Manipulator Subsystem: Risk Assessment Report

Mechatronics Omni-Challenge - Spring 2026

Subsystem: Arm / Manipulator Module

February 21, 2026

1 Introduction

This document outlines the risk assessment process and results for the Manipulator Subsystem of the Modular Omni-Wheel Mobile Manipulator. The goal of this Failure Mode and Effects Analysis (FMEA) style report is to proactively identify, analyze, and evaluate potential mechanical, electrical, software, and perception risks to minimize their negative impact on project performance, safety, and competition constraints.

2 Risk Assessment Matrix

The risk score R is calculated by the product of Likelihood (L) and Impact (I):

$$R = L \times I \tag{1}$$

Priority is determined by the following scale:

L	Description	I	Description	Score (R)	Risk Level
1	Rare	1	Insignificant	$1 - 4$	Low
2	Unlikely	2	Minor	$5 - 9$	Medium
3	Moderate	3	Moderate	$10 - 14$	High
4	Likely	4	Major	$15 - 20$	Extreme
5	Almost Certain	5	Catastrophic	$21 - 25$	Extreme

3 Identified Risks and Mitigation Strategies

3.1 Mechanical Risks (M)

Focuses on physical structure, spatial constraints, and gripper dynamics.

ID	Risk Description	L	I	R	Level	Mitigation Strategy
M-001	Arm tip deflection/oscillation	4	3	12	High	Use carbon fiber; S-curve profiling.
M-002	Base joint mechanical failure	2	5	10	High	Use thrust bearings; metal brackets.
M-003	Exceeding dimension constraints	2	5	10	High	Foldable kinematic chain; Week 3 CAD check.
M-005	Wire tangling or snapping	4	4	16	Extreme	Internal routing; drag chains; silicone wire.

3.2 Electromechanical Risks (E)

Concerns the intersection of control and physical output (torque/thermals).

ID	Risk Description	L	I	R	Level	Mitigation Strategy
E-001	Motors undersized for reach	3	5	15	Extreme	Static torque calcs; counter-weights.
E-002	Actuator overheating (static)	3	4	12	High	Current reduction; worm gears.
E-003	Gearbox backlash	4	3	12	High	Planetary gears; absolute output encoders.

3.3 Electrical & Power Risks (P)

Concerns power distribution and signal integrity.

ID	Risk Description	L	I	R	Level	Mitigation Strategy
P-001	MCU Brownout on high load	4	5	20	Extreme	Isolate logic/motor rails; by-pass caps.
P-003	Signal noise (I2C/SPI)	4	4	16	Extreme	Twisted pairs; shielded cables; CAN bus.

3.4 Software & Control Risks (S)

Concerns kinematics, safety states, and communication.

ID	Risk Description	L	I	R	Level	Mitigation Strategy
S-001	Self-collision/Hard stops	3	5	15	Extreme	Software limits; physical limit switches.
S-003	Comms timeout (Heartbeat)	3	4	12	High	10Hz ping; safe-state motor freeze.

3.5 Perception Risks (C)

Integration of sensors and QR vision systems.

ID	Risk Description	L	I	R	Level	Mitigation Strategy
C-001	QR lighting/shadow failure	3	5	15	Extreme	Active LED ring; auto-exposure pipeline.
C-002	Gripper obstructs camera FOV	4	4	16	Extreme	FOV modeling in CAD; off-set mounting.