

# Preliminary Design Review: Autonomous Delivery Robot System

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Team 3  
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Molnar, Mukundhan Rajendiran (Muku)

# Outline

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- Stakeholders
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  - Requirements Allocation Matrix
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  - Pareto Surface/Analysis
  - MAVF Analysis & Weighting
  - Recommendation
- Risk Analysis
- Conclusions
  - Insights
  - Next Steps
- Backup Slides

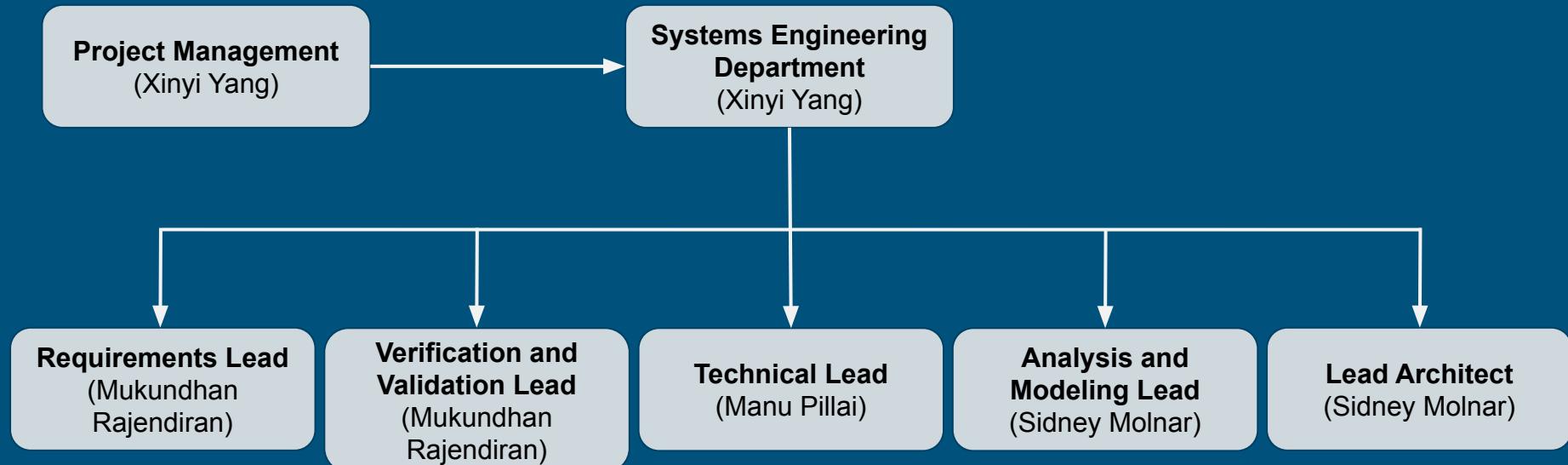
# Briefing Purpose

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- Evaluate scope
- Evaluate System-level Architecture Diagrams
- Define Stakeholder and System Requirements
- Receive approval of the Preliminary Design to enter Critical Design Phase
- Receive feedback to improve the design as we enter the Critical Design Phase

# Team & Team Responsibilities

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# Team Responsibilities

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**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

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

# Statement of Need

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- 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

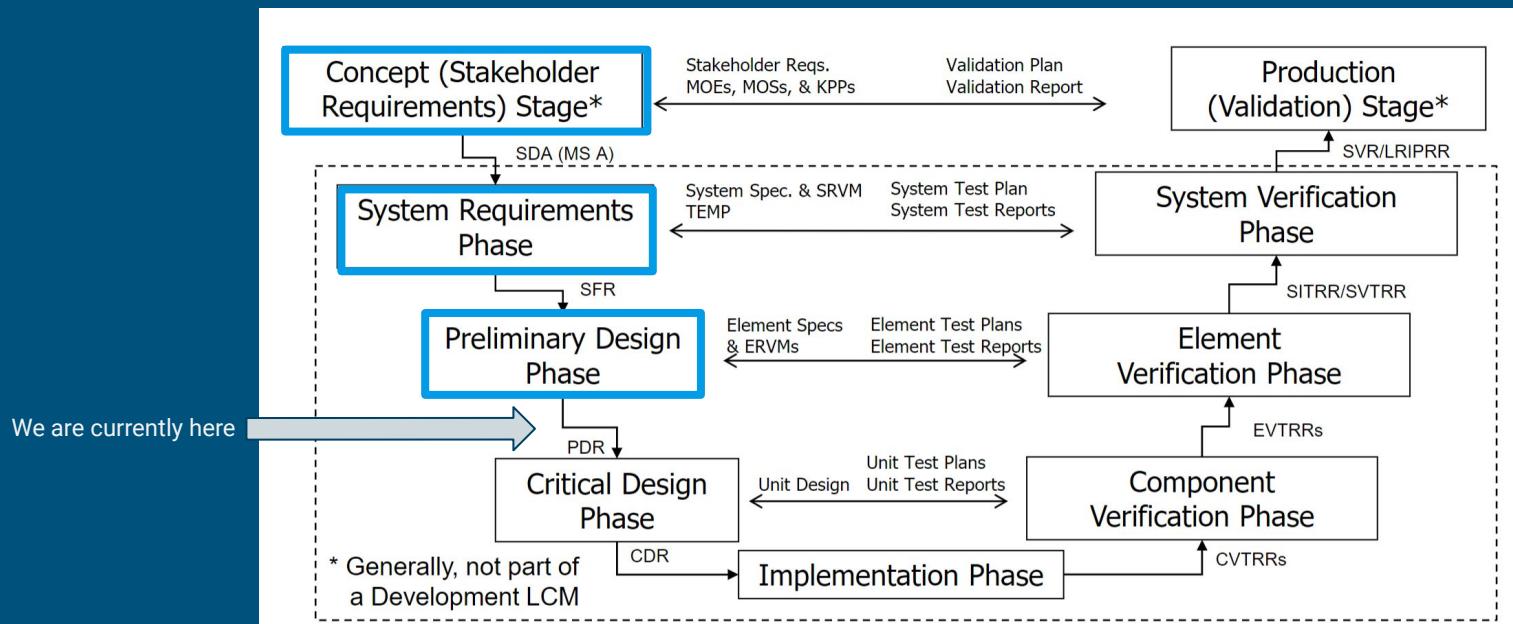
Capability I.D.	Capability	Priority
C1.1	Detect sidewalks, roads, pedestrian crossings, and road signs.	1
C1.2	Detect Motor vehicles, pedestrians, cyclists, animals, and similar dynamic obstacles.	2
C1.3	Detect plants, trees, buildings, railings, and similar static obstacles.	3
C1.4	Detect and identify 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)

<b>Cap ID</b>	<b>Attributes</b>	<b>Metric</b>	<b>MOE ID</b>	<b>Definition</b>	<b>Threshold Value (units)</b>	<b>Objective Value (units)</b>
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

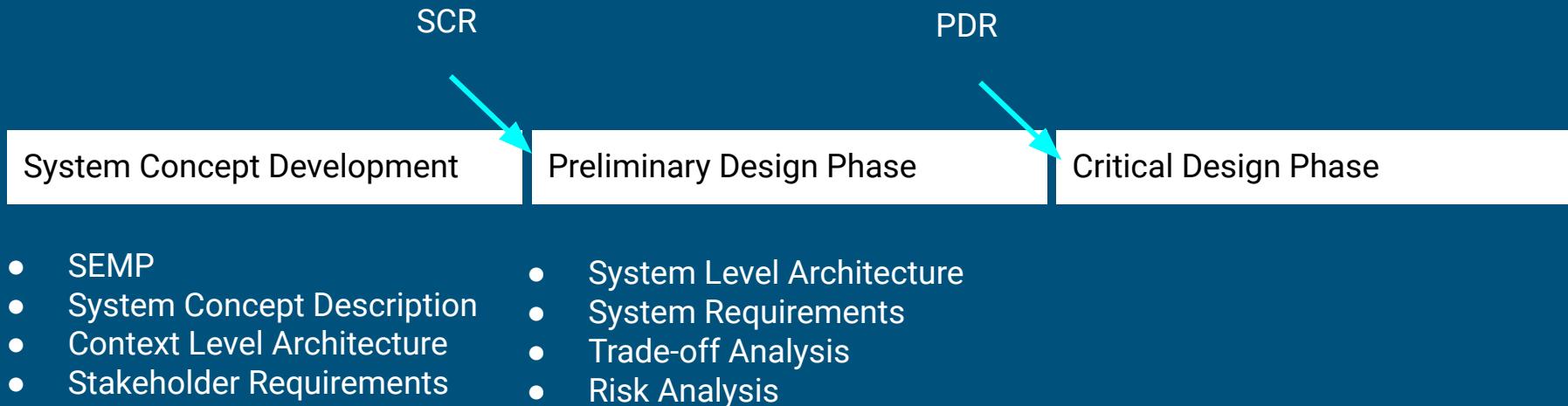
# Project Development Life Cycle Model

V Development Life Cycle Model (LCM)



# Project Development Scope and Status

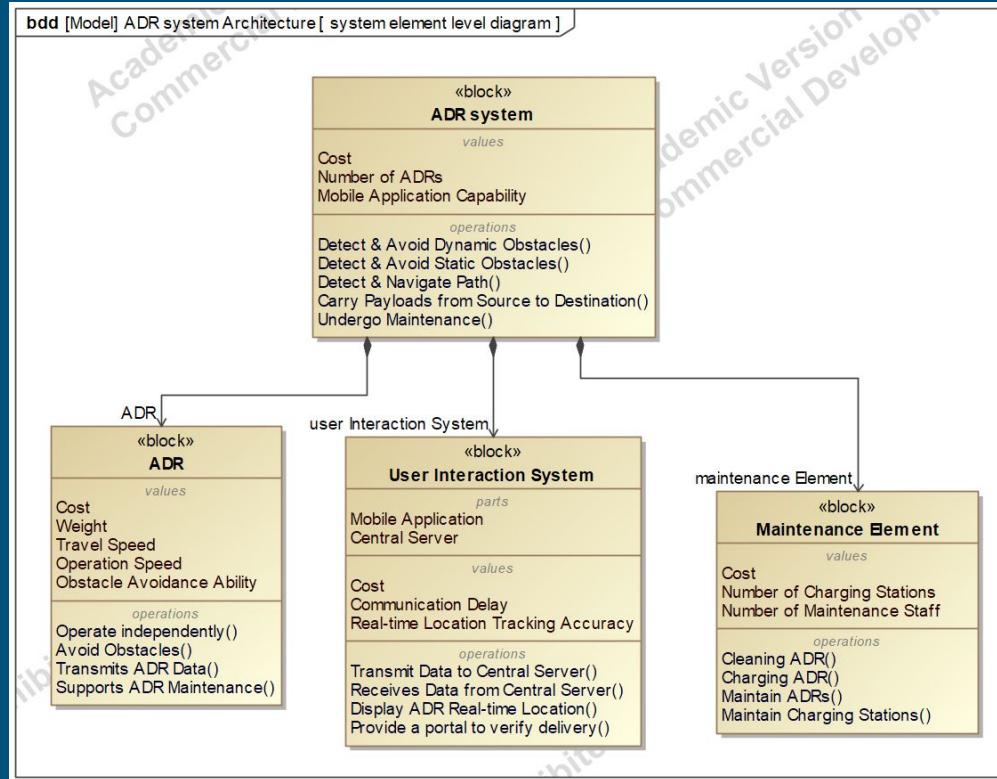
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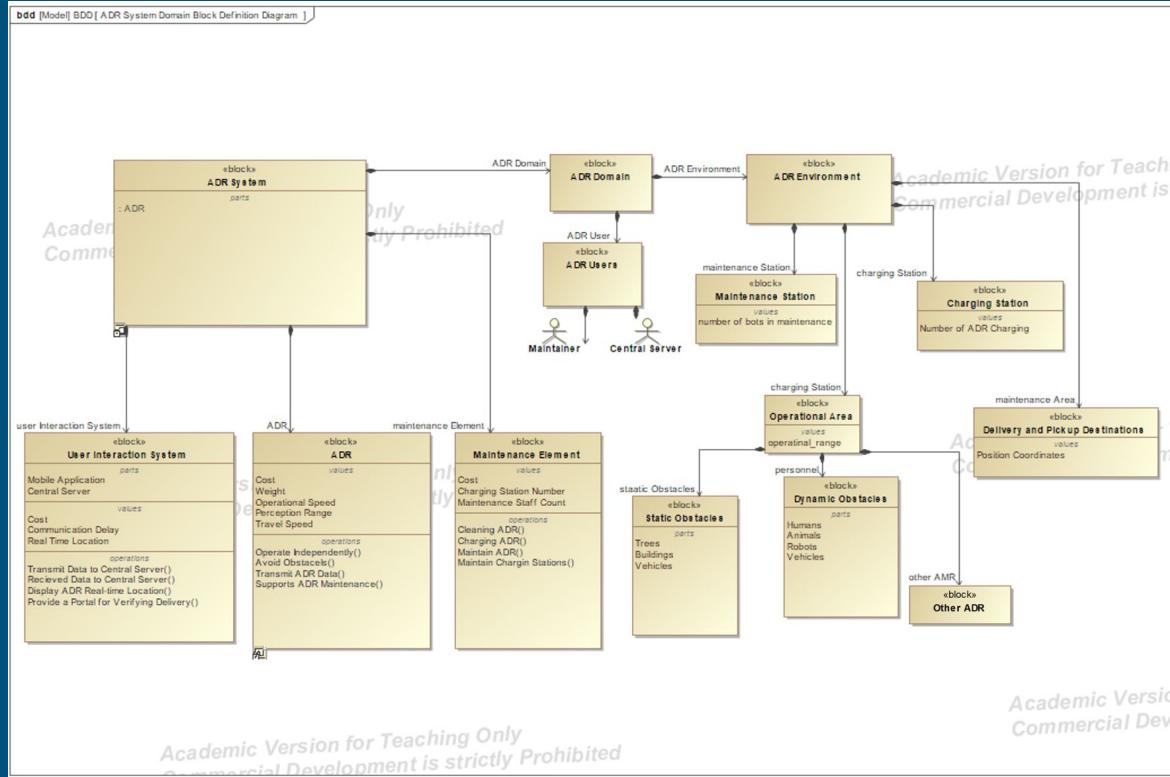
# (System-Level) System Architecture:

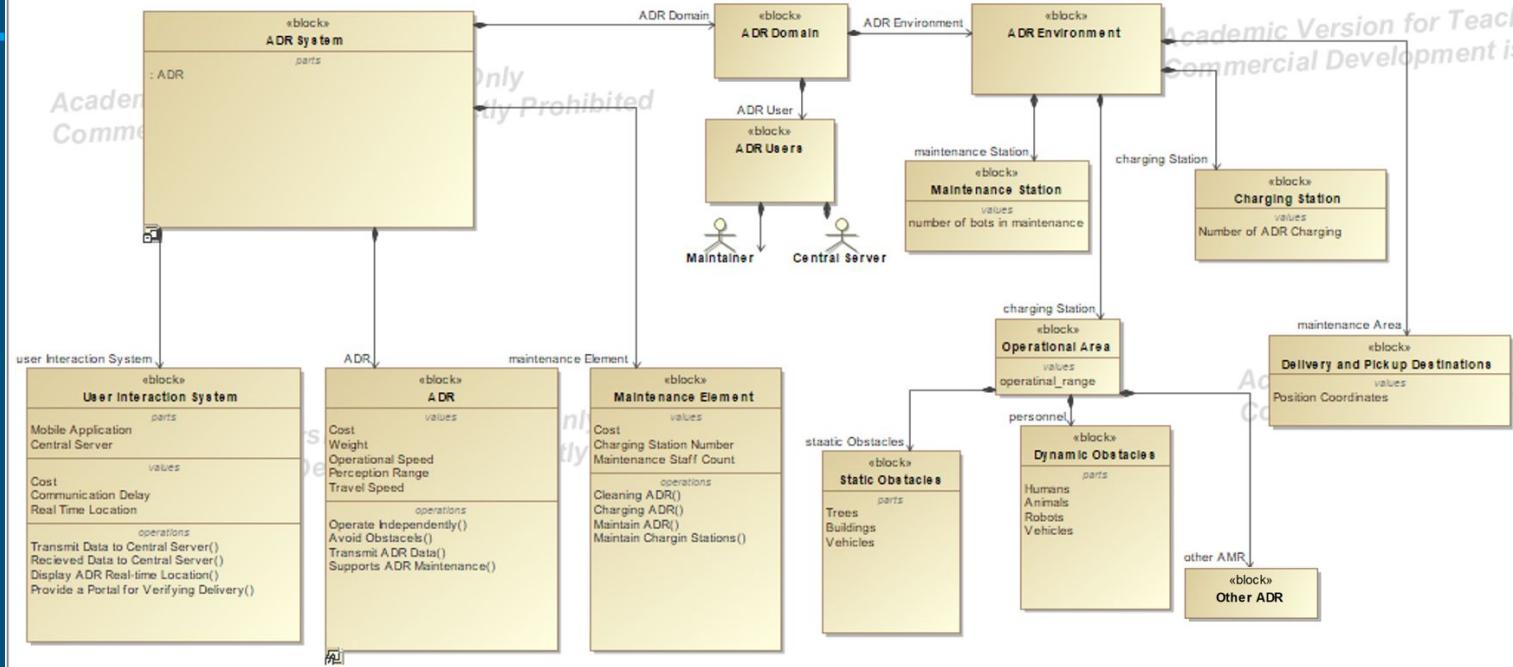
- System Concept
    - Domain Definition Block Definition Diagram (BDD)
    - System Context Internal Block Diagram (IBD)
    - System-Level Block Definition Diagram (BDD)
    - System-Level Internal Block Diagram (IBD)
    - Element-Level Block Definition Diagram (BDD)
  - System Operational Concept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



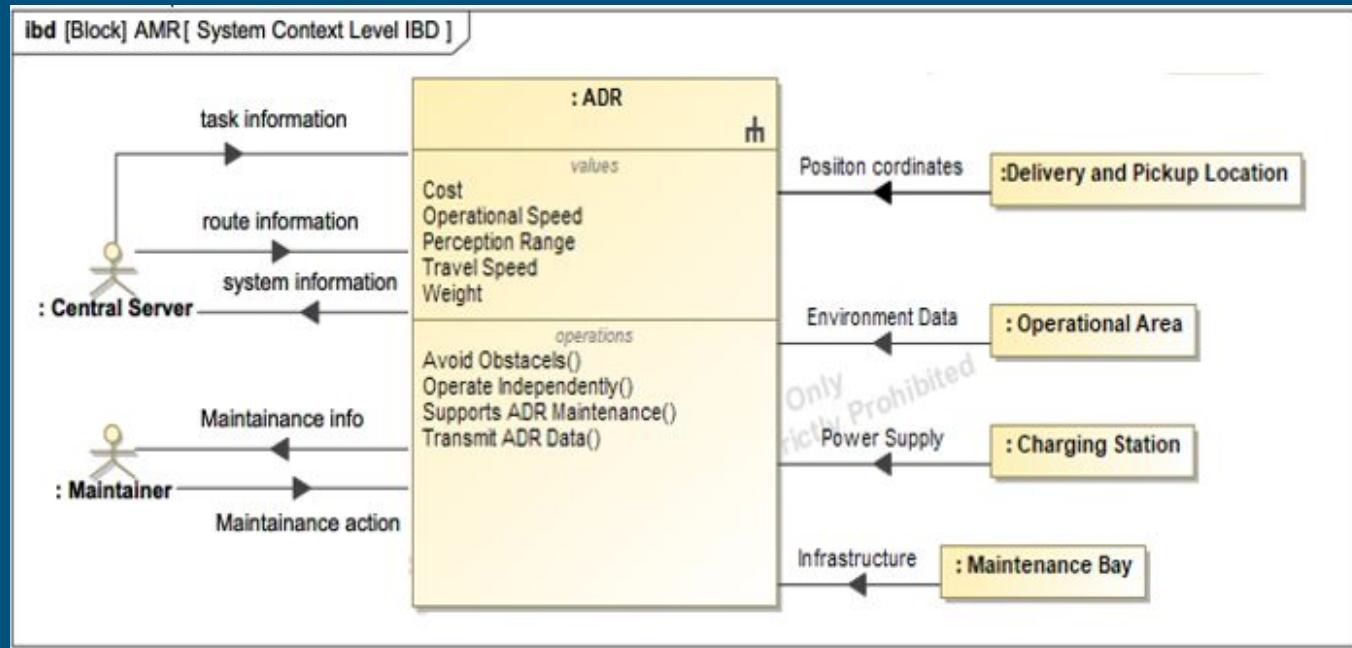
# Domain Definition Block Definition Diagram



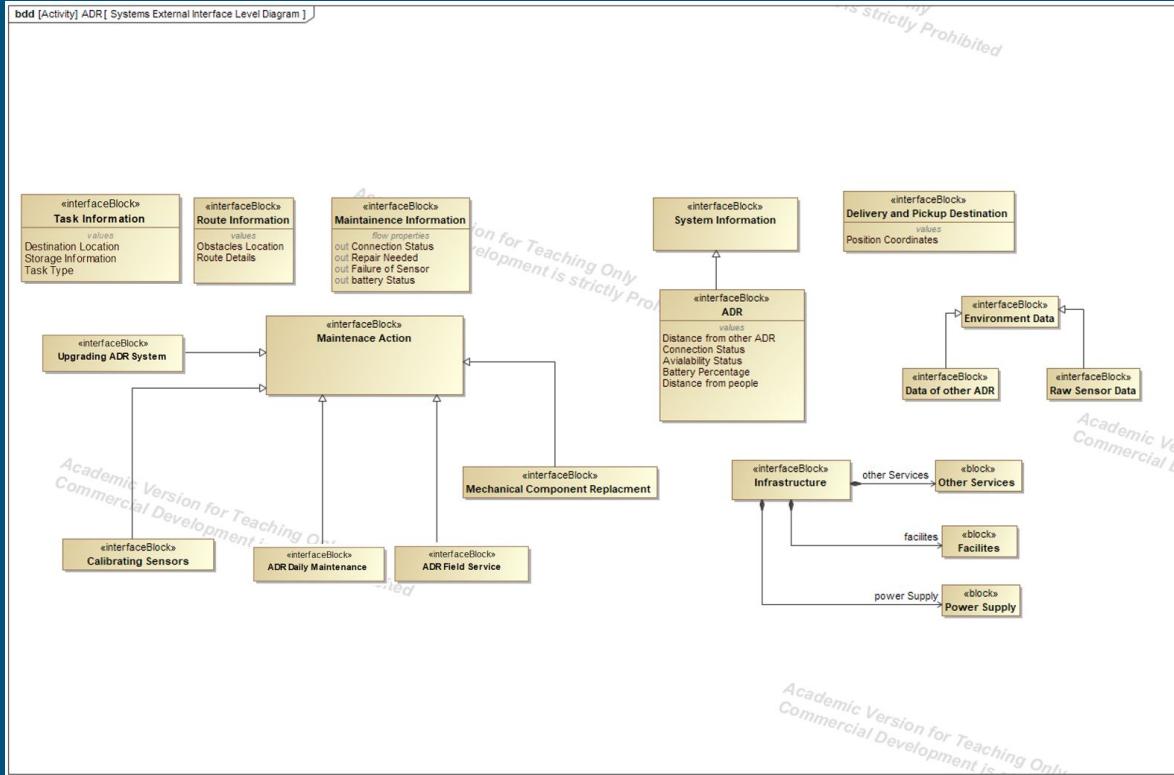


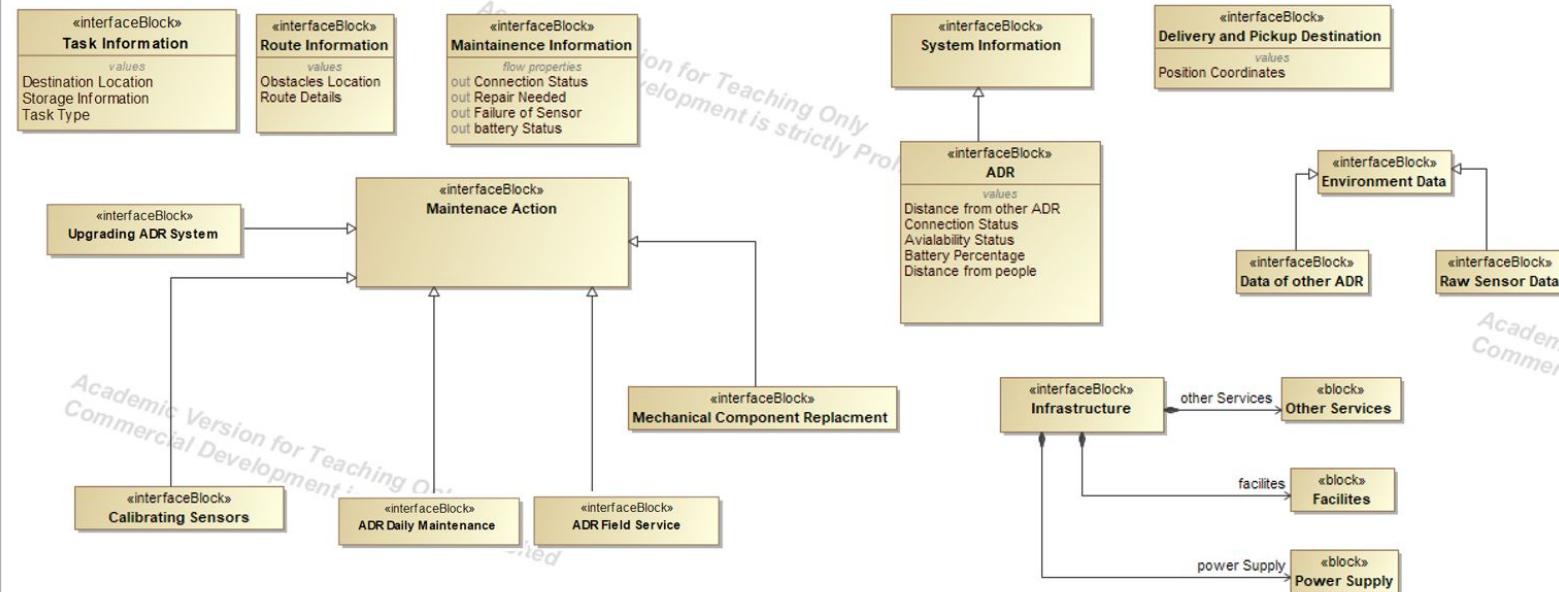
Academic Version for Teaching Only  
Commercial Development is strictly Prohibited

# System Context Internal Block Diagram

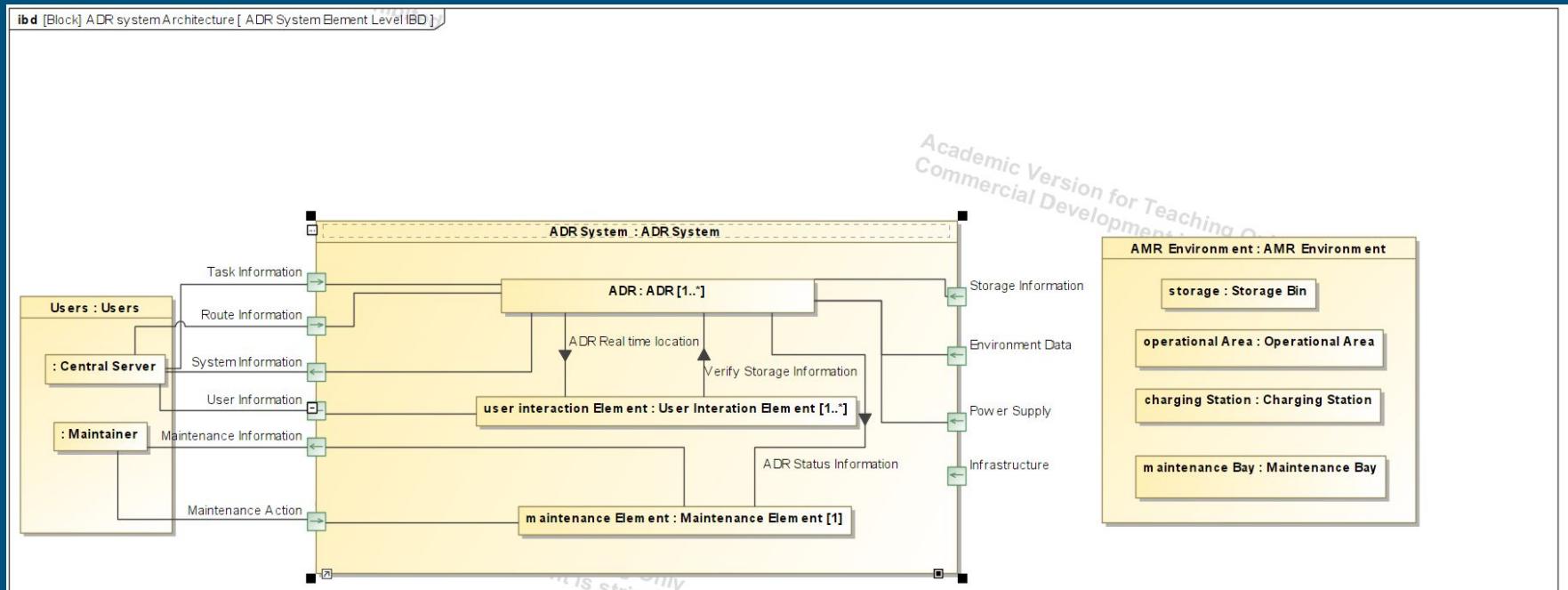


# System-Level Block Definition Diagram



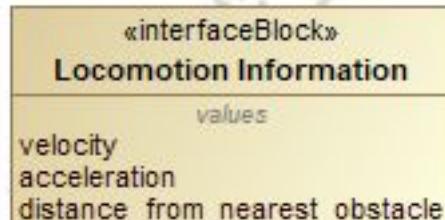
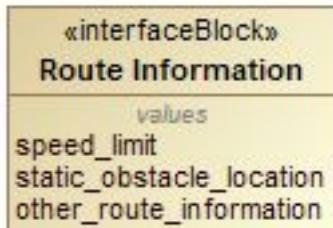
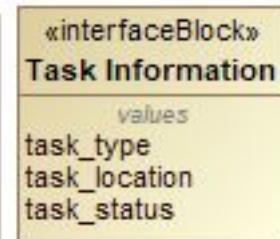
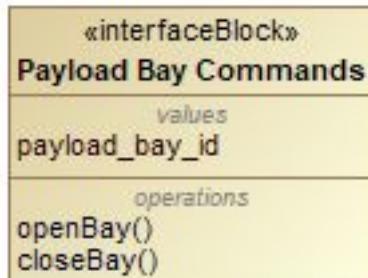
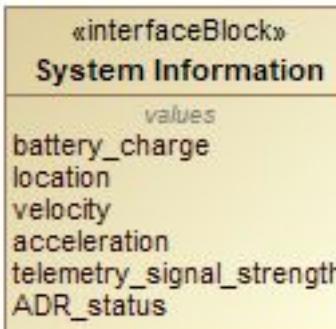


# System-Level Internal Block Diagram (IBD)



# Element Level Block Definition Diagram

bdd [Package] Block Definition Diagrams [ System Internal Interface BDD ]

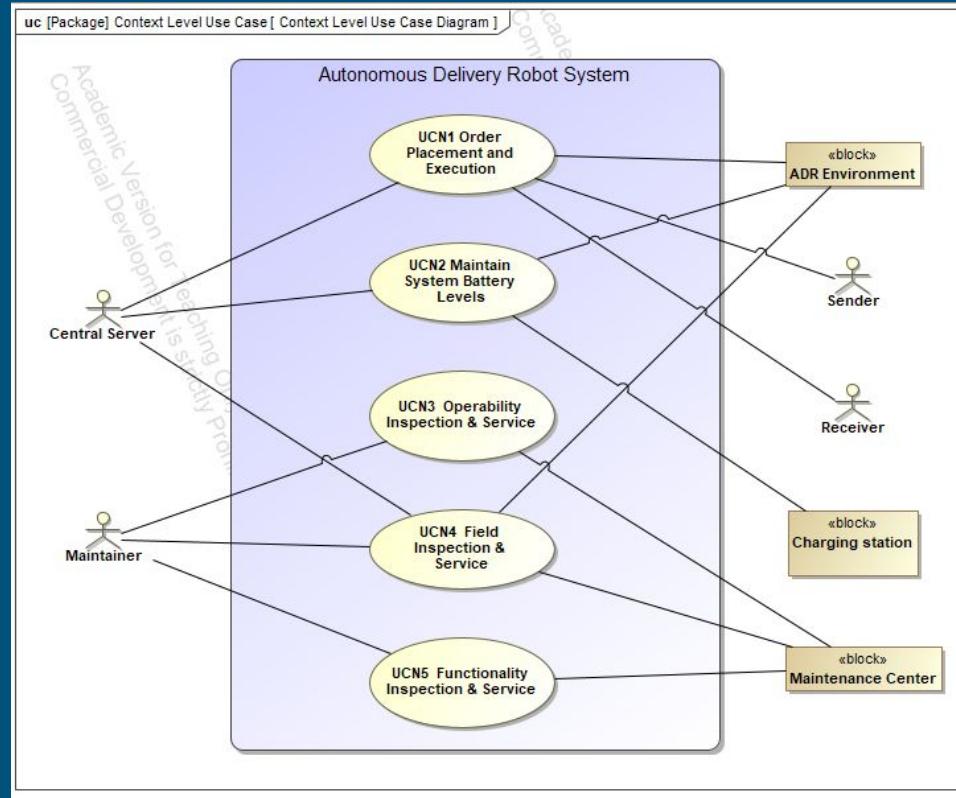


# System Operational Concept

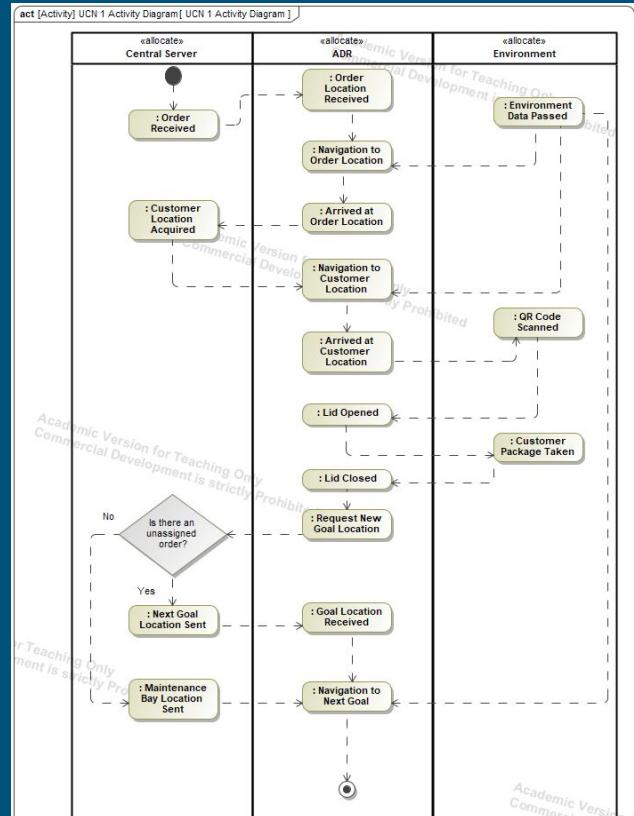
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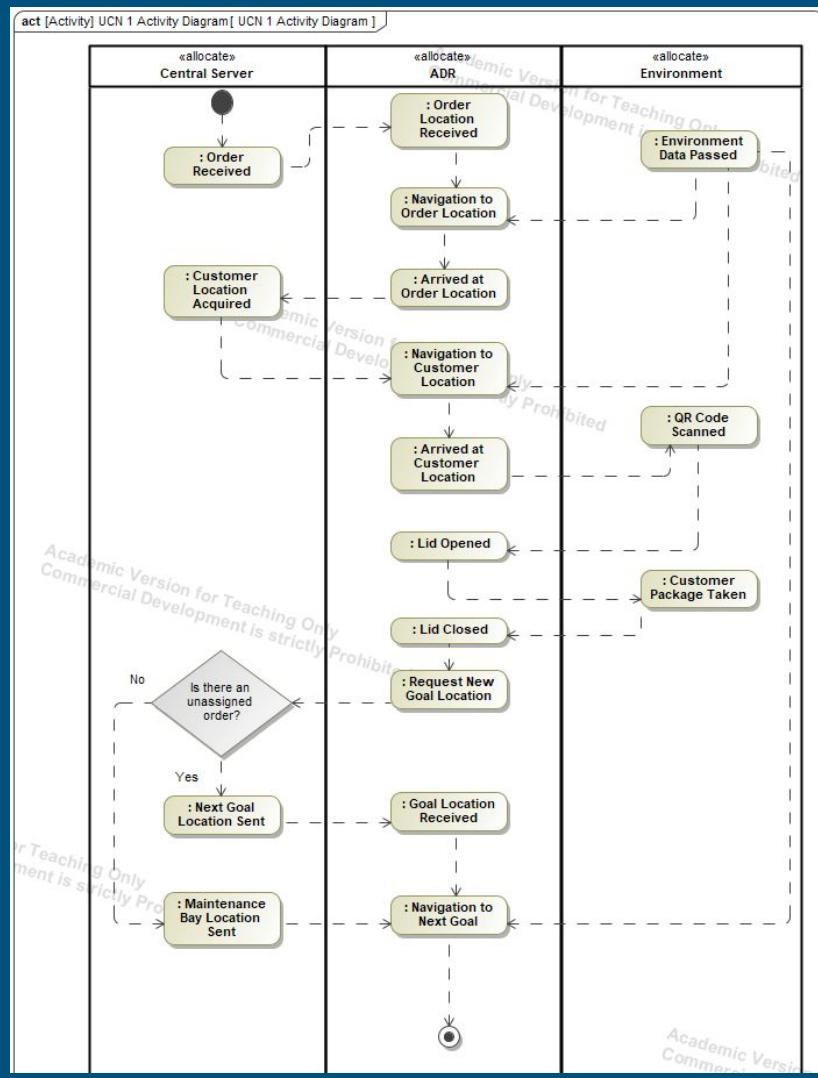
- Users: Faculty, Staff, and Students on large university campuses
- Orders placed on customer's app (UberEats, GrubHub, etc.)
- ADR navigates to order location before navigating to user location
  - Static and dynamic obstacle avoidance
  - Inclement weather conditions
- Payloads containing orders may 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





# 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

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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

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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

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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.

# System Requirements

- Requirements
    - Required States and Modes
    - System Capability Requirements
    - System External Interface Requirements
    - System Internal Interface Requirements
    - Design Constraints
  - Requirements Verification Matrix
  - Requirements Trace Matrix
  - Requirements Allocation Matrix
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# Capability Requirements

Requirement Number	Descriptions
3.2.1	Sensor System Requirements
3.2.1.1	Optical Sensing Requirements
3.2.1.1.1	The ADR shall detect sidewalks, roads, pedestrian crossings, and road signs
3.2.1.1.2	The ADR shall detect Motor vehicles, pedestrians, cyclists, animals, and similar dynamic obstacles
3.2.1.1.3	The ADR shall detect plants, trees, buildings, railings, and similar static obstacles.
3.2.1.1.4	The ADR shall detect and identify other ADRs
3.2.1.1.5	The ADR shall detect every static and dynamic obstacle in its line of sight within a distance of 165 ft
3.2.1.2	Global Positioning System Sensing Requirements
3.2.1.2.1	The ADR shall detect its Global Positioning System (GPS) coordinates with 4 ft accuracy
3.2.1.3	Proximity Sensing Requirements
3.2.1.3.1	The ADR shall detect and identify every entity in near proximity of 4ft.
3.2.2	Locomotion System Requirements
3.2.2.1	The ADR shall have a maximum speed of 15 mph
3.2.2.2	The ADR shall lift a maximum payload of 100 lbs
3.2.2.3	The ADR shall have a turning radius of 2.5 ft
3.2.2.4	The ADR shall have a turning speed of 0.785 rad/sec
3.2.3	Computing System Requirements
3.2.3.1	The ADR shall process information from the optical sensors, GPS sensors, and proximity sensors to make navigational decisions.
3.2.4	Communication System Requirements
3.2.4.1	The ADR shall use 915 MHz for its communication with the central server
3.2.4.2	The ADR shall have a 4G LTE (Long-Term Evolution) cellular connectivity for redundant communication with the central server
3.2.4.3	The ADR shall have two long range omnidirectional 915 Mhz antennas
3.2.4.4	The ADR shall have an omnidirectional 4G LTE antenna
3.2.4.5	THE ADR shall have a communication range of 2 miles
3.2.5	Power System Requirements
3.2.5.1	The ADR shall have an operational time of 8 hours on a single charge
3.2.5.2	The ADR shall have a sensor to measure battery voltage and calculate battery percentage
3.2.5.3	The ADR shall have temperature sensors for its battery packs

# Capability Requirements

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Requirement Number	Descriptions
3.2.5.4	The ADR shall enter into an overheat failure mode when the operating temperature rises over 115 F
3.2.6	Availability Requirements
3.2.6.1	The ADR shall have a steady state operational availability greater than 0.8
3.2.6.2	The sensor subsystem shall have a mean time between critical failures (MTBCF) greater than 2000 hours
3.2.6.3	The locomotion subsystem shall have a mean time between critical failures (MTBCF) greater than 1000 hours
3.2.6.4	The computing subsystem shall have a mean time between critical failures (MTBCF) greater than 2000 hours
3.2.6.5	The communication subsystem shall have a mean time between critical failures (MTBCF) greater than 2000 hours
3.2.6.6	The power subsystem shall have a mean time between critical failures (MTBCF) greater than 1500 hours
3.2.6.7	The ADR shall have a mean maintenance time less than 2 hours.
3.2.7	Accessibility Requirements
3.2.7.1	The ADR shall store a log containing time stamped history of each task performed
3.2.7.2	The ADR shall store maintenance history for each ADR element
3.2.7.3	The ADR shall provide access to all stored data to authorized users such as central server and maintainer.

# Data Dictionary

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Data Item	Abbreviation	Data Item Description	Units	Value Range
Task Information	TI	This data is sent from the central server to ADRs. This information consists of details about the task type, the task location and the task status (preparing, picking up, in delivery etc.).	N/A	N/A
Route information	RI	This data is sent from the central server to ADRs. This information consists of details about the current location speed limit of the ADR and static and dynamic obstacle location around the ADR.	N/A	N/A
Battery level	BL	It refers to the battery pack's state of charge.	Degree	0-100
System Information	SI	This data is sent from the ADRs to the central server. This information consists of details about the battery level, the location of the ADR, the velocity and acceleration of the ADR, telemetry signal strength of the ADR, and the status of the ADR (active in delivery/ inactive in delivery/ in maintenance).	N/A	N/A
Payload Bay ID	PB ID	Each Payload Bay has its unique QR code for the users to scan. Payload Bay ID is the unique QR code assigned to each payload Bay.	N/A	N/A
Order ID	OID	It is the unique number generated and assigned to the users when they placed a delivery order.	N/A	N/A
Payload Bay Information	PBI	This data is sent from the ADRs to the central server. This information consists of details about Payload Bay IDs, the payload weight and the lid of the Payload Bay status (open/closed), the number of occupied payload bay and the order ID for each Payload.	N/A	N/A
User Information	UI	This data is sent from the User Interaction system to the central server. This information consists of details about Order ID, name of the user, and the address of the user.	N/A	N/A
Locomotion Information	LI	This data is sent from the ADR to the central server. This information consists of details about the velocity and acceleration of the ADR as well as the distance between the nearest obstacle and the ADR.	N/A	N/A
Battery Health Information	BHI	This data is sent from the ADR to the central server. This information consists of details about the health of the battery pack on ADRs. This data is for maintenance purposes to see if the battery packs need to be replaced.	N/A	N/A
Malfunctioning Detection	MD	The operating status defines the ADRs current operating state. This state could be available/inspection/busy.	N/A	N/A
Connection Status	CS	The connection status refers to the ADRs connection to the network. It can be verified by pinging the central server.	Binary (on or off)	1 or 0

# Data Dictionary

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Data Item	Abbreviation	Data Item Description	Units	Value Range
Audio Signal	AS	The audio feedback refers to the buzzer of the ADR that is used to dissipate information regarding collision avoidance.	N/A	N/A
Visual Signal	VS	The visual feedback refers to the LED lights on the ADR that are used to dissipate information regarding operating status and states such as Idle, Available, Sensing and Failure.	N/A	N/A
Confirmation Commands	CC	The confirmation commands refer to the actions the user interaction system needs to take which the users need to verify the package in the payload bay.	N/A	N/A
Payload Bay Commands	PBC	The payload bay commands refer to the actions of the specific payload bay to open and close.	N/A	N/A
Daily Maintenance Check	DMC	The daily maintenance check refers to daily cleaning and charging of the ADR.	N/A	N/A
Field Service	FS	Field Service refers to the maintenance done on site without disturbing the tasks of the ADR. This usually consists of visual inspection and checks.	N/A	N/A
User Software Feedback	USF	The user software feedback refers to the data collected from the user reviews on the ADR software system using the user interaction system.	N/A	N/A
Cyber Security Checks	CSC	Cyber Security Checks refer to the testing performed to check if there are any vulnerabilities on the ADR system to avoid vicious attacks on the user information.	N/A	N/A

# Requirements Verification Matrix ( RVM )

System Req ID	System Req Title	Verification Method	Method Description	System Validation Test	Syst Valiation TRR Date	System Verifaction Test	Sys Verification TRR Date
S3.0	Provide ADR Capability	Test		x	TBD	x	TBD
S3.1	Provide ADR States & Modes	Test		x	TBD	x	TBD
S3.2	Provide ADR Capabilities	Test		x	TBD	x	TBD
S3.2.1.1	Optical Sensing	Test		x	TBD	x	TBD
S3.2.1	Sensor System	Test		x	TBD	x	TBD
S3.2.1.1.1	Roadway Detections	Test & Analysis	The ADR shall detect sidewalks, roads, pedestrian crossings, and road signs.				
S3.2.1.1.2	Traffic Detections		The ADR shall detect Motor vehicles, pedestrians, cyclists, animals, and similar dynamic obstacles	x	TBD	x	TBD
S3.2.1.1.3	Static Obstacle Detection	Test & Analysis	The ADR shall detect plants, trees, buildings, railings, and similar static obstacles.				
S3.2.1.1.4	ADR Detection		The ADR shall detect and identify other ADRs	x	TBD	x	TBD
S3.2.1.1.5	Minimum Detection Distance	Test & Analysis	The ADR shall detect every static and dynamic obstacle in its line of sight within a distance of 165 ft	x	TBD	x	TBD

Complete RVM in backup slides

# Requirements Verification Matrix ( RVM )

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System Req ID	System Req Title	Verification Method	Method Description	System Integration Test	System Intergration TRR Date	System Element Verification Test	System Element Verification TRR Dates
S3.0	Provide ADR Capability	Test		x	TBD	N/A	N/A
S3.1	Provide ADR States & Modes	Test		x	TBD	N/A	N/A
S3.2	Provide ADR Capabilities	Test		x	TBD	N/A	N/A
S3.2.1.1	Optical Sensing	Test		x	TBD	x	TBD
S3.2.1	Sensor System	Test		x	TBD	x	TBD
S3.2.1.1.1	Roadway Detections	Test & Analysis	The ADR shall detect sidewalks, roads, pedestrian crossings, and road signs.				
S3.2.1.1.2	Traffic Detections		The ADR shall detect Motor vehicles, pedestrians, cyclists, animals, and similar dynamic obstacles	x	TBD	x	TBD
S3.2.1.1.3	Static Obstacle Detection	Test & Analysis	The ADR shall detect plants, trees, buildings, railings, and similar static obstacles.				
S3.2.1.1.4	ADR Detection		The ADR shall detect and identify other ADRs	x	TBD	x	TBD
S3.2.1.1.5	Minimum Detection Distance	Test & Analysis	The ADR shall detect every static and dynamic obstacle in its line of sight within a distance of 165 ft	x	TBD	x	TBD

Complete RVM in backup slides

# Requirements Traceability Matrix (RTM)

System Req ID	System Req Title	SH 2 Performance Requirements	SH 2.1 Operation Time	SH 2.2 Operational Range	SH 2.3 Payload Capacity	SH 2.4 Automated Charging	SH 2.5 Collision Avoidance
S3.0	Provide ADR Capability	1					
S3.1	Provide ADR States & Modes	1					
S3.2	Provide ADR Capabilities	1			1		
S3.2.1	Sensor System	1					1
S3.2.1.1	Optical Sensing	1					1
S3.2.1.1.1	Roadway Detections	1					1
S3.2.1.1.2	Traffic Detections	1					1
S3.2.1.1.3	Static Obstacle Detection	1					1
S3.2.1.1.4	ADR Detection	1					1
S3.2.1.1.5	Minimum Detection Distance	1		1			1

Complete RTM in backup slides

# Requirements Traceability Matrix (RTM)

System Req ID	System Req Title	SH 3 External Interface Requirements	SH 3.1 User Interface Requirements	SH 3.2 External System Interface Requirements	SH 4 Specialty Engineering Requirements	SH 5 Functional Requirements	SH 5.1 Speed
S3.0	Provide ADR Capability						
S3.1	Provide ADR States & Modes						
S3.2	Provide ADR Capabilities						
S3.2.1	Sensor System					1	
S3.2.1.1	Optical Sensing					1	
S3.2.1.1.1	Roadway Detections					1	
S3.2.1.1.2	Traffic Detections					1	
S3.2.1.1.3	Static Obstacle Detection					1	
S3.2.1.1.4	ADR Detection					1	
S3.2.1.1.5	Minimum Detection Distance					1	

Complete RTM in backup slides

# Requirements Traceability Matrix (RTM)

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System Req ID	System Req Title	SH 5.2 Battery Capacity	SH 5.3 Dimensions	SH 5.4 Minimum Ground Clearance	SH 5.5 Climbing Inclination	Sum Chk
S3.0	Provide ADR Capability					1
S3.1	Provide ADR States & Modes					1
S3.2	Provide ADR Capabilities					2
S3.2.1	Sensor System					3
S3.2.1.1	Optical Sensing					3
S3.2.1.1.1	Roadway Detections				1	4
S3.2.1.1.2	Traffic Detections					3
S3.2.1.1.3	Static Obstacle Detection					3
S3.2.1.1.4	ADR Detection					3
S3.2.1.1.5	Minimum Detection Distance					4

Complete RTM in backup slides

# Requirements Allocation Matrix ( RAM )

System Req ID	System Req Title	ADR Element	UIS Element	Maintenance Element	Chk Sum
S3.0	Provide ADR Capability	N/A	N/A	N/A	
S3.1	Provide ADR States & Modes	N/A	N/A	N/A	
S3.2	Provide ADR Capabilities	N/A	N/A	N/A	
S3.2.1	Sensor System	1			1
S3.2.1.1	Optical Sensing	1			1
S3.2.1.1.1	Roadway Detections	1			1
S3.2.1.1.2	Traffic Detections	1			1
S3.2.1.1.3	Static Obstacle Detection	1			1
S3.2.1.1.4	ADR Detection	1			1
S3.2.1.1.5	Minimum Detection Distance	1			1

Complete RAM in backup slides

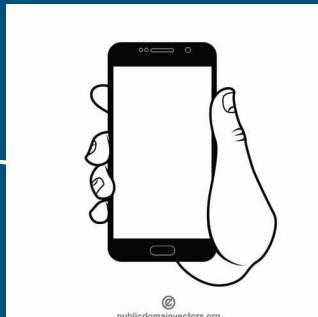
# Reference Design Concept

- Robot with obstacle avoidance capability, optimal operational speed and radius, and optimal battery life



## Central Server

- Central server to receive orders, monitor battery health, and alert maintenance requests



- Payloads to carry up to 100 lbs and to open respective compartment for a given order



- Mobile application used to provide order and customer locations using GPS features, and notify customer of order status

# Trade-off Analysis

- Objective
  - Design Option Factors & Decision (Design) Options
  - Pareto Surface/Analysis
  - MAVF Analysis & Weighting
  - Recommendation
-

# Objective

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The objective of the tradeoff analysis is to provide and recommended design options for ADR that meet the stakeholder's requirements and are efficient.

The metrics used for this analysis are cost and reliability are:

- 1) Minimize the cost per unit while meeting stakeholder requirements.

Metrics Used : Per -Unit cost ( USD/\$ )

- 2) Maximize reliability while meeting stakeholder requirements.

Metrics Used : Mean Time Between Failures - MTBF ( Hours )

# Design Option Factors & Decision (Design) Options

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- Design Approach : Platform Based
- Design Approach : Commercial Off The Shelf (COTS) products.

System	ID	Cost (USD/\$)	MTBF ( Hours )
Telemetry	ST1	400	160
	ST2	305	145
Propulsion	SP1	1735	84.5
	SP2	1765	102
Sensor	SS1	2200	139.5
	SS2	2305	149.5

# Pareto Frontier Analysis

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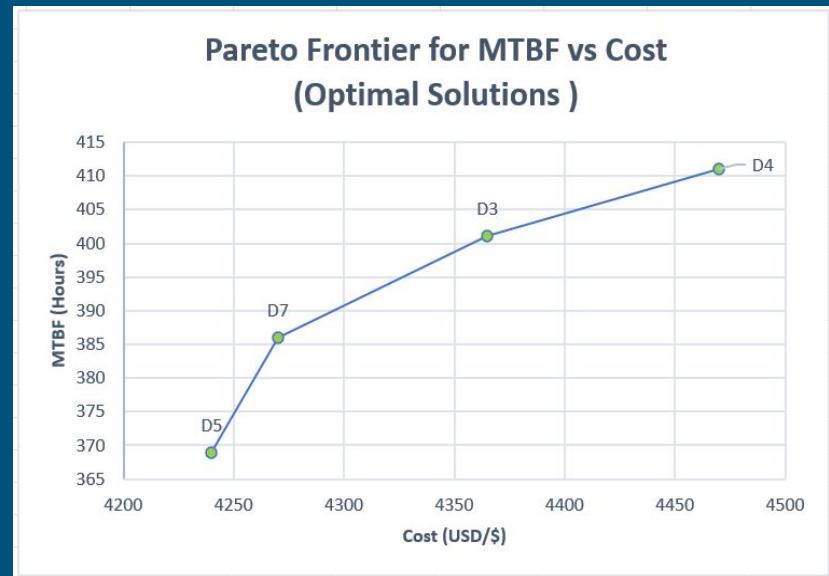
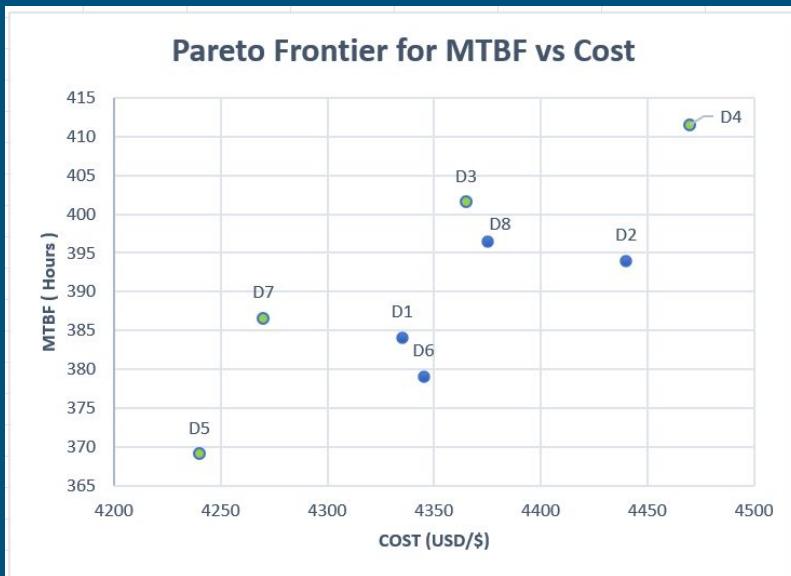
- Consists of the set of “solutions” to a problem that maximize the performance to a set of N performance metrics.
- It is used to find the Course of Actions (COAs) whose values for a set of performance metrics are “optimal”.

# Pareto Frontier Analysis

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Design ID	Design Options	Cost (USD/ \$)	MTBF (Hours)
D1	ST1,SP1,SS1	4335	384.00
D2	ST1,SP1,SS2	4440	394.00
D3	ST1,SP2,SS1	4365	401.50
D4	ST1,SP2,SS2	4470	411.50
D5	ST2,SP1,SS1	4240	369.00
D6	ST2,SP1,SS2	4345	379.00
D7	ST2,SP2,SS1	4270	386.50
D8	ST2,SP2,SS2	4375	396.50

# Pareto Frontier Analysis



# Multi-Attribute Value Function (MAVF) Analysis

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- In order to obtain the best possible solution (COAs) for your system, that reflect the relative importance of each metric, Multi-attribute Value Function Analysis (MAVF) on the Pareto Optimal Solutions is performed.
- To determine the weighting weights, Swing weighting method was used.
- Cost- C , Reliability - R

Cases	Cost (USD / \$)	MTBF (Hours)
Worst	4470	369.00
Worst C, Best R	4470	411.50
Best C, Worst R	4240	369.00

# Weighting

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	SH 1 Rank	SH 2 Rank	SH3 Rank	SH1 Weight	SH2 Weight	SH3 Weight
Worst	0	0	0			
Worst C, Best R	100	30	80	0.66	0.23	0.44
Best C, Worst R	50	100	100	0.33	0.76	0.55
Sum	150	130	180			

	SH1	SH2	SH3
WR	0.66	0.23	0.44
WC	0.33	0.76	0.55

- SH - Stakeholder
- WR- Reliability Weighted Values
- WC - Cost Weighted Values

# MAVF Analysis & Weighting

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Design ID	Cost (USD/\$)	MTBF (Hrs)	SVVF 1	SVVF 2	Multi Attribute Value Function ( MAVF)						
					av1	av2	Vc	Vr	SH1	SH2	SH3
D3	4365	401.5	0.456	0.764	0.654	0.522	0.586				
D4	4470	411.5	0	1	0.660	0.230	0.440				
D5	4240	369	1	0	0.330	0.760	0.550				
D7	4270	386.5	0.869	0.411	0.558	0.754	0.658				

# Formulae Used

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- Weights =  $R_i / \sum R_i$
- $V_c = (4470 - av_1) / 230$
- $V_r = (av_2 - 369) / 42.5$
- $V(av_1, av_2; w_1, w_2) = (w_c * V_c) + (w_r * V_r)$
- The rankings for reliability and cost are based on the needs of the Stakeholder 1,2 & 3







# Recommendation

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Using the results of the tradeoff analysis, the following Design Ids are recommended to the respective Stakeholders as they provide greatest value.

ID	Design Options	Cost (USD/ \$)	MTBF (Hours)	MAVF	Recommended To
D4	ST1,SP2,SS2	4470	411.50	0.660	SH1
D5	ST2,SP1,SS1	4240	369.00	0.760	SH2
D7	ST2,SP2,SS1	4270	386.50	0.658	SH3

# Next Steps

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- Obtain approval of Preliminary Design
- Begin the Critical Design phase based on recommendations from trade-off analysis
- Continue to assess risk as the project progresses
- Prepare unit design for implementation
- Introduce a plan for testing and verification procedures

# Risk Matrix

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We used a 5-level Risk Matrix.

		Risk				
Consequence	5	Medium	Medium	Med High	Very High	Very High
	4	Medium	Medium	Med High	Med High	Very High
	3	Med Low	Med Low	Medium	Med High	Med High
	2	Very Low	Med Low	Med Low	Medium	Medium
	1	Very Low	Very Low	Med Low	Medium	Medium
		1	2	3	4	5
Probability						

# Likelihood Table

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Likelihood	Rating	Technical Risks	Cost/Schedule Risks
	1	< 0.5%	< 20%
	2	0.5% to 1%	21% to 40%
	3	1% to 5%	41% to 60%
	4	5% to 10%	61% to 80%
	5	> 10%	> 80%

# Consequence Table

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		Severity				
Rating		1	2	3	4	5
Consequence Impact	Technical	< 5% utility loss	6% - 15% utility loss	16% - 50% utility loss	51%-75% utility loss	> 75% utility loss
	Schedule	Minimal to no impact	Segment schedule margin 5% to 25%	System schedule margin 5% to 25% or Segment schedule > 25%	System schedule margin 25% to 50%	System schedule margin > 50%
	Cost	< \$7350	\$7350 to \$7700	\$7700 to \$8750	\$8750 to \$10500	> \$10500

# Development Risks Table

Risk ID	Risk Title	Risk Statement	Probability	Technical Impact	Impact	Severity
R01	Regulatory Change Risk	Change in regulations affecting the project.	3	Requires modification of the project to meet the regulatory requirements	5	Med High
R02	Procurement Delay Risk	Components obtained are delayed.	3	Requires extension in schedule.	4	Med High
R03	Response Time Risk	ADR fails to respond to central server within 200 ms.	3	Requires improvement in telemetry modules on the ADR and at the Central Server.	4	Med High
R04	Payload Bay Risk	Payload bay lid of the ADR fails to open on authentication	2	Requires improvement in the opening mechanism of the payload lid.	4	Medium
R05	Positional Accuracy Risk	ADR fails to reach the target location within 1 meter accuracy.	2	Requires change in the positional system sensors.	3	Med Low
R06	Cost Risk	The Cost of an ADR unit exceeds \$7000.	2	Requires additional funding.	2	Med Low

# Insights

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- Development risk analysis allows to classify risks into levels based on probability and severity allowing to plan mitigating actions for major risks like procurement delay risk, response time risk and regulatory change risk.
- Conceptualizing and finalizing the requirements early in the life cycle helps reduce cost and delays.
- 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, helps the maintainers by cutting down time and effort needed for repair.

# Backup Slides

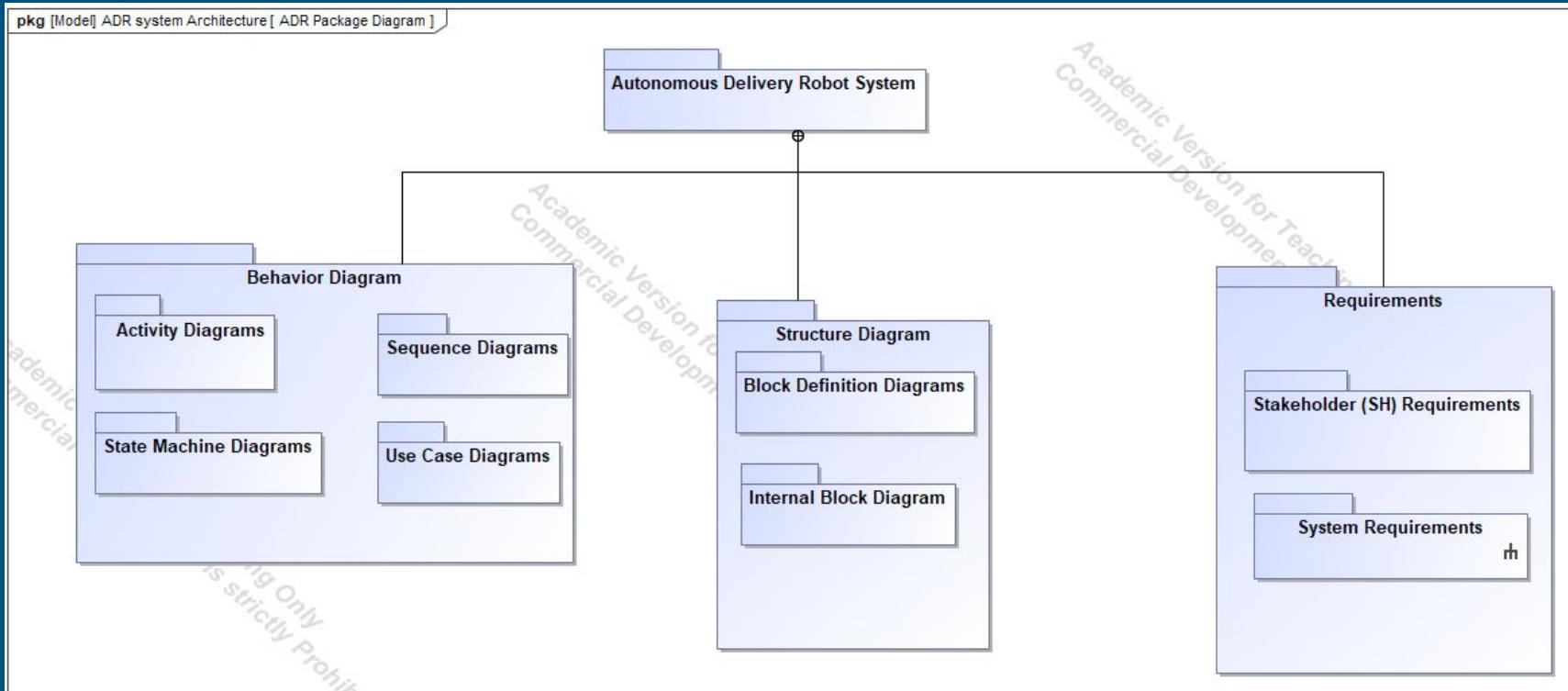
- Project Schedule
  - Package Diagram
  - Primary Use Case Narrative
  - Sequence Diagram
  - State Machine Diagram
  - Complete Set of SH RDs
  - Activity diagrams for remaining use cases
  - Full RVM, RAM, and RTM
  - Required States and Modes
  - External Interface Requirements
  - Internal Interface Requirements
  - Design Constraints
-

# Project Schedule

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		Project Schedule														
Development Phases	Activity	Week														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
System Concept Phase	Project Planning (Proposal, SEMP, Team Formation)															
	Stakeholder Context Definition															
	Stakeholder Requirements															
	System Concept Review															
System Requirements Phase	System Analysis															
	System Architecture															
	System Requirements (& Allocation)															
Preliminary Design Phase	Element Architecture															
	System Design/Preliminary Design Review														Working	review

# Package Diagram



# Primary Use Case Narrative

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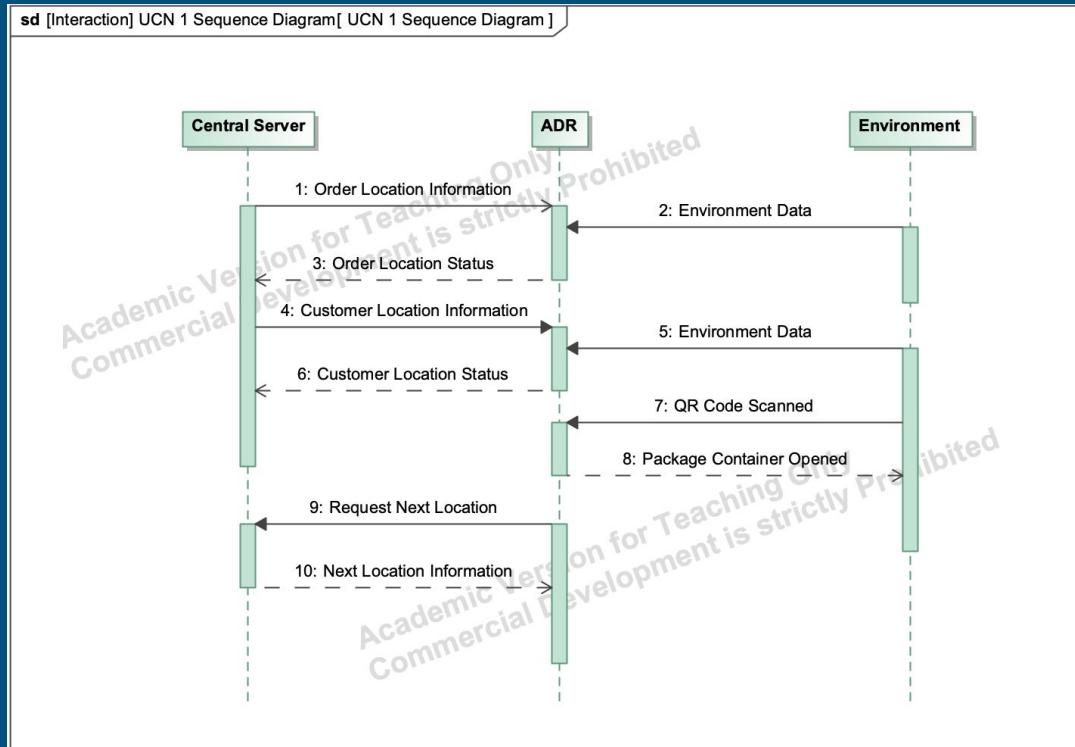
## Use Case Narrative: UCN1 Order Placement and Execution

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

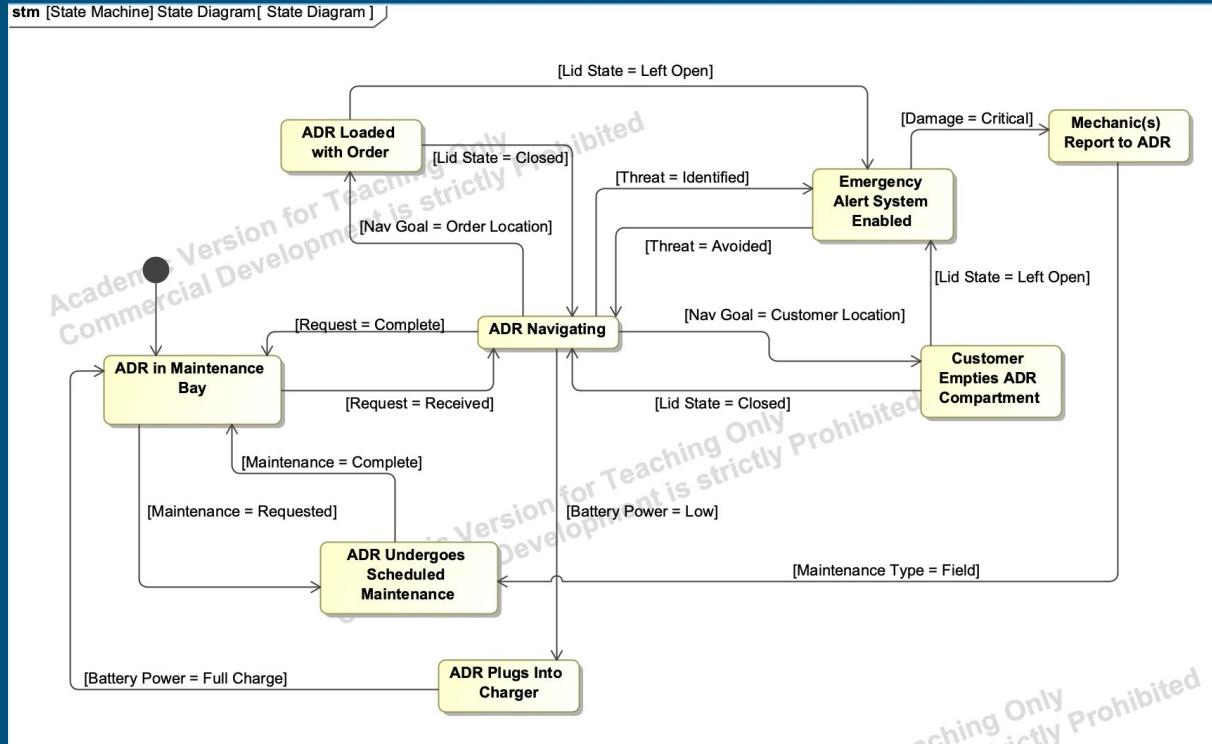
**Main Success Scenario:**

- 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.

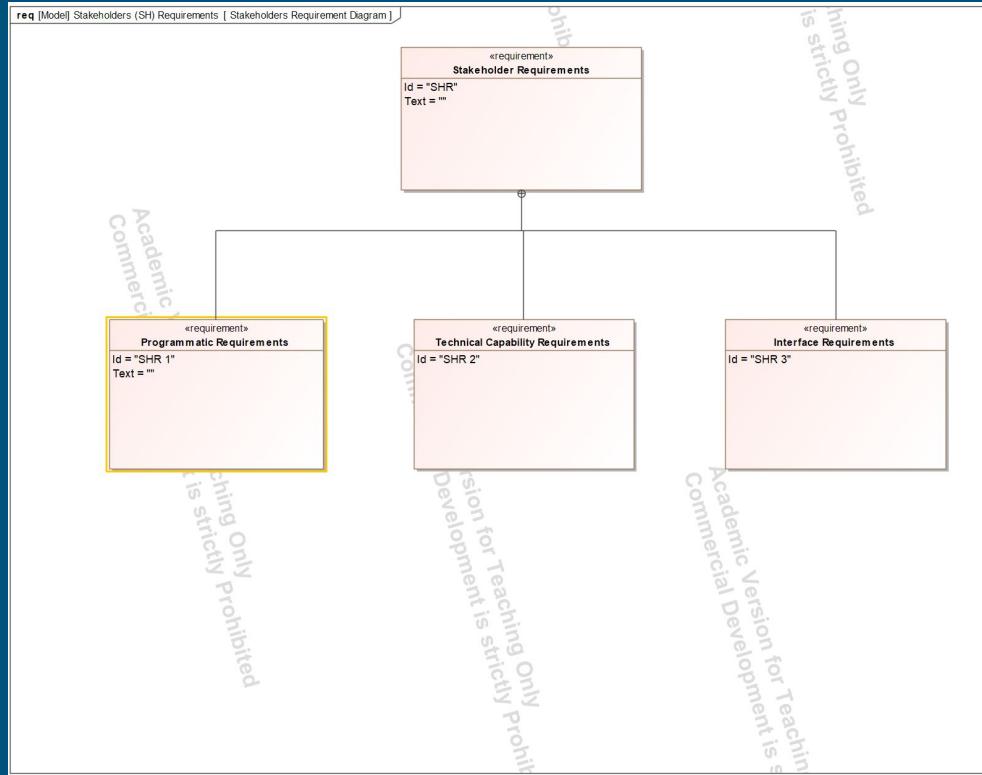
# Sequence Diagram



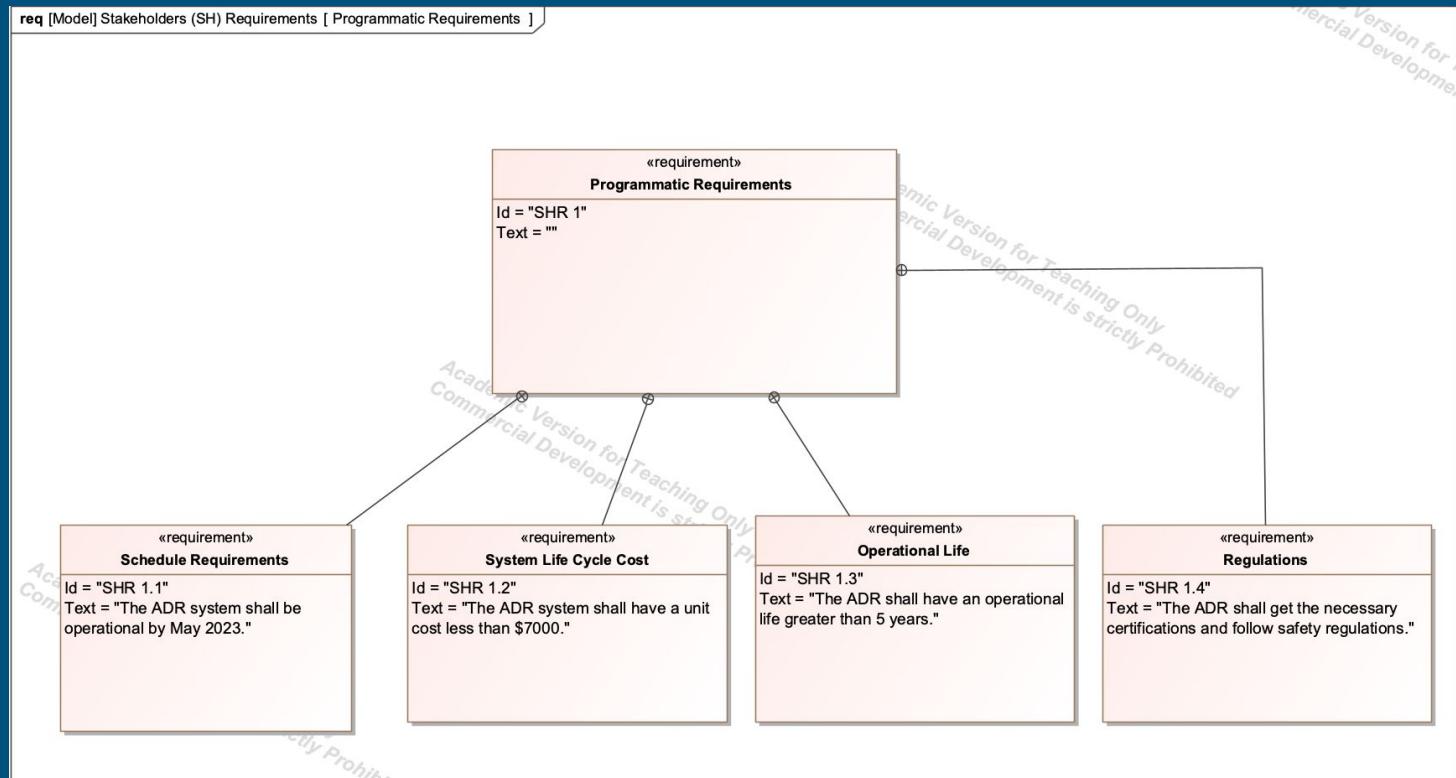
# State Machine Diagram



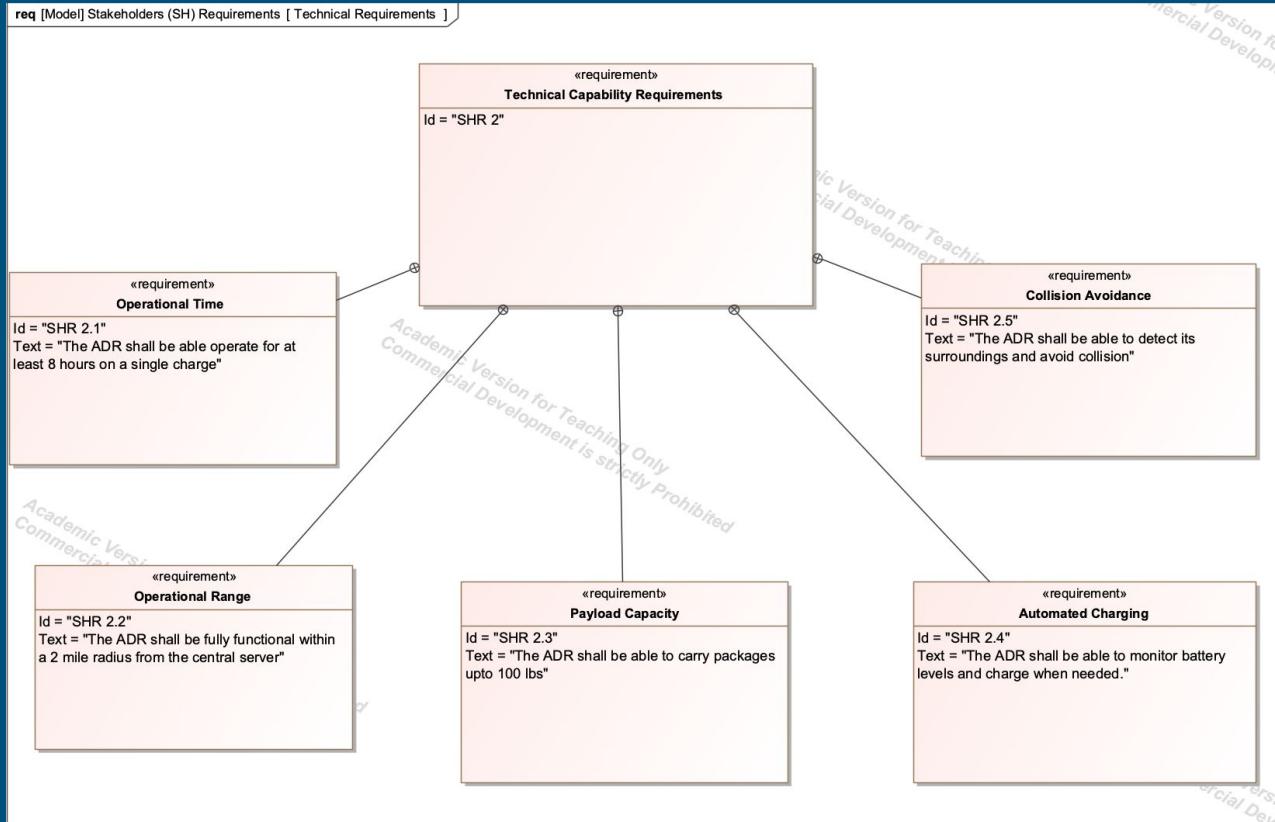
# Stakeholder Requirements Diagram



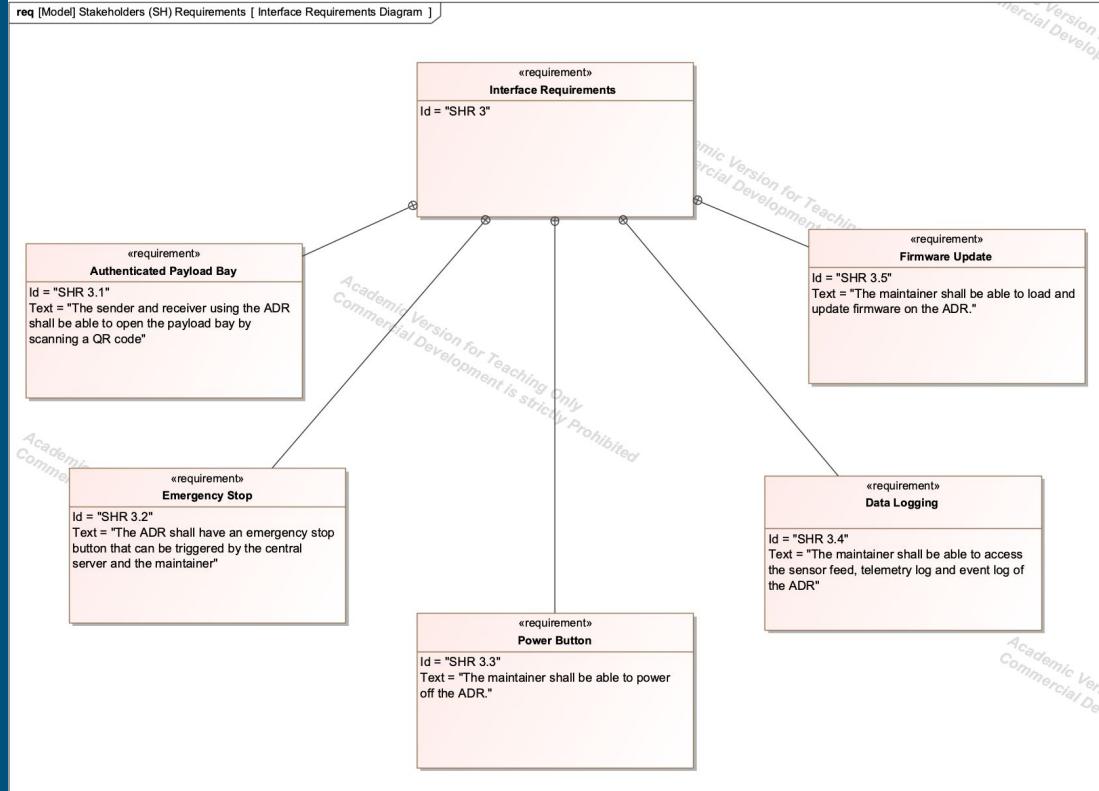
# Programmatic Requirements Diagram



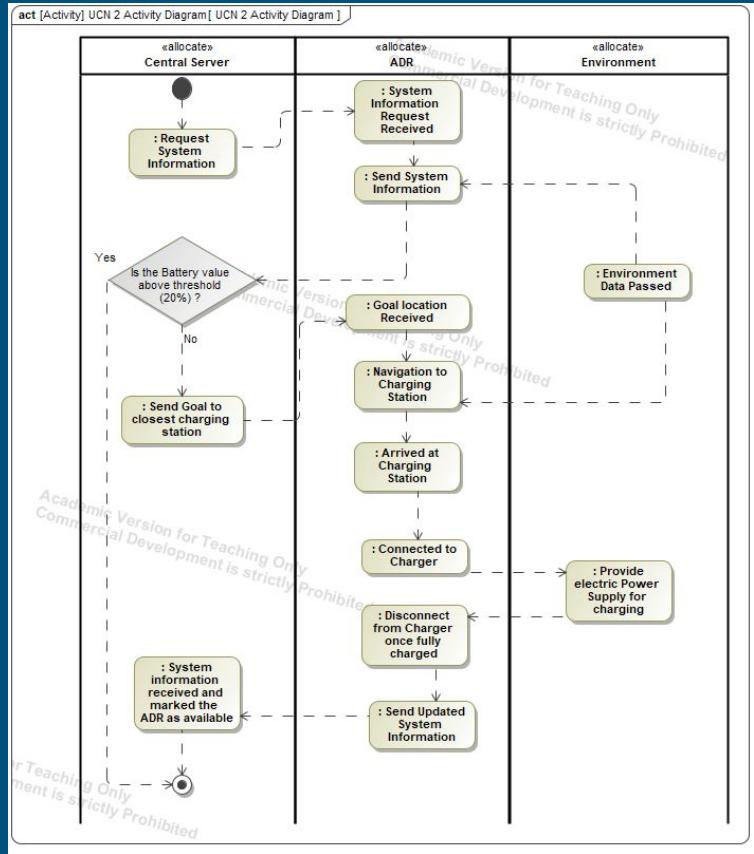
# Technical Requirements Diagram



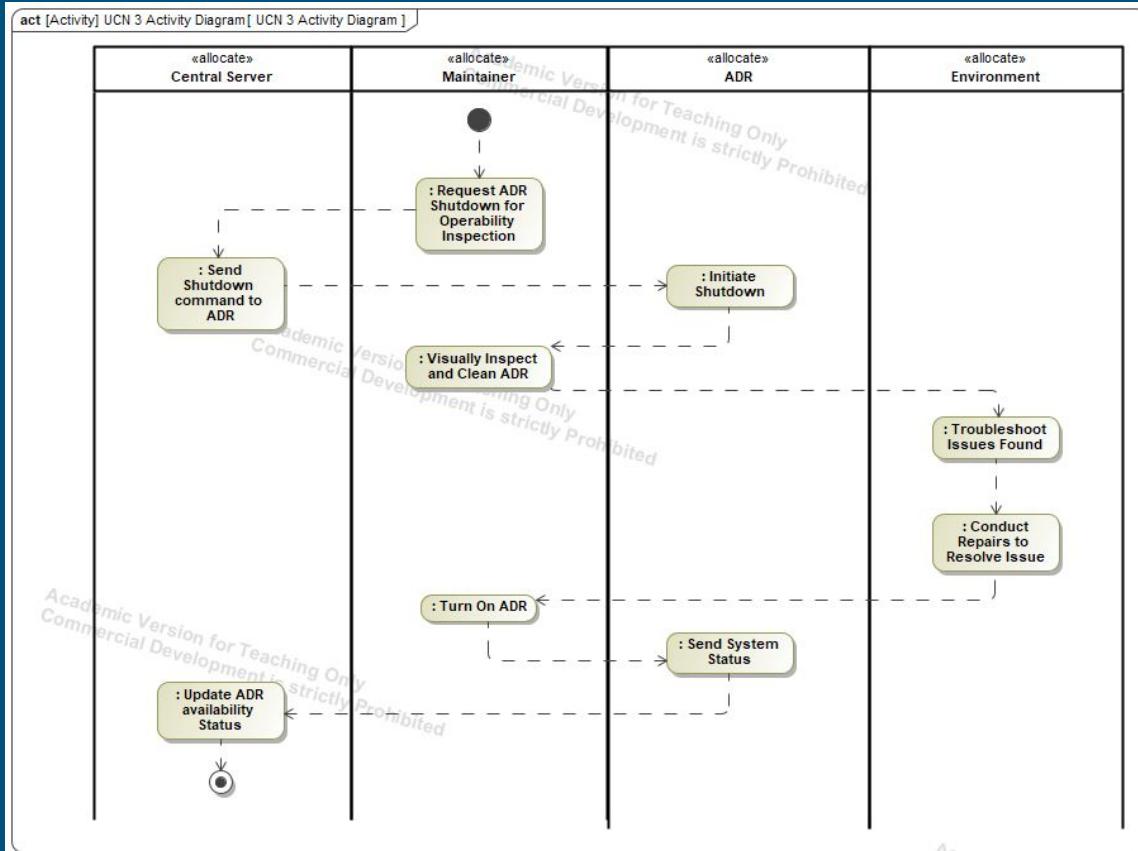
# Interface Requirements Diagram



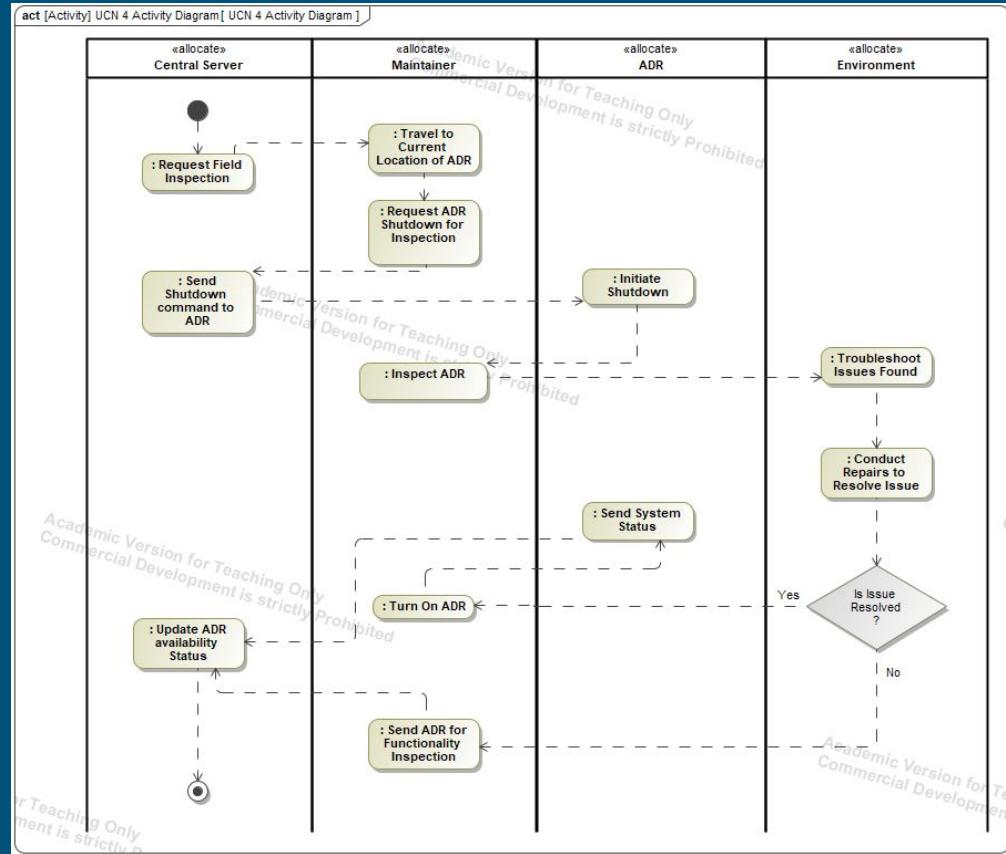
# Activity Diagram for UCN2- Maintain system battery levels



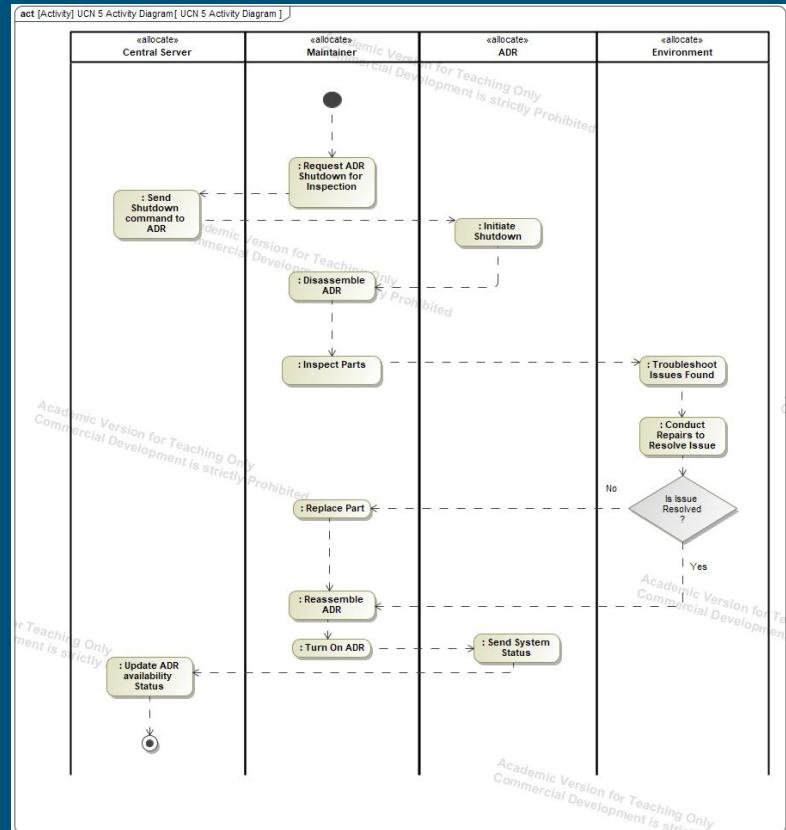
# Activity Diagram for UCN3- Operability inspection & service



# Activity Diagram for UCN4- Field inspection & service



# Activity Diagram for UCN5- Functionality inspection & service



# RVM

System Req ID	System Req Title	Verification Method	Method Description	System Validation Test	Syst Valiation TRR Date	System Verification Test	Sys Verification TRR Date	System Integration Test	System Intergration TRR Date	System Element Verification Test	System Element Verification TRR Dates
S3.0	Provide ADR Capability	Test		x	TBD	x	TBD	x	TBD	N/A	N/A
S3.1	Provide ADR States & Modes	Test		x	TBD	x	TBD	x	TBD	N/A	N/A
S3.2	Provide ADR Capabilities	Test		x	TBD	x	TBD	x	TBD	N/A	N/A
S3.2.1	Sensor System	Test		x	TBD	x	TBD	x	TBD	x	TBD
S3.2.1.1	Optical Sensing	Test		x	TBD	x	TBD	x	TBD	x	TBD
S3.2.1.1.1	Roadway Detections	Test & Analysis	The ADR shall detect sidewalks, roads, pedestrian crossings, and road signs.								
S3.2.1.1.2	Traffic Detections		The ADR shall detect Motor vehicles, pedestrians, cyclists, animals, and similar dynamic obstacles.	x	TBD	x	TBD	x	TBD	x	TBD
S3.2.1.1.3	Static Obstacle Detection	Test & Analysis	The ADR shall detect plants, trees, buildings, railings, and similar static obstacles.								
S3.2.1.1.4	ADR Detection		The ADR shall detect and identify other ADRs	x	TBD	x	TBD	x	TBD	x	TBD
S3.2.1.1.5	Minimum Detection Distance	Test & Analysis	The ADR shall detect every static and dynamic obstacle in its line of sight within a distance of 165 ft	x	TBD	x	TBD	x	TBD	x	TBD
S3.2.1.2	GPS Sensing			x	TBD	x	TBD	x	TBD	x	TBD
S3.2.1.2.1	GPS Accuracy	Test & Analysis	The ADR shall detect its Global Positioning System (GPS) coordinates with 4 ft accuracy.								
S3.2.1.3	Proximity Sensing			x	TBD	x	TBD	x	TBD	x	TBD
S3.2.1.3.1	Proximity Accuracy	Test & Analysis	The ADR shall detect and identify every entity in near proximity of 4ft.								
S3.2.2	Locomotion System			x	TBD	x	TBD	x	TBD	x	TBD
S3.2.2.1	Maximum Speed	Test, Analysis & Demonstration	The ADR shall have a maximum speed of 15 mph.								
S3.2.2.2	Maximum Payload		The ADR shall lift a maximum payload of 100 lbs.	x	TBD	x	TBD	x	TBD	x	TBD
S3.2.2.3	Minimum Turn Radius	Test, Analysis & Demonstration	The ADR shall have a turning radius of 2.5 ft.								
S3.2.2.4	Minimum Turn Speed		The ADR shall have a turning speed of 0.785 rad/sec.	x	TBD	x	TBD	x	TBD	x	TBD
S3.2.3	Computing System	Test		x	TBD	x	TBD	x	TBD	x	TBD
S3.2.3.1	Information Processing	Test	The ADR shall process information from the optical sensors, GPS sensors, and proximity sensors to make navigational decisions.								
S3.2.4	Communication System			x	TBD	x	TBD	x	TBD	x	TBD
S3.2.4.1	Communication Frequency	Test	The ADR shall use 915 MHz for its communication with the central server.								
S3.2.4.2	Cellular Connectivity		The ADR shall have a 4G LTE (Long-Term Evolution) cellular connectivity for redundant communication with the central server.	x	TBD	x	TBD	x	TBD	x	TBD

# RVM

System Req ID	System Req Title	Verification Method	Method Description	System Validation Test	Syst Valiation TRR Date	System Verification Test	Sys Verification TRR Date	System Integration Test	System Intergration TRR Date	System Element Verification Test	System Element Verification TRR Dates
S3.2.4.3	Antenna Frequency	Test	The ADR shall have two long range omnidirectional 915 MHz antennas.	x	TBD	x	TBD	x	TBD	x	TBD
S3.2.4.4	Antenna Connectivity	Test	The ADR shall have an omnidirectional 4G LTE antenna.	x	TBD	x	TBD	x	TBD	x	TBD
S3.2.4.5	Communication Range	Test , Analysis	THE ADR shall have a communication range of 2 miles.	x	TBD	x	TBD	x	TBD	x	TBD
S3.2.5	Power System	Test		x	TBD	x	TBD	x	TBD	x	TBD
S3.2.5.1	Operational Time	Test, Analysis & Demonstration	The ADR shall have an operational time of 8 hours on a single charge.	x	TBD	x	TBD	x	TBD	x	TBD
S3.2.5.2	Measurement Sensors	Test	The ADR shall have a sensor to measure battery voltage and calculate battery percentage.	x	TBD	x	TBD	x	TBD	x	TBD
S3.2.5.3	Temperature Sensors	Test	The ADR shall have temperature sensors for its battery packs	x	TBD	x	TBD	x	TBD	x	TBD
S3.2.5.4	Overheating Threshold	Test & Analysis	The ADR shall enter into an overheat failure mode when the operating temperature rises over 115 F.	x	TBD	x	TBD	x	TBD	x	TBD
S3.2.6	Availability	Test , Analysis		x	TBD	x	TBD	x	TBD	x	TBD
S3.2.6.1	Operational Availability	Test, Analysis & Demonstration	The ADR shall have a steady state operational availability greater than 0.8.	x	TBD	x	TBD	x	TBD	x	TBD
S3.2.6.2	Sensor Subsystem	Test	The sensor subsystem shall have a mean time between critical failures (MTBCF) greater than 2000 hours.	x	TBD	x	TBD	x	TBD	x	TBD
S3.2.6.3	Locomotion Subsystem	Test	The locomotion subsystem shall have a mean time between critical failures (MTBCF) greater than 1000 hours.	x	TBD	x	TBD	x	TBD	x	TBD
S3.2.6.4	Computing Subsystem	Test	The computing subsystem shall have a mean time between critical failure (MTBCF) greater than 2000 hours.	x	TBD	x	TBD	x	TBD	x	TBD
S3.2.6.5	Communication Subsystem	Test	The communication subsystem shall have a mean time between critical failures (MTBCF) greater than 2000 hours.	x	TBD	x	TBD	x	TBD	x	TBD
S3.2.6.6	Power Subsystem	Demonstration	The power subsystem shall have a mean time between critical failures (MTBCF) greater than 1500 hours.	x	TBD	x	TBD	x	TBD	x	TBD
S3.2.6.7	Maintenance Time	Inspection	The ADR shall have a mean maintenance time less than 2 hours.	x	TBD	x	TBD	x	TBD	x	TBD
S3.2.7	Accessibility	Test & Analysis		x	TBD	x	TBD	x	TBD	x	TBD
S3.2.7.1	Task Log	Test & Analysis	The ADR shall store a log containing time stamped history of each task performed	x	TBD	x	TBD	x	TBD	x	TBD
S3.2.7.2	Maintenance History	Test, Analysis & Demonstration	The ADR shall store maintenance history for each ADR element	x	TBD	x	TBD	x	TBD	x	TBD
S3.2.7.3	Data Access	Test	The ADR shall provide access to all stored data to authorized users such as central server and maintainer	x	TBD	x	TBD	x	TBD	x	TBD
S3.3	Provide External Interfaces	Test		x	TBD	x	TBD	x	TBD	x	TBD
S3.3.1	Central Server Interfaces	Test		x	TBD	x	TBD	x	TBD	x	TBD
S3.3.1.1	Central Server Interface Inputs	Test		x	TBD	x	TBD	x	TBD	x	TBD
S3.3.1.1.1	Task Information	Test, Analysis & Demonstration	The ADR system shall accept task information from the Central Server.	x	TBD	x	TBD	x	TBD	x	TBD
S3.3.1.1.2	Route Information	Test, Analysis & Demonstration	The ADR system shall accept route information from the Central Server.	x	TBD	x	TBD	x	TBD	x	TBD
S3.3.1.2	Central Server Interface Outputs	Test		x	TBD	x	TBD	x	TBD	x	TBD

# RVM

System Req ID	System Req Title	Verification Method	Method Description	System Validation Test	Syst Valiation TRR Date	System Verification Test	Sys Verification TRR Date	System Integartion Test	System Intergration TRR Date	System Element Verification Test	System Element Verification TRR Dates
53.3.1.2.1	Battery Level	Test, Analysis & Demonstration	The ADR system shall provide its battery level.	x	TBD	x	TBD	x	TBD	x	TBD
53.3.1.2.2	System Information	Test	The ADR system shall provide system information.	x	TBD	x	TBD	x	TBD	x	TBD
53.3.1.2.3	Payload Bay Information	Test	The ADR system shall provide the payload bay information.	x	TBD	x	TBD	x	TBD	x	TBD
53.3.1.2.4	User Information	Test & Analysis	The ADR system shall provide user information.	x	TBD	x	TBD	x	TBD	x	TBD
53.3.1.2.5	Locomotion Information	Test	The ADR system shall provide locomotion information.	x	TBD	x	TBD	x	TBD	x	TBD
53.3.2	Maintainer Interfaces	Test		x	TBD	x	TBD	x	TBD	x	TBD
53.3.2.1	Maintainer Interface Inputs	Test		x	TBD	x	TBD	x	TBD	x	TBD
53.3.2.1.1	Maintenance Tools	Test	The ADR system shall provide maintainers with the tools required to perform maintenance	x	TBD	x	TBD	x	TBD	x	TBD
53.3.2.1.2	Firmware Updates Access	Test	The ADR system shall provide access for firmware updates	x	TBD	x	TBD	x	TBD	x	TBD
53.3.2.1.3	Sensor Calibration Access	Test	The ADR system shall provide access for sensor calibration.	x	TBD	x	TBD	x	TBD	x	TBD
53.3.2.1.4	Malfunction Detection	Test & Analysis	The ADR system shall provide self malfunctioning detections to determine errors or failures	x	TBD	x	TBD	x	TBD	x	TBD
53.3.2.1.5	Parts Replacement Access	Test	The ADR system shall provide the access to maintainers for parts replacement.	x	TBD	x	TBD	x	TBD	x	TBD
53.3.2.1.6	Inspection Access	Test	The ADR system shall provide access for inspections	x	TBD	x	TBD	x	TBD	x	TBD
53.3.2.2	Maintainer Interface Outputs	Test		x	TBD	x	TBD	x	TBD	x	TBD
53.3.2.2.1	Battery Health Information	Test & Analysis	The ADR system shall provide battery health information	x	TBD	x	TBD	x	TBD	x	TBD
53.3.2.2.2	Connection Status	Test & Analysis	The ADR system shall provide connection status information	x	TBD	x	TBD	x	TBD	x	TBD
53.3.2.2.3	Diagnostic Information for Subsystems	Test & Analysis	The ADR system shall provide diagnostic information about subsystems	x	TBD	x	TBD	x	TBD	x	TBD
53.3.2.2.4	Diagnostic Information for Sensors	Test & Analysis	The ADR system shall provide diagnostic information about sensors.	x	TBD	x	TBD	x	TBD	x	TBD
53.3.3	Environment Interfaces	Test & Analysis		x	TBD	x	TBD	x	TBD	x	TBD
53.3.3.1	Environment Input Interfaces	Test & Analysis		x	TBD	x	TBD	x	TBD	x	TBD
53.3.3.1.1	Video and Proximity Data	Test & Analysis	The ADR system shall gather raw video and proximity data from the environment.	x	TBD	x	TBD	x	TBD	x	TBD
53.3.3.1.2	Charging Station	Test & Demonstration	The ADR system shall accept power from a charging station.	x	TBD	x	TBD	x	TBD	x	TBD
53.3.3.2	Environment Output Interfaces	Test & Analysis		x	TBD	x	TBD	x	TBD	x	TBD
53.3.3.2.1	Base Utilities	Test	The ADR system shall interface with operating base utilities - internet access and charging stations etc.	x	TBD	x	TBD	x	TBD	x	TBD
53.3.3.2.2	Audio Signals	Test	The ADR system shall provide audio signals.	x	TBD	x	TBD	x	TBD	x	TBD
53.3.3.2.3	Visual Signals	Test	The ADR system shall provide visual signals.	x	TBD	x	TBD	x	TBD	x	TBD
53.4	Provide Internal Interfaces	Test		x	TBD	x	TBD	x	TBD	x	TBD
53.4.1	ADR-US Interfaces	Test		x	TBD	x	TBD	x	TBD	x	TBD
53.4.1.1	ADR-US Input Interfaces	Test		x	TBD	x	TBD	x	TBD	x	TBD
53.4.1.1.1	Payload Bay Information	Test	The ADR shall provide payload bay information.	x	TBD	x	TBD	x	TBD	x	TBD
53.4.1.1.2	System Information	Test	The ADR shall provide its system information.	x	TBD	x	TBD	x	TBD	x	TBD
53.4.1.1.3	Locomotion System Information	Test	The ADR shall provide its locomotion information such as speed and acceleration etc.	x	TBD	x	TBD	x	TBD	x	TBD
53.4.1.1.4	Task Information	Test	The ADR shall provide its task information obtained from the Central Server.	x	TBD	x	TBD	x	TBD	x	TBD
53.4.1.1.5	Payload ID Number	Test	The ADR shall provide Payload Bay ID Number to ADR.	x	TBD	x	TBD	x	TBD	x	TBD
53.4.1.2	ADR-US Output Interfaces	Test		x	TBD	x	TBD	x	TBD	x	TBD

# RVM

System Req ID	System Req Title	Verification Method	Method Description	System Validation Test	Syst Valiation TRR Date	System Verification Test	Sys Verification TRR Date	System Integration Test	System Intergration TRR Date	System Element Verification Test	System Element Verification Dates
S3.4.1.2.1	Order ID Number	Test	The User Interaction System shall provide Order ID Number to ADR.	x	TBD	x	TBD	x	TBD	x	TBD
S3.4.1.2.2	Payload Bay Information	Test	The User Interaction System shall provide confirmation commands in accordance with the payload bay information	x	TBD	x	TBD	x	TBD	x	TBD
S3.4.1.2.3	Task Information	Test	The User Interaction System shall provide payload bay commands in accordance with task information.	x	TBD	x	TBD	x	TBD	x	TBD
S3.4.2	ADR - Maintenance System Interfaces	Test		x	TBD	x	TBD	x	TBD	x	TBD
S3.4.2.1	ADR - Maintenance System Input Interfaces	Test		x	TBD	x	TBD	x	TBD	x	TBD
S3.4.2.1.1	System Information	Test	The ADR shall provide the system information.	x	TBD	x	TBD	x	TBD	x	TBD
S3.4.2.1.2	Battery Information	Test	The ADR shall provide its battery levels.	x	TBD	x	TBD	x	TBD	x	TBD
S3.4.2.1.3	Malfunctioning Detection Information	Test	The ADR shall provide malfunctioning detections.	x	TBD	x	TBD	x	TBD	x	TBD
S3.4.2.2	ADR - Maintenance System Output Interfaces	Test		x	TBD	x	TBD	x	TBD	x	TBD
S3.4.2.2.1	ADR Field Service	Test, Analysis & Demonstration	The Maintenance System shall provide the ADR field service	x	TBD	x	TBD	x	TBD	x	TBD
S3.4.2.2.2	ADR Daily Maintenance Check	Test, Analysis & Demonstration	The Maintenance System shall provide the ADR daily maintenance check	x	TBD	x	TBD	x	TBD	x	TBD
S3.4.2.2.3	ADR System Updates	Test, Analysis & Demonstration	The Maintenance System shall provide the updates to ADRs	x	TBD	x	TBD	x	TBD	x	TBD
S3.4.2.2.4	ADR Component Replacement	Test, Analysis & Demonstration	The Maintenance System shall provide the component replacement repair to ADRs.	x	TBD	x	TBD	x	TBD	x	TBD
S3.4.3	UIS - Maintenance System Interfaces	Test		x	TBD	x	TBD	x	TBD	x	TBD
S3.4.3.1	UIS - Maintenance System Input Interfaces	Test		x	TBD	x	TBD	x	TBD	x	TBD
S3.4.3.1.1	Software Feedback Information	Test	The User Interaction System shall provide user software feedback	x	TBD	x	TBD	x	TBD	x	TBD
S3.4.3.1.2	Package Removal from ADR	Test, Analysis & Demonstration	The User Interaction System shall provide package takeout and minimal cleaning	x	TBD	x	TBD	x	TBD	x	TBD
S3.4.3.1.3	User Information	Test	The User Interaction System shall provide user information.	x	TBD	x	TBD	x	TBD	x	TBD
S3.4.3.2	UIS - Maintenance System Output Interfaces	Test		x	TBD	x	TBD	x	TBD	x	TBD
S3.4.3.2.1	Software update Information	Test	The Maintenance System shall provide constant software updates based on the user feedback	x	TBD	x	TBD	x	TBD	x	TBD
S3.4.3.2.2	Cleaning Services of Payload Bay	Test & Demonstration	The Maintenance System shall provide complete cleaning of the payload bay.	x	TBD	x	TBD	x	TBD	x	TBD
S3.4.3.2.3	Cyber Security Check	Test & Demonstration	The Maintenance System shall provide regular cyber security checks on user information.	x	TBD	x	TBD	x	TBD	x	TBD
S3.5	Design Constraints	Test & Analysis		x	TBD	x	TBD	x	TBD	x	TBD
S3.5.1	ADR Dimension Information	Test	The ADR shall have the dimensions : 4ft x 2ft x 2ft. (Length x Width x Height)	x	TBD	x	TBD	x	TBD	x	TBD
S3.5.2	ADR Mass Information	Test	The ADR shall have a mass of 150 pounds excluding the payload.	x	TBD	x	TBD	x	TBD	x	TBD
S3.5.3	ADR Ground Clearance Information	Test	The ADR shall have a ground clearance of 8 inches above the ground level.	x	TBD	x	TBD	x	TBD	x	TBD
S3.5.4	ADR Number of Payload Bays Information	Test	The ADR shall have the ten individual payload bays.	x	TBD	x	TBD	x	TBD	x	TBD
S3.5.5	ADR Disassembly Capability	Test, Analysis & Demonstration	The ADR shall be disassembled for replacement, inspection, packaging and transportation purposes effortlessly and efficiently.	x	TBD	x	TBD	x	TBD	x	TBD
S3.6	Other Requirements	Test		x	TBD	x	TBD	x	TBD	x	TBD
S3.6.1	ADR Compatibility Information	Test	The ADR shall be configured to be compatible with off the shelf components such as batteries	x	TBD	x	TBD	x	TBD	x	TBD
S3.6.2	ADR Electronics Safety System	Test, Analysis & Demonstration	The ADR shall make sure the electronics inside are not affected or tampered by external disturbances or environment such as heavy rain, snowfall, electromagnetic disturbances.	x	TBD	x	TBD	x	TBD	x	TBD

# RVM

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System Req ID	System Req Title	Verification Method	Method Description	System Validation Test	Syst Valiation TRR Date	System Verifaction Test	Sys Verification TRR Date	System Integration Test	System Intergration TRR Date	System Element Verification Test	System Element Verification TRR Dates
S3.6.3	ADR Efficency System	Test , Analysis & Demonstration	The central server and the algorithm shall make sure that all the idle ADRs are given a task when there are multiple orders.	x	TBD	x	TBD	x	TBD	x	TBD
S3.6.4	Systems Safety Requirements	Test , Analysis & Demonstration		x	TBD	x	TBD	x	TBD	x	TBD
S3.6.4.1	Environment Temperature Information	Test , Analysis & Demonstration	The ADR shall operate in an environment with temperature levels from 0 to 50 degrees.	x	TBD	x	TBD	x	TBD	x	TBD
S3.6.4.2	ADR Manual Operation Mode	Test , Analysis & Demonstration	The ADR shall be operated manually when necessary	x	TBD	x	TBD	x	TBD	x	TBD
S3.6.4.3	ADR Awareness Functionality	Test , Analysis & Demonstration	The ADR shall always be active and aware of its surroundings even if it is in idle mode, to make sure it shall react and avoid any damages to the system	x	TBD	x	TBD	x	TBD	x	TBD
S3.6.4.4	ADR Emergency Stop Button	Test , Analysis & Demonstration	The ADR shall have an emergency stop button that can be triggered by the central server and the maintainer.	x	TBD	x	TBD	x	TBD	x	TBD
S3.6.5	Systems Security Requirements	Test		x	TBD	x	TBD	x	TBD	x	TBD
S3.6.5.1	Security Protocol Information	Test	The ADR shall have security protocols and algorithms that help it prevent cyber attacks.	x	TBD	x	TBD	x	TBD	x	TBD
S3.6.5.2	Mechanical Security System	Test,Analysis & Demonstartion	The ADR shall have mechanical security systems that would alert the central server it was being tampered with without approval.	x	TBD	x	TBD	x	TBD	x	TBD

# RAM

ADR Requirements Allocaton Matrix (RAM)

System Req ID	System Req Title	ADR Element	UIS Element	Maintenance Element	Chk Sum
S3.0	Provide ADR Capability	N/A	N/A	N/A	
S3.1	Provide ADR States & Modes	N/A	N/A	N/A	
S3.2	Provide ADR Capabilities	N/A	N/A	N/A	
S3.2.1	Sensor System	1			1
S3.2.1.1	Optical Sensing	1			1
S3.2.1.1.1	Roadway Detections	1			1
S3.2.1.1.2	Traffic Detections	1			1
S3.2.1.1.3	Static Obstacle Detection	1			1
S3.2.1.1.4	ADR Detection	1			1
S3.2.1.1.5	Minimum Detection Distance	1			1
S3.2.1.2	GPS Sensing	1	1		2
S3.2.1.2.1	GPS Accuracy	1	1		2
S3.2.1.3	Proximity Sensing	1			1
S3.2.1.3.1	Proximity Accuracy	1			1
S3.2.2	Locomotion System	1			1
S3.2.2.1	Maximum Speed	1			1
S3.2.2.2	Maximum Payload	1			1
S3.2.2.3	Minimum Turn Radius	1			1
S3.2.2.4	Minimum Turn Speed	1			1
S3.2.3	Computing System	1			1
S3.2.3.1	Information Processing	1	1		2
S3.2.4	Communication System	1	1		2
S3.2.4.1	Communication Frequency	1	1		2
S3.2.4.2	Cellular Connectivity	1	1		2
S3.2.4.3	Antenna Frequency	1			1
S3.2.4.4	Antenna Connectivity	1			1
S3.2.4.5	Communication Range	1			1
S3.2.5	Power System	1		1	2
S3.2.5.1	Operational Time	1			1
S3.2.5.2	Measurement Sensors	1			1
S3.2.5.3	Temperature Sensors	1			1
S3.2.5.4	Overheating Threshold	1		1	2
S3.2.6	Availability	1		1	2
S3.2.6.1	Operational Availability	1		1	2

ADR Requirements Allocaton Matrix (RAM)

System Req ID	System Req Title	ADR Element	UIS Element	Maintenance Element	Chk Sum
S3.2.6.2	Sensor Subsystem	1		1	2
S3.2.6.3	Locomotion Subsystem	1		1	2
S3.2.6.4	Computing Subsystem	1		1	2
S3.2.6.5	Communication Subsystem	1	1	1	3
S3.2.6.6	Power Subsystem	1		1	2
S3.2.6.7	Maintenance Time			1	1
S3.2.7	Accessibility	1	1	1	3
S3.2.7.1	Task Log	1	1		2
S3.2.7.2	Maintenance History	1		1	2
S3.2.7.3	Data Access	1	1	1	3
S3.3	Provide External Interfaces	1	1	1	3
S3.3.1	Central Server Interfaces	1	1		2
S3.3.1.1	Central Server Interface Inputs	1	1		2
S3.3.1.1.1	Task Information	1	1		2
S3.3.1.1.2	Route Information	1	1		2
S3.3.1.2	Central Server Interface Outputs	1			1
S3.3.1.2.1	Battery Level	1			1
S3.3.1.2.2	System Information	1			1
S3.3.1.2.3	Payload Bay Information	1			1
S3.3.1.2.4	User Information	1			1
S3.3.1.2.5	Locomotion Information	1			1
S3.3.2	Maintainer Interfaces	1		1	2
S3.3.2.1	Maintainer Interface Inputs	1		1	2
S3.3.2.1.1	Maintenance Tools	1		1	2
S3.3.2.1.2	Firmware Updates Access	1		1	2
S3.3.2.1.3	Sensor Calibration Access	1		1	2
S3.3.2.1.4	Malfunction Detection	1		1	2
S3.3.2.1.5	Parts Replacement Access	1		1	2
S3.3.2.1.6	Inspection Access	1		1	2
S3.3.2.2	Maintainer Interface Outputs	1			1
S3.3.2.2.1	Battery Health Information	1			1
S3.3.2.2.2	Connection Status	1			1
S3.3.2.2.3	Diagnostic Information for Subsystems	1			1
S3.3.2.2.4	Diagnostic Information for Sensors	1			1
S3.3.3	Environment Interfaces	1			1
S3.3.3.1	Environment Input Interfaces	1			1
S3.3.3.1.1	Video and Proximity Data	1			1
S3.3.3.1.2	Charging Station	1			1
S3.3.3.2	Environment Output Interfaces	1			1
S3.3.3.2.1	Base Utilities	1			1
S3.3.3.2.2	Audio Signals	1			1
S3.3.3.2.3	Visual Signals	1			1

# RAM

ADR Requirements Allocation Matrix (RAM)

System Req ID	System Req Title	ADR Element	UIS Element	Maintenance Element	Chk Sum
S3.4	Provide Internal Interfaces	1	1	1	3
S3.4.1	ADR-UIS Interfaces	1	1		2
S3.4.1.1	ADR-UIS Input Interfaces	1	1		2
S3.4.1.1.1	Payload Bay Information	1			1
S3.4.1.1.2	System Information	1			1
S3.4.1.1.3	Locomotion System Information	1			1
S3.4.1.1.4	Task Information	1	1		2
S3.4.1.1.5	Payload ID Number	1			1
S3.4.1.2	ADR-UIS Output Interfaces	1	1		2
S3.4.1.2.1	Order ID Number	1	1		2
S3.4.1.2.2	Payload Bay Information		1		1
S3.4.1.2.3	Task Information		1		1
S3.4.2	ADR- Maintenance System Interfaces	1		1	2
S3.4.2.1	ADR- Maintenance System Input Interfaces	1			1
S3.4.2.1.1	System Information	1			1
S3.4.2.1.2	Battery Information	1			1
S3.4.2.1.3	Malfunctioning Detection Information	1			1
S3.4.2.2	ADR- Maintenance System Output Interfaces		1		1
S3.4.2.2.1	ADR Field Service		1		1
S3.4.2.2.2	ADR Daily Maintenance Check		1		1
S3.4.2.2.3	ADR System Updates		1		1
S3.4.2.2.4	ADR Component Replacement		1		1
S3.4.3	UIS - Maintenance System Interfaces	1	1		2
S3.4.3.1	UIS - Maintenance System Input Interfaces	1			1
S3.4.3.1.1	Software Feedback Information	1			1
S3.4.3.1.2	Package Removal from ADR	1			1
S3.4.3.1.3	User Information	1			1
S3.4.3.2	UIS - Maintenance System Output Interfaces		1		1
S3.4.3.2.1	Software update information		1		1
S3.4.3.2.2	Cleaning Services of Payload Bay		1		1
S3.4.3.2.3	Cyber Security Check		1		1
S3.5	Design Constraints	1			1
S3.5.1	ADR Dimension Information	1			1
S3.5.2	ADR Mass Information	1			1
S3.5.3	ADR Ground Clearance Information	1			1
S3.5.4	ADR Number of Payload Bays Information	1			1
S3.5.5	ADR Disassembly Capability	1			1
S3.6	Other Requirements	1	1	1	3
S3.6.1	ADR Compatibility Information	1			1
S3.6.2	ADR Electronics Safety System	1			1
S3.6.3	ADR Efficiency System		1		1
S3.6.4	Systems Safety Requirements	1	1	1	3

ADR Requirements Allocation Matrix (RAM)

System Req ID	System Req Title	ADR Element	UIS Element	Maintenance Element	Chk Sum
S3.6.4.1	Environment Temperature Information	1			1
S3.6.4.2	ADR Manual Operation Mode	1			1
S3.6.4.3	ADR Awareness Functionality	1			1
S3.6.4.4	ADR Emergency Stop Button	1	1	1	3
S3.6.5	Systems Security Requirements	1			1
S3.6.5.1	Security protocol Information	1			1
S3.6.5.2	Mechanical Security system Information	1			1

# RTM

ADR System Requirements Traceability Matrix (RTM)

		Source Requirement																
System Req ID	System Req Title	SH 2 Performance Requirements	SH 2.1 Operation Time	SH 2.2 Operational Range	SH 2.3 Payload Capacity	SH 2.4 Automated Charging	SH 2.5 Collision Avoidance	SH 3 External Interface Requirements	SH 3.1 User Interface Requirements	SH 3.2 External System Interface Requirements	SH 4 Specialty Engineering Requirements	SH 5 Functional Requirements	SH 5.1 Speed	SH 5.2 Battery Capacity	SH 5.3 Dimensions	SH 5.4 Minimum Ground Clearance	SH 5.5 Climbing Inclination	Sum Chk
S3.0	Provide ADR Capability	1																1
S3.1	Provide ADR States & Modes	1																1
S3.2	Provide ADR Capabilities	1			1													2
S3.2.1	Sensor System	1											1					3
S3.2.1.1	Optical Sensing	1					1					1						3
S3.2.1.1.1	Roadway Detections	1					1					1					1	4
S3.2.1.1.2	Traffic Detections	1					1					1						3
S3.2.1.1.3	Static Obstacle Detection	1					1					1						3
S3.2.1.1.4	ADR Detection	1					1					1						3
S3.2.1.1.5	Minimum Detection Distance	1		1			1					1						4
S3.2.1.2	GPS Sensing	1					1					1						3
S3.2.1.2.1	GPS Accuracy	1					1					1						3
S3.2.1.3	Proximity Sensing	1					1					1						3
S3.2.1.3.1	Proximity Accuracy	1										1	1		1			4
S3.2.2	Locomotion System	1		1								1					1	3
S3.2.2.1	Maximum Speed	1		1								1						3
S3.2.2.2	Maximum Payload	1			1							1						3
S3.2.2.3	Minimum Turn Radius	1										1					1	3
S3.2.2.4	Minimum Turn Speed	1										1					1	3
S3.2.3	Computing System	1														1		2
S3.2.3.1	Information Processing	1																1
S3.2.4	Communication System	1														1		2
S3.2.4.1	Communication Frequency	1																1
S3.2.4.2	Cellular Connectivity	1																1
S3.2.4.3	Antenna Frequency	1																1
S3.2.4.4	Antenna Connectivity	1																1
S3.2.4.5	Communication Range	1	1															2
S3.2.5	Power System	1														1		2
S3.2.5.1	Operational Time	1	1															2
S3.2.5.2	Measurement Sensors					1												1
S3.2.5.3	Temperature Sensors											1						1
S3.2.5.4	Overheating Threshold											1						1
S3.2.6	Availability																	0
S3.2.6.1	Operational Availability																	0
S3.2.6.2	Sensor Subsystem															1		1
S3.2.6.3	Locomotion Subsystem												1			1		2
S3.2.6.4	Computing Subsystem														1			1

# RTM

System Req ID	System Req Title	SH 2 Performance Requirements	SH 2.1 Operation Time	SH 2.2 Operational Range	SH 2.3 Payload Capacity	SH 2.4 Automated Charging	SH 2.5 Collision Avoidance	SH 3 External Interface Requirements	SH 3.1 User Interface Requirements	SH 3.2 External System Interface Requirements	SH 4 Specialty Engineering Requirements	SH 5 Functional Requirements	SH 5.1 Speed	SH 5.2 Battery Capacity	SH 5.3 Dimensions	SH 5.4 Minimum Ground Clearance	SH 5.5 Climbing Inclination	Sum Chk
S3.2.6.5	Communication Subsystem															1		1
S3.2.6.6	Power Subsystem															1		1
S3.2.6.7	Maintenance Time															0		0
S3.2.7	Accessibility									1								1
S3.2.7.1	Task Log									1								1
S3.2.7.2	Maintenance History									1								1
S3.2.7.3	Data Access									1								1
S3.3	Provide External Interfaces										1							1
S3.3.1	Central Server Interfaces										1							1
S3.3.1.1	Central Server Interface Inputs										1							1
S3.3.1.1.1	Task Information										1							1
S3.3.1.1.2	Route Information										1							1
S3.3.1.2	Central Server Interface Outputs										1							1
S3.3.1.2.1	Battery Level	1				1					1							3
S3.3.1.2.2	System Information											1						2
S3.3.1.2.3	Payload Bay Information										1	1						2
S3.3.1.2.4	User Information										1							1
S3.3.1.2.5	Locomotion Information													1				1
S3.3.2	Maintainer Interfaces										1							1
S3.3.2.1	Maintainer Interface Inputs										1							1
S3.3.2.1.1	Maintenance Tools										1							1
S3.3.2.1.2	Firmware Updates Access										1							1
S3.3.2.1.3	Sensor Calibration Access										1							1
S3.3.2.1.4	Malfunction Detection										1							1
S3.3.2.1.5	Parts Replacement Access										1							1
S3.3.2.1.6	Inspection Access										1							1
S3.3.2.2	Maintainer Interface Outputs																	0
S3.3.2.2.1	Battery Health Information													1				1
S3.3.2.2.2	Connection Status																	0
S3.3.2.2.3	Diagnostic Information for Subsystems																	0
S3.3.2.2.4	Diagnostic Information for Sensors																	0
S3.3.3	Environment Interfaces										1							1
S3.3.3.1	Environment Input Interfaces										1							1
S3.3.3.1.1	Video and Proximity Data										1							1
S3.3.3.1.2	Charging Station						1				1							2
S3.3.3.2	Environment Output Interfaces										1							1
S3.3.3.2.1	Base Utilities										1							1

# RTM

System Req ID	System Req Title	SH 2 Performance Requirements	SH 2.1 Operation Time	SH 2.2 Operational Range	SH 2.3 Payload Capacity	SH 2.4 Automated Charging	SH 2.5 Collision Avoidance	SH 3 External Interface Requirements	SH 3.1 User Interface Requirements	SH 3.2 External System Interface Requirements	SH 4 Specialty Engineering Requirements	SH 5 Functional Requirements	SH 5.1 Speed	SH 5.2 Battery Capacity	SH 5.3 Dimensions	SH 5.4 Minimum Ground Clearance	SH 5.5 Climbing Inclination	Sum Chk
S3.3.3.2.2	Audio Signals									1								1
S3.3.3.2.3	Visual Signals									1								1
S3.4	Provide Internal Interfaces									1								2
S3.4.1	ADR-UIS Interfaces									1								2
S3.4.1.1	ADR-UIS Input Interfaces									1								2
S3.4.1.1.1	Payload Bay Information									1								2
S3.4.1.1.2	System Information										1							1
S3.4.1.1.3	Locomotion System Information										1	1						2
S3.4.1.1.4	Task Information										1							1
S3.4.1.1.5	Payload ID Number										1							1
S3.4.1.2	ADR-UIS Output Interfaces										1							1
S3.4.1.2.1	Order ID Number										1							1
S3.4.1.2.2	Payload Bay Information										1							1
S3.4.1.2.3	Task Information										1							1
S3.4.2	ADR - Maintenance System Interfaces										1							1
S3.4.2.1	ADR - Maintenance System Input Interfaces										1							1
S3.4.2.1.1	System Information										1							1
S3.4.2.1.2	Battery Information						1				1		1					3
S3.4.2.1.3	Malfunctioning Detection Information										1							1
S3.4.2.2	ADR - Maintenance System Output Interfaces										1							1
S3.4.2.2.1	ADR Field Service										1							1
S3.4.2.2.2	ADR Daily Maintenance Check										1							1
S3.4.2.2.3	ADR System Updates										1							1
S3.4.2.2.4	ADR Component Replacement										1							1
S3.4.3	UIS - Maintenance System Interfaces										1							1
S3.4.3.1	UIS - Maintenance System Input Interfaces										1							1
S3.4.3.1.1	Software Feedback Information										1							1
S3.4.3.1.2	Package Removal from ADR										1							1
S3.4.3.1.3	User Information										1							1
S3.4.3.2	UIS - Maintenance System Output Interfaces										1							1
S3.4.3.2.1	Software update Information										1							1
S3.4.3.2.2	Cleaning Services of Payload Bay										1							1
S3.4.3.2.3	Cyber Security Check										1							1
S3.5	Design Constraints															1		1
S3.5.1	ADR Dimension Information															1		1
S3.5.2	ADR Mass Information																1	0
S3.5.3	ADR Ground Clearance Information																	0

# RTM

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System Req ID	System Req Title	SH 2 Performance Requirements	SH 2.1 Operation Time	SH 2.2 Operational Range	SH 2.3 Payload Capacity	SH 2.4 Automated Charging	SH 2.5 Collision Avoidance	SH 3 External Interface Requirements	SH 3.1 User Interface Requirements	SH 3.2 External System Interface Requirements	SH 4 Specialty Engineering Requirements	SH 5 Functional Requirements	SH 5.1 Speed	SH 5.2 Battery Capacity	SH 5.3 Dimensions	SH 5.4 Minimum Ground Clearance	SH 5.5 Climbing Inclination	Sum Chk
S3.5.4	ADR Number of Payload Bays Information					1												1
S3.5.5	ADR Disassembly Capability					1												1
S3.6	Other Requirements											1						1
S3.6.1	ADR Compatibility Information										1							1
S3.6.2	ADR Electronics Safety System										1							1
S3.6.3	ADR Efficiency System										1							1
S3.6.4	Systems Safety Requirements								1	1								2
S3.6.4.1	Environment Temperature Information									1								1
S3.6.4.2	ADR Manual Operation Mode									1								1
S3.6.4.3	ADR Awareness Functionality								1	1								2
S3.6.4.4	ADR Emergency Stop Button									1								1
S3.6.5	Systems Security Requirements									1								1
S3.6.5.1	Security protocol Information									1								1
S3.6.5.2	Mechanical Security system Information									1								1
Sum Check		29	3	3	4	4	10		19	18	15	41	8	2	12	1	5	

# Required States and Modes

3.1.1.	ADR States.	3.1.1.10.	The ADR shall transition from the Navigation state to the Order Emptied state if the navigation goal achieved is the customer location.
3.1.1.1.	The ADR shall have the following states: Maintenance Bay, Navigation, Order Loaded, Order Emptied, Emergency Alert, Field Inspection, Scheduled Maintenance, and Charging.	3.1.1.11.	The ADR shall transition from the Order Emptied state to the Navigation state if the payload lid is closed after the order has been taken by the customer.
3.1.1.2.	The ADR shall transition from the Maintenance Bay state to its Navigation state if an order request is received.	3.1.1.12.	The ADR shall transition from the Order Emptied state to the Emergency Alert state if the lid is left open and unattended after the order has been taken by the customer.
3.1.1.3.	The ADR shall transition from the Navigation state to the Maintenance Bay state when order requests are complete, and no maintenance is required.	3.1.1.13.	The ADR shall transition from the Field Inspection state to the Scheduled Maintenance state if field maintenance is deemed necessary after the damage to the ADR has been inspected.
3.1.1.4.	The ADR shall transition from the Navigation state to the Order Loaded state if the navigation goal achieved is at the order location.	3.1.1.14.	The ADR shall transition from the Scheduled Maintenance state to the Maintenance Bay state once maintenance on the ADR is complete.
3.1.1.5.	The ADR shall transition from the Order Loaded state to the Navigation state if the payload lid is closed after the order is placed within the payload.	3.1.1.15.	The ADR shall transition from the Maintenance Bay state to the Scheduled Maintenance state if maintenance is requested for an ADR in storage.
3.1.1.6.	The ADR shall transition from the Order Loaded state to the Emergency Alert state if the payload lid is left open and unattended after the order is placed within the payload.	3.1.1.16.	The ADR shall transition from the Navigation state to the Charging state if the detected battery power is deemed to be "low" (< 20% battery capacity).
3.1.1.7.	The ADR shall transition from the Navigation state to the Emergency Alert state if a threat is detected in transit.	3.1.1.17.	The ADR shall transition from the Charging state to the Maintenance Bay state once the ADR regains a full charge (100% battery capacity).
3.1.1.8.	The ADR shall transition from the Emergency Alert state to the Navigation state if the threat is deemed to be avoided, or the payload lid is shut.		
3.1.1.9.	The ADR shall transition from the Emergency Alert state to the Field Inspection state if damage to the ADR is deemed critical, such that it inhibits further navigation.		

# Required States and Modes

3.1.2.	States for the User Interaction System (UIS) Element.		
3.1.2.1.	The UIS shall have the following states: Order Placement, Order Transit, Customer Transit, Customer Reception, Error, and Idle.	3.1.2.11.	The UIS shall transition from the Customer Reception state to the Idle state once the order status is deemed complete (i.e. the order is delivered and the ADR moves to its next task).
3.1.2.2.	The UIS shall transition from the Order Placement state to the Order Transit state if the order placed has been accepted by an ADR.	3.1.2.12.	The UIS shall transition from the Error state to the Idle state when an order has been canceled or a navigation failure is not able to be amended.
3.1.2.3.	The UIS shall transition from the Order Placement state to the Error state if the order placed has been rejected by the central server.	3.1.2.13.	The UIS shall transition from the Idle state to the Order Placement state if the user application is deemed active.
3.1.2.4.	The UIS shall transition from the Error state to the Order Placement state if the order is resubmitted by the customer after it has been rejected by the central server.		
3.1.2.5.	The UIS shall transition from the Order Transit state to the Customer Transit state if the order has been successfully picked up by the ADR.		
3.1.2.6.	The UIS shall transition from the Order Transit state to the Error state if the ADR endures a navigation failure while in transit.		
3.1.2.7.	The UIS shall transition from the Error state to the Order Transit state once the navigation failure has been amended.		
3.1.2.8.	The UIS shall transition from the Customer Transit state to the Customer Reception state if the order has been delivered to (received by) the customer.		
3.1.2.9.	The UIS shall transition from the Customer Transit state to the Error state if the ADR endures a navigation failure while in transit.		
3.1.2.10.	The UIS shall transition from the Error state to the Customer Transit state once the navigation failure has been amended.		

# Required States and Modes

## 3.1.3. States for the Maintenance Element (ME).

- |           |   |           |  |
|-----------|---|-----------|--|
| 3.1.3.1.  | The ME shall have the following states: OFF, Scheduled Maintenance, Daily Inspection, Field Maintenance/Inspection, and ON.   | 3.1.3.11. | The ME shall transition from the ON state to the OFF state if maintenance services have been requested by the ADR or maintainer. |
| 3.1.3.2.  | The ME shall transition from the OFF state to the Scheduled Maintenance state if the ADR is shutdown by the maintainer's request.   |           |  |
| 3.1.3.3.  | The ME shall transition from the Scheduled Maintenance state to the OFF state when a part replacement is necessary.   |           |  |
| 3.1.3.4.  | The ME shall transition from the Scheduled Maintenance state to the ON state when scheduled maintenance tasks are complete.   |           |  |
| 3.1.3.5.  | The ME shall transition from the OFF state to the Daily Inspection state if the ADR is shutdown by an active charge station.  |           |  |
| 3.1.3.6.  | The ME shall transition from the Daily Inspection state to the OFF state when further maintenance is required.  |           |  |
| 3.1.3.7.  | The ME shall transition from the Daily Inspection state to the ON state if daily inspection tasks are complete.   |           |  |
| 3.1.3.8.  | The ME shall transition from the OFF state to the Field Maintenance/Inspection state if the ADR is shutdown due to an emergency alert while in transit.                   |           |  |
| 3.1.3.9.  | The ME shall transition from the Field Maintenance/Inspection state to the OFF state if damage levels are severe (i.e. the ADR is no longer fit for navigation purposes). |           |  |
| 3.1.3.10. | The ME shall transition from the Field Maintenance/Inspection state to the ON state once all field maintenance and inspection tasks are complete.                         |           |  |

# System External Interface Requirements

## 3.3.1. Central Server Interface Requirements.

### 3.3.1.1. Central Server Interface Input Requirements.

- 3.3.1.1.1. The ADR system shall accept task information from the Central Server.
- 3.3.1.1.2. The ADR system shall accept route information from the Central Server.

### 3.3.1.2. Central Server Interface Output Requirements.

- 3.3.1.2.1. The ADR system shall provide its battery level.
- 3.3.1.2.2. The ADR system shall provide system information.
- 3.3.1.2.3. The ADR system shall provide the payload bay Information.
- 3.3.1.2.4. The ADR system shall provide user information.
- 3.3.1.2.5. The ADR system shall provide locomotion information.

## 3.3.2. Maintainer Interface Requirements.

### 3.3.2.1. Maintainer Interface Input Requirements.

- 3.3.2.1.1. The ADR system shall provide maintainers with the tools required to perform maintenance.
- 3.3.2.1.2. The ADR system shall provide access for firmware updates.
- 3.3.2.1.3. The ADR system shall provide access for sensor calibration.

- 3.3.2.1.4. The ADR system shall provide self malfunctioning detections to determine errors or failures.

- 3.3.2.1.5. The ADR system shall provide the access to maintainers for parts replacement.
- 3.3.2.1.6. The ADR system shall provide access for inspections.

### 3.3.2.2. Maintainer Interface Output Requirements.

- 3.3.2.2.1. The ADR system shall provide battery health information.
- 3.3.2.2.2. The ADR system shall provide connection status information.
- 3.3.2.2.3. The ADR system shall provide diagnostic information about subsystems.
- 3.3.2.2.4. The ADR system shall provide diagnostic information about sensors.

## 3.3.3. Environment Interface Requirements.

### 3.3.3.1. Environment Interface Input Requirements.

- 3.3.3.1.1. The ADR system shall gather raw video and proximity data from the environment.

- 3.3.3.1.2. The ADR system shall accept power from a charging station.

### 3.3.3.2. Environment Interface Output Requirements.

- 3.3.3.2.1. The ADR system shall interface with operating base utilities - internet access and charging stations etc.

- 3.3.3.2.2. The ADR system shall provide audio signals.

- 3.3.3.2.3. The ADR system shall provide visual signals.

# System Internal Interface Requirements

## 3.4.1. ADR - User Interaction System Interface Requirements.

### 3.4.1.1. ADR - User Interaction System Interface Input Requirements.

- 3.4.1.1.1. The ADR shall provide payload bay information.
- 3.4.1.1.2. The ADR shall provide its system information.
- 3.4.1.1.3. The ADR shall provide its locomotion information such as speed and acceleration etc.
- 3.4.1.1.4. The ADR shall provide its task information obtained from the Central Server.
- 3.4.1.1.5. The ADR shall provide Payload Bay ID Number to ADR.

### 3.4.1.2. ADR - User Interaction System Interface Output Requirements.

- 3.4.1.2.1. The User Interaction System shall provide Order ID Number to ADR.
- 3.4.1.2.2. The User Interaction System shall provide confirmation commands in accordance with the payload bay information.
- 3.4.1.2.3. The User Interaction System shall provide payload bay commands in accordance with task information.

## 3.4.2. ADR - Maintenance System Interface Requirements.

### 3.4.2.1. ADR - Maintenance System Interface Input Requirements.

- 3.4.2.1.1. The ADR shall provide the system information.
- 3.4.2.1.2. The ADR shall provide its battery levels.
- 3.4.2.1.3. The ADR shall provide malfunctioning detections.

### 3.4.2.2. ADR - Maintenance System Interface Output Requirements.

- 3.4.2.2.1. The Maintenance System shall provide the ADR field service.
- 3.4.2.2.2. The Maintenance System shall provide the ADR daily maintenance check.
- 3.4.2.2.3. The Maintenance System shall provide the updates to ADRs.
- 3.4.2.2.4. The Maintenance System shall provide the component replacement repair to ADRs.

## 3.4.3. User Interaction System - Maintenance System Interface Requirements.

### 3.4.3.1. User Interaction System - Maintenance System Interface Input Requirements.

- 3.4.3.1.1. The User Interaction System shall provide user software feedback.
- 3.4.3.1.2. The User Interaction System shall provide package takeout and minimal cleaning.
- 3.4.3.1.3. The User Interaction System shall provide user information.

### 3.4.3.2. User Interaction System - Maintenance System Interface Output Requirements.

- 3.4.3.2.1. The Maintenance System shall provide constant software updates based on the user feedback.
- 3.4.3.2.2. The Maintenance System shall provide complete cleaning of the payload bay.
- 3.4.3.2.3. The Maintenance System shall provide regular cyber security checks on user information.

# Design Constraints

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- 3.5.1. The ADR shall have the dimensions : 4ft x 2ft x 3ft (Length x Width x Height).
- 3.5.2. The ADR shall have a mass of 150 pounds excluding the payload.
- 3.5.3. The ADR shall have a ground clearance of 5 inches above the ground level.
- 3.5.4. The ADR shall have the ten individual payload bays.
- 3.5.5. The ADR shall be disassembled for replacement, inspection, packaging and transportation purposes effortlessly and efficiently.