# Systems Concept Review: Autonomous Delivery Robot System

Team 3
Xinyi Yang, Manu Madhu Pillai, Sidney Leigh Molnar, Mukundhan Rajendiran (Muku)

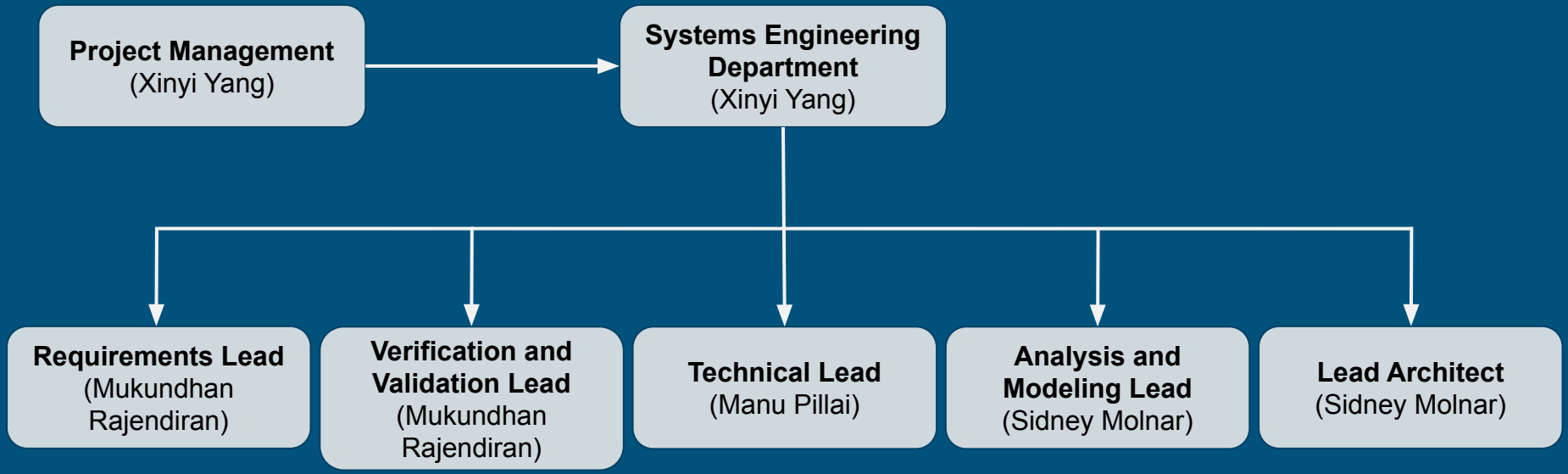
# Outline

- Introduction
  - Purpose and Background
  - Team and Responsibilities
- System Concept
  - Users and Statement of Need
  - Capabilities and Measures of Effectiveness
  - Project Development Life Cycle Model, Scope and Status
- System Architecture
- Requirements
- Conclusions
  - Insights
  - Next Steps

# Briefing Purpose

- Evaluate scope
- Evaluate System-level Architecture Diagrams
- Define Stakeholder Requirements
- Receive System Development Approval (SDA) to enter System Requirements and Preliminary Design Phase
- Receive feedback to integrate into next presentation, Preliminary Design Review (PDR)

# Team & Team Responsibilities



# Team Responsibilities

**CDRL and Responsibilities Matrix**

| CLIN | Covered | Draft Due | Final Due | Deliverable Name | Type | Product Lead(s) |
|---|---|---|---|---|---|---|
| HW1 | Week 1 | N/A | Week 2 | Personal Autobiographies | Individual | N/A |
| HW2 | Week 3 | N/A | Week 2 | Myers Briggs Personality Results | Individual | N/A |
| HW3 | Week 2 | Week 4 | Week 6 | Project Proposal | Team | Xinyi (Cindy) Yang |
| HW4 | Week 3 | N/A | Week 4 | Project SEMP | Team | Xinyi (Cindy) Yang |
| HW5 | Week 3-4 | Week 5 | Week 7 | System Concept Description-Part I | Team | Manu Pillai |
| HW6 | Week 5-6 | Week 7 | Week 9 | System Concept Description-Part II | Team | Manu Pillai |
| HW7 | Week 5 | Week 8 | Week 10 | Stakeholders' Requirements Document | Team | Mukundhan Rajendiran |
| HW8 | Week 7 | Week 9 | Week 12 | System-Level Architecture | Team | Sidney Molnar |
| HW9 | Week 7 | Week 9 | Week 12 | System Requirements Document | Team | Mukundhan Rajendiran |
| HW10 | Week 10 | N/A | Week 12 | RAM Performance Analysis | Individual | N/A |
| HW11 | Week 12 | Week 13 | Week 14 | Project Tradeoff Analysis | Team | Sidney Molnar |
| HW12 | Week 12 | Week 13 | Week 14 | Risk Analysis | Individual | N/A |
| HW13 | N/A | N/A | Week 15 | Teammate Assessment | Individual | N/A |
| P1 | Week 1-7 | Week 7 | Week 8 | System Concept Review Presentation | Team | Xinyi (Cindy) Yang/Manu Pillai |
| P2 | Week 9-13 | N/A | Week 14 | Preliminary Design Review Presentation | Team | Mukundhan Rajendiran/Sidney Molnar |

# Stakeholders

| 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 |

# Statement of Need

- Students and staff in the universities spend considerable time and effort collecting various items such as food, books, documents, etc..
- Issues with conventional delivery systems: Logistics Issues, Fixed Working Times, High Operational Cost, Safety Issues.
- The proposed system would help alleviate issues by delivering the required items to their doorstep such as :

1. Reduces Human Errors
2. Contactless deliveries
3. 24/7 Delivery possibilities
4. Environment Friendly
5. Efficient Logistics Handling
6. Enhanced Safety

# Top-level Capabilities

| Capability I.D. | Capability | Priority |
|---|---|---|
| C1.1 | Detect sidewalks, roads, pedestrian crossings, and road signs. | 1 |
| C1.2 | Detect Motor vehicles, pedestrians, cyclists, animals, and similar dynamic obstacles. | 2 |
| C1.3 | Detect plants, trees, buildings, railings, and similar static obstacles. | 3 |
| C1.4 | Detect and identify other ADRs. | 4 |
| C2 | Avoid Collisions with dynamic and static obstacles in the surroundings. | 5 |
| C3 | Navigate on the given path following road safety laws. | 6 |
| C4 | Carry payloads from source to destination as assigned. | 7 |
| C5 | Monitor the remaining battery and return to the charging station at the failsafe level. | 8 |
| C6.1 | Provide tracking status and maintain communication with the central server. | 9 |
| C6.2 | Report theft, vandalism, or tampering with the ADR and its payload. | 10 |
| C7 | Open respective payload bay among the segmented payload bays when authorized. | 11 |

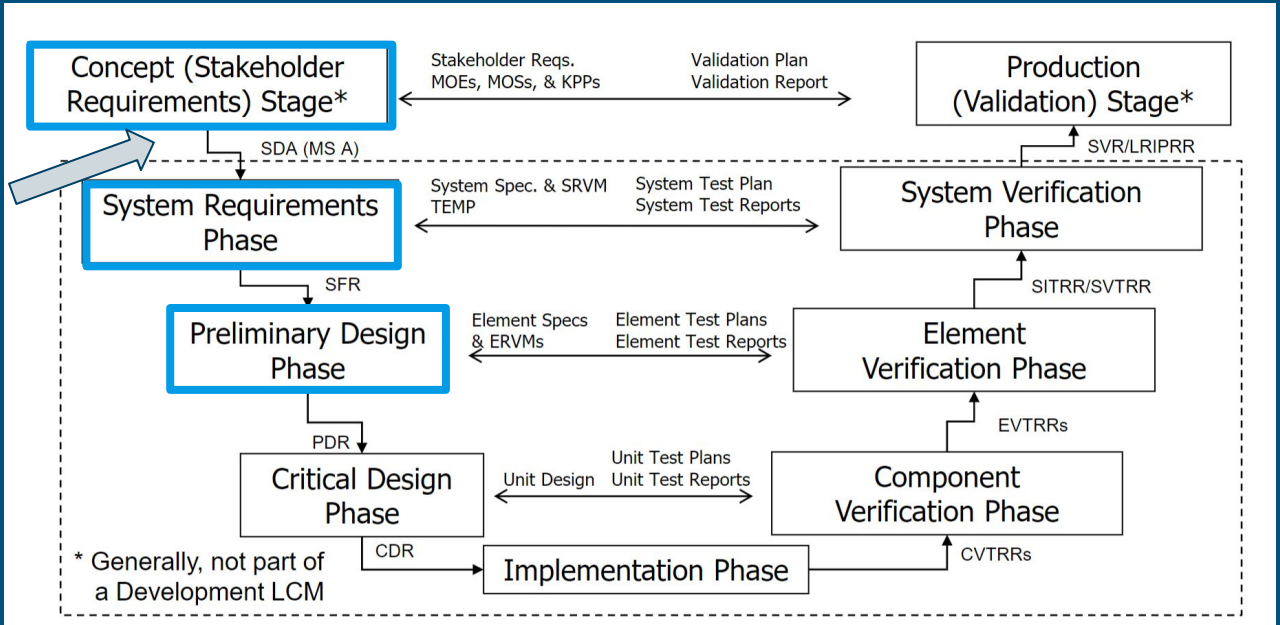
# Measures of Effectiveness (MOE)

| 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 |

# Project Development Life Cycle Model

We are currently here

V Development Life Cycle Model (LCM)



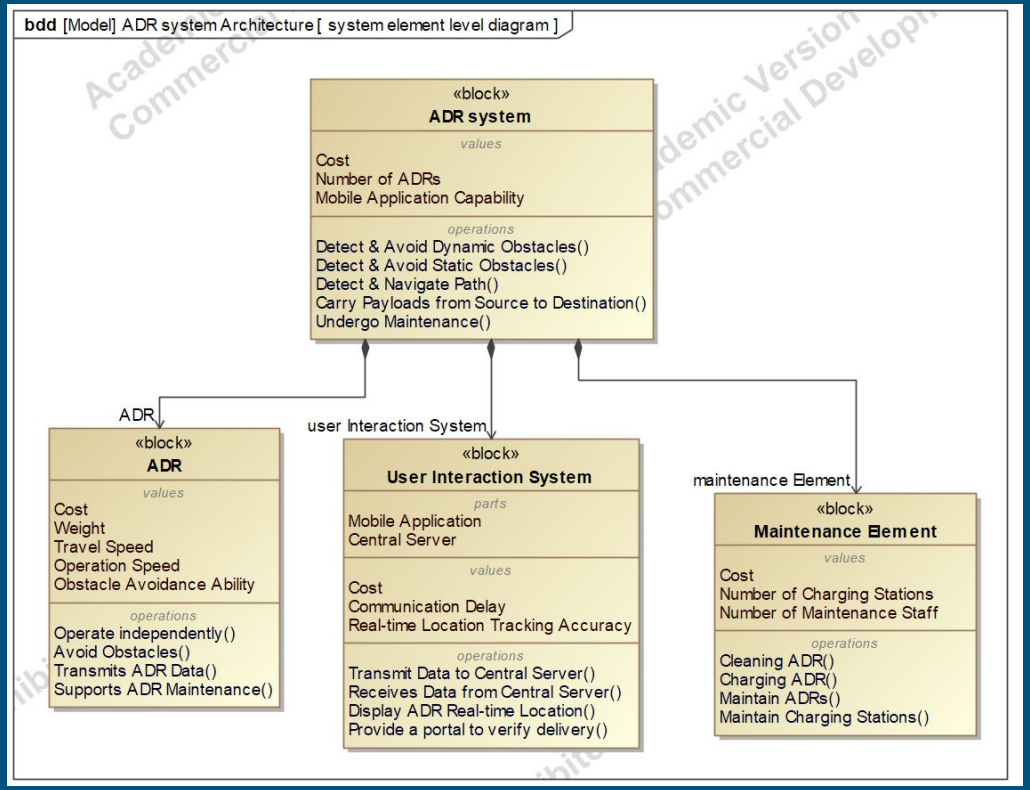
# Project Development Scope and Status

| Project Development Scope and Status | | | |
|---|---|---|---|
| Phase | **Concept Phase** | **Systems Requirements Phase** | **Preliminary Design Phase** |
| | | Stakeholders' Requirements Document | |
| | Project Proposal | System-Level Architecture | |
| | Project Systems Engineering Management Plan (SEMP) | System Requirements Document | |
| | System Concept Description | RAM Performance Analysis | |
| | | Project Trade-Off Analysis | |
| Deliverables | Preliminary Stakeholders' Requirements Document | Risk Analysis | Preliminary System Architecture Design |
| Exit Gate | System Concept Review | Requirements Baseline | Preliminary Design Review |
| | | | |
| Key | Completed | Current Status | Future Deliverables |

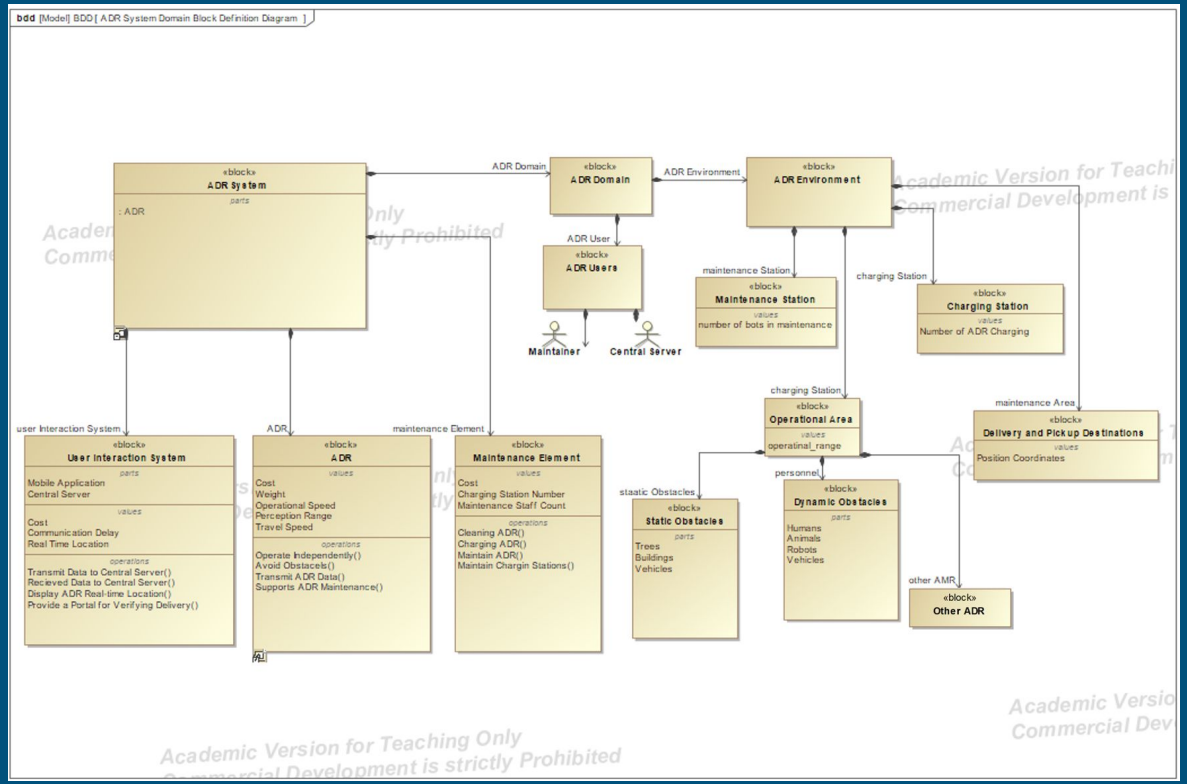
# (Context-Level) System Architecture:

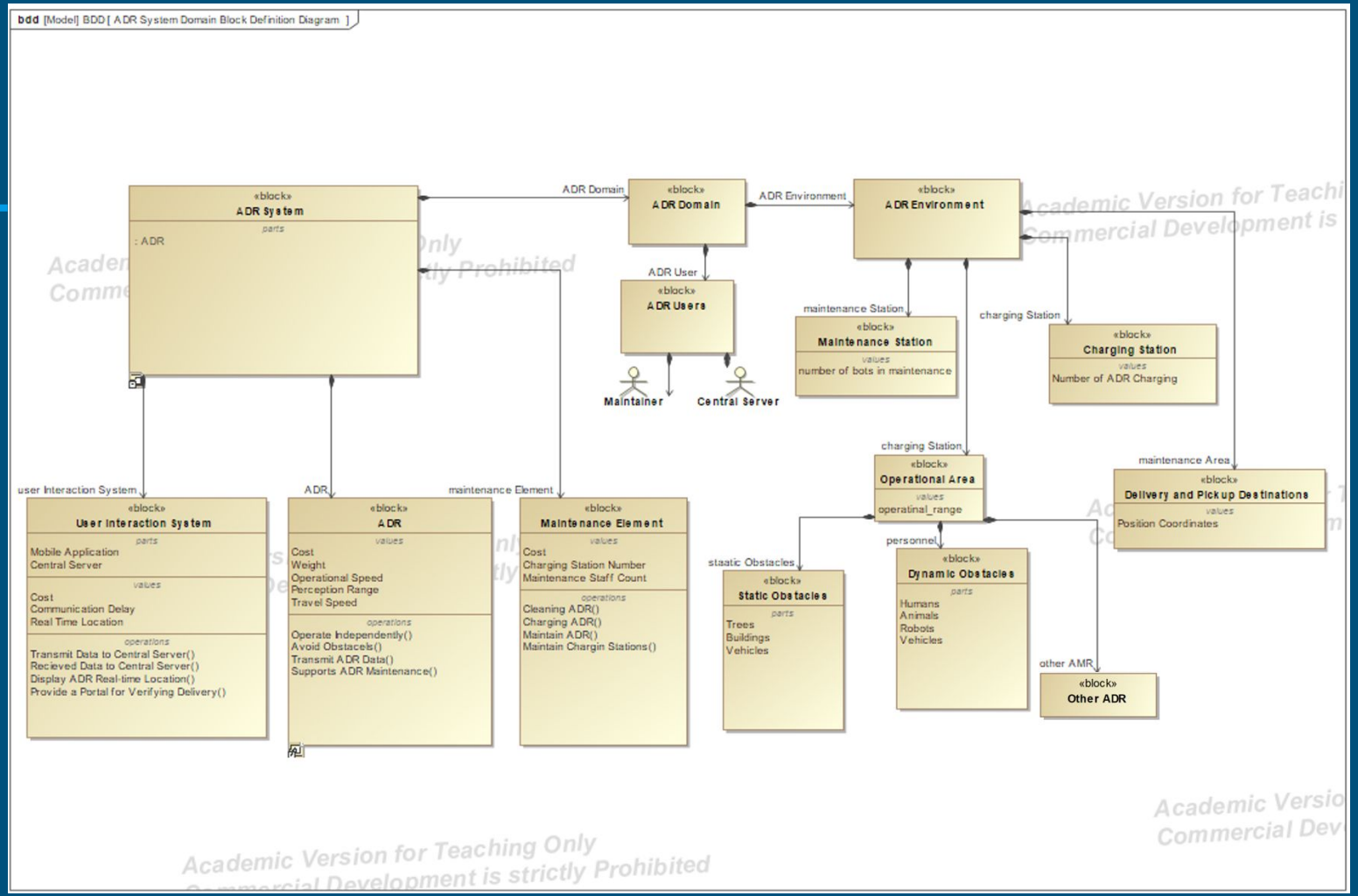
- System Concept
  - Domain Definition Block Definition Diagram (BDD)
  - System Context Internal Block Diagram (IBD)
  - Interface Definition Block Definition Diagram (BDD)
- System Operational Concept
  - Use Case Diagram (UC)
  - Activity Diagram for Primary Use Case

# System Concept

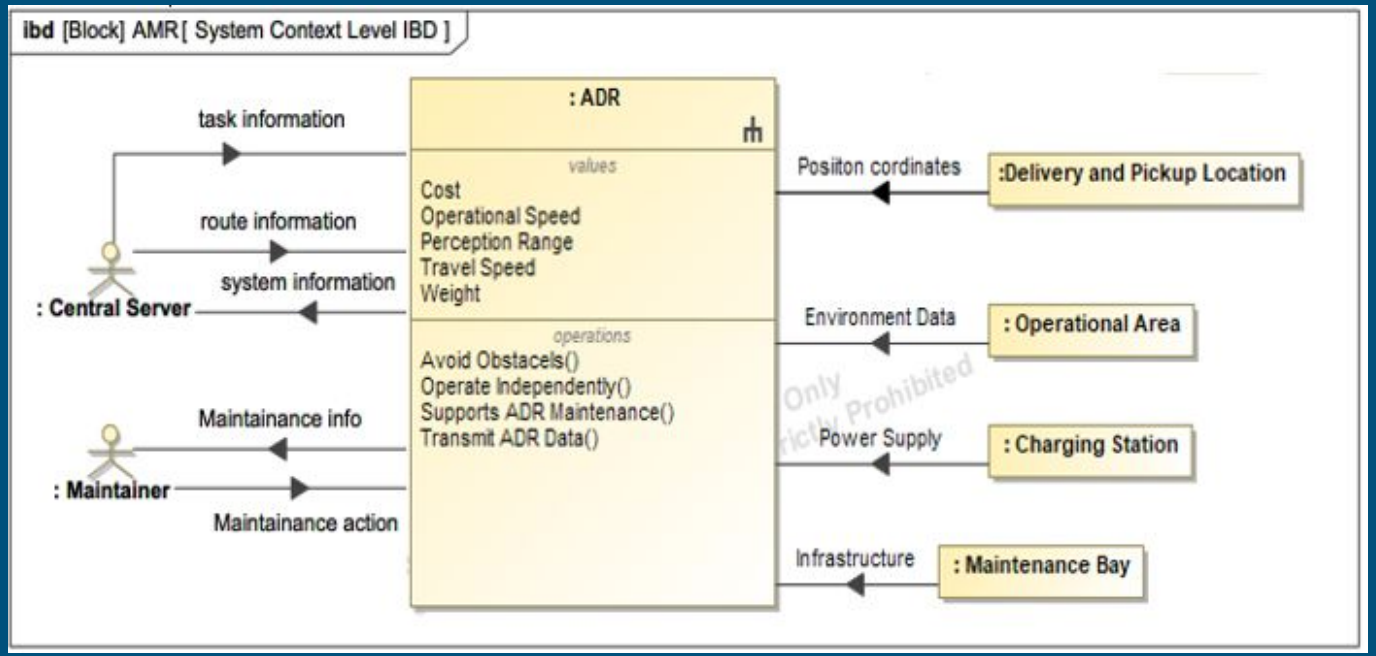


# Domain Definition Block Definition Diagram

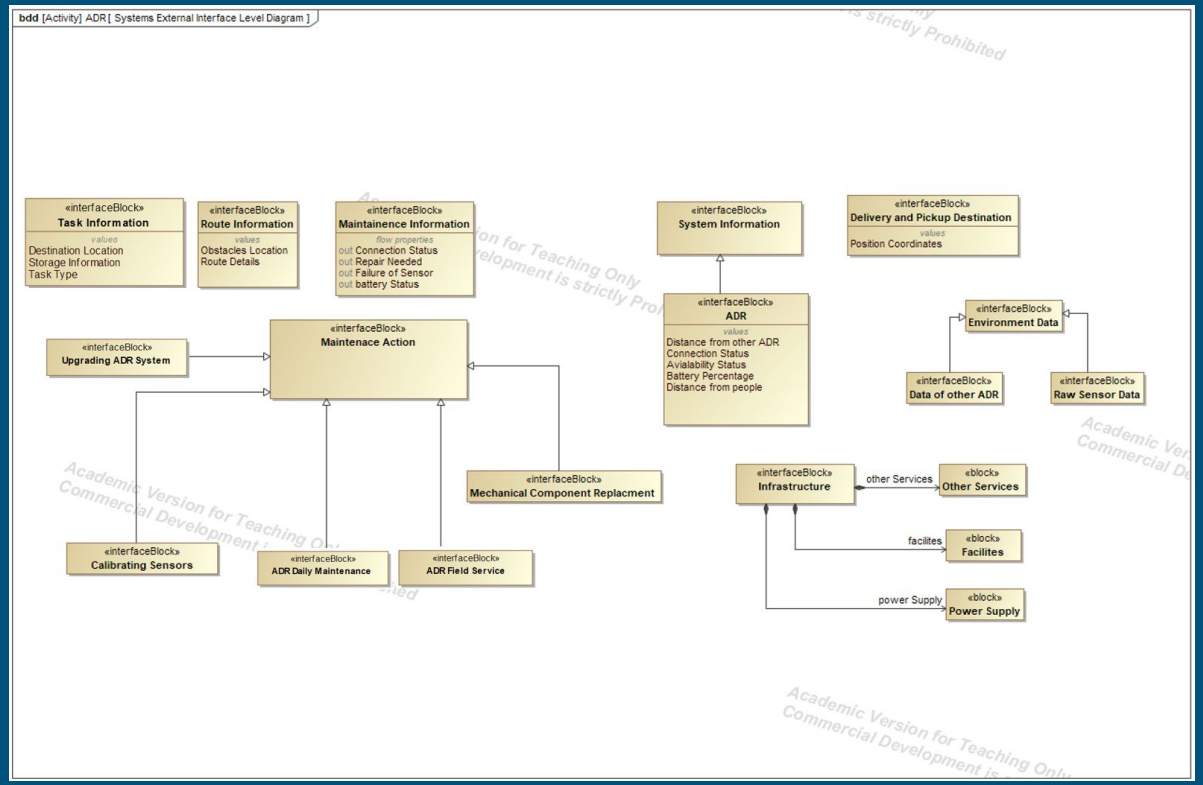


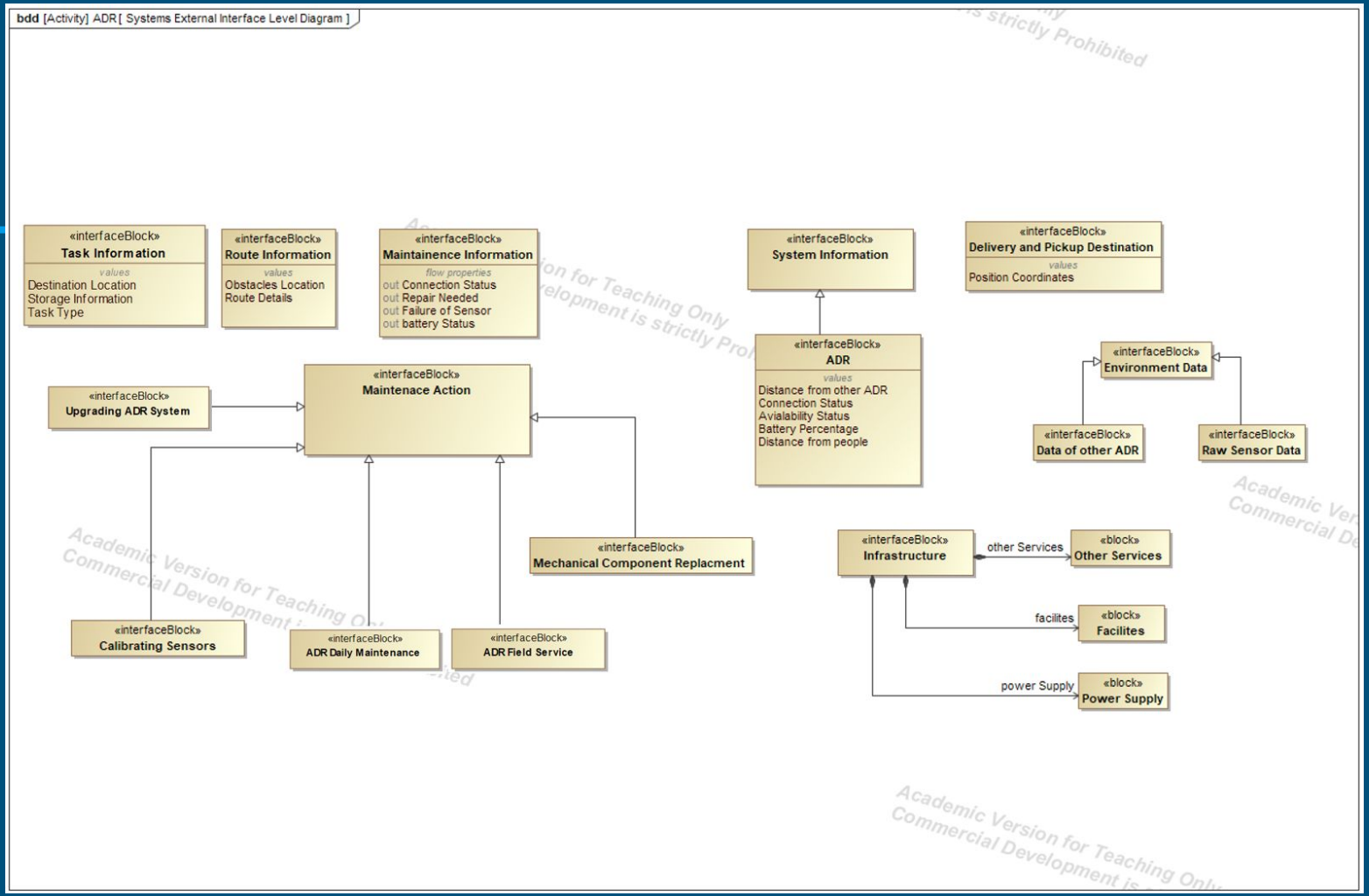

bdd [Model] BDD [ ADR System Domain Block Definition Diagram ]
«block»
ADR System
parts
: ADR
ADR Domain
«block»
ADR Domain
ADR Environment
«block»
ADR Environment
ADR User
«block»
ADR Users
Maintainer
Central Server
maintenance Station
«block»
Maintenance Station
values
number of bots in maintenance
charging Station
«block»
Charging Station
values
Number of ADR Charging
charging Station
«block»
Operational Area
values
operatinal_range
maintenance Area
«block»
Delivery and Pickup Destinations
values
Position Coordinates
user Interaction System
«block»
User Interaction System
parts
Mobile Application
Central Server
values
Cost
Communication Delay
Real Time Location
operations
Transmit Data to Central Server()
Recieved Data to Central Server()
Display ADR Real-time Location()
Provide a Portal for Verifying Delivery()
ADR
«block»
ADR
values
Cost
Weight
Operational Speed
Perception Range
Travel Speed
operations
Operate Independently()
Avoid Obstacels()
Transmit ADR Data()
Supports ADR Maintenance()
maintenance Element
«block»
Maintenance Element
values
Cost
Charging Station Number
Maintenance Staff Count
operations
Cleaning ADR()
Charging ADR()
Maintain ADR()
Maintain Chargin Stations()
staatic Obstacles
«block»
Static Obstacles
parts
Trees
Buildings
Vehicles
personnel
«block»
Dynamic Obstacles
parts
Humans
Animals
Robots
Vehicles
other AMR
«block»
Other ADR
Academic Version for Teaching Only
Commercial Development is strictly Prohibited

# System Context Internal Block Diagram



# Interface Definition Block Definition Diagram

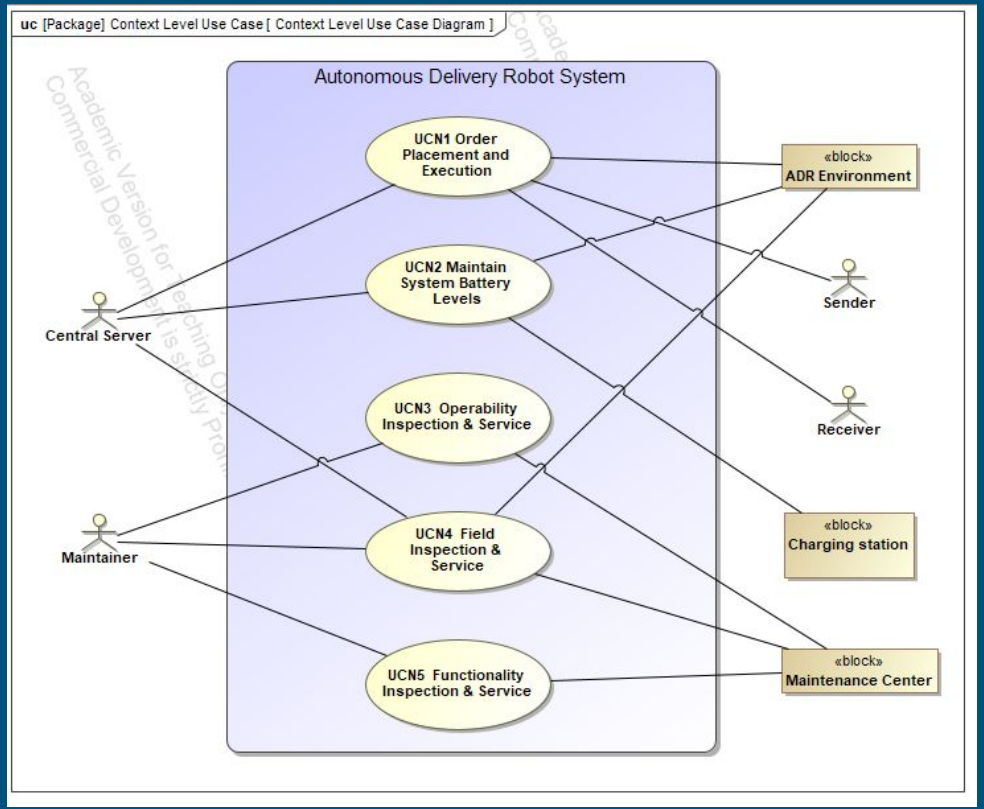



bdd [Activity] ADR [ Systems External Interface Level Diagram ]
«interfaceBlock»
Task Information
values
Destination Location
Storage Information
Task Type
«interfaceBlock»
Route Information
values
Obstacles Location
Route Details
«interfaceBlock»
Maintainence Information
flow properties
out Connection Status
out Repair Needed
out Failure of Sensor
out battery Status
«interfaceBlock»
System Information
«interfaceBlock»
Delivery and Pickup Destination
values
Position Coordinates
«interfaceBlock»
ADR
values
Distance from other ADR
Connection Status
Avialability Status
Battery Percentage
Distance from people
«interfaceBlock»
Environment Data
«interfaceBlock»
Data of other ADR
«interfaceBlock»
Raw Sensor Data
«interfaceBlock»
Upgrading ADR System
«interfaceBlock»
Maintenace Action
«interfaceBlock»
Mechanical Component Replacment
«interfaceBlock»
Calibrating Sensors
«interfaceBlock»
ADR Daily Maintenance
«interfaceBlock»
ADR Field Service
«interfaceBlock»
Infrastructure
other Services
«block»
Other Services
facilites
«block»
Facilites
power Supply
«block»
Power Supply

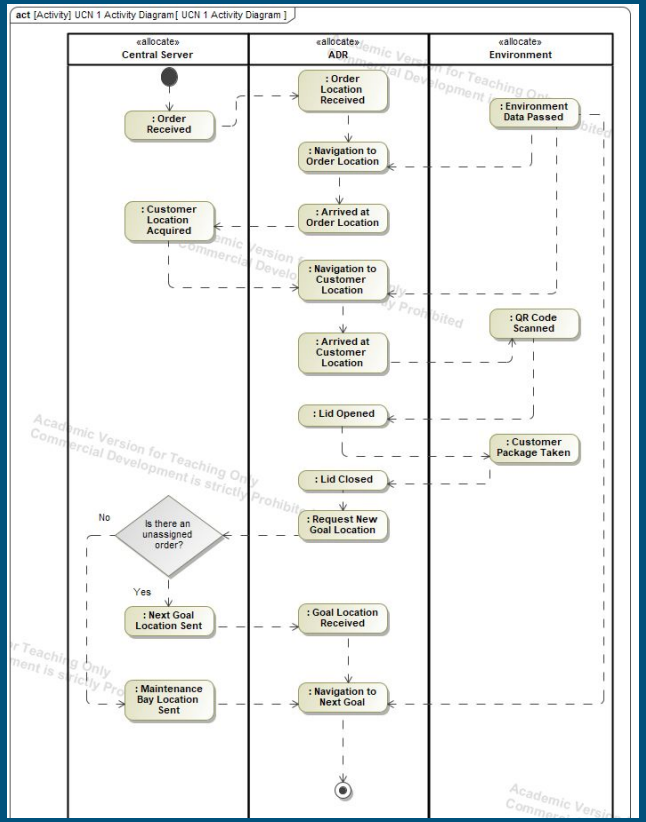
# System Operational Concept

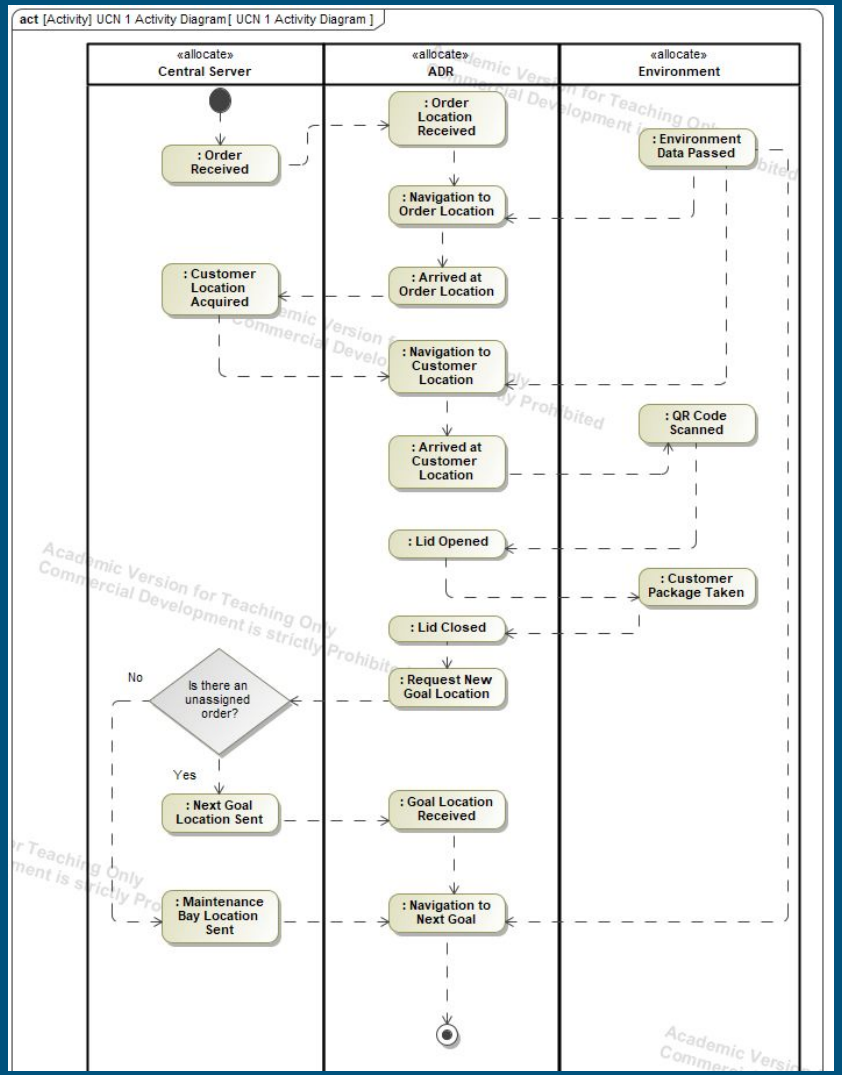
- Users: Faculty, Staff, and Students on large university campuses
- Orders placed on customer’s app (UberEats, GrubHub, etc.)
- ADR navigates to order location before navigating to user location
  - Static and dynamic obstacle avoidance
  - Inclement weather conditions
- Payloads containing orders may be accessed by scanning QR code
- Management team provides maintenance tasks
  - Field maintenance, scheduled maintenance
  - Daily ADR evaluations
  - Charging and cleaning tasks

# Use Case Diagram



# Primary Use Case Activity Diagram




act [Activity] UCN 1 Activity Diagram [ UCN 1 Activity Diagram ]
«allocate»
Central Server
«allocate»
ADR
«allocate»
Environment
: Order Received
: Order Location Received
: Environment Data Passed
: Navigation to Order Location
: Customer Location Acquired
: Arrived at Order Location
: Navigation to Customer Location
: QR Code Scanned
: Arrived at Customer Location
: Lid Opened
: Customer Package Taken
: Lid Closed
: Request New Goal Location
No
Is there an unassigned order?
Yes
: Next Goal Location Sent
: Goal Location Received
: Maintenance Bay Location Sent
: Navigation to Next Goal

# Stakeholder Requirements

Programmatic Requirements

- Schedule Requirement
- System Life Cycle Cost
- Operational Life
- Regulations

Technical Requirements

- Operation Time
- Operational Range
- Payload Capacity
- Automated Charging
- Collision Avoidance

Interface Requirements

- Authenticated Payload Bay
- Emergency Stop
- Power Button
- Data Logging
- Firmware Update

# Programmatic Requirements

| ID | Name | Requirement |
|---|---|---|
| SHR1.1 | Schedule Requirement | The ADR system shall be operational by May 2023. |
| SHR1.2 | System Life Cycle Cost | The ADR shall have a unit cost less than $7000. |
| SHR1.3 | Operational Life | The ADR shall have an operational life greater than 5 years. |
| SHR1.4 | Regulations | The ADR shall get the necessary certifications and follow safety regulations. |

# Technical Capabilities

| ID | Name | Requirement |
|---|---|---|
| SHR2.1 | Operation Time | The ADR shall be able operate for at least 8 hours on a single charge. |
| SHR2.2 | Operational Range | The ADR shall be fully functional within a 2 mile radius from the central server. |
| SHR2.3 | Payload Capacity | The ADR shall be able to carry packages upto 100 lbs. |
| SHR2.4 | Automated Charging | The ADR shall be able to monitor battery levels and charge when needed. |
| SHR2.5 | Collision Avoidance | The ADR shall be able to detect its surroundings and avoid collision. |

# Interface Requirements

| ID | Name | Requirement |
|---|---|---|
| SHR3.1 | Authenticated Payload Bay | The sender and receiver using the ADR shall be able to open the payload bay by scanning a QR code. |
| SHR3.2 | Emergency Stop | The ADR shall have an emergency stop button that can be triggered by the central server and the maintainer. |
| SHR3.3 | Power Button | The maintainer shall be able to power off the ADR. |
| SHR3.4 | Data Logging | The maintainer shall be able to access the sensor feed, telemetry log and event log of the ADR. |
| SHR3.5 | Firmware Update | The maintainer shall be able to load and update firmware on the ADR. |

# Insights

- The unique segmented payload system of the ADR eliminates the risk of the delivery item being misdelivered or damaged by other delivery items.
- The ADR’s self diagnosing feature to detect and rectify minor issues on the run, which helps the maintainers by cutting down time and effort needed for repair.
- Team Development activities played a vital role in visualizing this project efficiently.
- Cameo Systems Modeller is a powerful tool for creating and simulating systems architectures. It has smart, robust, and intuitive tools to define, track, and visualize all aspects of systems in the most standard-compliant SysML models and diagrams.

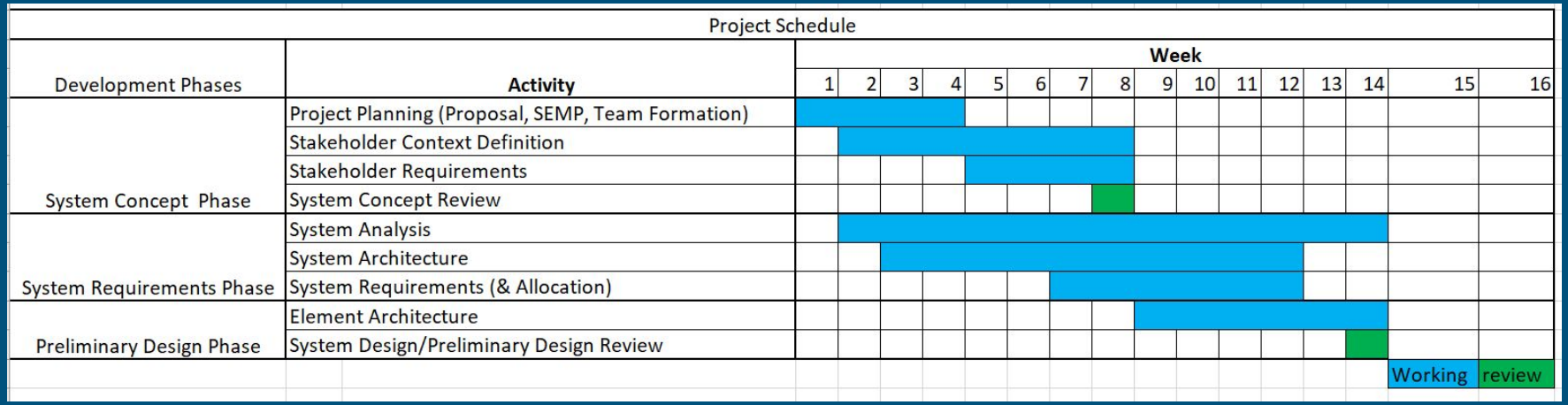
# Next Steps

- Obtain System Development Approval (SDA)
- Stakeholders’ Requirements Document
- System-Level Architecture
- System Requirements Document
- RAM Performance Analysis
- Project Trade-off Analysis
- Risk Analysis
- Preliminary Design Review (PDR)

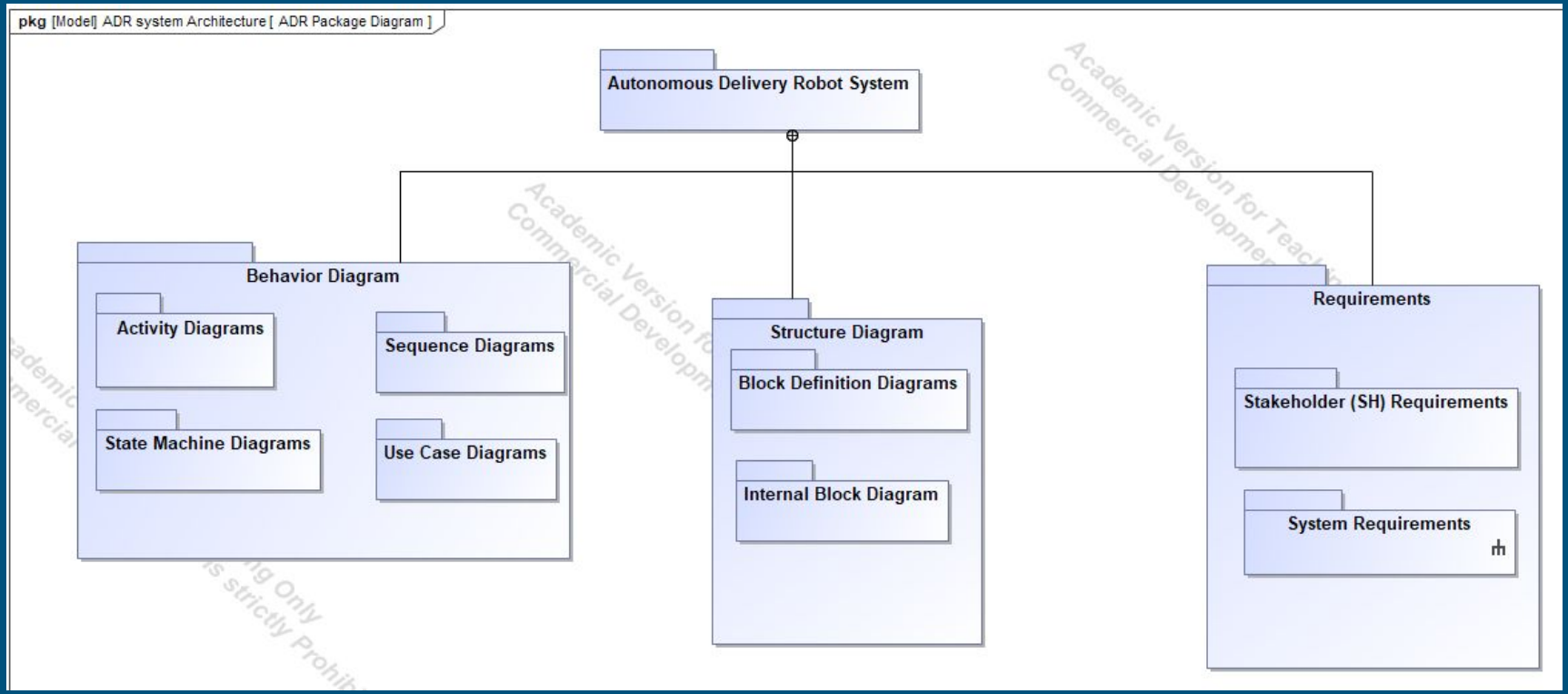
# Backup Slides

- Project Schedule
- Package Diagram
- Primary Use Case Narrative
- Sequence Diagram
- State Machine Diagram
- Complete Set of SH RDs
- Complete SH Reqs Table
- Activity diagrams for remaining use cases

# Project Schedule



# Package Diagram



# Primary Use Case Narrative

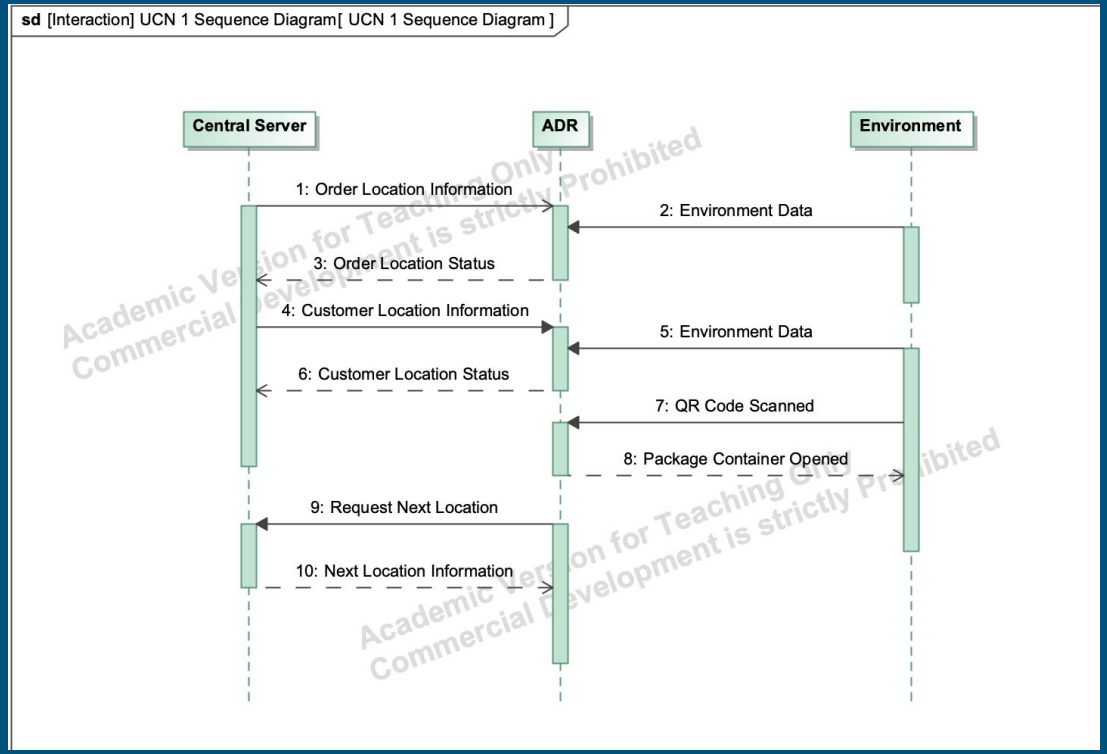
**Use Case Narrative: UCN1 Order Placement and Execution**

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

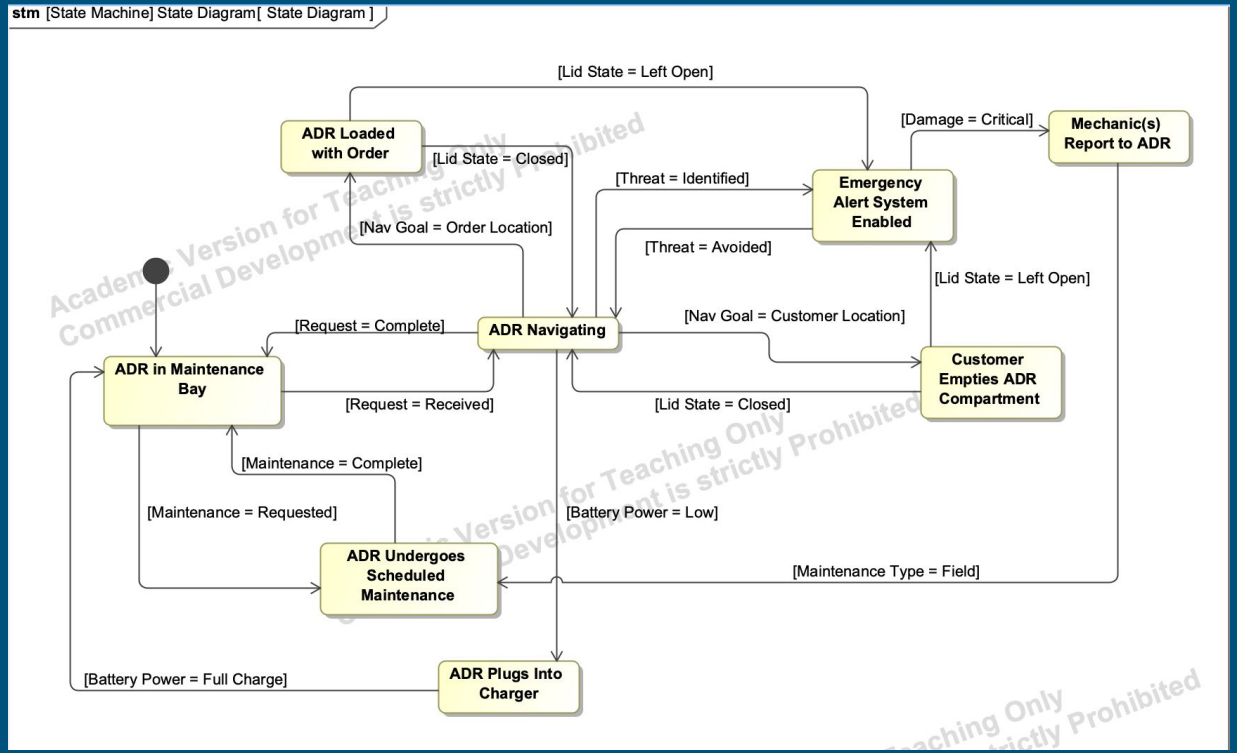
**Main Success Scenario:**

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.

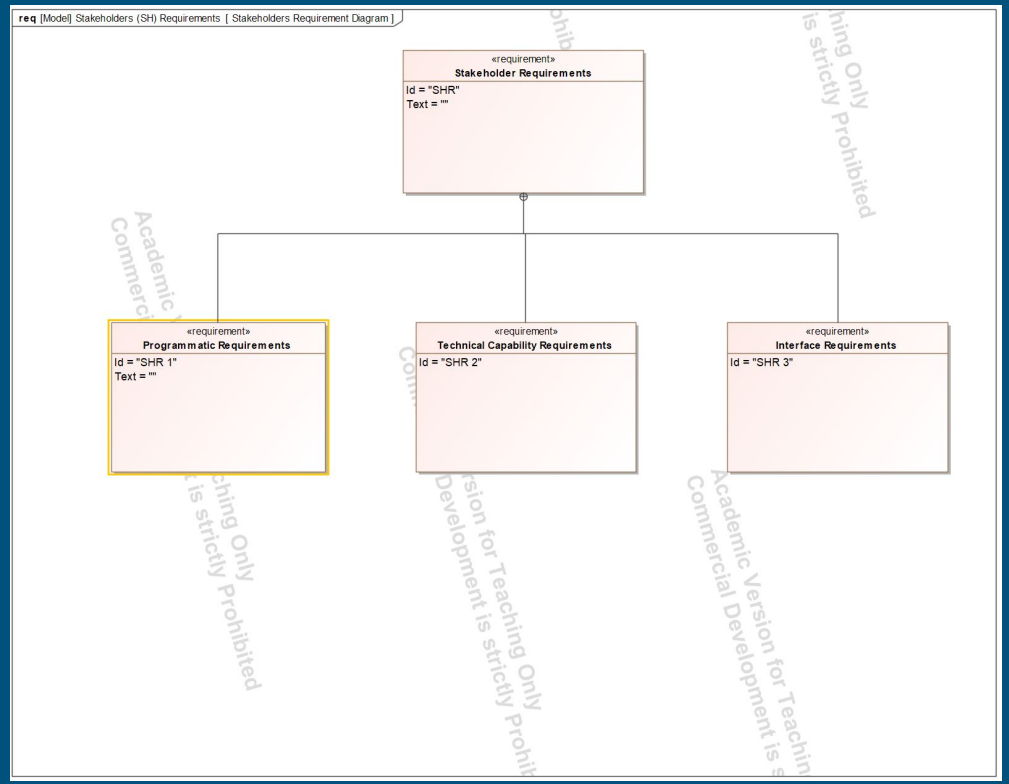
# Sequence Diagram



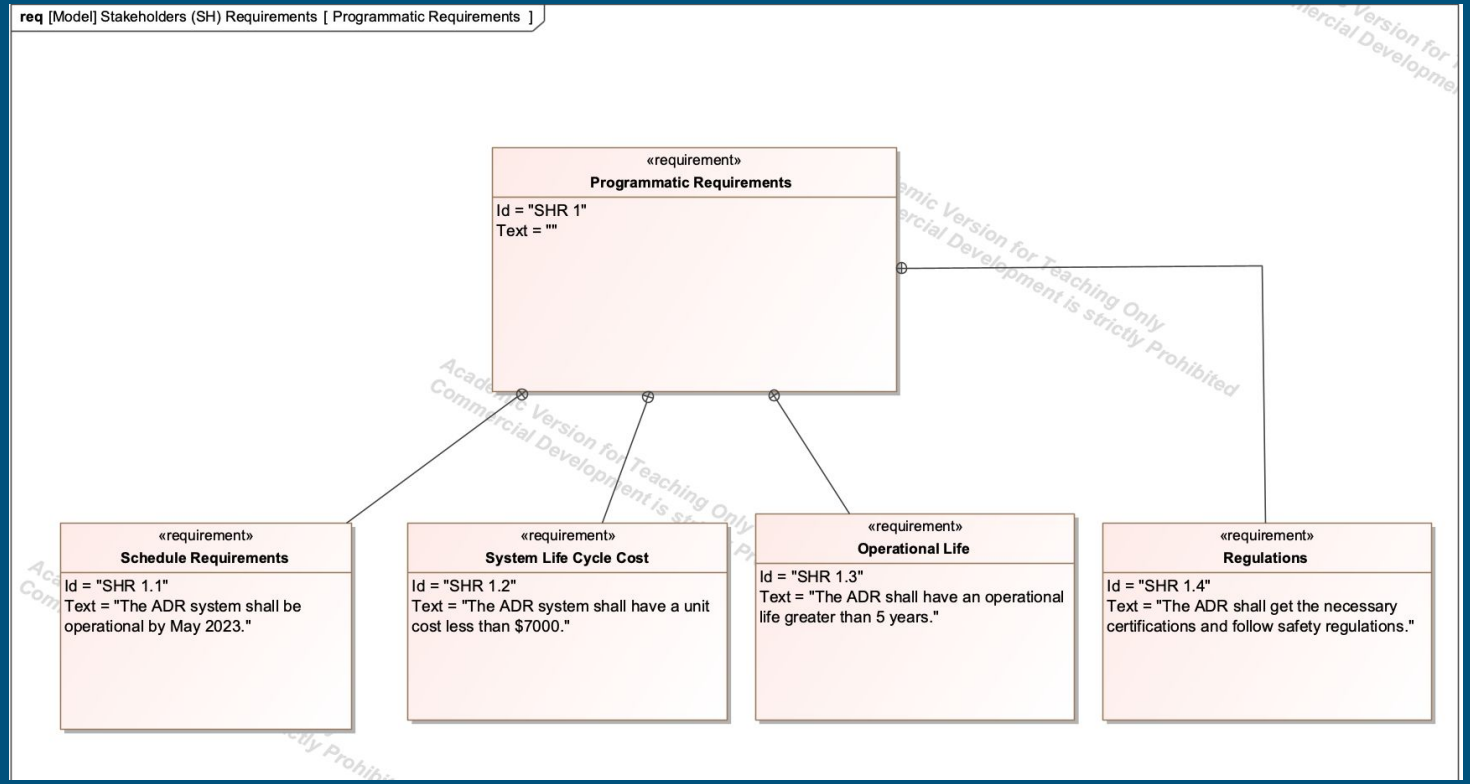
# State Machine Diagram



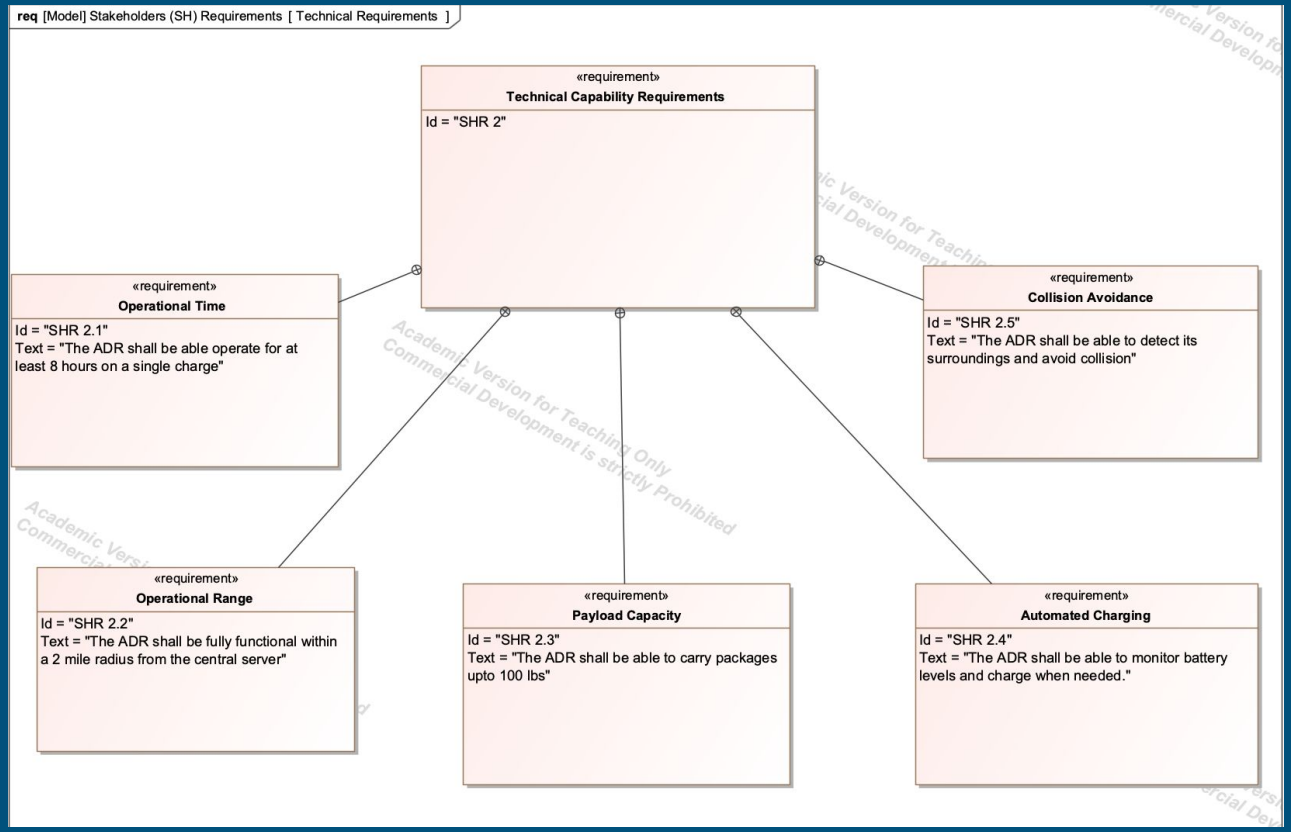
# Stakeholder Requirements Diagram



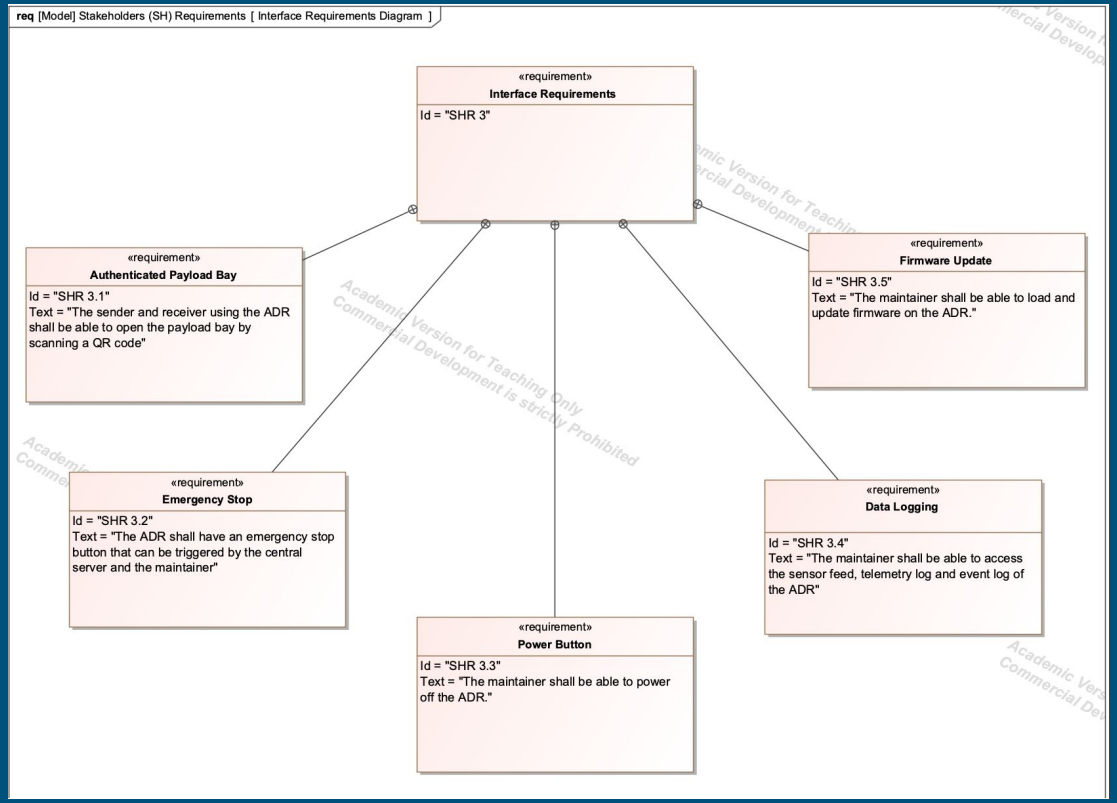
# Programmatic Requirements Diagram



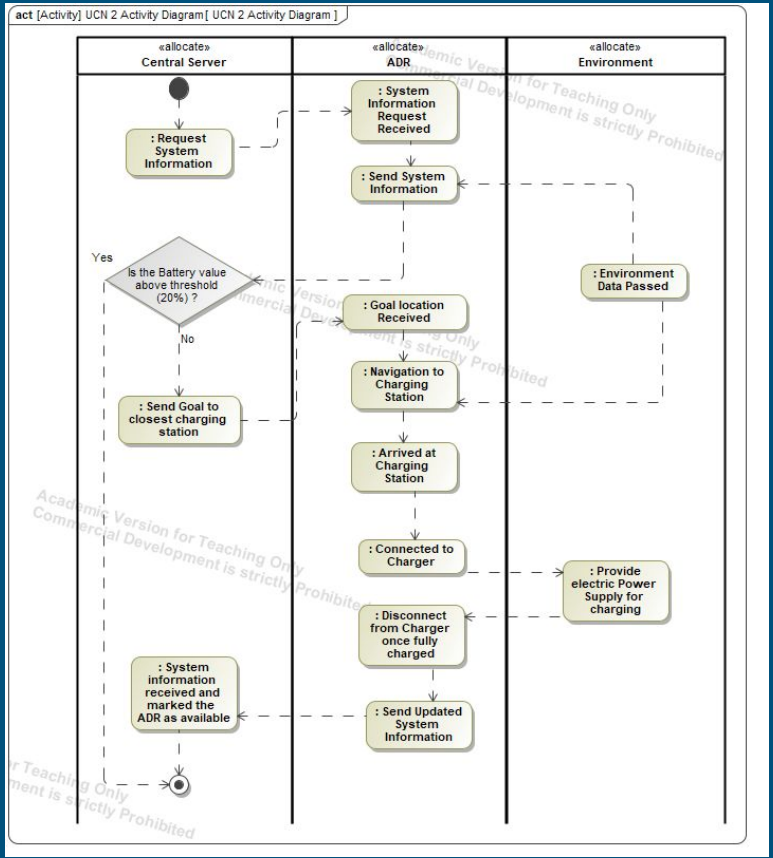
# Technical Requirements Diagram



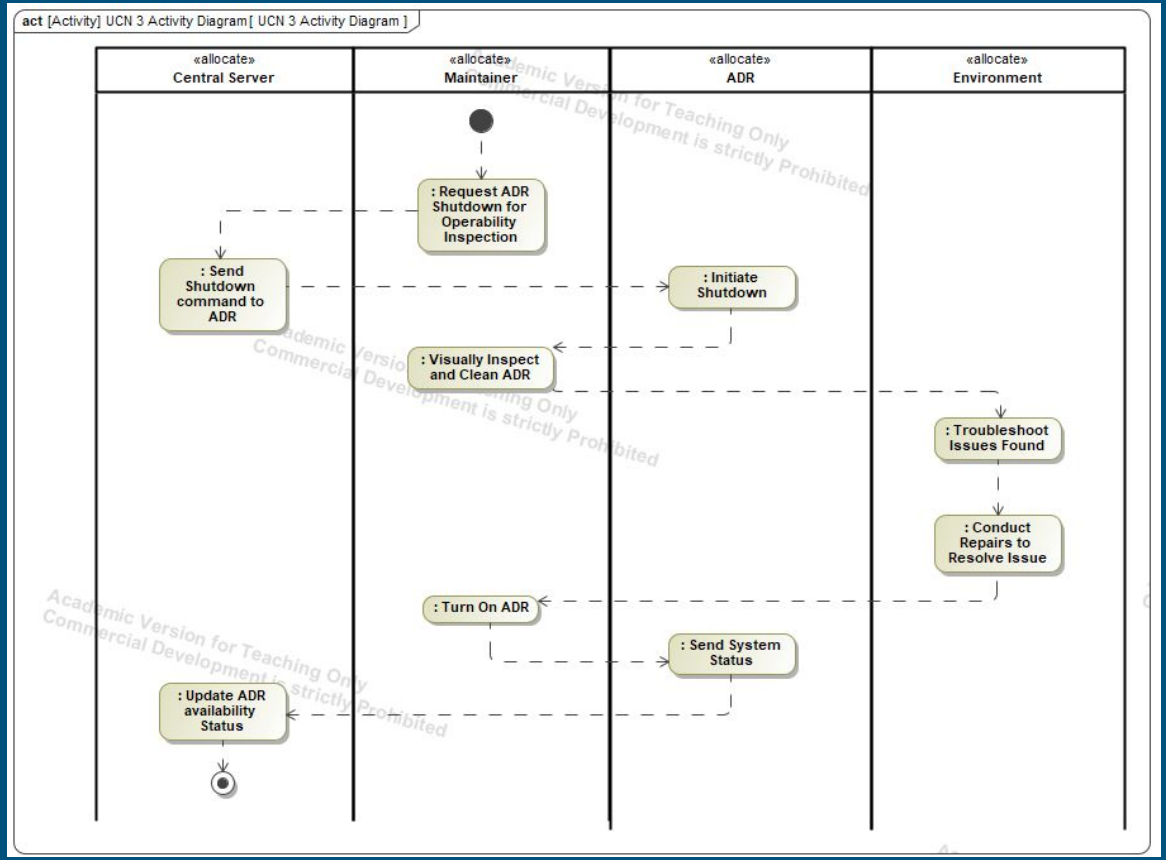
# Interface Requirements Diagram



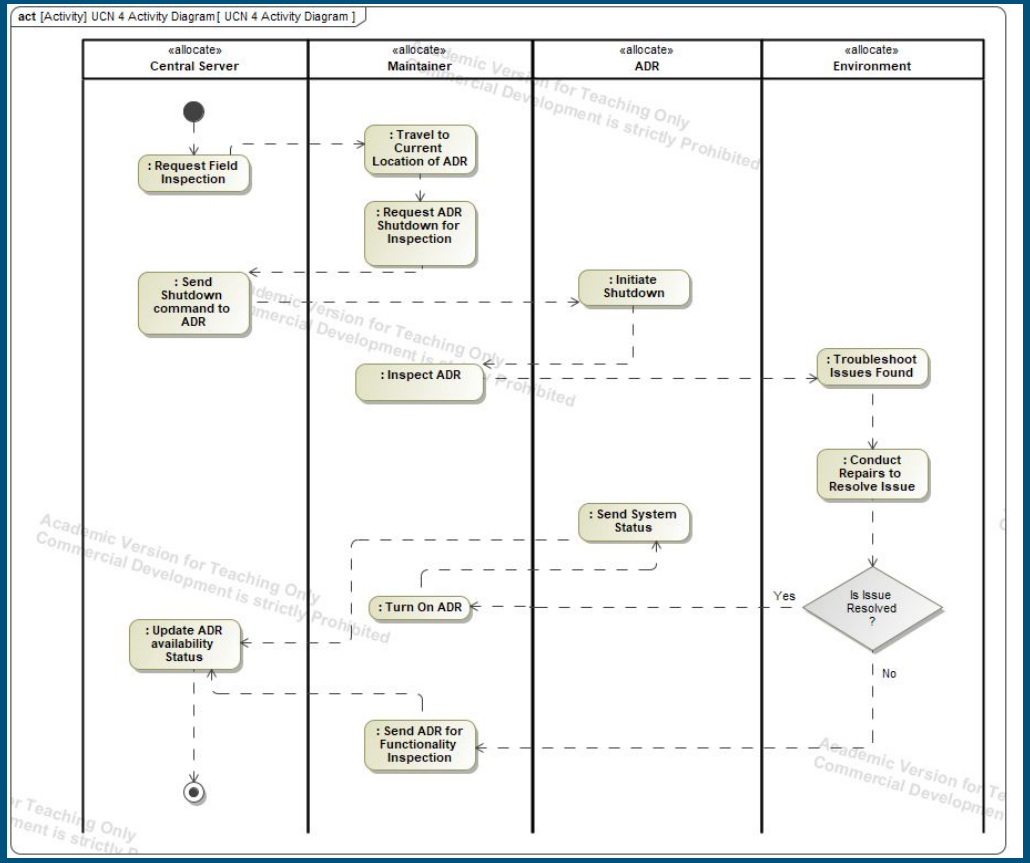
# Activity Diagram for  UCN2- Maintain system battery levels



# Activity Diagram for UCN3- Operability inspection & service



# Activity Diagram for UCN4- Field inspection & service



# Activity Diagram for UCN5- Functionality inspection & service