SMART LIGHTING AND HEATING SYSTEM – FIRST DELIVERY

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This report meets the requirements outlined in the Course Unit Description of the Critical Systems Laboratory, in the 1st year of the Master's in Critical Computer Systems Engineering.

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1. INTRODUCTION

This document underlines the development process of the chosen project for the subject Laboratório de Sistemas Críticos. It provides an overview of the problem context and details the components and technologies chosen for the project's implementation.

1.1. CONTEXT

In modern buildings like the one housing the CISTER unit, smart management of lighting and heating is essential for promoting environmentally friendly practices, reducing operational costs, and enhancing the well-being of researchers. This project aims to develop an automated climate control system tailored to the unique characteristics of the CISTER building, particularly focusing on its 3rd floor.

The floor comprises seven individual offices, each equipped with one smart blind and one smart heater, four double-occupancy offices with two independent smart blinds and heaters each, and the director's office, which features three smart blinds and four smart heaters. The building layout is illustrated in the accompanying diagram.

All offices are equipped with smart devices, including green blinds, red heaters, and orange ceiling lights, which can be monitored and controlled via wireless sensor networks (WSN) as shown in the Figure 1 .

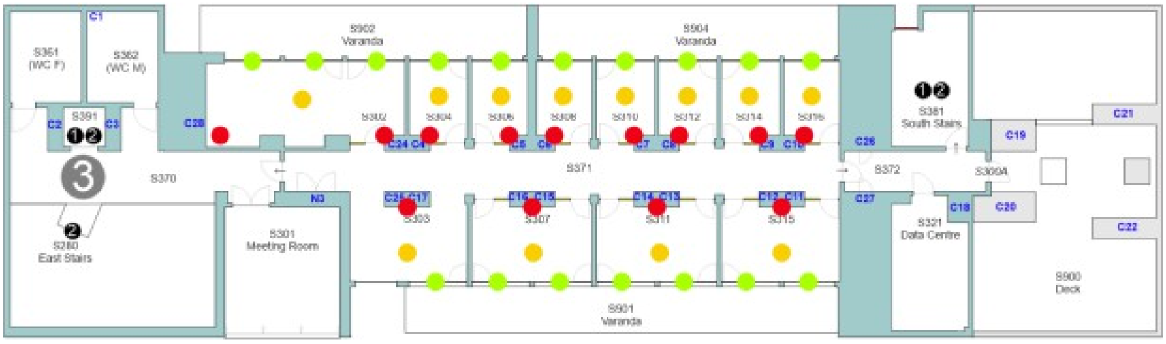


Figure 1- Floor 3 of CISTER building.

1.2. OBJECTIVES

The focus of this project is to automate the lighting and temperature control on the 3rd floor of the CISTER building, specifically targeting the individual offices due to the variety of office types present on the floor.

The first task involves automating the control of office lighting. Priority is given to natural sunlight, with the blinds automatically adjusting to maximize natural light entry. When natural light is insufficient, artificial lighting will compensate to maintain the desired illumination level.

The second task addresses the control of heating through the smart heater installed in the office.

Additionally, the envisioned automated climate control system will include a user interface that allows office occupants to configure their preferences for lighting and temperature, as well as manually adjust the blinds, lights, and heater. The system will also notify occupants if their preferences cannot be met, potentially indicating an operational issue.

The objective is to design and implement a prototype system that fulfills these requirements. Due to limited access to the building (in line with current government guidelines) and the potential risks of interacting with real infrastructure—such as damaging the blinds, which could result in costly repairs or user inconvenience—the implementation will primarily rely on simulated behaviors. However, integrating physical sensors or actuators, such as representing blind movements with LED colors, is strongly encouraged. When such actuators are included, their status (enabled/disabled) must be clearly indicated.

2. DESIGN

This chapter outlines the understanding of the problem and the design of the solution that will guide the project's development.

2.1. PROBLEM OVERVIEW

The project involves managing various actuators based on environmental parameters. Since temperature and light intensity are the key factors, it is essential to use sensors capable of accurately measuring these values.

2.1.1. Components Used

Component	What we would like to use	What we will be using
Temperature Sensor	DHT11	DHT11
Luminosity Sensor	TSL2561	LDR5539
Blinds Mechanism	SG90 LED 2x	SG90 LED 2x
Heater Mechanism	Heating Plate	LED
Smart Lights	LED	LED

As mentioned above, there are alternative components we would prefer to use instead of the ones currently chosen. We will now explain the reasons for selecting these components and explain why we would choose some others over the ones initially planned.

Temperature Sensor:

We have decided to keep the DHT11 sensor for temperature measurement. Despite its limitations in terms of accuracy compared to other sensors, such as the DHT22, the DHT11 is sufficient for our project’s requirements. It is cost-effective, easy to interface with, and provides reasonably accurate temperature readings within a suitable range

Luminosity Sensor:

The TSL2561 is a digital sensor that offers higher precision and a wider dynamic range than the LDR5539. However, due to budget and simplicity concerns, we have opted for the LDR5539, which provides adequate performance for our needs while being cost-effective and easy to integrate.

Blinds Sensor:

We have chosen to use the SG90 motor for the blind's mechanism, as it is a low-cost, widely available, and reliable option for small projects. It offers sufficient torque and precision for controlling small blinds, and it is easy to integrate with microcontrollers like Arduino.

Heater Mechanism:

We initially planned to use a heating plate to control temperature more directly. However, due to power constraints and the nature of the project, we decided to substitute the heating plate with an LED, which will allow us to simulate the heating process more efficiently without requiring additional power resources.

Smart Lights:

We have chosen LEDs because they fit the functional requirements of the smart lights in our project, and their colour can be controlled using RGB LEDs, making them versatile for various lighting effects.

2.1.2. Technologies

Technologies
MQTT
TCP/IP
NODE-RED

MQTT:

We chose to use MQTT to manage the data received from the Arduinos. The data is first transmitted from the Arduino to our control unit (TCP server), then sent to Node-RED (User interface) via MQTT. Additionally, MQTT is used to send user inputs if the user decides to provide them.

TCP/IP:

We selected TCP/IP for communication between components/devices in the system. This protocol ensures reliable, connection-oriented communication between the Arduinos, the control unit, and other networked components.

NODE-RED:

Node-RED is used to create the user interface and manage the flow of data between devices. It allows for easy integration of the various components, enabling the visualization and control of the system.

2.2. Problem Domain Design

In this section, it will be discussed the problem domain design created in order to answer the problem posed in this assignment.

2.2.1. Black Box

First, we identified the Stakeholder Needs, the requirements that the stakeholders have for the assignment. The identified Stakeholder Needs were:

	id	text
User Needs	SN-1	
Automated Lighting Control	SN-1.1	When natural sunlight is available, the system shall adjust blinds to allow the required amount of light. If natural sunlight is insufficient, the system shall activate artificial lighting to compensate.
Automated Heating Control	SN-1.2	The system shall control the heating in the office using smart heaters.
User Interface	SN-1.3	The system shall provide a user interface that allows office occupants to configure their preferences for lighting and temperature, and manually change the status of blinds, lights, and heaters.
Hazard Mitigation	SN-1.4	The system shall include measures to prevent or mitigate failures by identifying malfunctioning components, providing temporary fixes, and providing long-term fixes.
Notification System	SN-1.5	If the occupant's preferences are not being met, the system shall notify the occupant and indicate a potential problem with the system.
WSN Network	SN-1.6	Where possible, the system shall utilize Wireless Sensor Networks (WSNs) for communication and control.

Figure 2 Stakeholder Needs

The next step was creating the system context, where we represented the system needed and the interaction between these systems.

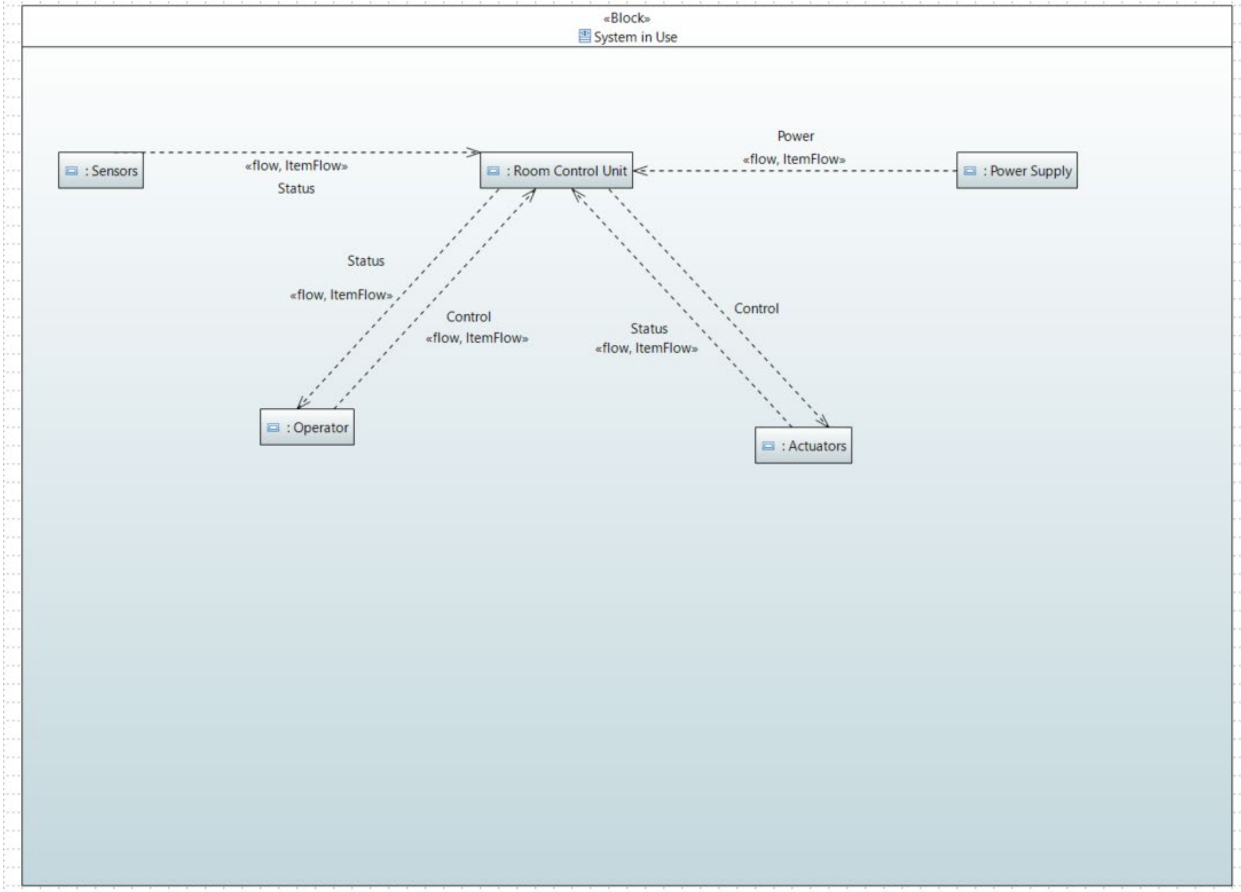


Figure 3 System Context

Following the creation of the system context, were created a use case diagram for the use cases that we found.

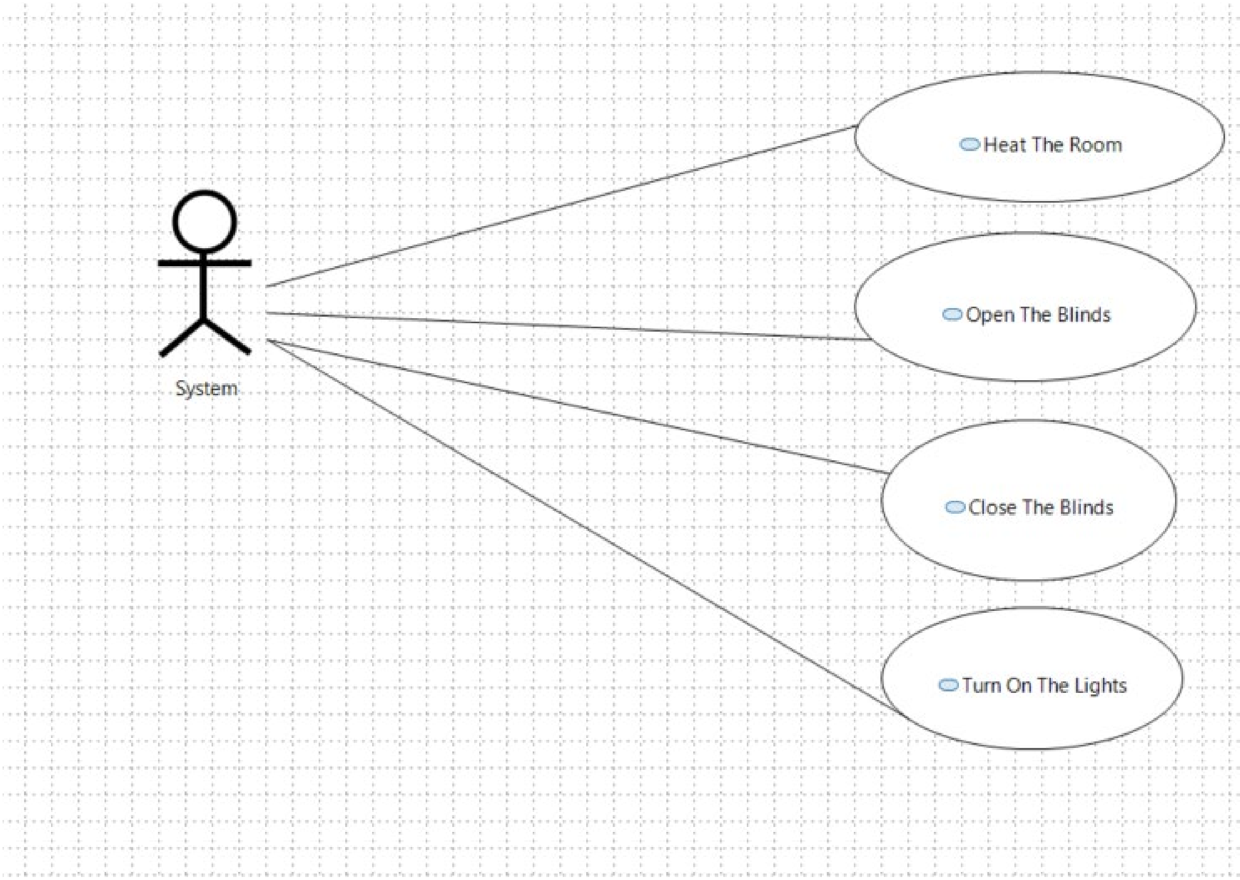
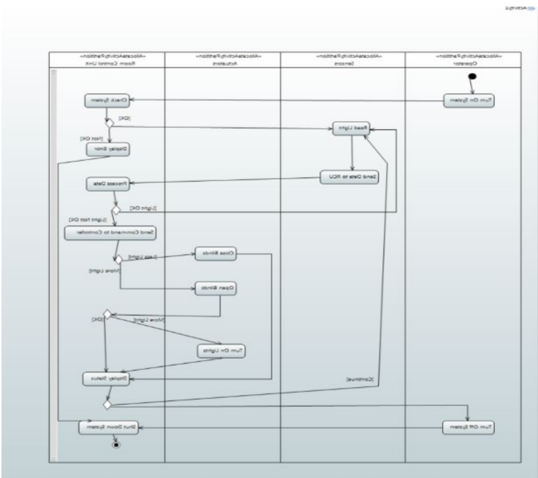


Figure 4 Use Case Diagram

Using the use cases that we found, we created two activity diagrams for these use cases, showing the flow of the systems during execution, and further explaining what happens between these systems.



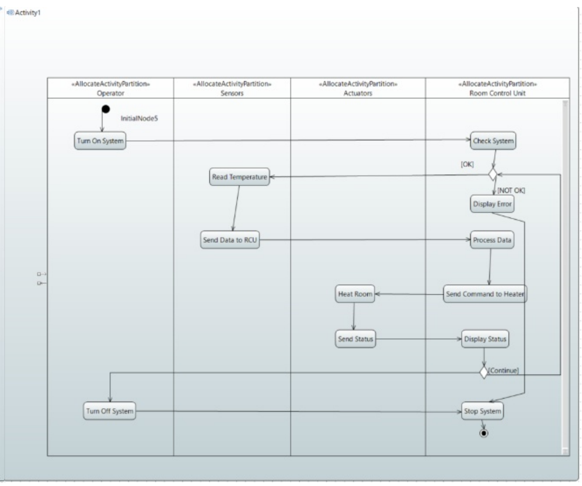


Figure 5 Activity Diagram for Heating

Figure 6 Activity Diagram for Light Changes

To finish the black box design, the measures of effectiveness, the metric that ensure the system is working correctly, are created.

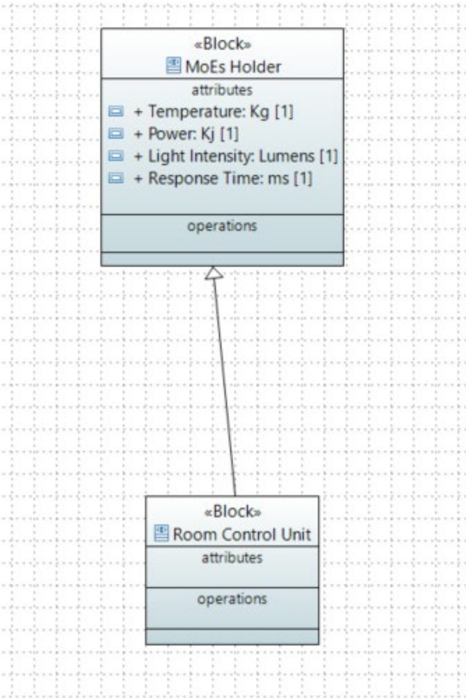


Figure 7 Measures of Effectiveness

2.2.2. White Box

The first thing done for the white box model was figure out what were the conceptual subsystems needed for the room control unit system. The following figure is the representation of these conceptual subsystems.

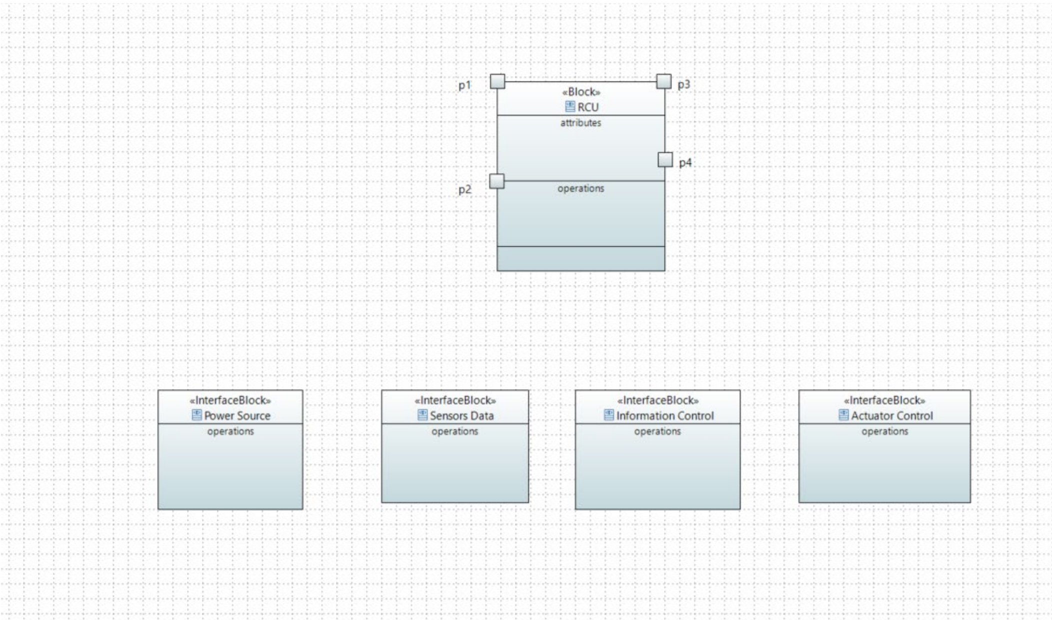


Figure 8 Conceptual Subsystems

The next step of the modelling process was to represent the interaction between these conceptual subsystems and with the outside systems.

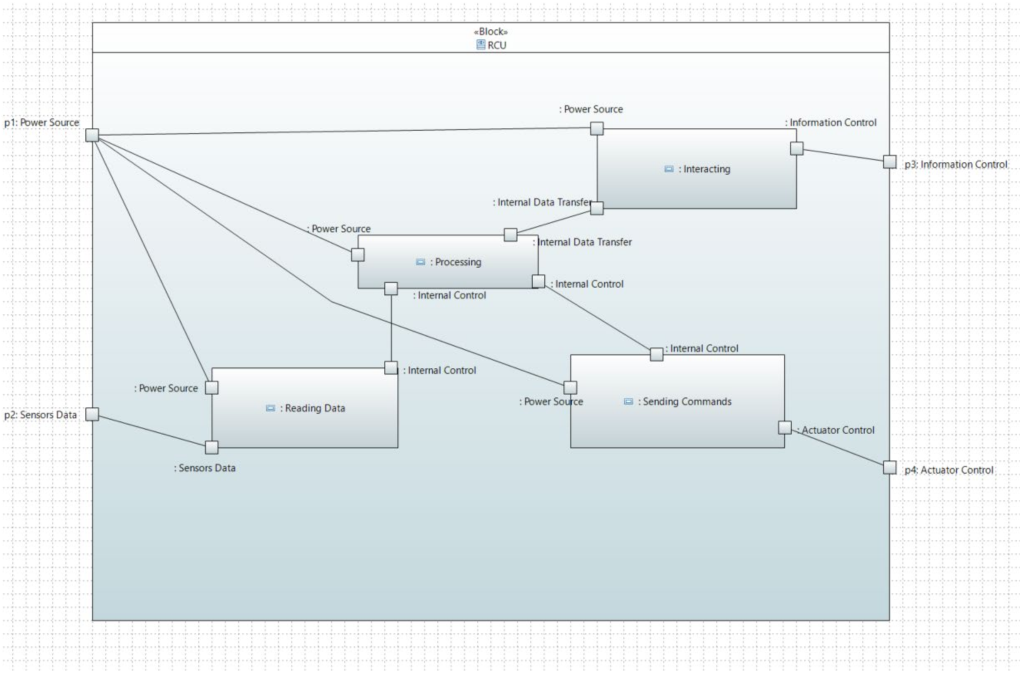


Figure 9 Interactions of the Conceptual Subsystems

Like in the black box model we created an activity diagram to represent the flow of execution of these conceptual subsystems.

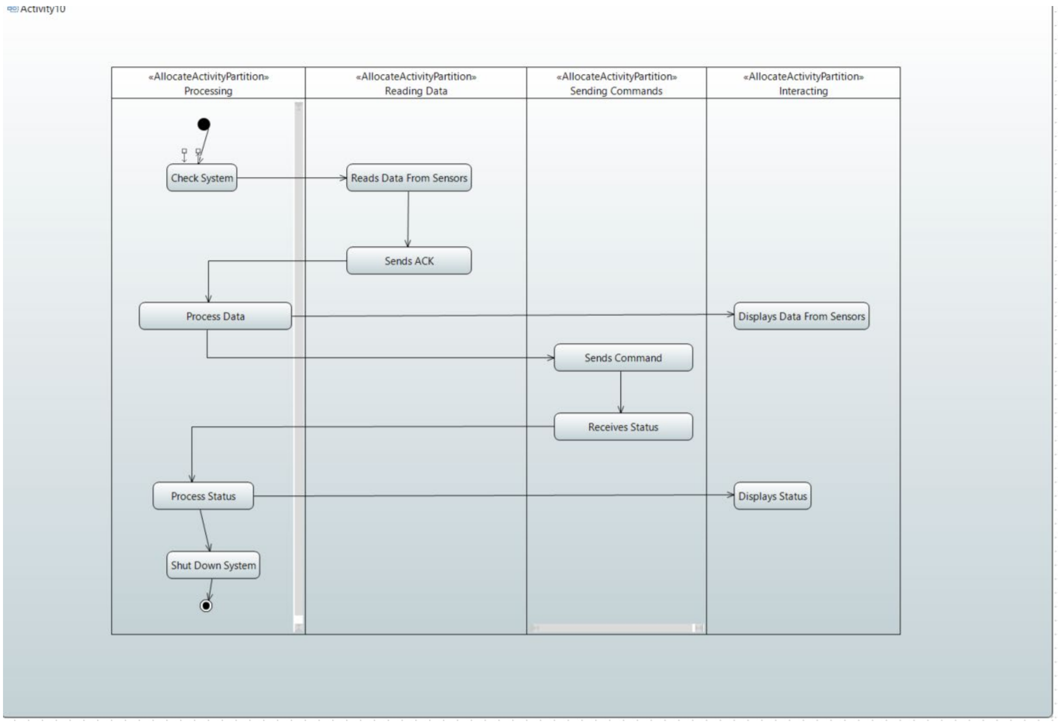


Figure 10 Conceptual Subsystems Activity Diagram

Lastly, we represented the measure of effectiveness used by these subsystems.

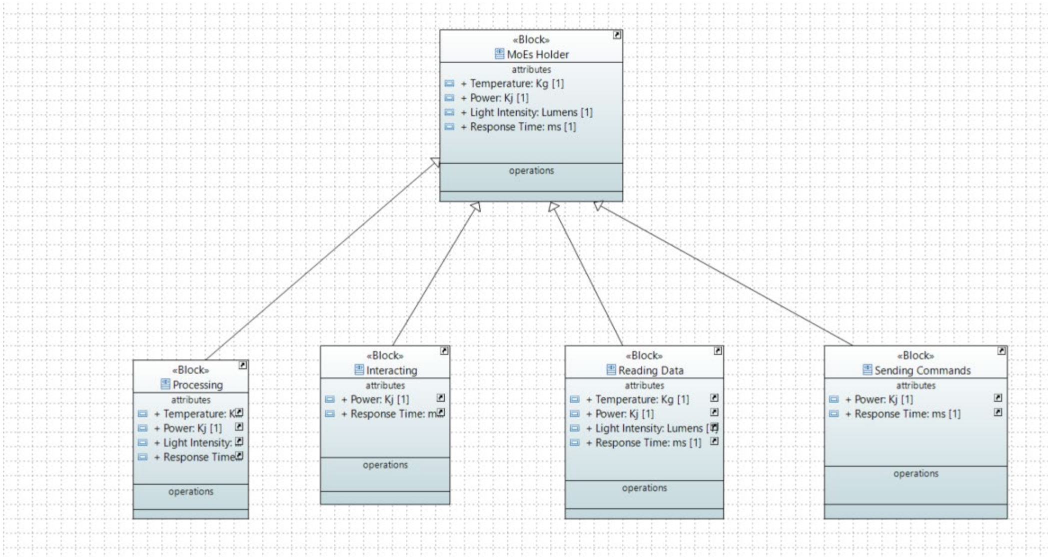


Figure 11 Measures of Effectiveness of Conceptual Subsystems

2.2.3. Traceability

The last part of the problem domain is the traceability between the Stakeholder Needs and the systems and subsystems.

		A	B	C	D	E	F
		Automated Lighting Control	Automated Heating Control	User Interface	Hazard Mitigation	Notification System	WSN Network
0	System in Use	☐	☐	☐	☐	☐	☐
2	Property1 : Room Control Unit	☑	☑	☐	☐	☐	☑
3	Property2 : Sensors	☑	☑	☐	☐	☐	☐
4	Property3 : Actuators	☑	☑	☐	☐	☐	☐
5	Property4 : Power Supply	☑	☑	☑	☑	☑	☑
6	Property5 : Operator	☐	☐	☑	☐	☑	☐
7	Sending Commands	☑	☑	☐	☐	☐	☐
8	Reading Data	☑	☑	☐	☑	☐	☐
9	Interacting	☐	☐	☑	☐	☑	☐
10	Processing	☑	☑	☐	☑	☐	☑

Figure 12 Traceability