System Requirements Specification
MECHTRON 4TB6

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Table 1: Revision History

Date	Developer(s)	Change
2023-11-10	Lisa Ji, Haoyu Lin Yuntian Wang, Zichun Yan	Revision 0

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1 Introduction

This document provides an overview of the System Requirements Specification (SRS) for the UWheeledChair project of Group 1.

1.1 Project Purpose

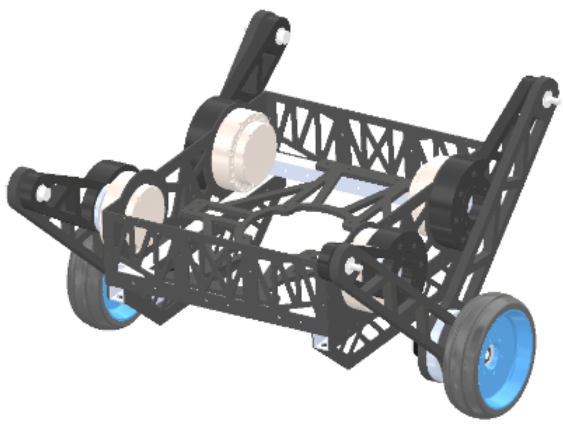

Figure 1: WBR Mechanical Platform

This project is to develop the software and control system for a fully-autonomous delivery robot, based on the existing assembly of a Wheeled Bipedal Robot (WBR) provided by the MacRobomaster Club (MacRM), as shown in Figure 1. The project will be referred to as the WBR project in the following documents.

For MacRM, WBR was constructed following the constraints defined in the rules, Committee (2023), of the 2024 RoboMaster University League (RMUL) Competition, whose host is SZ DJI Technology Co., Ltd. (DJI). Details of the constraints is shown in section 2.

Since the mechanical and electronic hardware are fixed constraints, the WBR project mainly focuses on the software and control system, while the MacRM is responsible for the mechanical design, provision, and maintenance.

1.2 Document Purpose

The purpose of this document is to locate a full range of system requirements for the development of a WBR. It encompasses a broad spectrum of aspects, including general behaviors, functional breakdown, and in-depth performance criteria. It delves into strategies for addressing unforeseen circumstances and the likelihood of changes in these requirements. It also acts as a benchmark to evaluate whether the future design meets all specified requirements.

1.3 Organization of Document

This document is a modified Volere template as in Robertson and Robertson (2012) and has been adopted according to project needs. The document follows the general organization of the Volere template with some additional sections to better suit for Mechatronics. It contains scope of the requirements and overview of system behaviours, which gives readers general concept of what are contained in this document. The performance requirements are separated into two parts, functional and nonfunctional. Referring to different requirements, the normal operation and undesired event handling are covered. The likelihood of Each requirement is determined. This allows readers to follow a flow from general to specific details for the system requirements of WBR.
Neglected subsections from the Volere template are: the hands-on users of the product, persona, priorities assigned to users, users participation, maintenance users and service technicians,implementation environment of the current system, partner or collaborative applications, off-the-shelf software, anticipated workplace environment, enterprise constrains, relevant facts, business rule.

1.4 The Stakeholders

1.4.1 The Client

- Dr.Alan Wassyng, Professor from McMaster University, Computing and Software Department.
- MacRobomaster Club (MacRM), a robotics engineering club of McMaster University

1.4.2 The Customers

- People who wants to save time moving objects over a moderately long distance and moderately complex terrain.
- People who requires unmanned transportation of goods over a moderately long distance and moderately complex terrain.
- People who requires secured transportation of goods over a moderately long distance and moderately complex terrain.

1.4.3 Other Stakeholders

N/A

2 Design Constraints

2.1 Mechanical Platform

As mentioned in section 1.1, the WBR is constrained by the rules of 2024 RMUL. From page 26 to 27 of the robot specification manual, Committee (2023), our "Balancing Standard Robot" is constrained to have all ground-contacting surfaces aligned on the same line and cannot keep balance without dynamic adjustment. Additionally, to win the competition, the robot shall be light, fast, robust, and small.

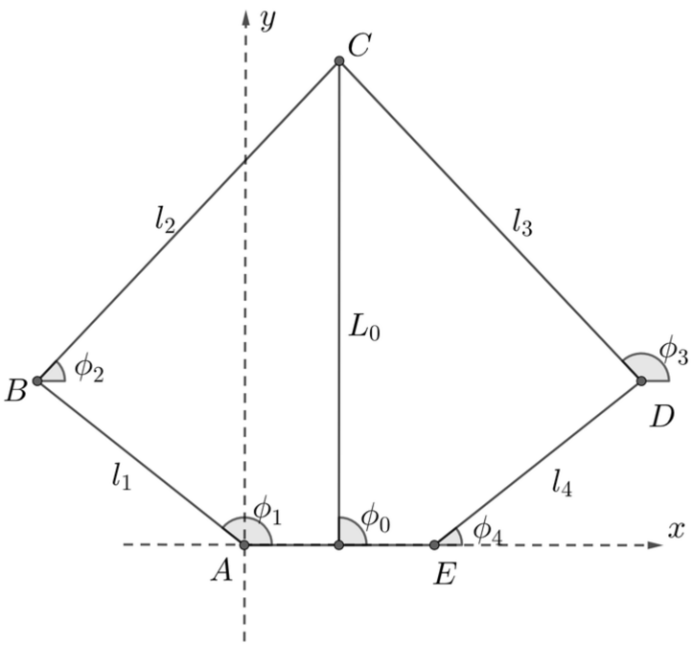

Figure 2: Sketch of WBR Leg Linkage, from Wang (2022)

Therefore, MacRM decided to put a five-bar linkage configuration on per side of the WBR, by following the paper Wang et al. (2021). Shape of each linkage, as illustrated in figure 2, is controlled by a pair of two hip-joint motors, which changes the overall robot posture as a result. The two motors contacting the ground are drive motors, which regulates the horizontal movement.

2.2 Electronic Platform

MacRM designed the electronic system according to the rules of RMUL as shown in figure 3. The rationale of choice of each specific component is out of scope of this document.

3 Project Constraints

3.1 Mandated Constraints

MC1	The complete project design needs to be done by the end of academic year
Description	Based on the course outline, the deadline of the capstone project is by the end of the academic year
MC2	The cost of the whole project should not exceed $750
Description	There is a budgetary constraint on this project to deter individuals from acquiring pre-packaged "solutions."
MC3	The design should be a combination of software and hardware.
Description	As a hard requirement for all Mechatronics groups, the design must encompass not only software components but also integrate hardware elements.

3.2 Relevant Facts and Assumptions

3.2.1 User Characteristics

Users of the WBR are anticipated to have specific demands related to object delivery. These users might lack the time to personally handle deliveries or seek to allocate time to more crucial tasks. Additionally, the WBR suits individuals who facing mobility challenges. Users are expected to possess fundamental knowledge of controlling the robot's movement through the use of a remote control unit, enabling them to interact effectively with the technology.

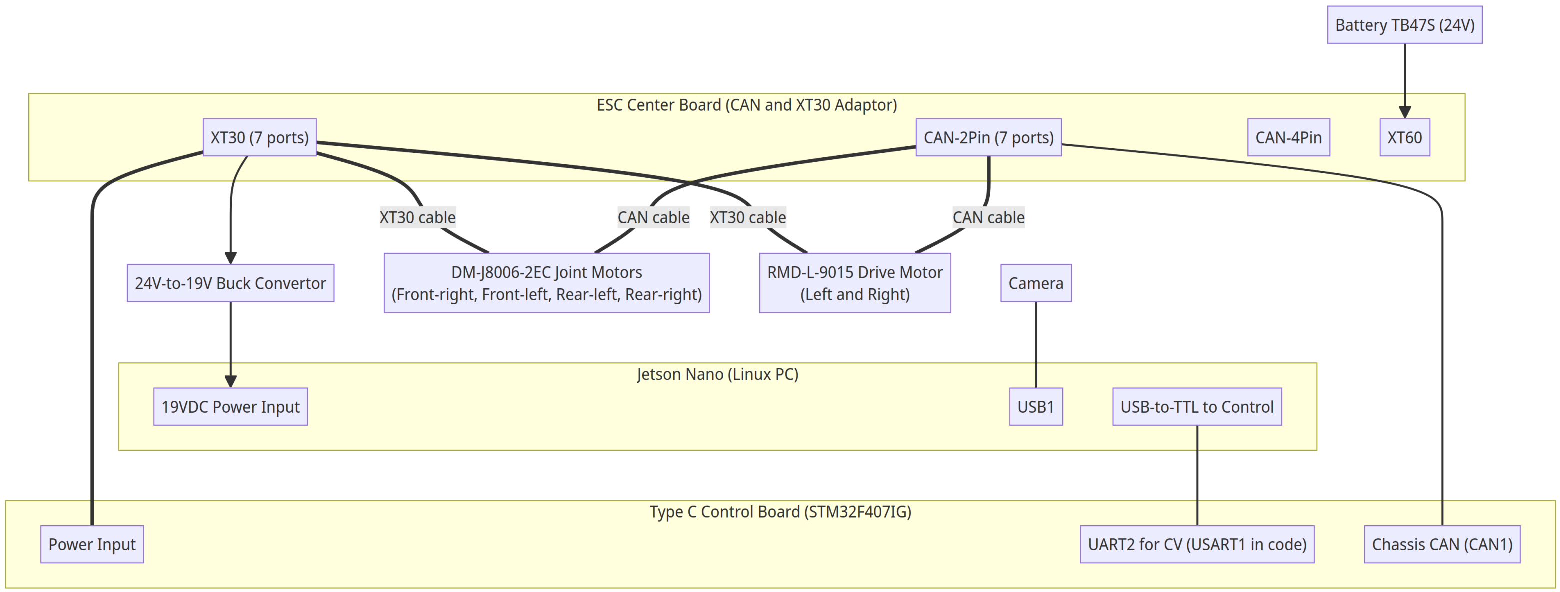

Figure 3: WBR Electronic System

3.2.2 Reader Characteristics

The potential readers of this document comprises technicians and individuals with engineering backgrounds or a keen interest in robotic designs. Given the technical nature of the content, readers are expected to possess some professional knowledge and understanding in both hardware and software fields. Familiarity with the engineering design process is crucial to facilitate comprehension and navigation through the document. This feature enables efficient searching, allowing readers to locate their relevant area of interest promptly without the need to invest time in comprehending the entire document.This technical resource is also open to enthusiastic learners without prior engineering knowledge. Rationales are provided where concepts may be challenging, enabling readers to follow and understand the content effectively.

3.2.3 Assumptions and Dependencies

AD1: The user should be capable of visually tracking or observing the robot's movements with their eyes.
Rationale: In order to control the movement of the robot, the user should have a basic idea where the robot goes and what its destination is, so they can monitor the robot's path or ensure it navigates as intended.

AD2: Assuming that users interacting with the robot have a basic understanding of how to control it using a remote control unit.

AD3: Assuming the robot works within a predetermined and specified environmental conditions.
Rationale: The extreme weather, such as -30 degree celsius condition would prevent the robot from working normally. Therefore, assuming it is placed in moderate working conditions.

4 Scope

4.1 Scope of Requirements

The responsibilities of the stakeholders and the WBR are as follows:

- Package Sender Responsibilities: The Package Sender is responsible to provide appropriate inputs and environment to the system as mentioned in the relevant parts of Assumptions and Dependencies.

- Package Receiver Responsibilities: The Package Receiver is responsible to provide appropriate inputs to the system as mentioned in the relevant parts of Assumptions and Dependencies.
- WBR Responsibilities: The WBR provides suggestion of paths to reach the target location and let Package Sender choose the path to go; determines the robot's intended routes and desired motions; It processes data received from sensors, which detect obstacles and unfamiliar terrain. The motor system primarily handles the robot's mechanical movements.

4.2 The Scope of the Work

4.2.1 The Context of the Work

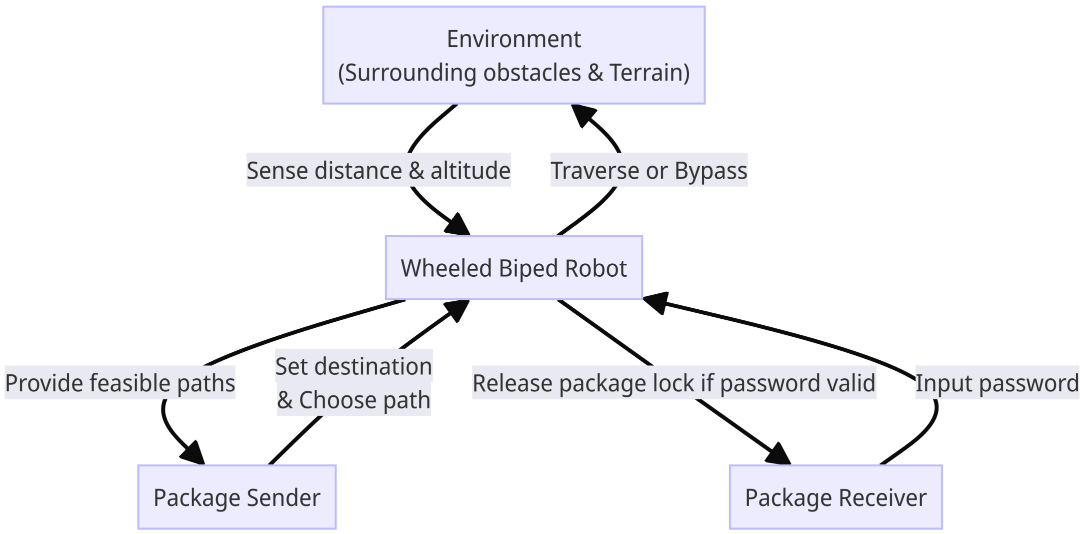

Figure 4: System Context Diagram

The following picture shows the design of the context diagram of the project, it illustrates the core interaction between the WBR and its immediate external entities. In this diagram, the WBR is the central system, the information regarding the condition of the environment is detected, such as the distance from the nearest obstacle, then the WBR takes the reaction on how to handle a certain situation. The package sender acts as the external entity, it sets the destination and picks a route for the WBR and the WBR provides it the feasible path and goes to complete the package delivery. The package receiver is another external entitle, it inputs password, in response to it, the WBR releases the package once it confirms the validity of the password.

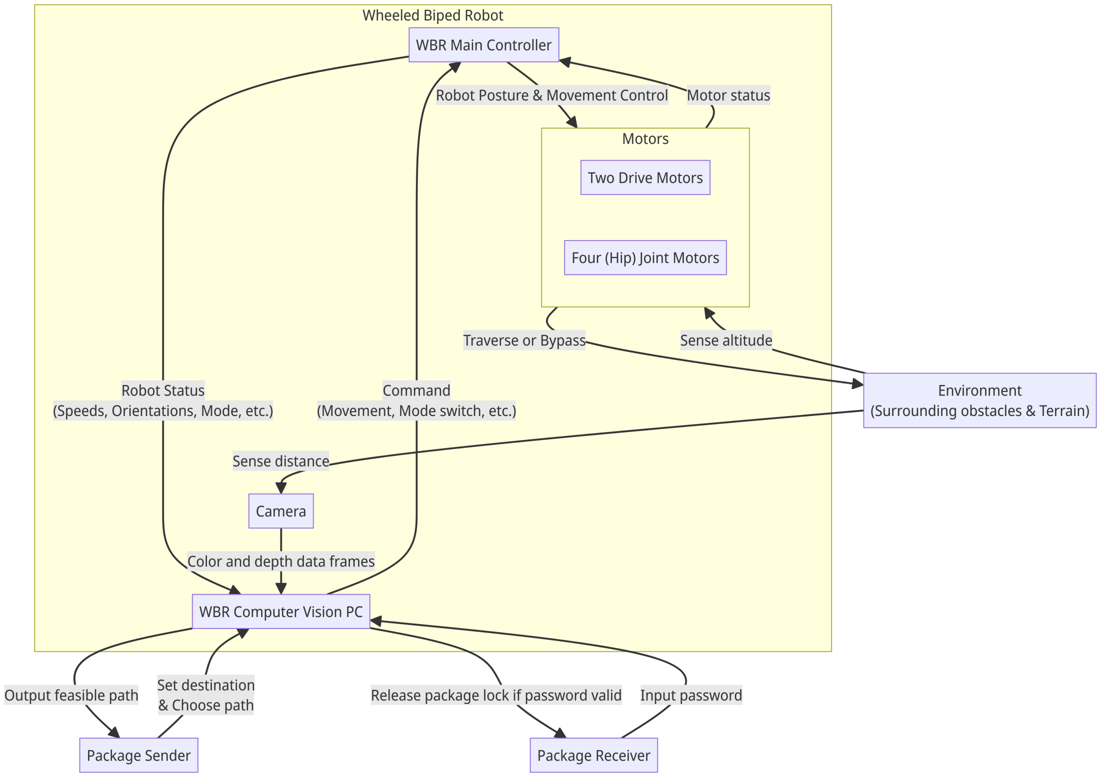

Figure 5: Complete System Diagram

5 Behaviour Description

To make the behaviour of the product to achieve the target task, the Finite State Machine is created to describe the behaviour with detailed description provided after the picture.

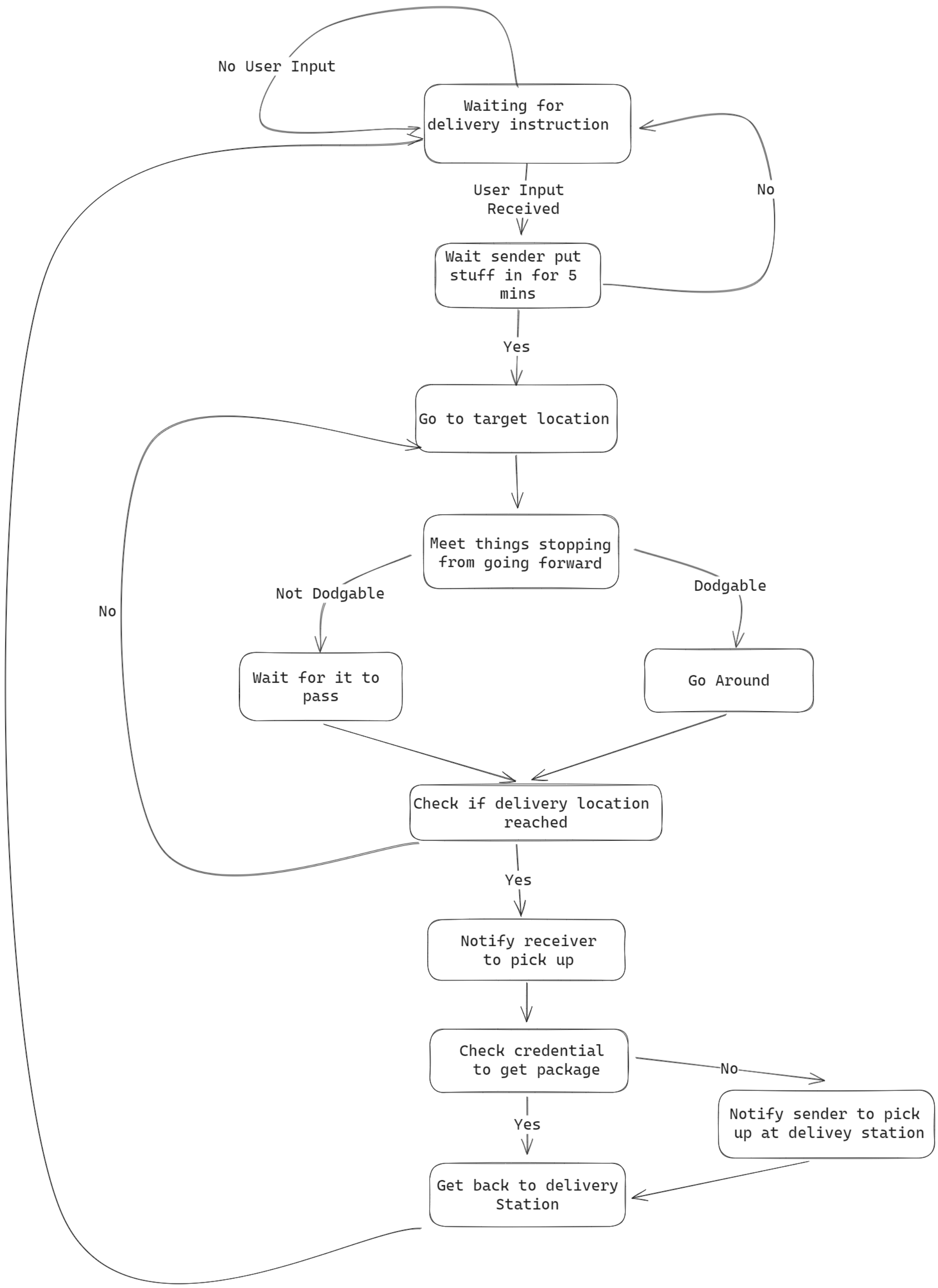

Figure 6: System Behaviour Finite State Machine

5.1 State Transition Descriptions

The Finite State Machine diagram briefly introduces the following general behaviours state. The description is given below:

Waiting for delivery instruction: It will need to stay in the delivery station to wait for new delivery instructions coming in from a client

Wait sender put stuff in for 5 mins: Upon receiving a delivery instruction, the robot initiates waiting status to allow sender side client to put stuff in delivery box for 5 mins. If there is nothing inside after 5 mins, it will return back the first status to waiting next delivery instruction

Go to target location: After sender side client put stuff in for delivery. Robot will start navigation to the target location.

Meet things stopping from going forward : When the sensor detects nearby obstacles, it communicates this information to the control system. The system temporarily interrupts the ongoing path travel task and initiates the execution of a special task.

Check if delivery location reached: When going closer to the delivery location or algorithm detect WBR reached target destination. It will go check if it actually reached or not.

Notify Reciver to pick up : After comfirming the target destination is reached, WBR will notify Reciver to pick package up.

Check credential to get package : This status will ensure only the person will credential can get the package, other wise it will bring the package back to original delivery station.

Get back to delivery Station : After finishing delivery task, it will go back to delivery station for next delivery task or wait there until previous failed delivery to be pick up.

5.2 State Behaviour Description and Rationales

Waiting for delivery instruction: When the WBR is positioned in delivery Station, in the absence of any initial user commands, it enters an ”Idle” state. During this state, the robot’s motor system is powered on, and the robot readies itself to receive and respond to user commands once they are initiated. .

Wait sender put stuff in for 5 mins: 5 mins is a reasonable length to detect if client has put stuff in or not. If there is already stuff in, WBR will stay in unavailable status until it being picked up by either client or MacRM.

Go to target location: This is the starting state for delivery navigation. Once WBR enter this status. It means it is in delivery process now.

Meet things stopping from going forward : This status has 2 solution, one is wait until the object go away and one is finding a workaround. Since we do not want the robot just to stand at 1 position for whole day. That is the reason why we will have a timeout as well for waiting.

Check if delivery location reached: This status is to check if the algorithm working alright on WBR. We will have at at least 3 ways to decide if robot reach the destination or not.

Notify Receiver to pick up : This action is to make sure the receiver knows WBR is there and will be notify to avoid missing delivery.

Check credential to get package : This state will make sure that package is delivered to the correct person.

Get back to delivery Station : This is the final status of WBR delivery task. Since it need to go back to the delivery station whatever it finished delivery or not(if receiver didn’t pick it up in certain amount of time).

5.3 Jump Behaviour

The figure 7 shows the whole process of jump action of WBR, including the process before it receives the jump command and after if fully completes the jump action and resumes initial position.

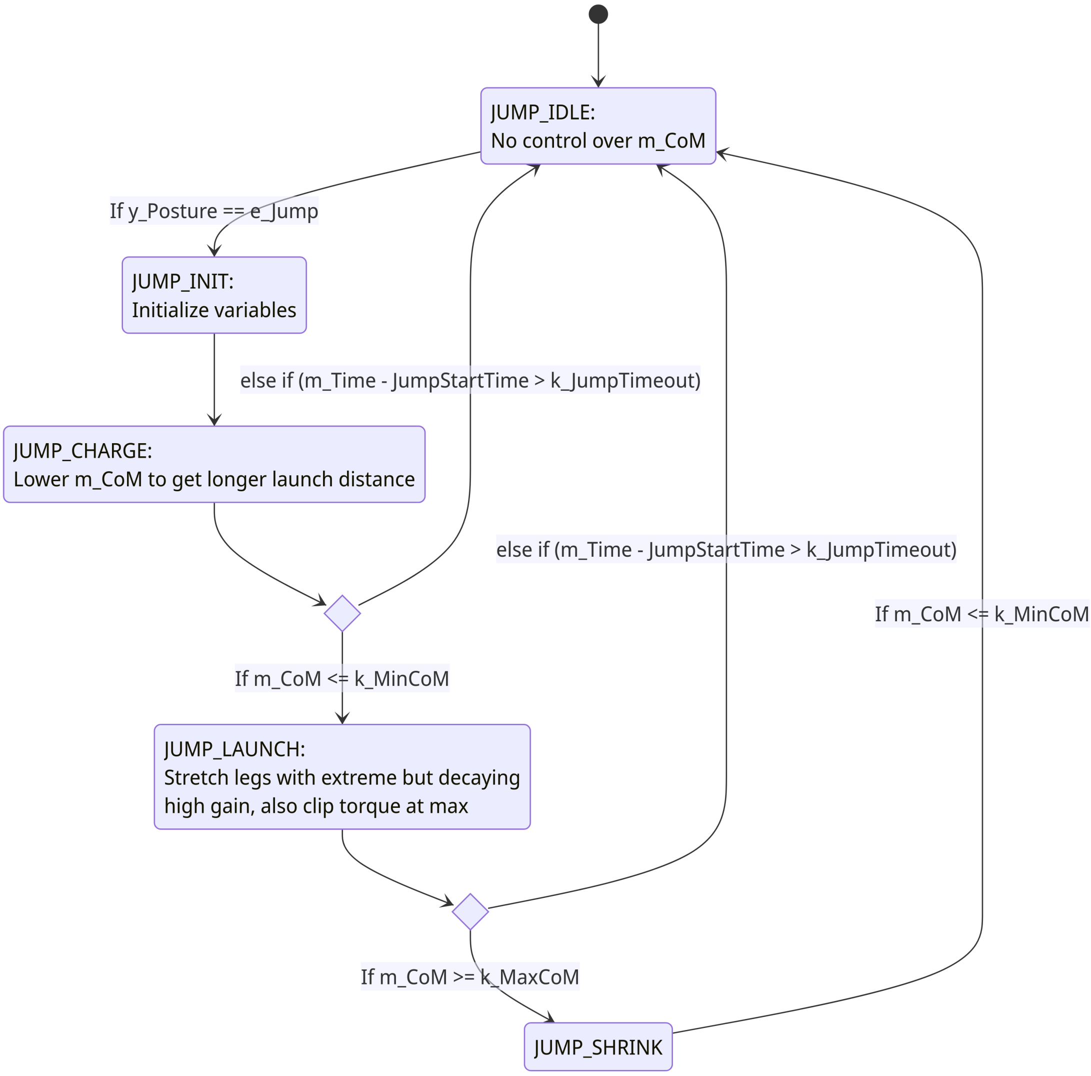

Figure 7: Jump FSM

5.3.1 State Descriptions

JUMP_IDLE: WBR stays idle when there is no command received.

JUMP_CHARGE: WBR lower the CoM to a predetermined level for the purpose of getting a longer launch distance. This primarily aimed at accumulating more energy for a higher jump. It is important to ensure CoM remains within the robot's bearing capacity, and it should not exceed the lowest acceptable CoM level.

JUMP_LAUNCH: Stretching legs but with decaying gain. The intentional reduction in gain serves as a buffer, mitigating large torques to prevent potential damage to the components.

JUMP_SHRINK: Lower CoM to its initial position.

6 Functional Requirements

The following are the functional requirements of the project. They are separated into 2 main parts: robot mobility and environment sensing. Note: All monitored, controlled variables and constants can be found in section 13.1.

6.1 Functional Decomposition and Work Partitioning

The following table shows the work partitioning of the project. It lists all possible events taking place during the operation of the WBR. The functional decomposition diagram is also attached as figure 8.

Table 2: Work Partitioning

Event Name	**Input**	**Output**
CV Obstacle Detection	Depth and colour data frame from camera	Characteristic distances to major obstacles, e.g. perpendicular distance to walls.
Posture Determination	Current chassis orientation; distances to nearby obstacles that reduces safe workspace.	Desired posture as joint configurations.
Path Determination	distances to nearby obstacles that eliminates alternative routes to go	Desired horizontal velocity including rotational and translational velocity.
Motors Control	Motor feedback data, Chassis orientation, and desired robot kinematics	Desired torques of all motors. The integrated motor controller hardware will ensure the torque further.

Trigger conditions:

- **Path Determination Event:** Triggered when the system determines the optimal path for the wheeled biped robot based on various inputs, including obstacle detection and posture determination.

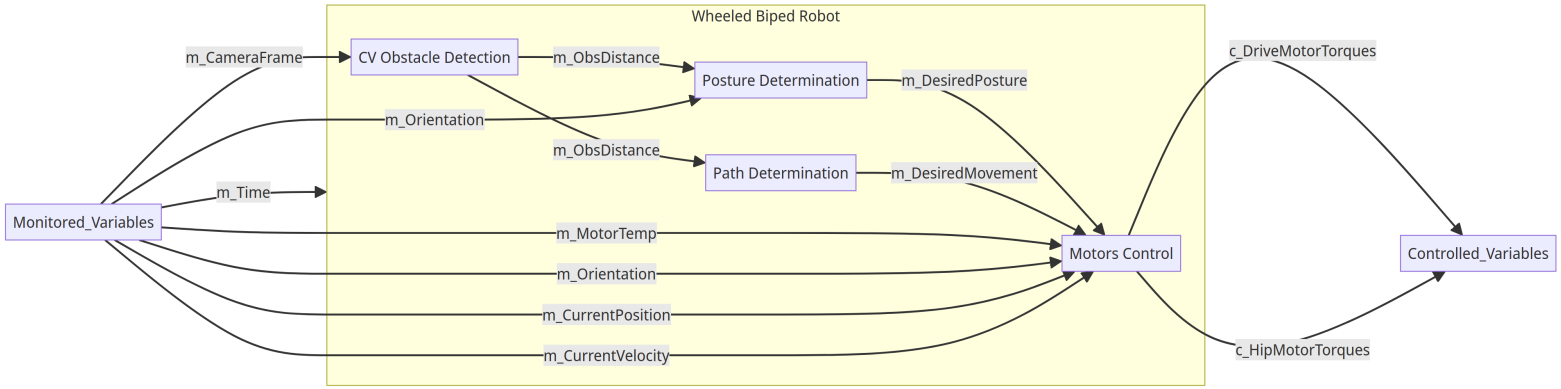

Figure 8: Functional Decomposition Diagram

- **Motors Control Event:** Involves the control of motors to execute movements, influenced by the desired path, posture, and obstacle detection.
- **Obstacle Detection Event:** Activated when the system detects obstacles in the robot's path, influencing the path determination and motors control processes.
- **Posture Determination Event:** Occurs when the system determines the optimal posture or position for the robot, affecting the motors control process.
- **Input Update Event:** Involves updating the input parameters, including obstacle information, orientation, current position, and current velocity of the robot.
- **Desired Path Update Event:** Triggered when the system updates the desired path based on various factors, including obstacle detection and the current posture.
- **Jump State Event:** Activated when the system encounters a condition requiring to jump, influencing the posture determination process.
- **Position Update Event:** Involves updating the current position of the robot, impacting the motors control process.
- **Velocity Update Event:** Occurs when the system updates the current velocity of the robot, influencing the motors control process.
- **Output Generation Event:** Involves generating output parameters, including position, velocity, and acceleration, which are sent as commands to the WBR.

6.2 Robot Mobility

RM1: The WBR must be capable of moving smoothly and without jerky motions in various directions, including forward, backward, left, right, and rotation.
Rationale: Seamless movement ensures the WBR's agility and adaptability in unpredictable environments, promoting efficient navigation and minimizing disturbances for improved overall performance and user experience.

RM2: The robot should be able to follow the command from Computer Vision board to go through unpredictable environments with obstacles of varying sizes and shapes. It must react to command fast.

Rationale: Since the control board for WBR movement is separated from the path finding and tracking one which process all the data from sensor. So the control board need to react fast enough to the command passing from Computer Vision board

RM3: The robot should maintain stability while moving on uneven terrain and when transitioning between different types of surfaces, such as from smooth floors to rough terrain.
Rationale: The stability requirement ensures the WBR's capability to navigate diverse environments safely, mitigating the risk of instability during transitions between surfaces.

RM4: The robot's average speed should be at most 5m/s when navigating through typical outdoor environments. The maximum speed for safety should not exceed that.

6.3 Environment Sensing

ES1: The robot must detect obstacles in its path using LiDAR, cameras, or other methods. It should identify obstacles at least 2 meters before reaching them.

ES2: The robot should be able to sense the environment, including changes in elevation, and surface irregularities, to give out command accordingly.

ES3: The robot should be able to recognize and differentiate between various objects in its environment, such as people, furniture, and other potential obstacles.
Rationale: The ability for object recognition is crucial as it enables the robot to distinguish between diverse environmental elements, enhancing navigation precision and enabling informed decision-making to navigate safely through varied scenarios.

7 Nonfunctional Requirements

The next paragraphs will talk about about non-functional requirements in the designing of the WBR, which will be discussed in several different parts.

7.1 Look and Feel Requirements

N/A

7.2 Usability and Humanity Requirements

7.2.1 User Interface Design

UID1: The robot's user interface should be designed with simplicity and clarity, ensuring operators can easily understand and navigate controls without extensive training or guidance.

UID2: The robot's control interface should support customization to accommodate users with different physical and cognitive abilities.

7.3 Performance Requirements

PR1: The robot should maintain optimal performance on various terrains, including smooth floors and rough outdoor environments.

PR2: Control system's response time to Computer Vision Board commands should be within 0.2s to ensure real-time interaction.

PR3: The robot should be highly reliable, with a low probability of system failures or malfunctions during operation

PR4: The robot should be able to withstand minor collisions or impacts without sustaining significant damage that would impair its performance.

7.4 Operational and Environmental Requirements

OER1: The robot should able to operate within normal weather condition.

7.4.1 Communication Requirements

OER2: The robot should be capable of establishing and maintaining wireless communication with external systems for data transfer.

7.5 Maintainability and Support Requirements

MSR1: The robot should support remote diagnostics, allowing maintenance teams to identify and address issues without physical intervention.
MSR2: The software should be easily upgradable, enabling the implementation of new features and improvements as technology advances.

7.6 Security Requirements

SR1: The robot's control systems should implement authentication mechanisms to prevent unauthorized access, ensuring secure and controlled operation.
SR2: The robot must have an emergency stop mechanism that can be activated to halt all movements in case of an imminent collision or other safety concerns.
SR3: The robot should be equipped with mechanisms or sensors to prevent tipping over when navigating uneven or inclined terrain.

8 Durability and Reliability

Operating Time: The robot should be capable of continuous operation for at least 20 mins before requiring recharging or maintenance.
Reliability: The robot should be highly reliable, with a low probability of system failures or malfunctions during operation.
Robustness: The robot should be able to withstand minor collisions or impacts without sustaining significant damage that would impair its performance.

8.1 Battery Life

Battery Endurance: The robot's onboard power source should provide sufficient energy for the robot to operate for at least 5 hours on a single charge.
Recharge Time: The time required for recharging the robot's batteries should not exceed 2 hours to minimize downtime.

8.2 Communication

Wireless Communication: The robot should be capable of establishing and maintaining wireless communication with external systems for data transfer.

8.3 Safety

Emergency Stop: The robot must have an emergency stop mechanism that can be activated to halt all movements in case of an imminent collision or other safety concerns.
User Interface: The robot should have a user interface that reject suspicious behavior.
Hit prevent: The robot should have soft material surround it to prevent undesired behavior damaging any surrounding.

8.4 Compliance

Regulatory Requirements: The robot's performance should comply with all relevant safety and regulatory standards for robotics in the intended operating environment.

9 Traceability and Priority

For both functional and non-functional requirements, the dependency matrix is made and priorities are assigned to each requirement. The Traceability matrix and priority table are shown below. In addition, the likelihood change of the requirements and the future plan of the requirements are also shown below.

9.1 Requirement Matrix

Functional Requirement ID	Nonfunctional Requirement ID
RM1	UID1
RM2	UID2
RM3	PR1
RM4	PR2
ES1	PR3
ES2	PR4
ES3	OER1
	CR1
	MSR1
	MSR2
	SR1
	SR2
	SR3

Table 3: Requirement Traceability Matrix

9.2 Priority Table

Functional Requirement ID	Nonfunctional Requirement ID	Priority
RM1		HIGH
RM2		HIGH
RM3		HIGH
RM4		HIGH
ES1		HIGH
ES2		HIGH
ES3		HIGH
	SR1	HIGH
	SR2	HIGH
	SR3	HIGH
	UID1	MED
	UID2	MED
	PR1	MED
	PR2	MED
	PR3	MED
	PR4	MED
	OER1	HIGH
	CR1	MED
	MSR1	MED
	MSR2	MED

Table 4: The Priority Table for each Requirement

9.3 Requirements Likely to Change

Requirement ID	Likelihood	Ways to Change
UID1	MED	Changing requirements for User Interface
UID2	MED	Remove
PR1	MED	Changing requirements to be restricted area
PR2	MED	Changing to longer delay
PR3	MED	Change requirements to fit progress
PR4	MED	Due to restriction given by MacRM
MSR4	MED	Change to wired diagnostics
MSR4	HIGH	Due to restriction given by MacRM

Table 5: Requirements that are likely to change

9.4 Requirements Unlikely to Change

(with our current progress, many of them are in progress or done already)

Requirement ID	Likelihood	Justification
RM1	LOW	In progress without any roadblock found
RM2	LOW	In progress without any roadblock found
RM3	LOW	In progress without any roadblock found
RM4	LOW	Can be easily done
ES1	LOW	In progress without any roadblock found
ES2	LOW	In progress and it is fun
ES3	LOW	Done
SR1	LOW	Can be easily done
SR2	LOW	Can be easily done
SR3	LOW	Can be easily done
OER1	LOW	Basic Requirement
CR1	LOW	Basic Requirement

Table 6: Requirements that are unlikely to change

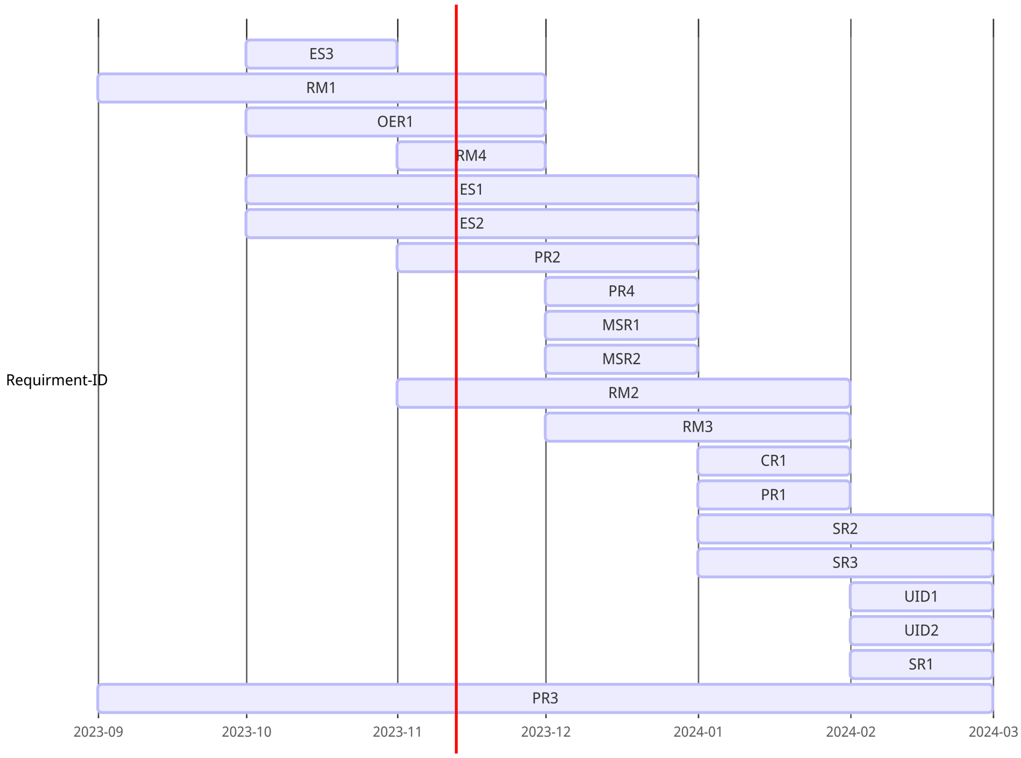

Figure 9: Gantt Chart

10 Normal Operation

NO1: Able to stay at delivery station and wait for task.
System Behaviour: It should able to stay at delivery station when it is in idle state. And also wait for sender to put stuff in.
Rationale: It need to stay at delivery station for task to come in and wait for package to be put in delivery box. WBR should able to tell if stuff is been put in or not.
Associated Requirement ID: CR1, MSR1, MSR2

NO2: Go to target location
System Behaviour: Once it receive delivery task and sender has put stuff in. It should start navigation to destination and doge object on its way.
Rationale: WBR need to deliver the package to its destination. With one pre-generated global plan. And during delivery, it shouldn't be too fast or too slow.

Associated Requirement ID: RM1, RM2, RM3, RM4, PR1, PR2, PR3, SR3

NO3: Dodge object during delivery
System Behaviour: WBR should able to dodge objects during delivery and arrange the best path to its destination.
Rationale: In order to make the delivery, WBR should able to dodge objects and find path. And it should able to sense surrounding
Associated Requirement ID: ES1, ES2, ES3, PR4

NO4: Client can access to setup delivery task
System Behaviour: Client is able to login and schedule delivery task, then put stuff in the robot.
Rationale: The User Interface should be easy to access and run smoothly without issue and schedule tasks in queue.
Associated Requirement ID: UID1, UID2

NO5: Client can access WBR when it reach destination
System Behaviour: Receiver should able to open delivery box with given credential.
Rationale: Receiver should able to get the package.
Associated Requirement ID: SR1, SR2

11 Undesired Event Handling

UEH1: Collision or Obstacle Blocking
System Behaviour: The robot initiates an emergency stop, halting all movements, and attempts to re-plan its path to navigate around the obstacle.
Rationale: This behavior ensures immediate safety by stopping the robot upon detecting an obstacle, preventing collisions and providing the opportunity to find an alternative path.
Associated Requirement ID: RM1, ES1, ES2, PR4, SR2

UEH2: Loss of Communication
System Behaviour: The robot attempts to re-establish the communication link,

and if unsuccessful within a predefined time, it enters a safe mode, ceasing movements and alerting operators.
Rationale: This response prioritizes safety in the absence of communication, preventing the robot from executing commands without proper control or supervision.
Associated Requirement ID: CR1

UEH3: System Fault
System Behaviour: The robot logs the error, performs a self-diagnosis, and initiates an emergency stop if the fault impacts safety or functionality, providing detailed reports for maintenance teams.
Rationale: This response prioritizes safety and maintenance by halting the robot and providing crucial diagnostic information for timely troubleshooting and repairs.
Associated Requirement ID: PR3

UEH4: Human Interference
System Behaviour: The robot, designed to respond safely, avoids collisions with humans, initiates an emergency stop if necessary, and alerts operators.
Rationale: This behavior prioritizes human safety by preventing collisions and provides timely alerts for operators to address potential safety concerns.
Associated Requirement ID: SR2

UEH5: Loss of Localization
System Behaviour: TThe robot attempts to re-establish its position within the environment, and if unsuccessful, enters a safe mode, ceasing movements.
Rationale: This response ensures the robot does not continue operation in an uncontrolled state, minimizing the risk of unpredictable behavior in the absence of accurate localization.
Associated Requirement ID: ES2

12 Appendix A

12.1 Naming Conventions

The following naming conventions are observed in this document:

- k_ : constant value
- m_: monitored variable
- c_ : controlled variable
- e_ : enumerated values
- y_ : enumeration
- i_ : input variable (individual component)
- o_: output variable (individual component)
- d_: data variable (data in communications packet)
- s_: Data Structures
- t_: Data Types

The first letter of the constant shall be lower case, and all subsequent starting characters are upper case, for example, "k_SomeTextHere".
Previous values shall be represented by a subscript "-x" where x represents how far in the past, for example, "k_SomeTextHere-3".

12.2 Table of Units

Throughout this document SI (Système International d'Unités) is employed as the unit system. In addition to the basic units, several derived units are used as described below. For each unit, the symbol is given followed by a description of the unit and the SI name.

symbol	**unit**	**SI**
m	length	metre
kg	mass	kilogram
s	time	second
°C	temperature	centigrade
J	energy	Joule
W	power	Watt ($\mathrm{W} = \mathrm{J\,s^{-1}}$)
m/s	speed	meter/second
m/s^2	acceleration	meter per second square
A h	electric charge	ampere hour
cm	length	centimeter
V	voltage	volt
N m	torque	newton per meter
rad	angle	radian

12.3 Abbreviations and Acronyms

symbol		description
CoM	=	Center of Mass
DJI	=	SZ DJI Technology Co., Ltd.
FSM	=	Finite State Machine
IMU	=	Inertial Measurement Unit
MacRM	=	MacRobomaster Club
MSR	=	Maintainability and Support Requirements
N/A	=	Not Applicable
NO	=	Normal Operation
OER	=	Operational and Environmental Requirements
PID	=	Proportional–integral–derivative
PR	=	Performance Requirements
RMUL	=	RoboMaster University League
SR	=	Security Requirements
SRS	=	System Requirements Specification
TBD	=	To be declared
UEH	=	Undesired Event Handling
UID	=	User Interface Design
WBR	=	Wheeled Bipedal Robot

13 Appendix B

13.1 VARIABLES MASTER LIST

Table 7: Monitored Variables

Variable Name	**Type**	**Unit**	**Description**
m_BatteryVolt	Analog	V	Battery voltage as an estimate of remaining power
m_Orientation	Analog Array	rad	Orientation of chassis to be sensed by IMU
m_MotorTemp	Analog	°C	Temperature of motor
m_Time	Analog	s	Real-world time
m_CameraFrame	Analog	N/A	Optical input to camera
m_ObsDistance	Digital	m	Distances to major obstacles, format is not yet decided. It might be representation of several linearly-square-fitted obstacle planes.

Table 8: Controlled Variables

Variable Name	**Type**	**Unit**	**Description**
c_DriveMotorTorques	Digital Array	N m	Desired torque of drive motors
c_HipMotorTorques	Digital Array	N m	Desired torque of hip motors

Table 9: Enumerated Variables

Enumerated Name	**Description**	**Range**
y_Posture	Robot posture state	{e_Jump, e_Normal, TBD}

13.2 CONSTANTS MASTER LIST

Almost all constants are not yet determined, but will be after details of mechanical model is finalized, assembled, and measured by MacRM.

Table 10: Constants

Constant Name	Type	Unit	Value	Description
k_RobotMass	Digital	kg	TBD	Approximate mass of robot without cargo.
k_PidGains	Digital Array	N/A	TBD	Gains for each PID controller feedbacks.
k_L1Length	Digital	m	TBD	Length of link l1 in 2. Note that linkages on left and right sides are symmetric.
k_L2Length	Digital	m	TBD	Length of link l2 in 2. Note that linkages on left and right sides are symmetric.
k_L3Length	Digital	m	TBD	Length of link l3 in 2. Note that linkages on left and right sides are symmetric.
k_L4Length	Digital	m	TBD	Length of link l4 in 2. Note that linkages on left and right sides are symmetric.
k_MaxCoM	Digital	m	TBD	The maximum allowable height CoM of WBR can reach
k_MinCoM	Digital	m	TBD	The minimum allowable height CoM of WBR can reach
k_JumpTimeout	Digital	second	TBD	The maximum amount of time the WBR shall finish any stage of jump mode

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