REPORT

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CSLAB

Smart Lighting and Heating System

G01

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1. Requirement Specification

1.1. Black Box

1.1.1. Requirements

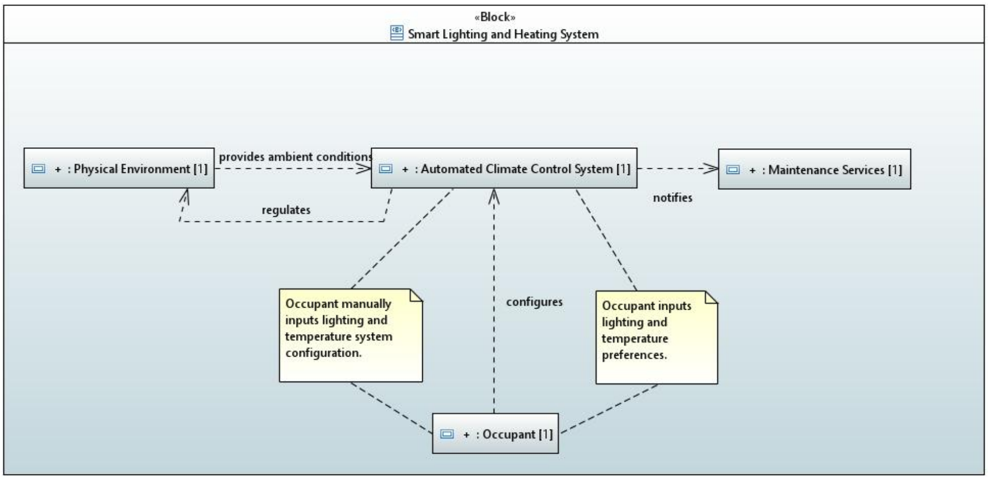
The following requirements describe the expected behavior of the Automated Climate Control System (ACCS) when stimulated by external inputs or environmental changes. Each requirement is expressed in a clear, testable, and implementation-agnostic manner, following the black-box perspective. The table below enumerates all functional requirements currently identified for the system.

Table 1: Requirements Specification.

ID	TITLE	DESCRIPTION
R-1	Automatic Natural Light Optimization	While the system is in Automatic Mode, the ACCS shall adjust the smart blinds to the fully open position to maximize natural sunlight entry.
R-2	Artificial Light Compensation	When the blinds are fully open and natural light level is measured below the user-defined threshold, the ACCS shall activate the artificial smart lights to achieve user-defined light preferences.
R-3	Automatic Temperature Regulation	While the system is in Automatic Mode, the ACCS shall regulate the smart heater output to maintain the office temperature within the user-defined temperature preferences.
R-4	User Preference Configuration	When the Occupant inputs configuration changes via the User Interface, the ACCS shall store the new preferences for lighting and temperature.
R-5	Manual Override Control	When a manual command is received for a specific device (Blinds/Lights/Heater), the ACCS shall suspend automatic control for that device and adjust it to the user-requested value.
R-6	Performance Deviation Alert	If the measured environmental parameters (light/temperature) deviate from the current system configuration target values for 1 minute, the ACCS shall display a warning message on the User Interface.

1.1.2. System Context

The Smart Lighting and Heating System operates within a broader environment involving physical conditions, human interaction, and external support services. The System Context defines the system boundaries and identifies all external entities that interact with the ACCS. This clarifies what lies inside the system and what remains outside.



1.1.3. Use Cases

This section describes the functional interactions between external actors and the Smart Lighting and Heating System. It identifies the interactions between users, external services, and the ACCS, capturing how each actor initiates or participates in system functions. The following table presents the use cases identified as well as their description.

Table 2: Description of Use Cases.

ID	TITLE	DESCRIPTION
UC-1	Configure System Preferences	The Occupant inputs or updates lighting and temperature preferences. The ACCS stores these preferences for use in automatic regulation.
UC-2	Override System Configuration	The Occupant manually controls a specific device (e.g. blinds, lights, heater). The ACCS suspends automatic control for that device and applies the requested setting.
UC-3	View Alert Messages	The Occupant views warning or informational messages generated by the ACCS, typically related to performance deviations or detected malfunctions.S
UC-4	Regulate Light Level	The ACCS automatically adjusts smart blinds and/or artificial lighting to achieve the desired light level based on sensor readings and configured preferences.
UC-5	Regulate Temperature Level	The ACCS controls the smart heater to maintain indoor temperature within the user-defined range.
UC-6	Store Occupant Preferences	The ACCS saves updated lighting and temperature configurations submitted by the Occupant.

ID	TITLE	DESCRIPTION
UC-7	Monitor System Configuration Deviations	The ACCS continuously compares environmental conditions with the target values. If deviations persist beyond a defined duration, the system prepares an alert.
UC-8	Send Alert Messages	When abnormal conditions or potential malfunctions are detected, the ACCS issues alert messages to the Occupant and, when necessary, to Maintenance Services.
UC-9	Receive Malfunctioning Alert Messages	Maintenance Services receives fault notifications from the ACCS, enabling appropriate maintenance actions.

Diagram 1 presents the use cases associated with their respective actors.

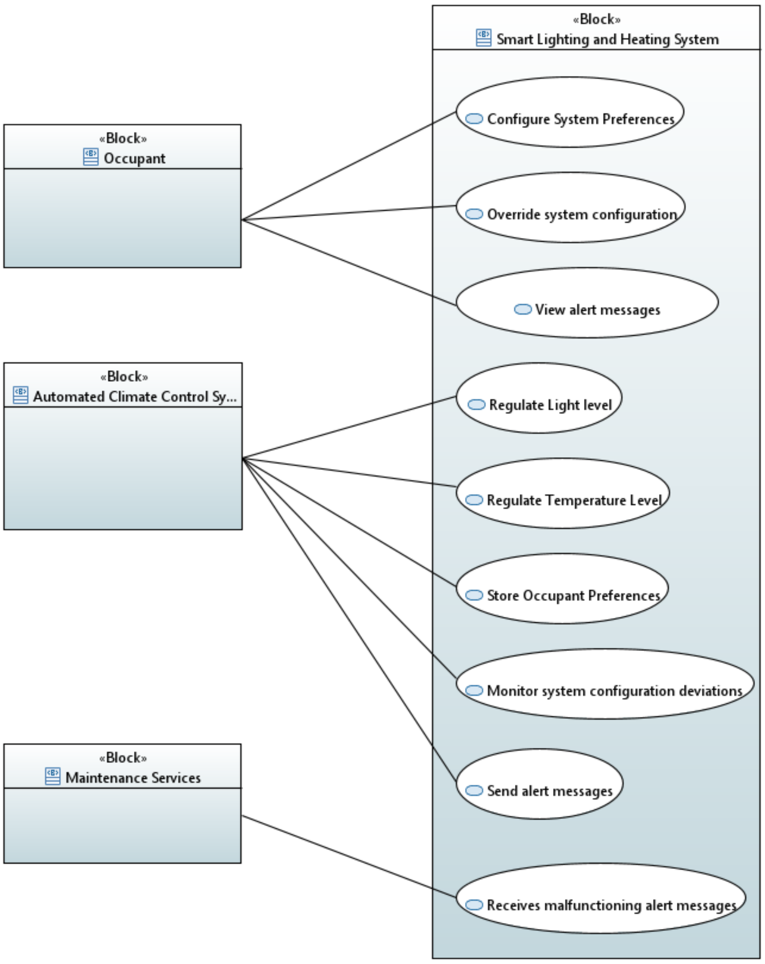


Diagram 1: Use Case Diagram.

1.1.3.1. Activity Diagrams

Considering the use cases presented in the previous section, the following activity diagrams were developed for the main use cases of the system.

- ***Regulate Temperature Level***

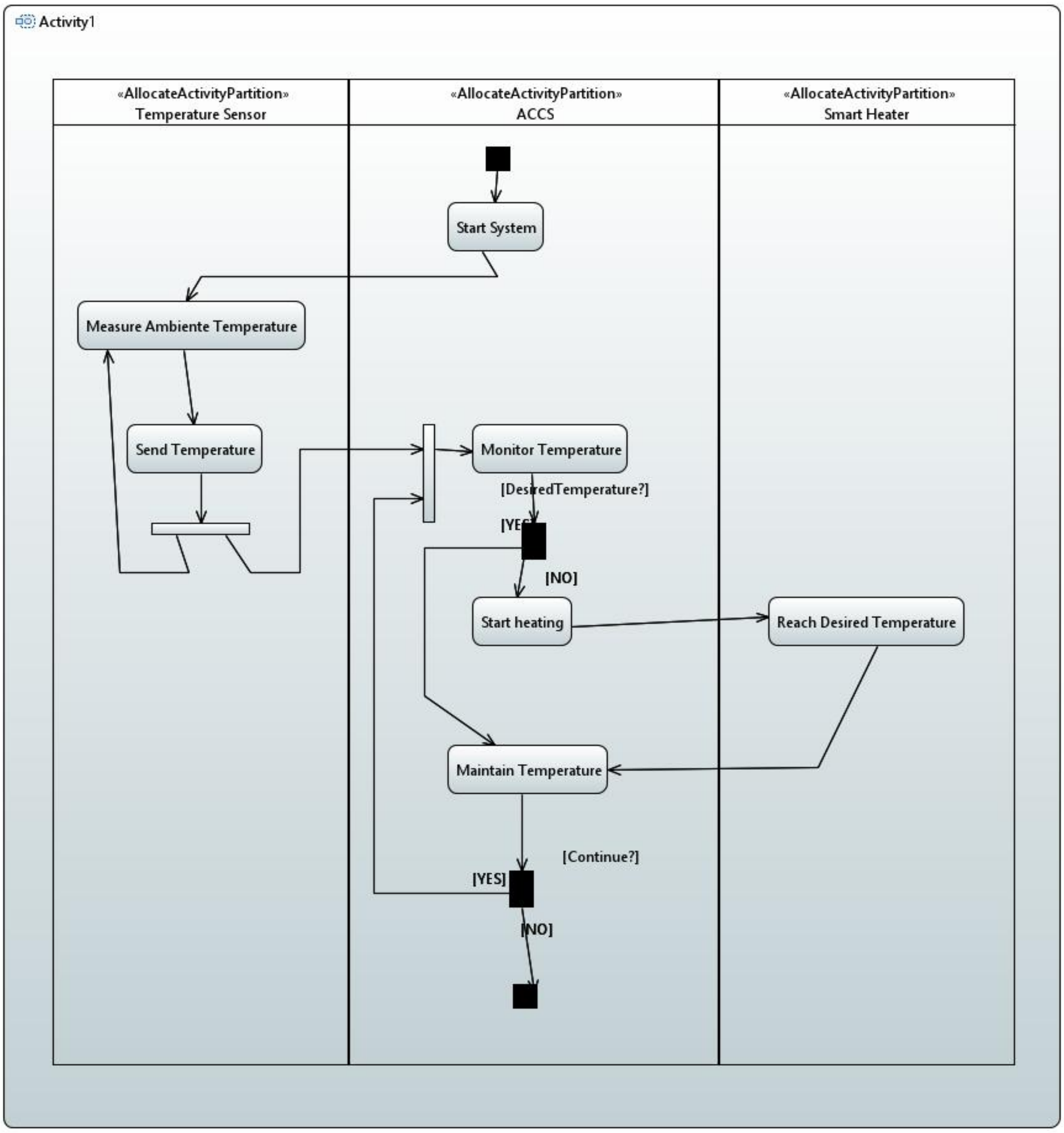


Diagram 2: "Regulate Temperature Level" Activity Diagram.

- ***Regulate Light Level***

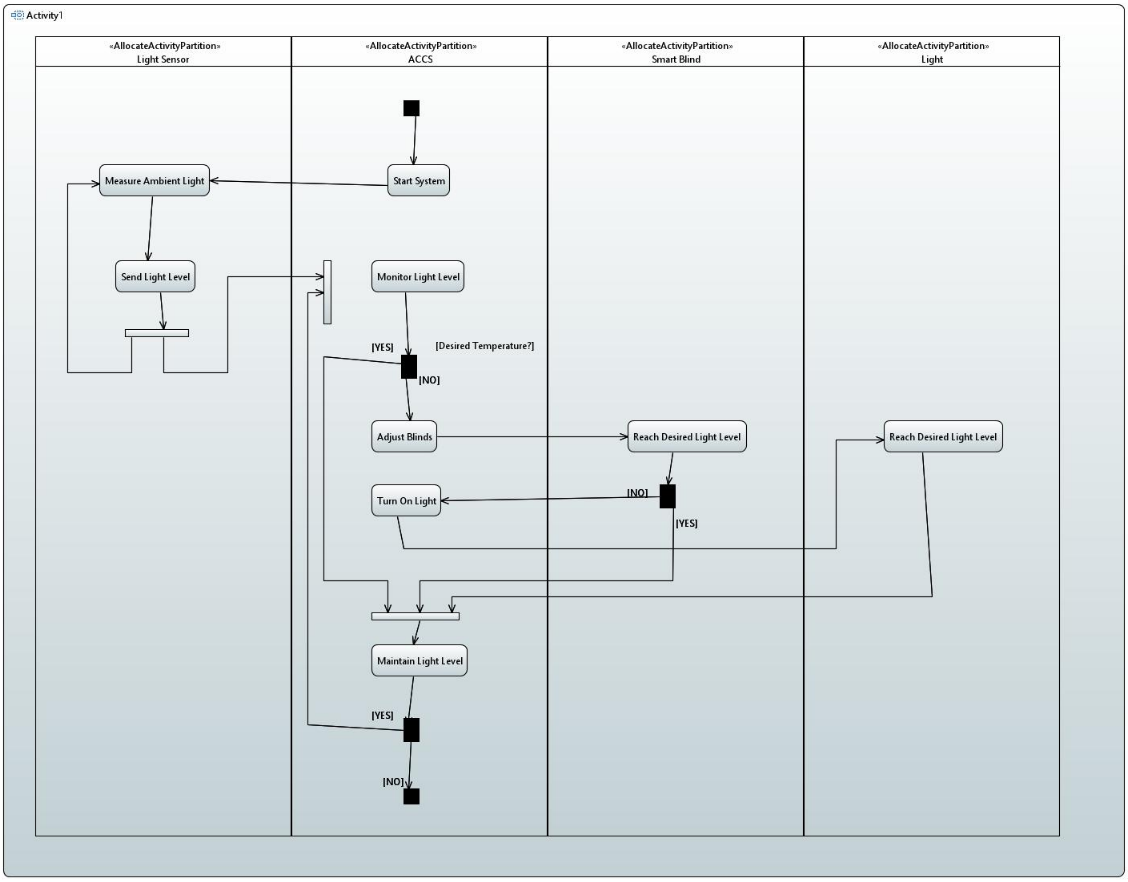


Diagram 3: "Regulate Light Level" Activity Diagram.

1.2. White Box

1.2.1. Conceptual Subsystems

The ACCS is composed of three internal subsystems: the Office Control Unit, Heating Control, and Light Control. This section defines the system's internal structure and identifies the key functional blocks.

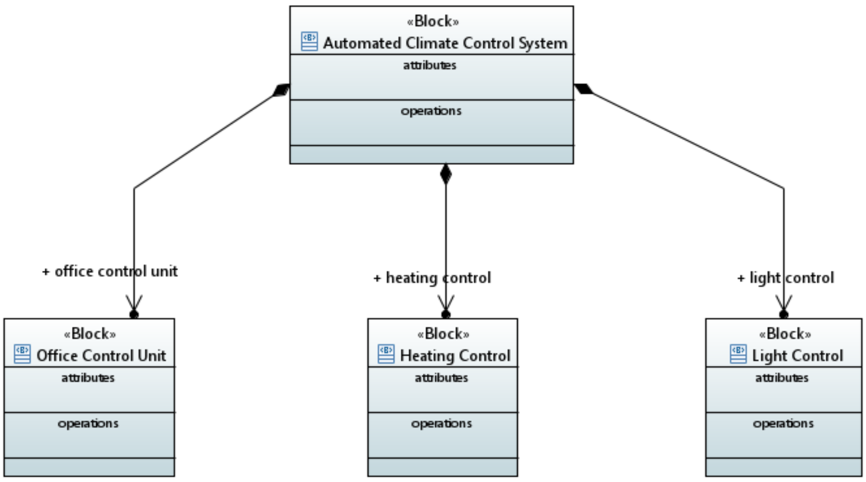


Diagram 4: Conceptual Subsystems.

1.2.2. Conceptual Interfaces

The Smart Lighting and Heating System interacts with its environment through a set of defined input and output ports. This section specifies these interaction points, detailing the flow of sensor data and user commands into the system, and the corresponding control updates sent to actuators like heaters and blinds.

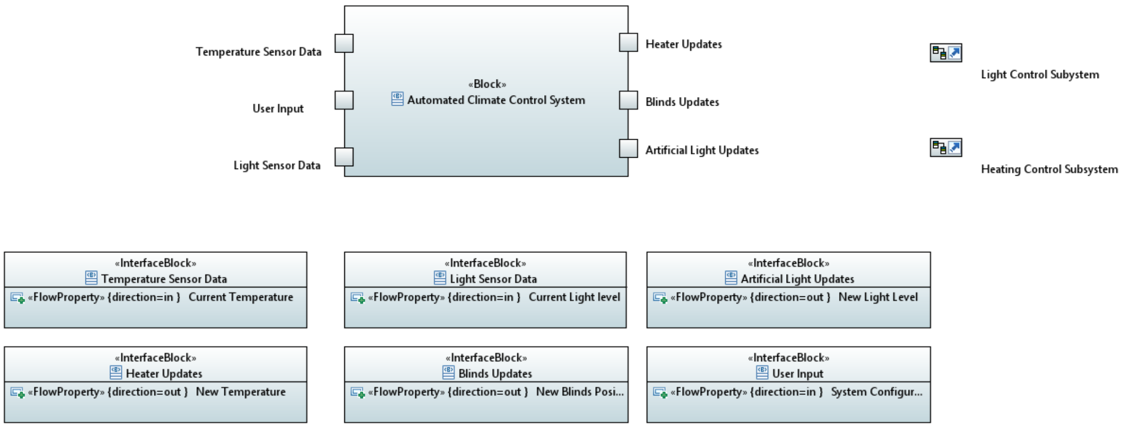


Diagram 5: Conceptual Interfaces.

1.3. Traceability

This section describes the links between the system components and the requirements introduced earlier. Due to space limitations, only a shortened version of the traceability table is provided.

	A	B	C	D	E	F	G
	User Input	Heating Control Info...	Light Control Infor...	Temperature Se...	Heater Upd...	Information Output	Information Input
Deviation Alert	☐	☐	☐	☐	☐	☑	☐
Manual Override Control	☐	☐	☐	☐	☐	☐	☑
User Preference Configuration	☐	☐	☐	☐	☑	☐	☑
Automatic Temperature Regulation	☐	☑	☐	☑	☐	☐	☐
Artificial Light Compensation	☐	☐	☑	☐	☐	☐	☐
Automatic Natural Light Optimiz...	☐	☐	☑	☐	☐	☐	☐

Diagram 6: Traceability between system components and requirements.

1.4. Hazard Analysis

The Hazard Analysis identifies potential failure modes that could disrupt the system's operation. This section outlines specific risks associated with actuator and sensor malfunctions and defines the necessary mitigation strategies to maintain system reliability and user comfort.

Table 3: Hazard Analysis.

HAZARD	MITIGATION
One of the smart heater actuators is malfunctioning	Identify the failure, provide user with temporary fix (regulate by hand), and initiate long-term fix (send message to maintenance services)
The smart blind actuator is stuck in the "closed" position during the day.	Detect discrepancy between command and state. Notify the Occupant to manually adjust the blind and send message to maintenance services.

The smart light actuator fails to switch OFF (stuck ON).	Detect continuous energy usage or light input when not requested. Notify user to manually switch off the switch and send message to maintenance services.
The smart light actuator fails to switch ON (bulb/circuit failure).	Detect lack of change in light intensity after command. Notify user and suggest using natural light and send message to maintenance services.
The temperature sensor is malfunctioning	Implement Dual-Sensor Redundancy and Range Validation. Each sensor is first checked against a realistic range. If both are valid, they are compared; if the difference exceeds a threshold, the system disables automation and notifies the occupant and sends message to maintenance services.
The light sensor is malfunctioning	Implement Dual-Sensor Redundancy and Range Validation. Each sensor is first checked against a realistic range. If both are valid, they are compared; if the difference exceeds a threshold, the system disables automation and notifies the occupant and sends message to maintenance services.

2. List of Technologies

The system uses a communication architecture using UDP and MQTT to balance performance and manageability.

- **UDP (User Datagram Protocol) with Custom QoS:** UDP is used for local communication between the Worker Devices and the Control Unit. To mitigate the inherent unreliability of standard UDP, we are implementing a custom Quality of Service (QoS) layer. This layer utilizes a Syn-Ack style protocol to verify the delivery of critical sensor readings and actuator commands, ensuring data integrity without the overhead of full TCP.
- **MQTT (Message Queuing Telemetry Transport):** The Office Control Units (OCUs) communicate with the central Configuration Center using MQTT. This protocol is selected for its robust handling of remote connections and efficient message distribution.

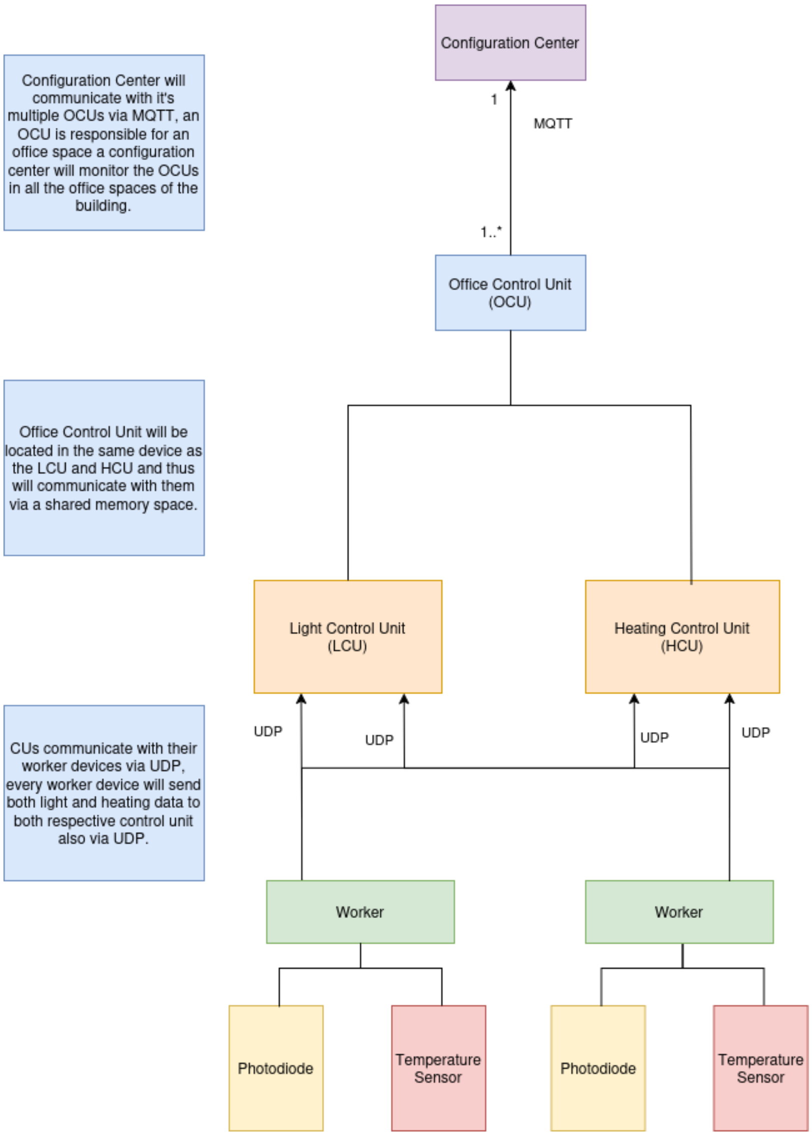


Diagram 7: Component Communication.

3. List of Physical Sensor(s)/Actuators

Considering composition of Automated Climate Control System presented in Diagram 7, the following hardware components have been selected to implement the system:

- 2 Micro-controllers
- 2 Temperature sensors
- 2 Photo-diodes (Light sensors)
- 4 LED lights
- 2 Servo motors

4. List of Real-Time Tasks

Based on the use cases defined in section 4, the following are classified as real-time tasks due to their specific timing constraints:

- **Override system configuration:** this task is defined as a real-time task as any office conditions updates or overrides must take effect in less than 60 seconds.
- **Regulate Light level:** this task is defined as a real-time task because the system is considered to have failed if the office light level does not change within 5 seconds of an update command, or if the sensor readings fail to reach the appropriate control unit within 2 seconds of being captured by the Worker Device.
- **Regulate Temperature level:** this task is defined as a real-time task because the system is considered to have failed if the office temperature does not change within 30 seconds after an update command, or if the temperature readings from the sensors fail to reach the appropriate control unit within 2 seconds of being captured by the worker.