
Prolonged use of electronics may cause warmth or skin irritation, especially in elderly users with sensitive skin.

Prevention Measures:

- Low-power components (ESP32, MAX30102)
- Duty-cycled sensing (not continuous LED usage)
- Breathable, hypoallergenic strap materials
- Heat-insulating enclosure design

System Response (if detected):

- Reduces sensor sampling rate
- Sends maintenance alert if temperature rises abnormally

Safety Justification:

- Prevents burns, rashes, or discomfort
- Ensures long-term wearability for elders

Failure Handling Overview

Failure Scenario	**Detection**	**System Action**	**Safety Benefit**
Device not worn	No pulse + no motion	Notify caregiver	Avoid false alerts
Low battery	Voltage monitoring	Power saving + alert	Emergency readiness
Sensor failure	Invalid readings	Flag + partial operation	Data reliability
False positives	Multi-sensor validation	Alert confirmation	Reduced panic
Overheating	Power & duty control	Sampling reduction	User comfort