Autonomous Delivery Robot (ADR)

Project System Concept Description – Part 2

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Team Name: Team 3
Lead Author: Manu Madhu Pillai
Contributing Author(s): Sidney Leigh Molnar, Mukundhan Rajendiran, Xinyi Yang

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1. Introduction

1.1. Document Purpose

This document provides an Autonomous Delivery Robot (ADR) system description. The description will be used to guide the development of the Stakeholder Requirements Document.

1.2. References

This section provides a list of references used in the development of this document.

1. HW 5&6 System Concept Description - Template for Parts I & II - V1, by Dr. Tony Barber, 2022.
2. HW3 Team 3 Project Proposal, by Xinyi Yang, Sidney Leigh Molnar, Manu Madhu Pillai, Mukundhan Rajendiran, 2022.
3. HW5 Team 3 Project System Concept Description – Part 1, by Manu Madhu Pillai, Sidney Leigh Molnar, Mukundhan Rajendiran, Xinyi Yang, 2022.
4. Autonomous Delivery Vehicles, by Derick Omondi, 2021. [CrossRef]
5. 621 Wk 4.6 Lecture,The Block & The Block Definition Diagram, John MacCarthy, 2022.
6. 621 Wk 4.4 Lecture,Intro to SysML&Cameo SM, John MacCarthy, 2022.

1.3. Document Structure

This document follows the structure specified in [1] and it is organized as shown below:

1. Section 1 describes the purpose of this document, organizational structure, and references used by the document.
   - 1.1. Subsection 1.1 defines the purpose of this document.
   - 1.2. Subsection 1.2 lists the references used by the document.
   - 1.3. Subsection 1.3 defines the document's organizational structure.
2. Section 2 identifies the key stakeholders and identifies their roles
3. Section 3 describes the system capabilities and mentions the rationale behind those capabilities.
4. Section 4 defines and describes the Measures of Effectiveness (MOEs) for the system and their association with system capabilities.
5. Section 5 indicates the system’s usage from the user’s perspective to accomplish their goals.
6. Section 6 describes how the maintenance is carried out by the system.
   - 6.1. Section 6.1 describes the level 1 operability inspection and service of ADR system.
   - 6.2. Section 6.2 describes the level 2 field inspection and service of ADR system.
   - 6.3. Section 6.3 describes the level 3 functionality inspection and service of ADR system.
   - 6.4. Section 6.4 describes the level 4 software & hardware enhancements of ADR system.
7. Section 7 describes the context level capabilities and use cases of the system, and provides use case narratives of different use cases during system operation.
8. Section 8 describes the context level architecture of the system and the system of interest(SOI).

8.1. Section 8.1 identifies the principal users of the system and defines the environment in which the system operates and the associated system boundary.

8.2. Subsection 8.2 identifies and defines the interfaces between the system of interest, the system user, and the environment.

8.3. Section 8.3 provides the activity and sequence diagrams for the system's use cases.

8.4. Section 8.4 provides the system's state machine diagram which identifies and describes the principal states of the system.

8.5. Section 8.5 identifies and briefly describes the principal conceptual elements that make up the system of interest.

8.6. Section 8.6 provides the project's system architectural framework and organization of its internal structure.

9. Appendix A: This section includes the expanded Use Case Narratives for use cases.

2. System Stakeholders and Statement of Need

Table 1 identifies the principal stakeholders for the system and their respective roles.

Table 1: Stakeholder List

ID	Stakeholder	Role(s)	Priority
SH1	**Uber Eats**	Customer, User & Maintainer	Primary
SH2	**DoorDash**	Customer, User & Maintainer	Primary
SH3	**Grubhub**	Customer, User & Maintainer	Primary
SH4	**FedEx**	Customer, User & Maintainer	Primary
SH5	**UPS**	Customer, User & Maintainer	Primary
SH6	**Public Universities**	Potential Customer & User	Secondary
SH7	**Private Universities**	Potential Customer & User	Secondary

3. System Capabilities

The system capabilities and their priorities are documented in Table 2. In addition to this, the system's goals are defined in terms of the lower-level capabilities in Table 2.

Table 2: ADR System capabilities and their priorities

Cap ID	Capability	Rationale	Priority
C1.1	Detect sidewalks, roads, pedestrian crossings, and road signs.	Defines “Path Detection”	1
C1.2	Detect Motor vehicles, pedestrians, cyclists, animals, and similar dynamic obstacles.	Defines “Dynamic Obstacle Detection”	2
C1.3	Detect plants, trees, buildings, railing, and similar static obstacles.	Defines ”Static Obstacle Detection”	3
C1.4	Detect and identify other ADRs.	Defines “Dynamic Obstacle Detection”	4
C2	Avoid Collisions with dynamic and static obstacles in the surroundings.	Defines “Safety”	5
C3	Navigate on the given path following road safety laws.	Defines “Navigation”	6
C4	Carry payloads from source to destination as assigned.	Defines” Payload Delivery”	7
C5	Monitor the remaining battery and return to the charging station at the failsafe level.	Defines “Status Monitoring”	8
C6.1	Provide tracking status and maintain communication with the central server.	Defines “Communication”	9
C6.2	Report theft, vandalism, or tampering with the ADR and its payload.	Defines “Security”	10
C7	Open respective payload bay among the segmented payload bays when authorized.	Defines “Security”	11

4. System Measures of Effectiveness (MOEs)

Table 3 identifies the (MOEs) for the system and their associated threshold and objective values.

Table 3: ADR System MOEs

Cap ID	Attributes	Metric	MOE ID	Definition	Threshold Value (units)	Objective Value (units)
C5	Endurance	Continuous operating time	MOE1	Maximum Operational Time on a single charge	> 4 hours	> 8 hours
C3 & C5	Operational Range	Operational radius	MOE2	Maximum operational range (radius) on a single charge	> 1 mile	> 2 miles
C4	Payload	Payload Capacity	MOE3	Maximum payload capacity	> 50 lbs	> 100 lbs
C5	Charging Time	Time to charge	MOE4	Empty to full charging time	< 4 hours	< 2 hours
C6	Communication Range	Radius for optimal communication	MOE5	Maximum communication (telemetry) range from central server	> 1 mile	> 2 miles
C1 & C2	Collision avoidance	Farthest object detected	MOE6	Perception Range for Collision avoidance	> 66 ft	> 165 ft
C3	Operational Speed	Maximum safe navigational speed	MOE7	Maximum Operational speed	> 5 mph	> 15 mph

5. System Operational Concept

The intended users of the system of interest are faculty, staff, and students on large university campuses. Users can order a delivery that can then be transported from one end of campus to the other. Once an order has been placed by the user in the customer's app (primary stakeholders like UberEats and Grubhub), an ADR is deployed from the nearest warehouse to the pickup location. The ADR has to navigate through the streets and sidewalks on the university campus and the surrounding region.

This puts the ADR in a dynamic environment where it will need to avoid several moving obstacles such as pedestrians, cars, bikes, and scooters. Conversely, pedestrians and people operating vehicles must know to navigate around the ADR. As such, the ADR will have a signaling structure that exists at eye level for greater visibility to cars and pedestrians.

ADR uses obstacle avoidance sensors to detect and avoid obstacles. Aside from the dynamic aspects of a university campus, the ADR will need to be able to navigate along sidewalks and roads, avoiding stairs, construction, and otherwise dangerous terrains. Additionally, for campuses that face seasonal changes, the ADR will need to travel through various types of inclement weather such as rain, high winds, or snow.

When the ADR reaches its source, it requires a user verification QR code to open the package storage compartment of the ADR. When the sender scans the QR code painted on the ADR, it is authenticated through the app and the information is sent to the ADR via the central server. The control system verifies the code before opening the storage compartment by sending a signal to the lock system. Thus, the assigned payload bay opens allowing the sender to place the package to be delivered.

The sensor system sends sensor data to the control system to check if the payloads are inside ADR and if there are any static and/or dynamic obstacles in the surroundings. The control system controls the ADR to avoid obstacles, navigate to destinations, and make sure that the payloads are put into the ADR at the source (restaurants/stores) and taken out at the destination (users) by using the data received from the sensor system. The motion system receives directions from control and derives power from the power supply to move (left/right/forward/backward/stop). The wireless communication system sends the real-time location of the ADR from the sensor data to the user by a mobile application.

Once the ADR makes it safely to the intended location, users will be able to access their order in the secured compartment using the QR code authentication. The ADR moves on to the next order, repeating this process until it requires recharging. In case there are no new orders or the ADR requires recharging, it returns to the nearest warehouse.

The management system provides maintenance and logistical support for the ADRs including charging, cleaning, and regular maintenance.

6. System Maintenance Concept

There are mainly 4 levels of maintenance for this system. The period of maintenance will vary according to the level of maintenance described below. The maintenance shall primarily take place on the following four elements of the ADR system: electro-mechanical system, sensors, firmware, and software application.

6.1. Level 1: Operability Inspection & Service of ADR System

At this level, the system is checked and maintained on a daily basis. This level mostly consists of overall inspection and cleaning of the system. The tasks are cleaning the sensors like cameras for better visibility

and inspecting the electro-mechanical body for cracks, dents, and any other damages which could affect the operation of the ADR, and also cleaning and removing any leftover items in the individual storage system. The time required to conduct this level of maintenance would be around five to ten minutes for each ADR.

6.2. Level 2: Field Inspection & Service of ADR System

Second-level maintenance includes a little bit of in-depth inspection of the ADR. It includes the inspection of mechanical and electronic systems on board the ADR. Tasks like checking and fixing lubricating levels, sensor calibration & wheel alignment. This level of maintenance check can be done using the user manual given to the user and the self-diagnosis feature in the ADR. The time required to conduct this level of maintenance would be around thirty to sixty minutes for each ADR. This level of maintenance is scheduled once a month.

6.3. Level 3: Functionality Inspection & Service of ADR System

All the components have a life span until which they would work efficiently. The components can be mechanical parts such as wheels, motors, and suspension systems and they can also be electrical components like batteries, sensors, and wirings. These components are inspected and the decision is taken to either service the part for extended life or replace it with a new part. This decision can be taken by the user as the details regarding each component and its life span, range, and other specifications would be provided in the user manual. The time required for maintenance shall vary on the hours and conditions under which the ADR was utilized. This user may order spare parts and shall be provided with a manual to replace the parts. Further assistance such as a technician would be sent if necessary.

6.4. Level 4: Enhancements of ADR System

The firmware in the ADR would be upgraded based on feedback and the data collected while the ADR is operating. The firmware is updated wirelessly via the central server during charging or at stand-by in the warehouse. Upgrades in firmware mainly focus on eliminating flaws hindering the efficiency and safety of the system. Enhancements can be requested and accommodated due to the different climatic and environmental conditions of the locations.

Multiple ADRs aid in an efficient workflow. Even if one of the ADRs fails due to a problem, another ADR with the availability of space could take over the task of the malfunctioning ADR, thereby not affecting the workflow. The malfunctioning ADR can be commanded or manually overridden to either return to the base or stop at a nearby safe location for further inspection of the issue. If the ADR stops abruptly and is immobile, assistants/technicians are sent to the location to assess the severity of the situation and repair the ADR accordingly. Depending on the severity of the issue, the technicians at the warehouse will resolve it or send it to the manufacturer.

The application used by the user and the customer is also updated according to the feedback and data collected for seamless usage of the application for the user. As the number of users increases, server load handling capacity and the number of ADRs would be appropriately updated.

7. Context-Level Use Case Diagram and Use Case Narratives

This section identifies and describes the principal high-level use cases for the ADR system.

A SysML Use Case Diagram (UCD) is described in Figure 1 to define and view the Use Cases and actors that derive from the system, and the relationship between them. Also, it provides a high-level description of the system functionality in terms of how users and external systems use the system to achieve their goals.

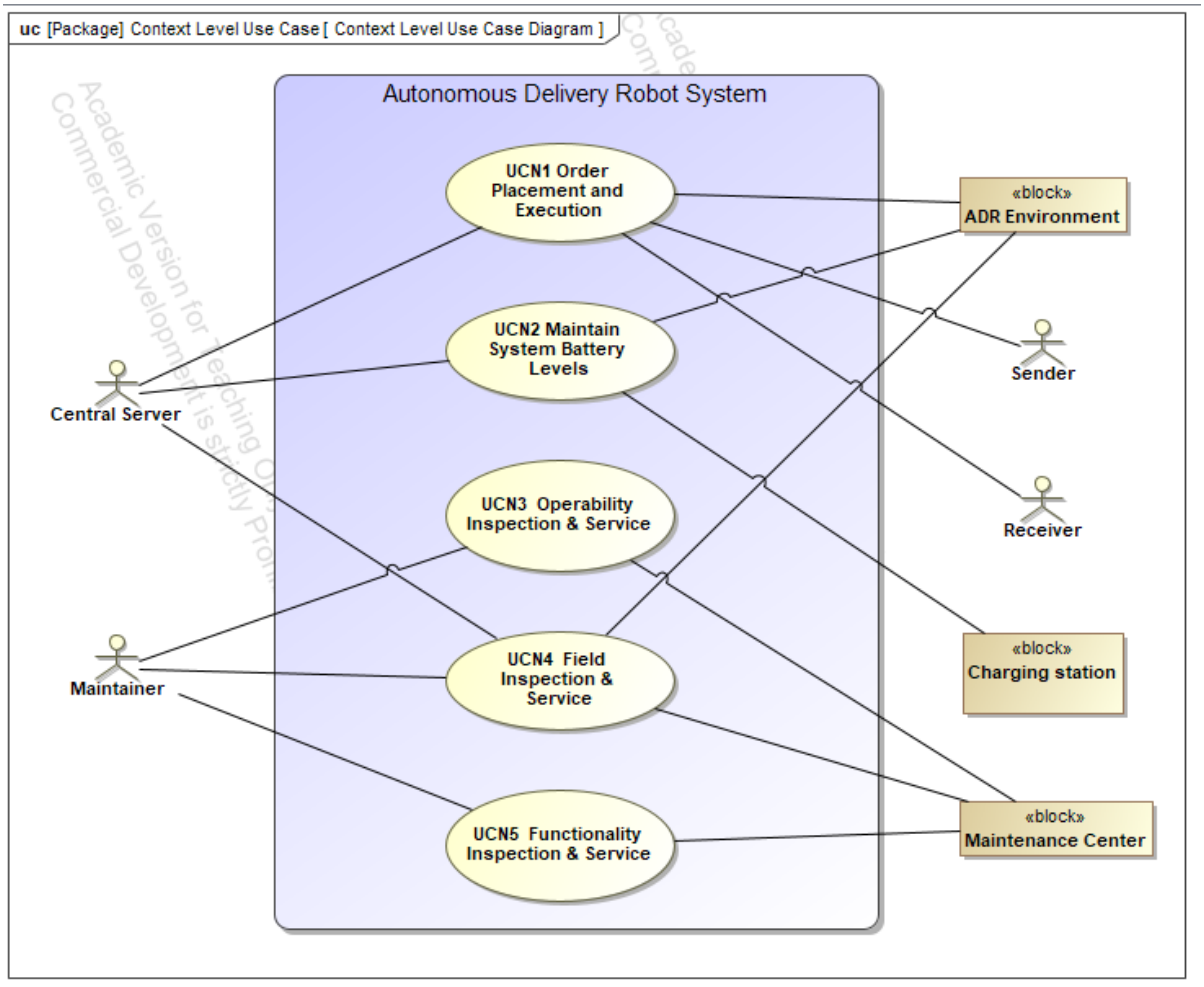

Figure 1: ADR Context Level Use Case Diagram

Figure 1 describes a SysML Context-Level Use Case Diagram (UCD) that indicates the most important top-level user goals and system capabilities. Also, it shows the use cases (UC) within the scope of the

system and the actors in the environment with which each use case is associated. The “primary” actors are identified as the Central Server and the Maintainer, who activate the use case. This Use Case Diagram (UCD) is used to generate Activity diagrams, Sequence diagrams, and State Machine diagrams in the next sections.

A use case narrative is a structured narrative showing what the system must do to respond to a specific event. An expanded use case narrative is documented for every use case corresponding to an external event which captures the sequence of messages from an actor to the system as well as the system’s response to each message. The narrative also reveals the structure and content of the messages.

Use Case Narrative: UCN1 Order Placement and Execution

Trigger: An order is placed for the ADR to pick up and deliver.

Main Success Scenario:

1) The central server receives an order.
2) The central server sends the pickup location to the nearest available ADR.
3) The ADR navigates to the order location.
4) The package is placed in the payload bay of ADR.
5) The ADR accepts the customer location from the central server.
6) The ADR navigates to the customer location.
7) The customer accesses the package being carried by the ADR and closes the lid.
8) The ADR notifies the central server that the order is complete.
9) The central server notifies the ADR of the next order location or if all orders are satisfied.
10) The ADR navigates to the next location request.

Use Case Narrative: UCN2 Maintain system battery levels

Trigger: The central server asks the ADR for the system information.

Main success scenario:

1) The central server requests the ADR to send its system information.
2) The ADR responds with the current battery levels.
3) The central server locates the closest charger to the ADR.
4) The central server sends route and task information to the ADR.
5) ADR follows route and task information to go to the charger.
6) ADR keeps sensing the environment to avoid collision.
7) ADR plugs itself into the charger.
8) ADR unplugs itself from the charger once it is fully charged.
9) ADR send current battery information to the central server.
10) The central server assigns a new status to ADR.

Use Case Narrative: UCN3 Operability inspection & service

Trigger: Scheduled daily at the end of operational hours of the ADR.

Main success scenario:

1) The ADR system is physically cleaned by the maintainer.
2) The ADR system payload bay is cleared out and cleaned by the maintainer.
3) The ADR system is inspected for physical damage.

Use Case Narrative: UCN4 Field inspection & service

Trigger: ADR requests the central server for a field inspection.

Main success scenario:

1) The central server requests the maintainer to inspect the ADR at its current location.
2) The maintainer goes to the ADR's current location.
3) The maintainer inspects the ADR for issues.
4) The maintainer fixes the issues of the ADR.

Use Case Narrative: UCN5 Functionality inspection & service

Trigger: Scheduled based on the expected lifespan of the critical parts in ADR, or requested by the central server due to escalation of lower inspection and services.

Main success scenario:

1) The maintainer disassembles the ADR and separates the critical parts.
2) The maintainer performs a functionality inspection of critical components.
3) The maintainer checks mechanical components like wheels for wear and tear.
4) The maintainer checks electrical components like motors for wear and tear.
5) The maintainer decides whether to replace the components.
6) The maintainer replaces the required components.
7) The maintainer reassembles the ADR.
8) The maintainer performs a functionality inspection of the assembled ADR.

The extensions and expanded UCN are described and documented in the Appendix section - Appendix A.

8. Context-Level System Architecture

This section focuses on the system's context-level system architecture depicted through block diagrams. Section 8.1 focuses on the Block Definition Diagram(BDD) which describes the system domain. Section 8.2 describes the Internal Block Diagram(IBD) to focus on the detail about the context diagram which identifies the important interfaces of the system and an Interface Definition BDD to define each interface.

8.1. System Domain Definition

This section identifies the principal users of the system and defines the environment in which the system would operate and also defines the associated system boundary. From Figure 2, it can be seen that the principal users of the system would be the maintainer and the user via the central server. Also, the environment consists of : Charging Stations, Operating Area, Maintenance Area,Delivery Pickup

andDestinations. The operational areas include static obstacles, dynamic obstacles and other ADRs.

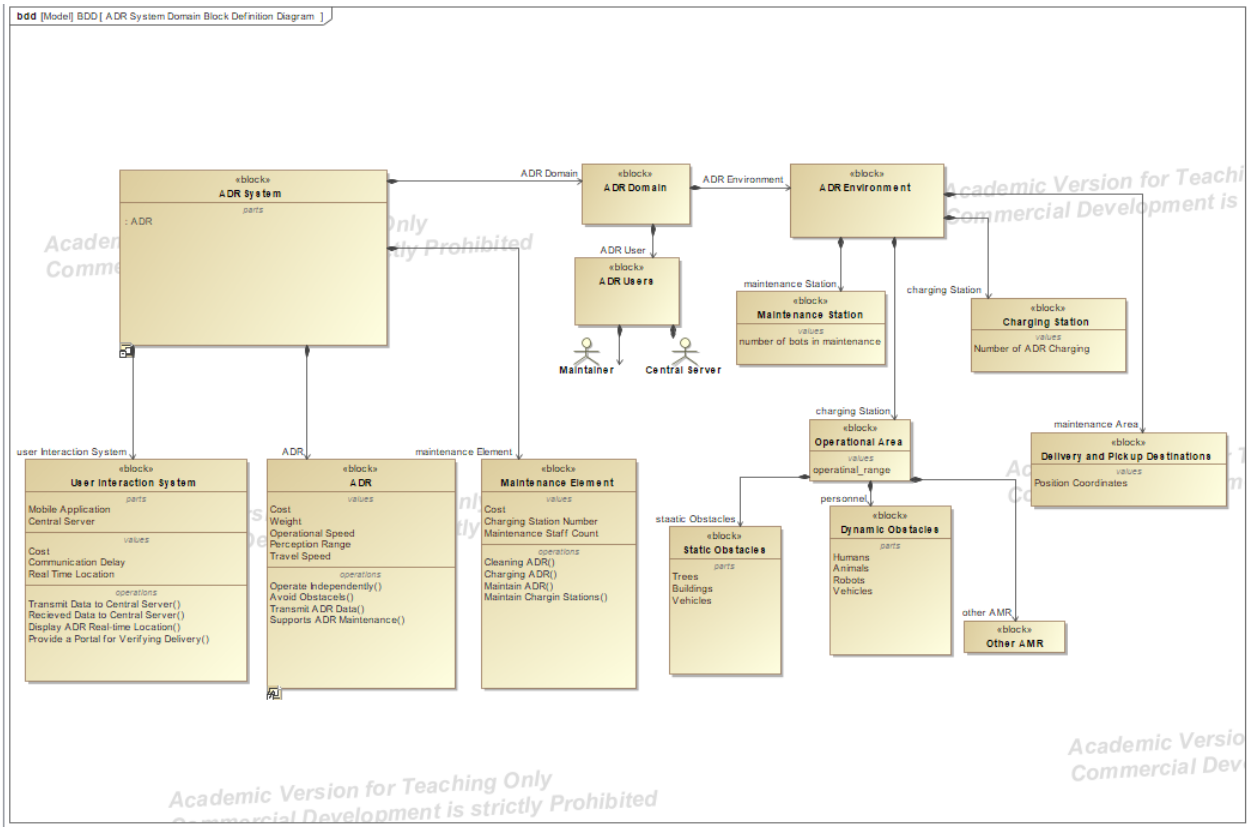

Figure 2: ADR System Domain Block Definition Diagram

8.2. System Domain Interface Definitions

The section describes the interfacing between the ADR system, use and the environment. The system level context level diagram indicates the interfaces between the SOI and its environment (users and external systems). The information from the central server consists of task data(destination and details) and route information(end location). The information from the environment consists of the location coordinates of pickup and drop off locations, power, data from sensors, and infrastructure like repair facilities. The information is transferred to the maintainer from the ADR about the failure status and performs different levels of maintenance depending on the information obtained.

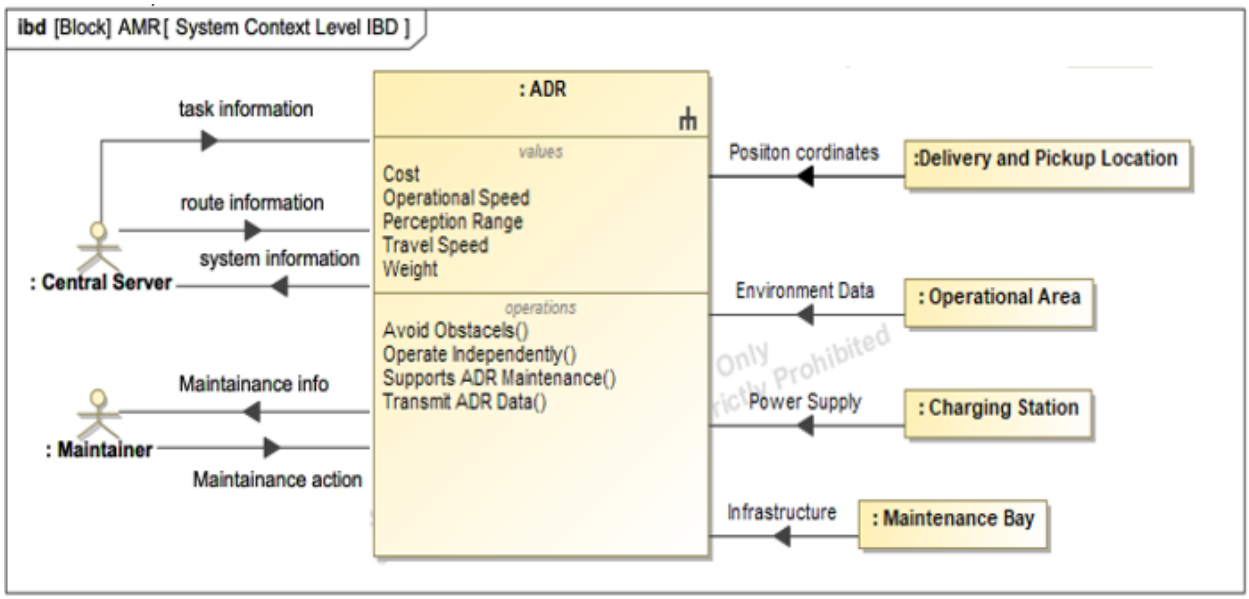

Figure 3: ADR System Context Level Internal Block Diagram

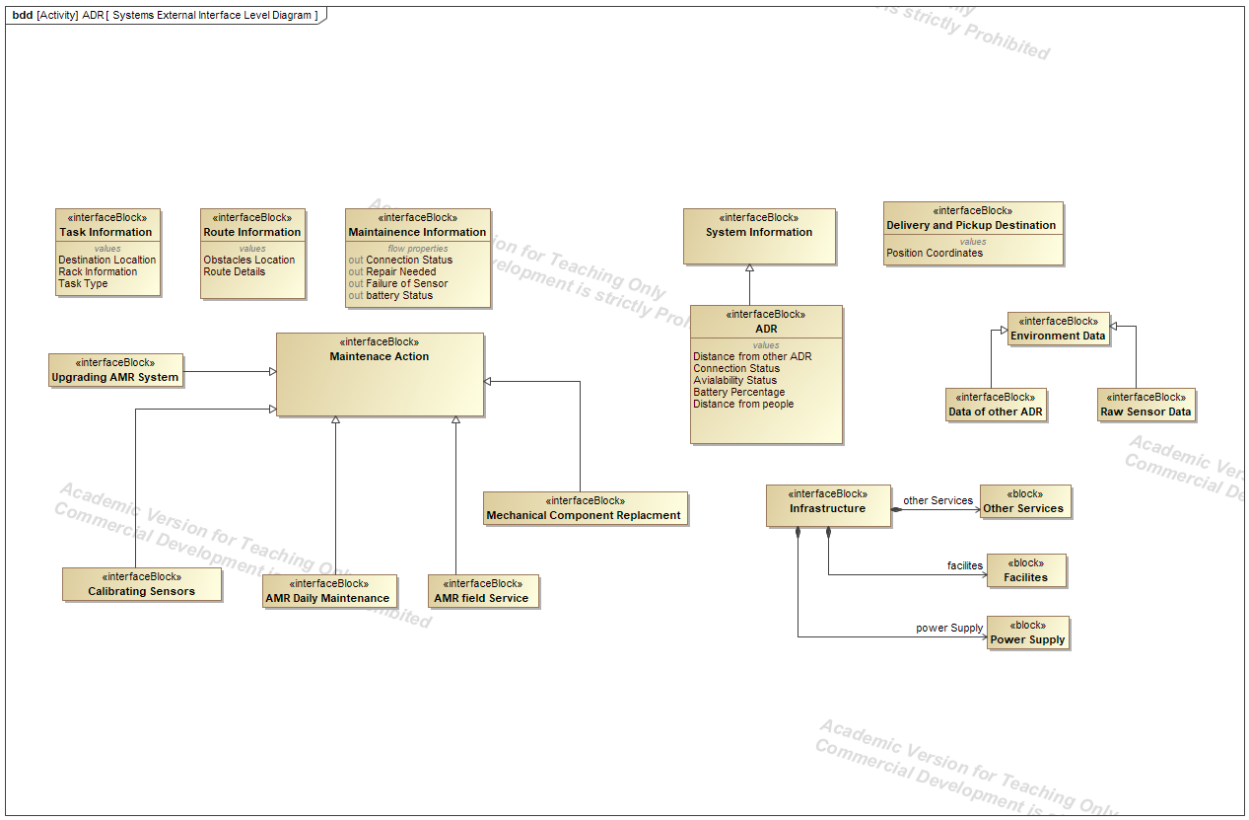

Figure 4: Interface Flow for the ADR System Context Level Internal Block Diagram

Figure 4 provides the Interface Flow Block Diagram that defines the information and items that flow over the interfaces indicated in Figure 3 - ADR System Context Diagram Internal Block Diagram.

The purpose of such a context diagram is to identify the interfaces that the system needs to account for, identify the scope of operation, and build a better understanding of the context in which the system is working.

8.3. System Behavior Definition

This section provides SysML Activity Diagrams (with swim lanes) for each Use Case Narrative (UCN). These activity diagrams show the principal actions taken by the users, the system, and external systems in accomplishing the Use Cases' goals. The Activity diagram represents the sequence of actions that describe the behavior of a Block or other structural element and the sequence is defined using Control Flows. The Actions can contain Input and Output Pins that act as buffers for items that flow from one Action to another as the task carried out by the Action either consumes or produces them. The items, in our system's case, can range from physical materials, power, raw sensor data, information.

Figure 5 provides a schematic representation of UCN1 - Order Request and Execution using an Activity Diagram. Figure 6 provides a schematic representation of UCN2- Maintain system battery levels using an Activity Diagram. Figure 7 provides a schematic representation of UCN3- Operability inspection & service using an Activity Diagram. Figure 8 provides a schematic representation of UCN4- Field inspection & service using an Activity Diagram. Figure 9 provides a schematic representation of UCN5- Functionality inspection & service using an Activity Diagram.

Also, Figure 10 shows a sequence diagram of the system to execute UCN1 - Order Request and Execution. The purpose of the Sequence Diagram is to specify dynamic system behaviors as message-passing collaborations among Blocks (Parts) of the system. It is a form of Interaction diagram, which shows how the users will interact with the system and what happens internally to accomplish the use case. They provide a visual representation of the objects communicating with the system of interest, and what messages trigger those communications.

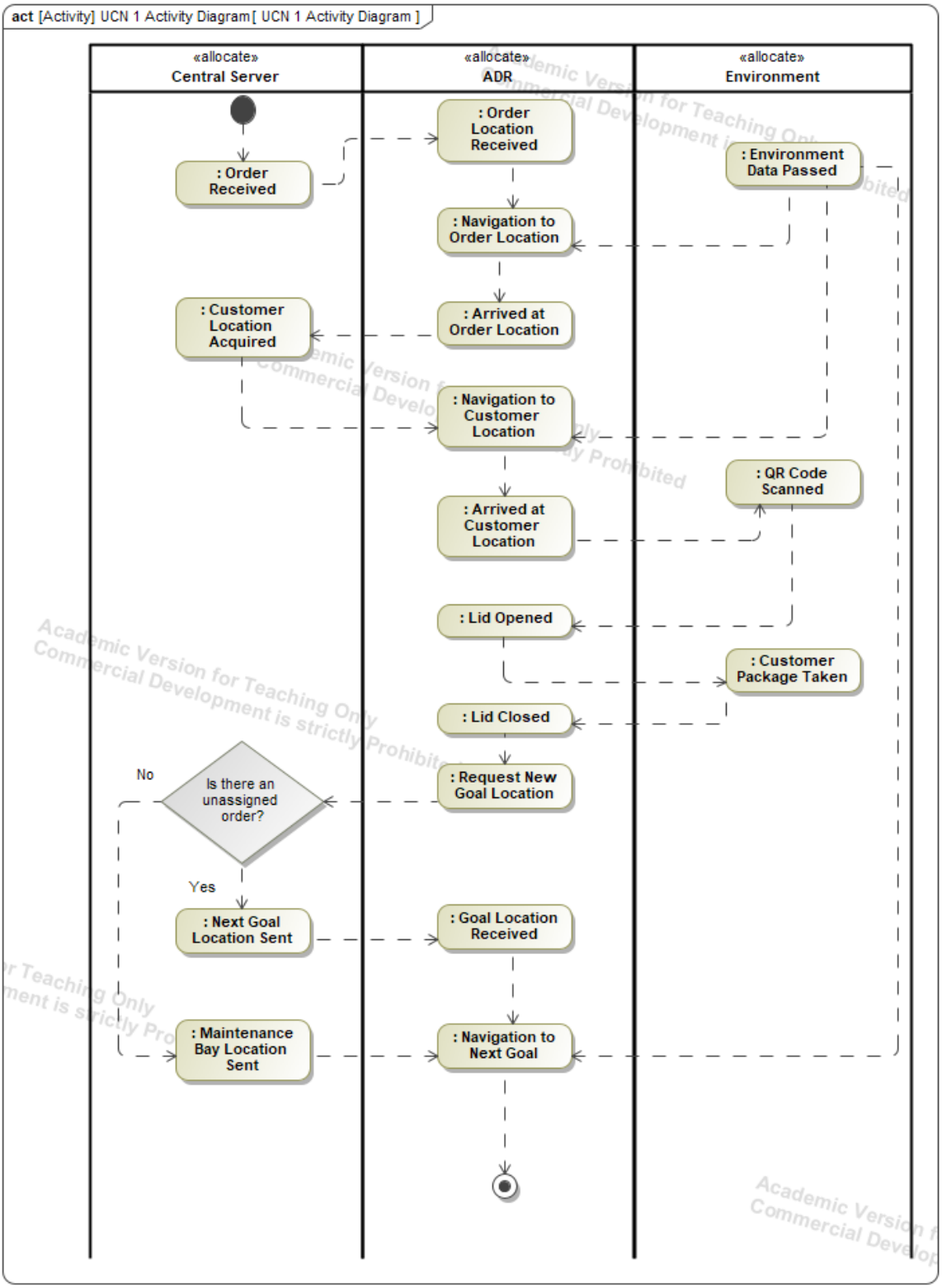

Figure 5: SysML Context-Level Activity Diagram for UCN1 - Order Request and Execution

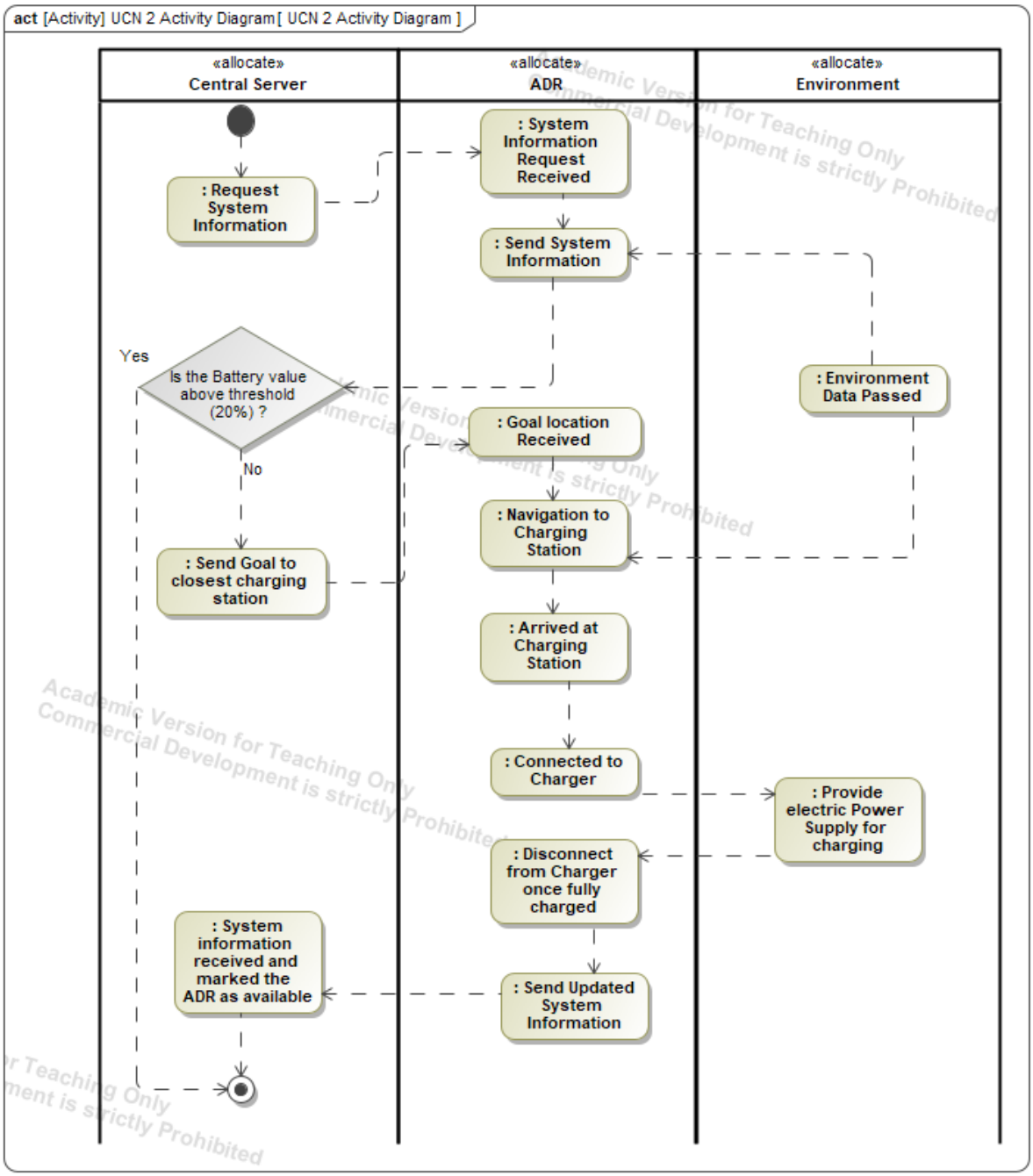

Figure 6: SysML Context-Level Activity Diagram for UCN2- Maintain system battery levels

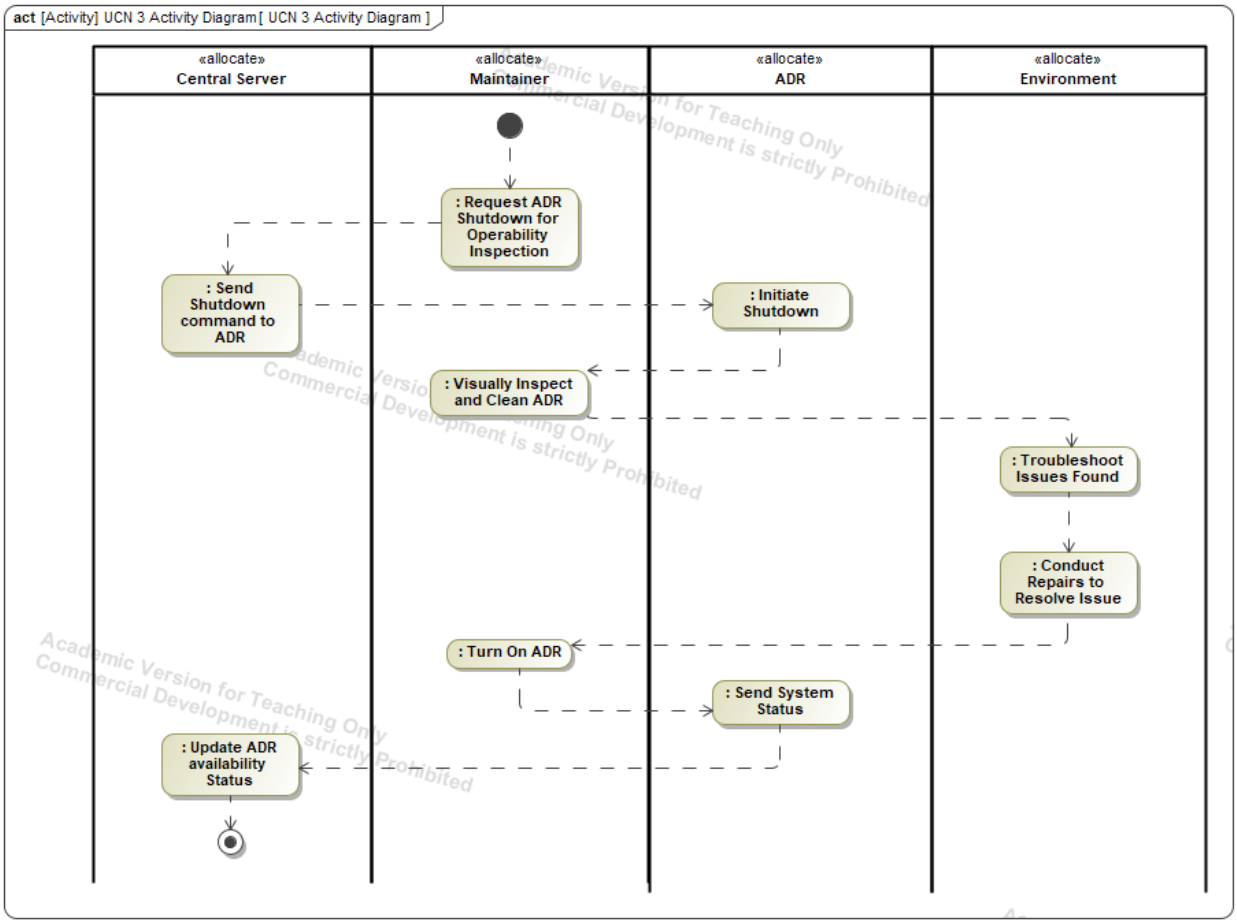

Figure 7: SysML Context-Level Activity Diagram for UCN3- Operability inspection & service

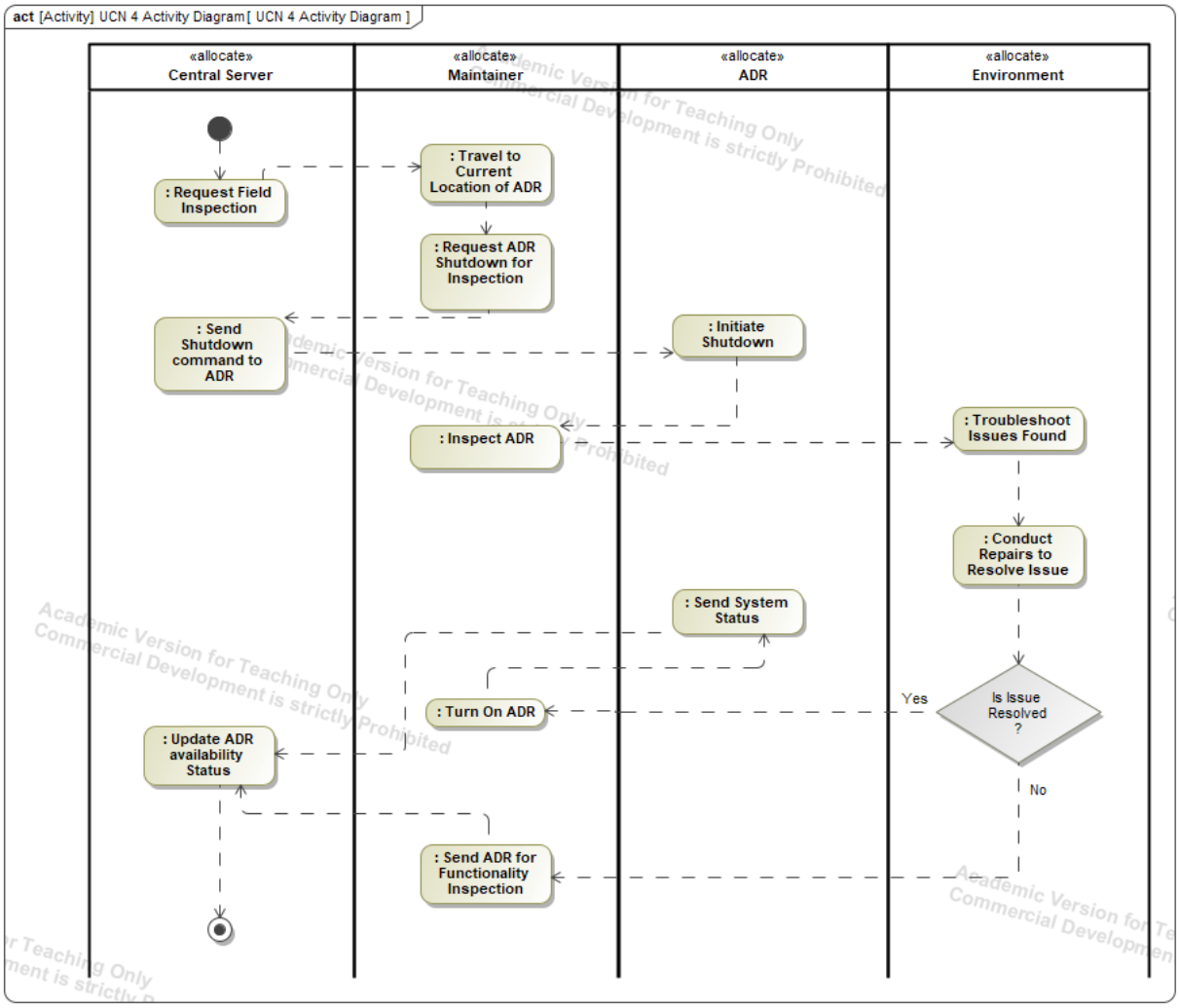

Figure 8: SysML Context-Level Activity Diagram for UCN4- Field inspection & service

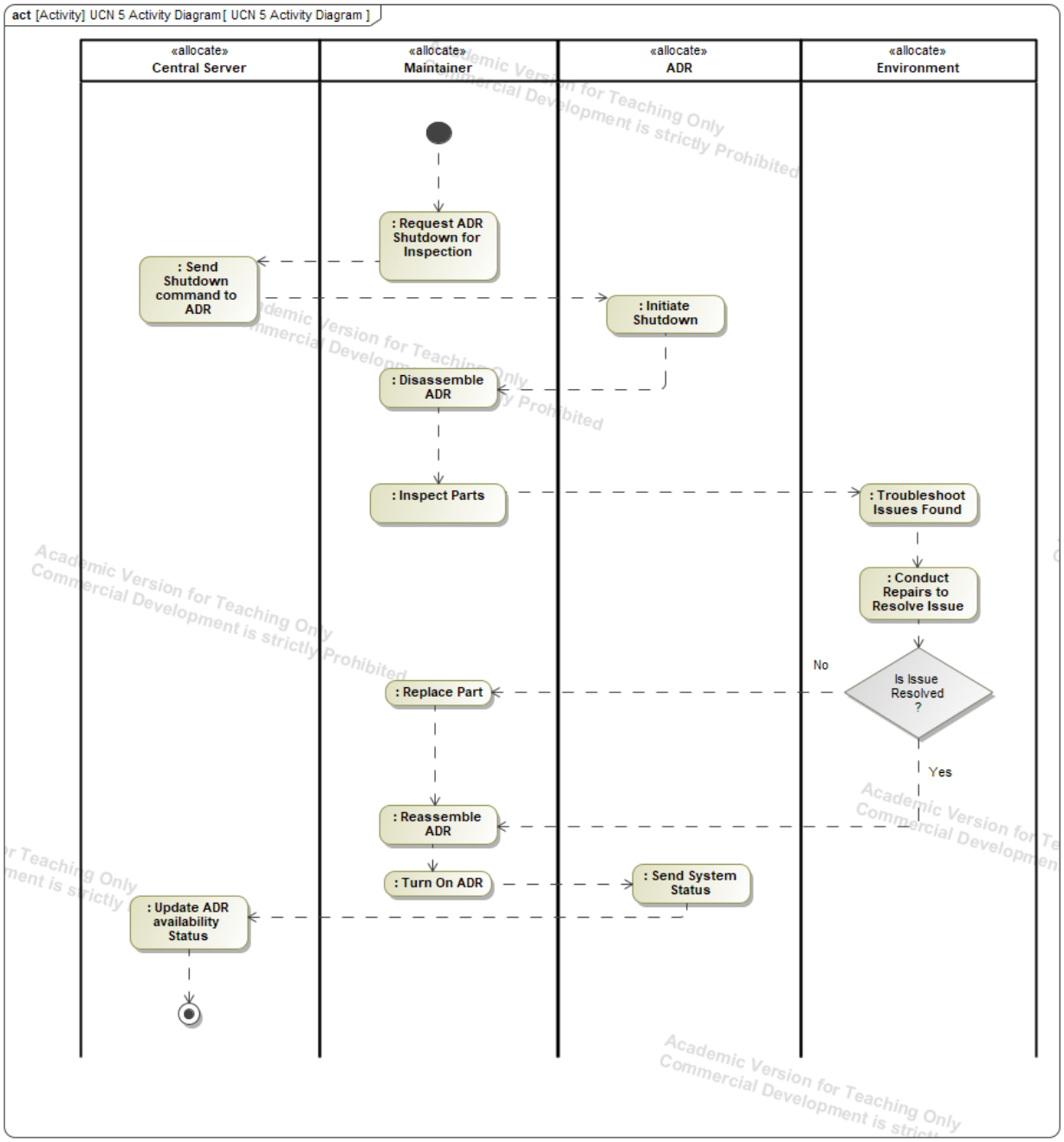

Figure 9: SysML Context-Level Activity Diagram for UCN5- Functionality inspection & service

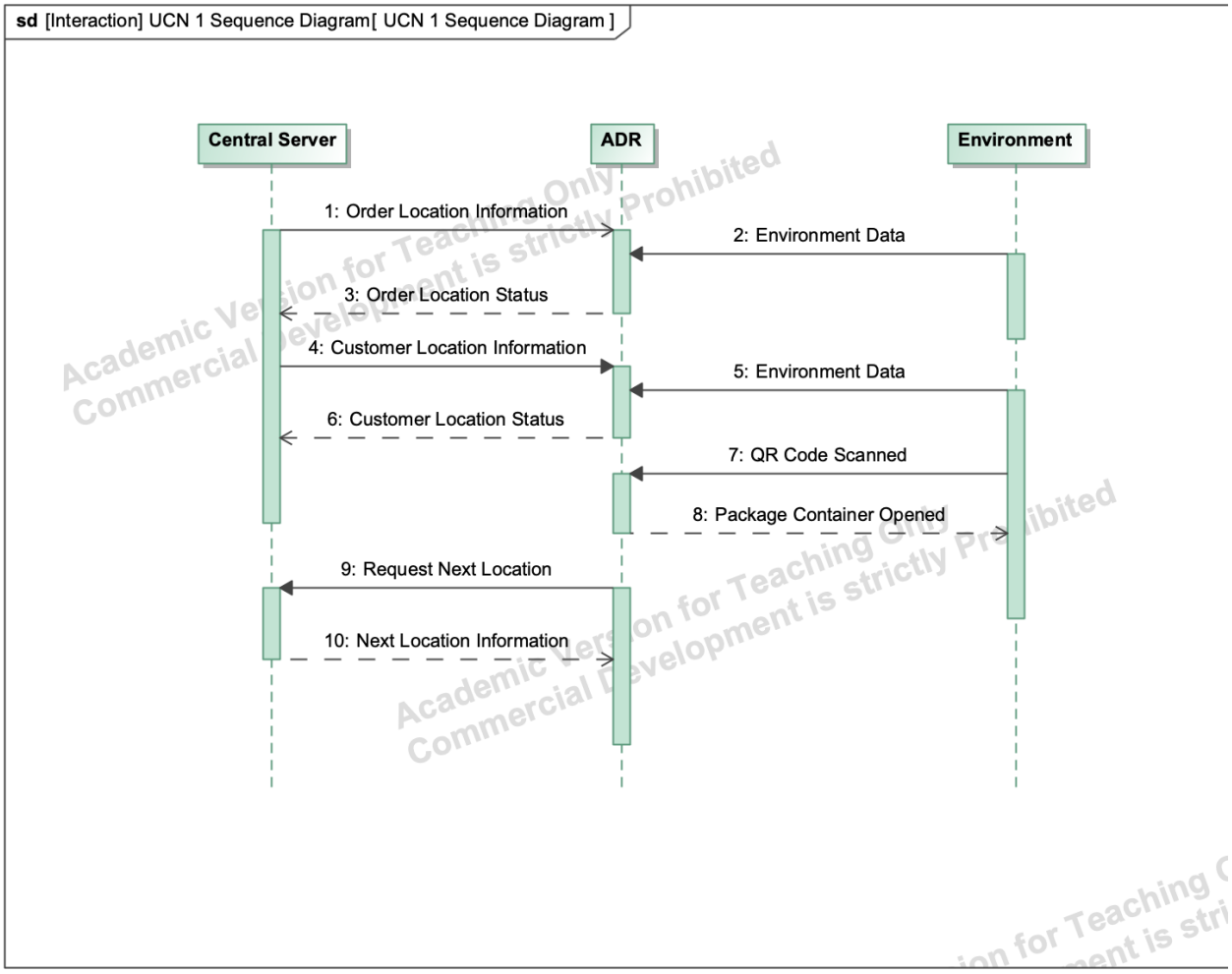

Figure 10: SysML Context-Level Sequence Diagram for Use Case 1 - Order Request and Execution

8.4. System States

Figure 10 describes a SysML State Machine Diagram (SMD) that identifies the principal states of the ADR system as it performs its intended tasks and the triggers that cause state transitions. A SysML SMD aims to contextualize how different events, or “Triggers”, result in certain actions that the system may take when in a certain state. The SMD illustrates the complex behaviors that a system may take on in its lifetime.

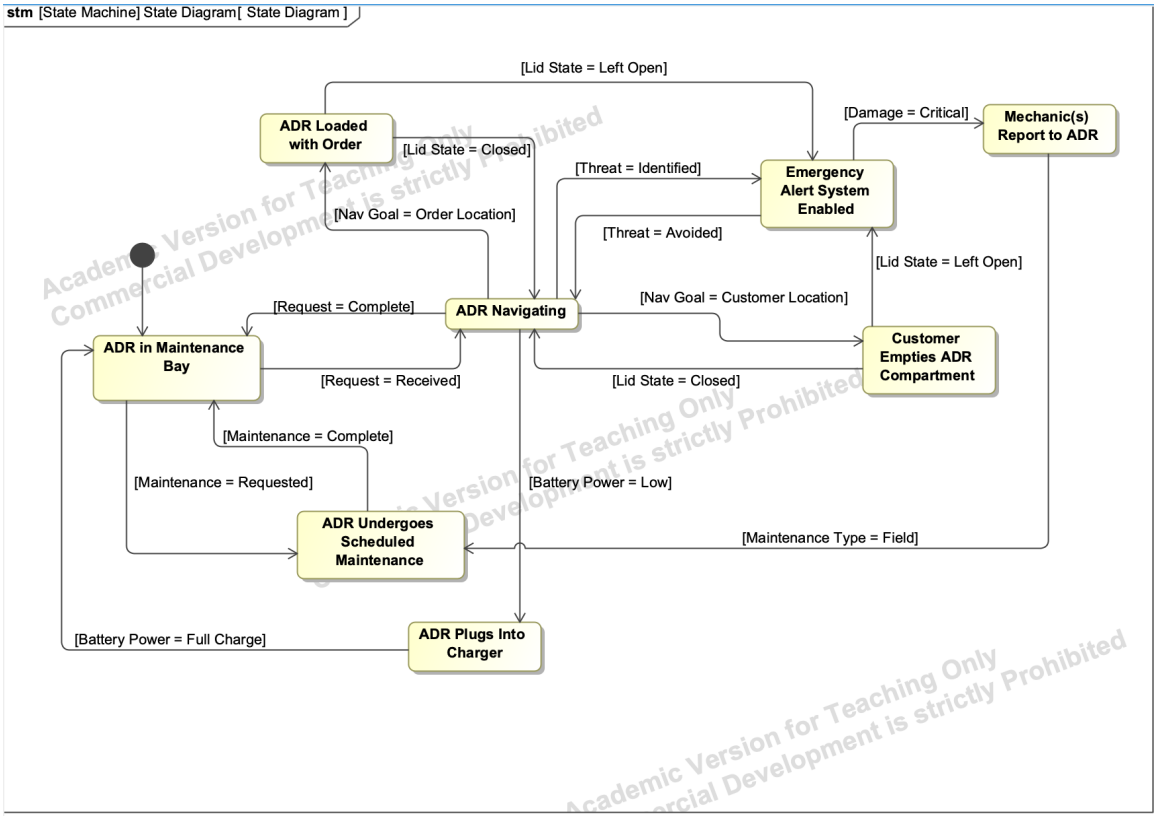

Figure 11: ADR System Element-Level SMD

8.5. System Conceptual Design

The ADR system consists of Autonomous Delivery Robot Elements (ADREs), the User Interaction Element (UIE), and the Support Element (SE) conceptually.

Figure 12 provides a visual representation of the conceptual architecture of the ADR system using a SysML System Block Definition Diagram (BDD). The purpose of a System Definition BDD is to show the hierarchy trees and classification trees of the ADR system. Also, it shows elements like blocks and values types and the relationships between them [5].

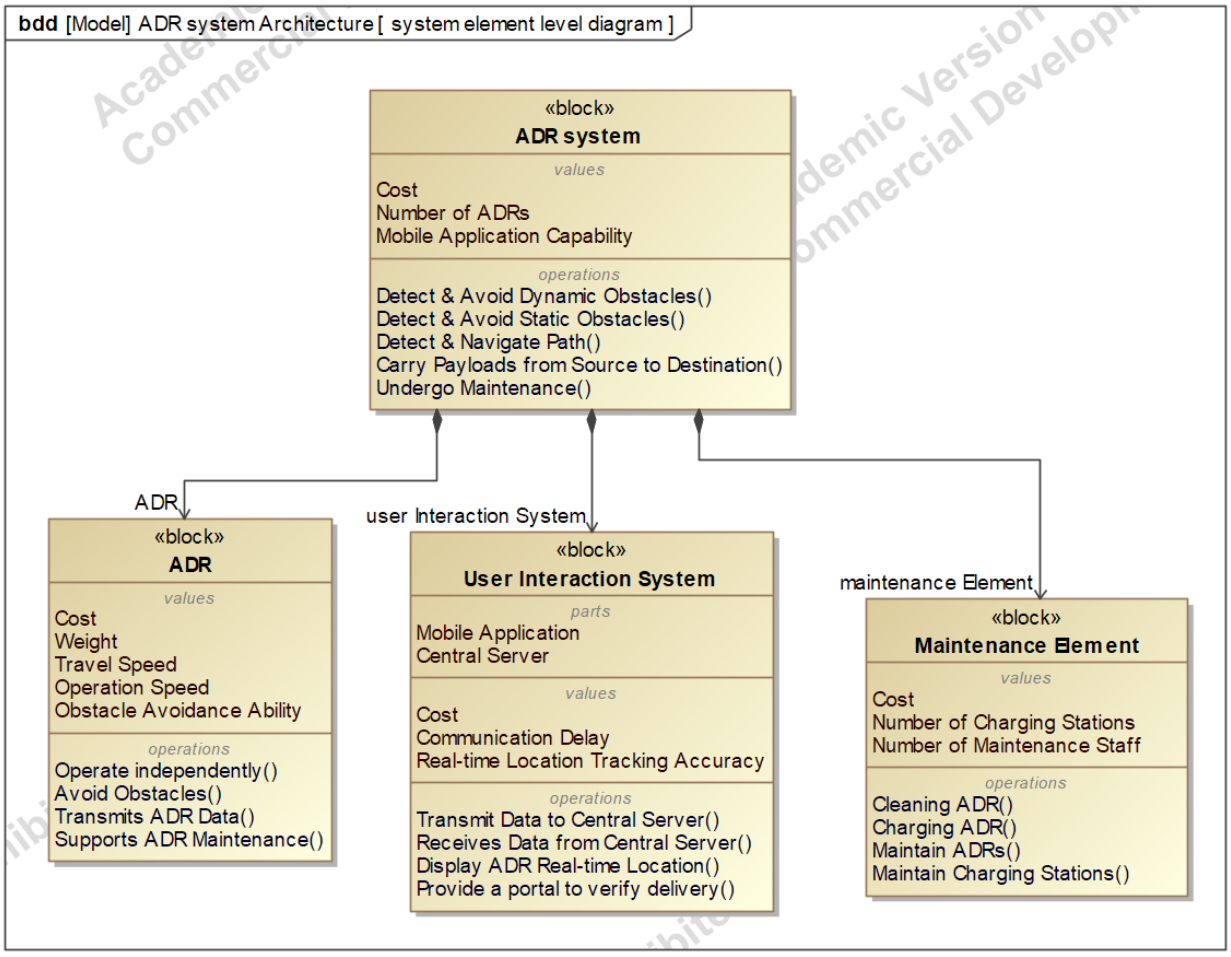

Figure 12: ADR Conceptual Architecture (BDD)

1. Autonomous Delivery Robot consists of 1) chassis and storage bins; 2) the sensor packages used to detect dynamic or static obstacles (pedestrians, vehicles etc.); 3) hardware and software for processing the sensor data; 4) hardware and software for motion control which uses the sensor data and controls the motion of the ADR (forward/backward/left/right); 5) hardware and software for telecommunication which allows the ADR to transmit data to the central server for monitoring, management,and usage for mobile application purposes. 6) QR code sticker on the body for users to scan (identify if the ADR reaches the user so it can open the storage bin).
2. User Interaction Element consists of 1) a mobile application to communicate with the central server to get the ADR live location and display it to the users; 2) user scanning the QR code on the ADR to verify the ADR has reached its destination.
3. Support Element consists of cleaning and charging the ADRs, replacing parts if needed, and maintaining the system.

The different operations performed by the sub-systems are also documented in the diagram at a contextual level.

8.6. Project System Architecture Framework

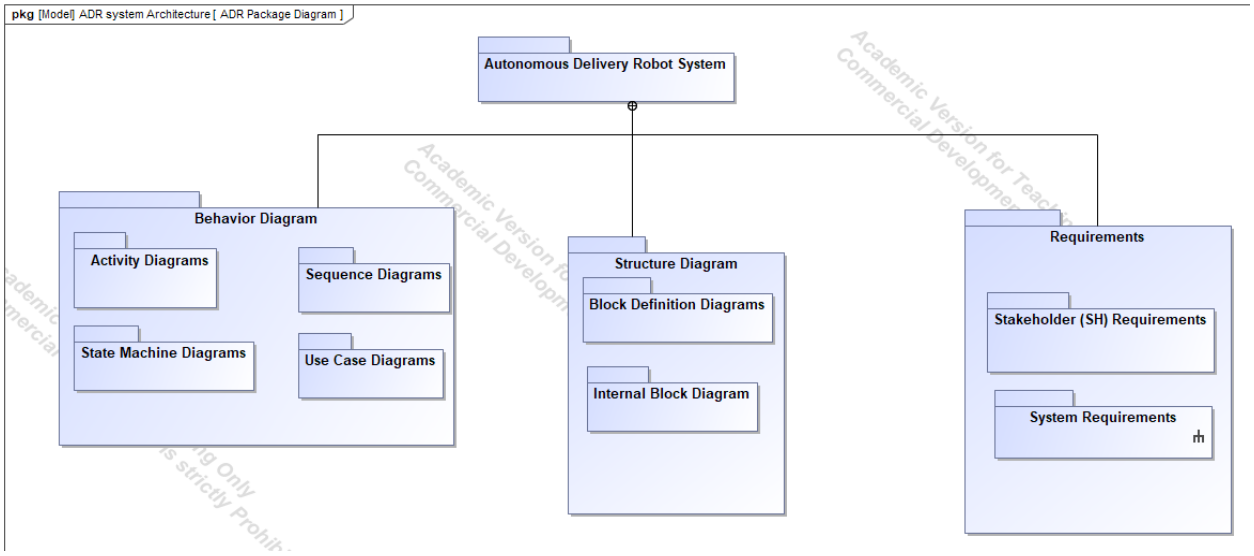

Figure 13: SysML Package Diagram for ADR

The architecture of the ADR system is provided in a SysML Package Diagram as shown above in Figure 13. The System Element Package is used to create and organize the model into sub-packages which consists of several SysML diagrams. The purpose of it is to help model navigation and reuse, and access and change control. The whole system of interest can be organized into Behavior Diagrams, Structure Diagrams, and Requirements. And they can be divided into sub-packages for easy documentation of the several SysML diagram types [6].

The Behavior Diagram package represents the static aspects of the ADR system. So it consists of Activity Diagram and Sequence Diagram for the use cases, State machine diagram of the ADR system, and Use Case Diagram of the system.
The Activity Diagram package and the Sequence Diagram package consists of activity diagrams and sequence diagrams respectively for:

- Use Case 1: Transport food to Destination using ADRs without colliding with any obstacles
- Use Case 2: Opening the storage bin accordingly with QR code
- Use Case 3: Inspection and maintenance

The State Machine Diagram package consists of the ADR state machine diagram. The use case diagram package holds the context level use case diagram for the system.

The Structure Diagram is used to help to provide structural architecture views including the physical structure of the ADR system, its elements, and its environment. Therefore, it consists of Block Definition Diagram and the Internal Block Diagram of the system. The Block Definition Diagram Package consists of the following diagrams:

- System Domain Definition Diagram
- System Element Level Diagram
- System External Interface Level Diagram

The Internal Block Diagram consists of the System's Context level internal block diagram which displays the internal structure of the ADR system.

The Requirements Package contains the SysML requirements diagrams and requirements tables that are used to create the Stakeholders' Requirements Document and System Requirements Document.

The rationale behind the structure of our package diagram is to easily navigate and access through the principal capabilities of the ADR system and display its internal and external behavior and interactions through the behavior and structure diagram.

Appendix A

Expanded Use Case Narratives

This section provides the expanded UCNs for the Use Cases described in Section 7 of this document.

A.1 Use Case Narrative: UCN1 - Order Placement and Execution

Introductory Information:

Use Case ID: 1

Use Case Name: Order Placement and Execution

Configuration Control Information:

Version:1.0
Date:10/14/2022
Team Name: Team 3
Author: Manu Madhu Pillai
Level: System and Element Level
Primary Actor(s):

1. Central Server

Supporting Actor(s):

1. Sender
2. Receiver

Precondition(s): Central Server is fully operational and connected to all the ADRs in the operating area. At least one ADR is available to commence the task.
Post-condition(s):
Minimum Condition(s):

1. ADR is able to receive Order location, Customer Location and routes from the Central Server.
2. ADR is able to avoid collisions with the surroundings.

Success Condition(s):

1. ADR reaches the order location and package is placed in the payload bay.
2. ADR successfully reaches the customer location and opens the payload bay when the QR code is scanned and authenticated.

Trigger: The central server asks ADR to complete an order.

Main Success Scenario:

1. The central server receives an order.
2. The central server sends the pickup location to the nearest available ADR.

3. The ADR navigates to the order location.
4. The package is placed in the payload bay of ADR.
5. The ADR accepts the customer location from the central server.
6. The ADR navigates to the customer location.
7. The customer accesses the package being carried by the ADR and closes the lid.
8. The ADR notifies the central server that the order is complete.
9. The central server notifies the ADR of the next order location or if all orders are satisfied.
10. The ADR navigates to the next location request.

Extensions:

Extension 1: E1.1 ADR failure during navigation

Extension trigger: ADR experiences a critical failure

E1.1.1 ADR reports critical failure to the central server

E1.1.2 Central Server Requests a Field Inspection and Service

Extension 2: E1.2 ADR experiences failure while available

Extension trigger: ADR experiences a critical failure

E1.2.1 ADR reports critical failure to the central server

E1.2.2 Central Server Requests a Functionality Inspection and Service

Note: More extensions are possible.

A.2 Use Case Narrative: UCN2- Maintain system battery levels

Introductory Information:

Use Case ID: 2

Use Case Name: Maintain System Battery Levels

Configuration Control Information:

Version:1.0
Date:10/14/2022
Team Name: Team 3
Author: Manu Madhu Pillai
Level: System and Element Level
Primary Actor(s):

1. Central Server

Supporting Actor(s):

1. Charging Station

Precondition(s): Central Server is fully operational and connected to all the ADRs in the operating area.
Post-condition(s):
Minimum Condition(s):

1. ADR is able to charge its battery.

Success Condition(s):

1. ADR replies to the central server when it is fully charged.
2. Central Server assigns new status to the fully-charged ADR.

Trigger: The central server asks the ADR for the system information

Main success scenario:

1. The central server requests the ADR to send its system information.
2. The ADR responds with the current battery levels.
3. The central server locates the closest charger to the ADR.
4. The central server sends route and task information to the ADR.
5. ADR follows route and task information to go to the charger.
6. ADR keeps sensing the environment to avoid collision.
7. ADR plugs itself into the charger.
8. ADR unplugs itself from the charger once it is fully charged.
9. ADR send current battery information to the central server.
10. The central server assigns a new status to ADR.

Extensions:

Extension 1: E2.1 ADR battery is sufficiently charged.

Extension trigger: The current battery levels sent to the central server by ADR is above the required threshold levels of operation.

E2.1.1 The central server requests the ADR to send its system information.

E2.1.2 The ADR responds with battery levels above threshold levels.

E2.1.3 The central server assigns new status to ADR.

Extension 2: E2.2 ADR battery is below operating levels during executing a task.

Extension trigger: The current battery levels sent to the central server by ADR is below the required threshold levels of operation.

E2.2.1 The central server requests the ADR to send its system information.

E2.2.2 The ADR responds with battery levels below threshold levels.

E2.2.3 The central server assigns new status to ADR that overrides current status.

E2.2.4 The central server updates the route destination to the nearest charging station to the ADR to commence charging.

Extension 3: E2.3 ADR experiences battery failure during transit.

Extension trigger: The current battery levels are not being sent to the central server by ADR.

E2.3.1 ADR reports critical failure to the central server.

E2.3.2 The central server assigns new status to ADR that overrides current status.

E2.3.3 Maintainer takes the ADR to the maintenance bay.

Note: More extensions are possible.

A.3 Use Case Narrative: UCN3- Operability inspection & service

Introductory Information:

Use Case ID: 3

Use Case Name: Operability inspection & service

Configuration Control Information:

Version:1.0

Date:10/14/2022

Team Name: Team 3

Author: Manu Madhu Pillai

Level: System and Element Level

Primary Actor(s):

1. Maintainer

Supporting Actor(s):

1. Central Server

Precondition(s): Central Server is fully operational and connected to the ADR. Maintainer is available for inspection and service.

Post-condition(s):

Minimum Condition(s):

1. ADR is able to turn off when requested by the central server.

Success Condition(s):

1. ADR replies to the central server when turned on.
2. Central Server assigns new status to the serviced ADR.

Trigger: Scheduled daily at the end of operational hours of the ADR.

Main success scenario:

1. The ADR system is physically cleaned by the maintainer.
2. The ADR system payload bay is cleared out and cleaned by the maintainer.
3. The ADR system is inspected for physical damage.

Extensions:

Extension 1: E3.1 Issue found in ADR is beyond repair skills of the maintainer.

Extension trigger: The maintainer troubleshoots the issue found upon inspection of the ADR.

E3.1.1 The maintainer requests the central server for functionality inspection and service.

E3.1.2 The central server issues a functionality inspection and service request for the ADR.

E3.1.3 The central server assigns new status to ADR.

Note: More extensions are possible.

A.4 Use Case Narrative: UCN4- Field inspection & service

Introductory Information:

Use Case ID: 4

Use Case Name: Field inspection & service

Configuration Control Information:

Version:1.0
Date:10/14/2022
Team Name: Team 3
Author: Manu Madhu Pillai
Level: System and Element Level
Primary Actor(s):

1. Central Server

Supporting Actor(s):

1. Maintainer

Precondition(s): Central Server is fully operational and connected to the ADR. Maintainer is available for inspection and service. Maintainer is able to travel within the operational area of the ADR.
Post-condition(s):
Minimum Condition(s):

1. ADR is able to turn off when requested by the central server.
2. ADR is able to send its current location to the central server.

Success Condition(s):

1. ADR replies to the central server when turned on.
2. Central Server assigns new status to the serviced ADR.

Trigger: ADR requests the central server for a field inspection.

Main success scenario:

1. The central server requests the maintainer to inspect the ADR at it's current location.
2. The maintainer goes to the ADR's current location.
3. The maintainer inspects the ADR for issues.
4. The maintainer fixes the issues of the ADR.

Extensions:

Extension 1: E4.1 Issue found in ADR is beyond repair skills of the maintainer.

Extension trigger: The maintainer troubleshoots the issue found upon inspection of the ADR.

E4.1.1 The maintainer requests the central server for functionality inspection and service.

E4.1.2 The maintainer brings the ADR to the maintenance bay.

E4.1.3 The central server issues a functionality inspection and service request for the ADR.

E4.1.4 The central server assigns new status to ADR.

Note: More extensions are possible.

A.4 Use Case Narrative: UCN5- Functionality inspection & service

Introductory Information:

Use Case ID: 5

Use Case Name: Functionality inspection & service

Configuration Control Information:

Version:1.0
Date:10/14/2022
Team Name: Team 3
Author: Manu Madhu Pillai
Level: System and Element Level
Primary Actor(s):

1. Central Server

Supporting Actor(s):

1. Maintainer

Precondition(s): Central Server is fully operational and connected to the ADR. Maintainer is available for inspection and service.
Post-condition(s):
Minimum Condition(s):

1. ADR is able to turn off when requested by the central server.

Success Condition(s):

1. ADR replies to the central server when turned on.
2. Central Server assigns new status to the serviced ADR.

Trigger: Scheduled based on the expected lifespan of the critical parts in ADR, or requested by the central server due to escalation of lower inspection and services.

Main success scenario:

1. The maintainer dissasembles the ADR and separates the critical parts.
2. The maintainer performs a functionality inspection of critical components.
3. The maintainer checks mechanical components like wheels for wear and tear.
4. The maintainer checks electrical components like motors for wear and tear.
5. The maintainer decides whether to replace the components.
6. The maintainer replaces the required components.
7. The maintainer reassembles the ADR.
8. The maintainer performs a functionality inspection of the assembled ADR.

Extensions:

Extension 1: E5.1 Issue found in ADR is beyond repair skills of the maintainer.

Extension trigger: The maintainer replaces the faulty component of the ADR.

E5.1.1 The maintainer requests assistance from the manufacturer..

E5.1.2 The ADR is sent to the manufacturer for troubleshooting and service.

Note: More extensions are possible.