*ENSC 386 – An Introduction to Mechanical Design and Analysis of Robots*

**Project 1**

# Modular Walker

Due Date: April 27th/ 2025



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# *Abstract*

This project presents the design and analysis of a **Modular Walker** robot developed to support aging-in-place living. This transformer robot features a modular, self-configurable system that transforms into different modes—walking support, table, and seating—to assist elderly individuals in everyday tasks. Equipped with linear actuators, a call system, and docking capabilities, the design promotes safety, autonomy, and usability. The report outlines the design concept, mechanical analysis, actuation system, and integration within a home environment.

# *Introduction*

The rising elderly population poses challenges for independent living. Robotic systems offer innovative solutions to enhance autonomy and reduce social isolation. This project proposes a **transformer robotic system**—the Modular Walker—targeted at elderly users who require assistance with mobility, eating, and transitioning between sitting and standing.

**Existing Products:**

- Standard walkers lack dynamic support or smart features.
- Sit-to-stand lift chairs offer seating assistance but lack mobility.
- Robotic assistants like ElliQ and mobile tables are single-purpose.

Our design combines and extends these functionalities through a reconfigurable robotic system.

# *Design Problems and Constraints*

**Design Problem:**
To design a multi-purpose robotic walker system that autonomously adapts to support sitting, standing, walking, and meal delivery.

**Constraints:**

- Must support up to 250 lbs for sitting support.
- Must integrate into typical home layouts.
- Must allow modular reconfiguration and remote control.
- Must use commercially available actuators and parts.

**Use Case Layouts & Challenges:**

- **Bedroom → Living Room**
    - Supports the user when moving off the bed into a standing position.
    - Supports the user when standing as a walker.
    - Motorized wheels to alleviate the force required to move the module.
    - Supports the user when sitting with back support and a motor lockout to prevent movement.
- **Kitchen Docking**
    - Self-driving to the kitchen station using motors and infrared sensors.
    - Automatic alignment with the kitchen module to dock.
    - Automatic food delivery onto the walker in table mode.
    - Automatic delivery of food to the user using self-driving.
- **Challenges**
    - Navigating cluttered environments with limited sensors.
    - Automatic docking and connecting to the bed and kitchen modules.

**Design Summary:**

- Modular walker with transformable seat/chair
- Bed/chair interface module and kitchen docking.
- Remote summon functionality and self-alignment via sensors.

# *Type Synthesis*

**Considered Concepts:**

- Single-purpose walker (too limited)
- Robotic exoskeleton (complex, not modular)
- Multi-purpose transformer walker ✅

After discussing possible ideas for the modular robotic system, it was agreed that the best idea was a multi-purpose walker to support users in a home with the following features:

- Capable of supporting the user as a walker
- Capable of supporting the user as a chair
- Can navigate the living area autonomously
- Walker can switch between walker and chair mode
- Capable of supporting the user in other daily tasks

**Walker Module:**

- Rigid walker with wheels and sensors to navigate the living area
    - Supports the user in navigating the house
    - Carrying space to increase the functionality
    - Simple design, low functionality, little to no innovation
- Linear actuator walker to switch between a chair & walking mode
    - Chair mode allows the user to sit
    - Table mode to deliver food
    - Moderate complexity, offers innovative support, and is expensive
- Two sets of linear actuators to allow for a floor, chair, & walking
    - Chair mode allows the user to sit
    - Table mode to deliver food
    - More complex design, heavier, & most expensive

**Final Concept:**

A **parallel-bar style modular walker** with:

- One set of extendable double-acting cylinders.
- Swappable bed and chair interface modules.
- Docking and delivery module for the kitchen.

# *Size Synthesis*

## Walker Module

| Mode | Primary Cylinder | Seat/Table Height |
|---|---|---|
| Seat | Retracted | 0.58m |
| Table | Extended | 1m |

- **Cylinder Stroke:** 0.305m
- **Total Lift Support:** 115kg (safety ratio considered, max support: 185kg)
- **Seat Dimensions:** 0.4572m x 0.305m
- **Dimensions:** 0.610m x 0.305m x 0.914m
- **Materials:** Aluminum frame and supports, canvas seat/table, rubber caster wheels

## Kitchen Module

- **Overall Dimensions:**
  Length: 0.92 m  Width: 0.46 m  Height: 0.20 m
- **Base Dimensions:**
  Length: 0.92 m  Width: 0.43 m  Height: 0.14 m
- **Overhang Dimensions:**
  Length: 0.11 m  Width: 0.46 m  Height: 0.05 m
- **Main Belt Length:** 1.5641 m
- **Secondary Belt Length:** 0.2494 m
- **Belts Width:** 0.32671 m
- **Attachment Module:** 0.3048 m x 0.2032 m
- **Module Mass:** 17.5 kg
- **Weight Allowance:** 7 kg rated, 25 kg max
- **Materials:** ⅓ infill PC-ABS ( blend of Polycarbonate (PC) and Acrylonitrile Butadiene Styrene (ABS)) Frame, ¼ infill Aluminum Alloy rollers and motor enclosure, rubber belts

## Bed Module

- **Contracted Position Dimensions**

  Length: 0.13m Width: 0.38 m Height: 0.44m

- **Extended Position Dimensions**

  Length: 0.13m Width: 0.38 m Height: 0.59m

- **Bed Frame Hanger:** 0.381 m x 0.127 m x 0.0508 m
- **Electrical Actuators:** 0.279 m x 0.432 m x 0.0381 m
- **Wheel Bed:** 0.114 m x 0.0381 m x 0.029 m
- **Module Mass:** 4.83 kg
- **Actuator Stroke Length:** 0. 152 m
- **Materials:** Aluminum frame supports supports Aluminum Actuators and Polyethylene Wheelbed

# *Detailed Component Design*

## Modules & Features:

- **Main Frame:** Parallel bar design with height-changing table.
- **Cylinders:**
  - *Primary:* 102 lbs force @ 100 psi
- **Support Beam:** Reinforced crossbeam at the top and bottom of the cylinders.
- **Piston Mounts:** Mounts directly to the base and crossbeams
- **Remote & Sensor Unit:** Bluetooth or Wi-Fi controlled; IR or ultrasonic for alignment.

# Module 1 - Walker Module

### Configurations:

- Walker mode - Seat at 0.585m, Wheels moving
- Chair mode - Seat at 0.585m, Wheels locked out
- Table mode - Seat at 1m, Wheels moving, Locked out wheels at Kitchen and Bed module

## Size:

Length: 0.56 m Width: 0.33 m Height: 1.02 m

## Materials:

- Aluminium components

## Movement:

The module moves using two motors for the front two wheels. The wheels rotate as the walker is pushed in walker mode. Infrared sensors guide the module to the required location, allowing it to move autonomously. The module can self-drive between the kitchen, bed, and the user. The user can control the module with a remote, which can change the configuration or send it to a location.

# Module 2 - Kitchen Module

## Configuration:

- The base portion of the module lies on top of the kitchen counter with the overhang portion resting against the side of the counter.
- The overhang portion includes a proximity sensor and electromagnets. The proximity sensor activates the electromagnets to hold the walker in place as the module moves an object (e.g., a plate of food) onto the walker.

## Size:

- Overall:

  Length (x): 0.92 m Width (y): 0.46 m Height (z): 0.20 m

- Base:

  Length (x): 0.92 m Width (y): 0.43 m Height (z): 0.14 m

- Overhang:

  Length (x): 0.11 m Width (y): 0.46 m Height (z): 0.05 m

## Materials:

- PC-ABS ( blend of Polycarbonate (PC) and Acrylonitrile Butadiene Styrene (ABS))
- Aluminium Alloy
- Rubber

## Movement:

This module uses a compact DC motor to rotate the first set of rollers attached to the motor using bevel gears. The main belt of this module rotates around the rollers, carrying an object (a plate filled with food) to the next belt, which will move with the force of the object's already existing acceleration as well as the force of gravity, as the secondary belt has approximately a 20-degree decline. Following the second belt, the object will be smoothly pushed onto the "table" portion of the walker.

## Attachment:

Attaches to the kitchen module using electromagnets, and a sensor detects the walker's presence.

## Module 3 - Bed Module

**Configuration:**

- Compacted: The actuators are retracted to reduce the footprint of the module
- Extended: The IR Sensors have detected that the module has been deployed and signal the Arduino to self configure

**Size**

Length: 0.13m    Width: 0.38 m    Height: 0.59m

**Materials:** Aluminum alloy and Polyethylene
**Movement:** Two Electrical actuators receive a signal from IR sensors in the modules hanging attachment. This signals them that the module has been deployed. The actuators then lengthen to fit the size of the bed frame that the module is attached to.
**Attachment:** The Walker Attaches to the bed module using electromagnets and a sensor to detect the walkers presence

# *Specifications*

## Actuators:

*Walker Module*

- McMaster Impact-Resistant Round Body Air Cylinders
  - Air-driven, 102 lbs @ 100 psi each
  - Mounted with guiding rails and locking mechanisms
- Air compressor
- Motors
- Front Wheels, Back Wheels

*Kitchen Module*

- Compact Round-Face DC Motor
  - Motor Speed: 4535 rpm @ 0.0812 N-m
  - Starting Torque: 0.5437 N-m
  - Required torque: 4.14 N-m
    - $\tau_{required} = F_{friction} \times radius = 9.81M_{Max} \times \mu = 108.69 \times 0.5 = 4.14$
    - Note: This calculation is for an unlubricated system; a lubricated system would need significantly less torque.
  - Roller Gear to Motor Gear ratio: 8:1
- 5V Electromagnet

*Bed Module*

- McMaster Electric Actuator
    - 11.3kg Dynamic load capacity
    - 136kg static load capacity
    - Maximum speed 76.2mm/s
- 5V Electromagnet

### Motion Transmission:

- Linear lifting via cylinder extension (Walker Module)
- Load transfer through piston brackets and reinforced beams (Walker Module)
- Rotational motion transmission via bevel gears (Kitchen Module)

### Control Source:

- IR Sensors
- Arduino Uno
- ROS-based command structure

# *Case Study Static Analysis*

## Walker Module

**Payload:**

- Max load: 250 lbs = 1113 N
- Cylinder support force: 400 lbs = 1780 N
- Safety ratio: 1.6

**Weight:**

- Walker module total mass: 21kg = 206.01 N
- Seat mass: 2kg = 19.62 N
- Cylinder mass: 1.5kg = 14.715 N (each)
- Base mass: 7.5kg = 73.575 N
- Supports mass: 6kg = 58.86 N

**Tipping Analysis:**

- Consider CoG shift during transformation
- Counterbalanced base and locking wheels prevent forward tipping
- Simulation to confirm balance under 40” extended table height with load

**Static stability analysis:**

Centre of mass location: X - .200m Y - .380m Z - .125m (related to the bottom wheel)

Angle of tipping: $\Theta = arctan(\frac{.200}{.380}) = 27.76°$ (tipping can only occur around the z-axis as the module would roll in any other direction**)**

Max Horizontal Force: $\Theta < arctan(\frac{Max\ Force}{Total\ Mass})$

$Max\ Force = 206\ tan(27.76°) = 108.5N$

# Kitchen Module

**Payload:**

- Max load: 25 kg

**Weight:**

- Kitchen module total mass: 17.5 kg = 171.675 N
- Frame mass: 6.23 kg = 61.1163 N
- Rollers mass: 9.56 kg = 93.7836 N
- Main belt mass: 1.08 kg = 10.5948 N
- Secondary belt mass: 0.09 kg = 0.8829 N
- Motor and enclosure mass: 0.27 kg = 2.6487 N

**Attached Actuators:**

- 2x electromagnets

**Static Stability Analysis:**

Center of mass relative to the back bottom corner of the base: X = 0.47 m, Y = 0.2 m, Z = 0.06 m

For the structure to tip over, the center of gravity's X component must be located past 0.75 m. To see how much weight would shift the center of gravity past the tipping point, the following calculations were done:

$$X_{tip} = \frac{m_{structure}x_{structure} + m_{object}x_{object}}{m_{structure} + m_{object}} \rightarrow 0.75 = \frac{(17.5)(0.47)+(0.92)m_{object}}{17.5+m_{object}}$$

Solving for $m_{object}$, it is determined that the object must weigh 28.8 kg or more to cause the module to tip over and fall off the counter when the object reaches the end of the belt. Since the module has a maximum load capacity of 10 kg, tipping over is not a concern.

To make sure the object won't slip off the secondary belt, the maximum acceleration of the object can be calculated as shown below (note: the coefficient of static friction between dry glass and rubber was used):

$$\Sigma F = ma \rightarrow F_{friction} = ma \rightarrow 9.81 sin(20) m = ma \rightarrow a = 0.73\, m/s^2$$

As shown above, the maximum acceleration allowed is 0.73 $m/s^2$ to prevent the object from slipping on the belt's surface.

## Bed Module

**Payload:**
- Max Load: 300 lbs = 1335 N

**Weight:**
- Arduino uno: 11.83 g = 0.1160523 N
- Hanging frame: 2.98 kg = 29.2338 N
- Electromagnets: 22.2 g = 0.217782 N
- Electric actuators: 1.72 kg = 16.8732 N
- Wheelbeds = 94.5 g = 0.927045 N

**Attached Actuators:**
- 2x electromagnets
- 2x Linear Actuators

**Static Stability Analysis:**
The center of mass relative to the back corner of the left wheel bed:
X = 18.67cm, Y = 42.79cm, Z = 0.88cm

The bed module is suspended from the bed frame, and the wheel beds rest on the ground. This means that, to tip the bed module, it would either need to be disconnected from the bed frame or the bed frame itself would have to tip over. Therefore, the tipping point is determined by the stability of the bed frame. The module itself is not designed to support any weight other than the walker wheels in the wheel beds, which are in contact with the ground. Since this weight is also supported by the ground, the maximum load on the module would be the combined weight of the walker module and the person.

The pressure exerted by one of the wheels when the person leans on it is approximately one quarter of the combined weight of the person and the walker (75lb). Given that the compressive strength of polyethylene is about 3000 psi (20.7MPa), the wheel beds can support the maximum payload without any deformation. This is shown below (note: wheel bed area = 1.69 $in^2$):

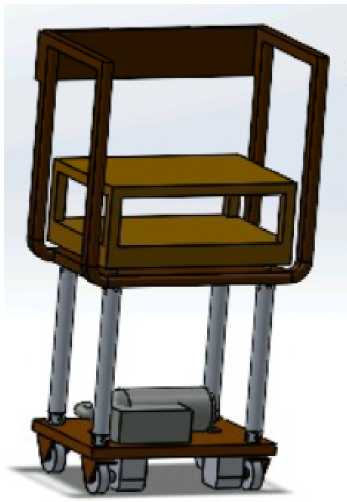
$$\sigma = \frac{F}{A} \rightarrow \sigma = \frac{2413}{1.69} = 1427\, psi$$

This is much less than the allowable compression strength of the wheel bed.

# *Image and Animated Videos*

Note: Videos of the modules can be viewed in the project folder under images directory/ animation, as they cannot be added to this document.

## Walker Design



Chair & Walker Configuration

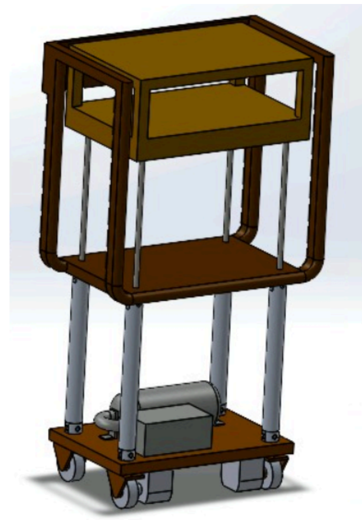
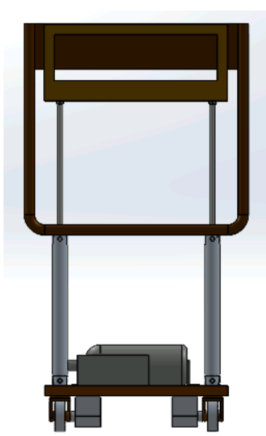
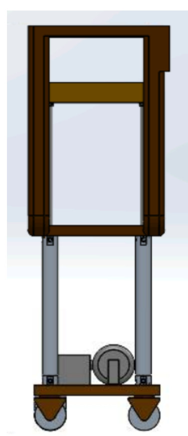


Table Configuration



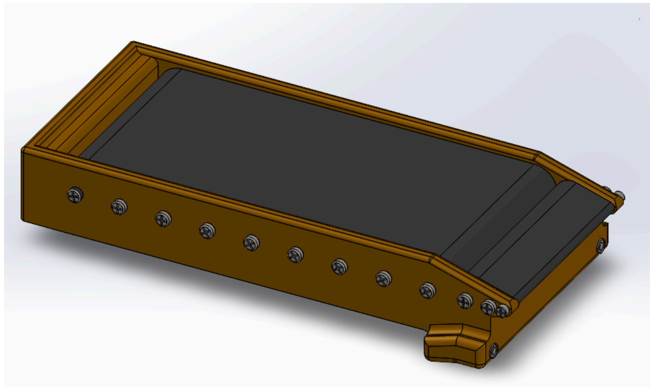
Front View



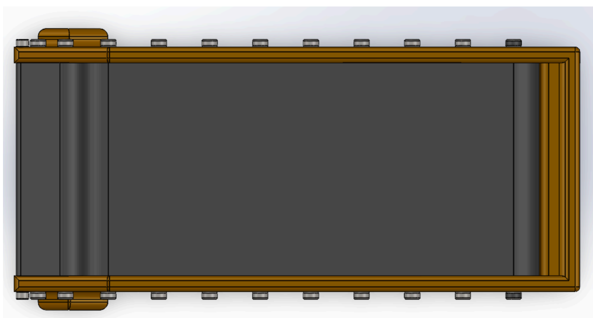
Side View

Top View

# Kitchen Module

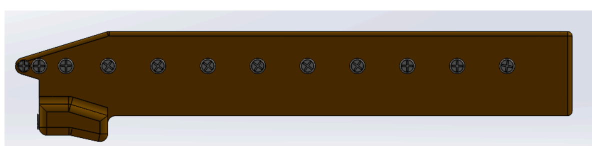


Kitchen Module Simulation



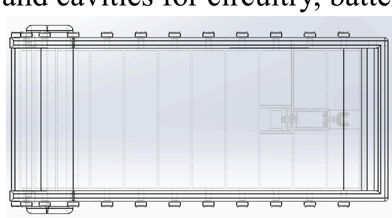
Top View of the Kitchen Module

Front View of the Kitchen Module

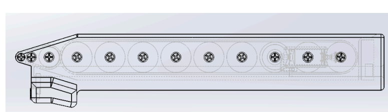


Side View of the Kitchen Module

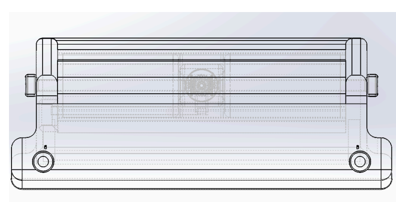
The hidden lines visible model shown below shows More Detail, including pathways for wiring and cavities for circuitry, batteries, fans, etc.



Top View of the Kitchen Module



Side View of the Kitchen Module

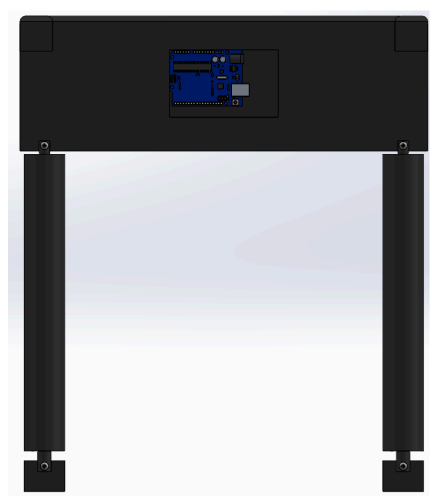


Front View of the Kitchen Module

## **Bed Module**

Bed Module Simulation

Side View of the Bed Module



Front View of the Bed Module

Top View of the Bed Module

# *Discussion and Future Work*

The Modular Walker fulfills key functions for elderly care in a modular form. The design fulfills all the functionalities specified in the synthesis design, which supports the user moving around their home and performing daily tasks like food delivery. These functions are fulfilled using three modules: the walker module, the bed module, and the kitchen module.

The walker module is the primary component that the user interacts with. This module supports the user when moving around their home and provides a place to sit anywhere. The walker can be summoned or its configuration changed using a Wi-Fi button remote.

The bed module connects to the walker and provides a place for the walker to be stored and charged when not in use. It can also help the user get out of bed and into a standing or seated position on the walker.

The kitchen module connects to the walker through electromagnets. This connection ensures the walker's position is accurate and provides a direct connection to ensure the walker is in the correct configuration. This module delivers food onto the walker, placing a plate onto the walker in table mode. The walker then disconnects from the kitchen module and autonomously delivers the food to the user.

Future improvements include:

- A more stable design which is not prone to tipping
- Battery-powered air compressor for cylinder actuation
- Enhanced sensor fusion for better alignment
- Voice control or integration with smart home systems
- Enhanced wheel design to navigate around tight spaces and corners
- An adjustable seat height to maximize the comfort of the user
- More sensors, such as load cells, to allow more accuracy while completing tasks
    - i.e. load cell kitchen module to ensure full transfer of object.

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# *Appendices*

## Appendix A - SolidWorks Files

### A.1 Walker Module

**Air_Compressor.SLDPRT - Air compressor to refill the air storage**

**Air_Storage.SLDPRT - Air storage compartment**

**Base_6471k334_Impact-Resistant Round Body Air Cylinder.SLDPRT - Base of the cylinders**

**Rod_Cylinder.SLDPRT - The extending cylinder rod**

**Cylinder_Top_Plate.SLDPRT - The top plate and arm supports**

**Motor.SLDPRT - Motors for the front wheels**

**Seat_Table2.SLDPRT - The Seat and Table the changes height**

**Wheel.SLDPRT - Wheels for the base**

**Assem2.SLDASM - Fully Assembled design of the walker**

### A.2 Kitchen Module

**0.5in-roller.SLDPRT** - 0.5 inch roller

**1in-roller.SLDPRT** - 1 inch roller

**2in-roller.SLDPRT** - 2 inch roller

**3in-roller.SLDPRT** - 3 inch roller

**3in-roller-gear-attachment.SLDPRT** - 3 inch roller which attaches to a Metal bevel Gear

**3in-roller-motor-attachment.SLDPRT** - 3 inch roller which attaches to a the side of the motor enclosure

**3in-roller-motor-cutout.SLDPRT** - 3 inch roller with the middle thinned out to allow for the motor enclosure

**6331K65_Compact Round-Face DC Motor.SLDPRT** - Model of the DC motor (from Manufacturer)

**6529K53_Metal Miter Gear.SLDPRT** - Model of a bevel gear

**motorbox.SLDPRT** - Enclosure for the motor

**housing.SLDPRT** - Frame and base for the entire module

**motor-gear-connector.SLDPRT** - A piece for  motor and bevel gear connection

**electromagnet.SLDPRT** - Rough model of the 5V Electromagnet

**sensor.SLDPRT** - Rough model of the proximity sensor

**plate.SLDPRT** - Rough model of a plate for simulation purposes

**boxed-motor.SLDASM** - Assembly of the enclosed motor

**final-assembly.SLDASM** - Complete assembly of the kitchen module

## A.3 Bed module

**hanger.SLDPRT** - Hangs the module to the frame of the user's bed

**Arduino_Uno.STEP** - Model of Arduino Uno (from Manufacturer)

**screw.SLDPRT** - Screw used for assembling the module

**piston rod.SLDPRT** - Extending rod of the electric actuator

**wheelbed.SLDPRT** - Holds the wheels of the walker stable when it is docked at the bed module

**piston body.SLDPRT** - Aluminum body of the electric actuator

**electromagent.SLDPRT** - Rough model of the 5V Electromagnet

**Arduino_Uno.SLDPRT** - Model of Arduino Uno (from Manufacturer)

**Assem1.SLDASM** - Final Assembly of the bed module

# Appendix B – Technical specification of the selected actuators and sensors

## B.1 Actuators

*B.1.1 Walker Module*

**Actuator 1:** McMaster Impact-Resistant Round Body Air Cylinders

- Part Number: 6471K334
- Type: Double-acting pneumatic cylinder
- Force: 102 lbs (454 N) @ 100 psi
- Stroke: 0.305 m (12 inches)
- Mounting: Guided rails with locking mechanism
- Safety Ratio: 1.6 (max support: 185 kg / 408 lbs)
- Application: Seat/table height adjustment (0.58m retracted → 1m extended).
- Vendor: McMaster-Carr

**Actuator 2:** Air Compressor

- Type: Portable electric air compressor (to power cylinders)
- Pressure: 100 psi minimum
- Duty Cycle: Continuous (for repeated actuation)
- Future Upgrade: Battery-powered compressor (e.g., VIAIR 90P).

*B.1.2 Kitchen Module*

**Actuator 1:** Compact Round-Face DC Motor

- Part Number: 6331K65
- Speed: 4535 RPM @ 0.0812 N-m
- Starting Torque: 0.5437 N-m
- Gear Ratio: 8:1 (motor-to-roller)
- Output Torque: 4.14 N-m (after gearing)
- Application: Drives kitchen module's main belt for food transfer.
- Vendor: McMaster-Carr

**Actuator 2:** 5V Electromagnets

- Holding Force: 10 kg (per magnet)
- Voltage: 5V DC
- Quantity: 2 (for docking alignment)
- Application: Secures walker module to kitchen station during food transfer.
- Vendor: Digikey

*B.1.3 Bed Module*

**Actuator 1:** Electric Linear Actuator

- Type: Battery-powered linear actuator (to replace pneumatic cylinders)
- Stroke: 0.152 m
- Load Capacity: 300 lbs (136 kg)
- Speed: 76 mm/s (adjustable)
- Application: Delopy the wheel beds

**Actuator 2:** 5V Electromagnets
- Holding Force: 10 kg (per magnet)
- Voltage: 5V DC
- Quantity: 2 (for docking alignment)
- Application: Secures walker module to kitchen station during food transfer.
- Vendor: Digikey

## B.2 Sensors

*B.2.1 Walker Module*

**Sensor 1:** Infrared (IR) Proximity Sensors
- Type: IR reflectance sensor
- Detection Range: 0.1–0.8 m
- Interface: Digital I/O
- Application: Autonomous navigation and alignment with bed/kitchen modules.

**Sensor 2:** Wheel Encoders
- Type: Optical rotary encoder (integrated with motors)
- Resolution: 12 pulses per revolution (PPR)
- Application: Speed/distance tracking for motorized wheels.

*B.2.2 Kitchen Module*

**Sensor 1:** Proximity Sensor With Interrupt, IRED, and I2C Interface
- Part Number: 751-VCNL3040TR-ND - Tape & Reel (TR)
- Detection Range: 0–300 mm
- Interface: I2C
- Application: Detects walker module for docking alignment.
- Vendor: DigiKey/RobotShop

*B.2.3 Bed Module*

**Sensor 1:** Proximity Sensor With Interrupt, IRED, and I2C Interface
- Part Number: 751-VCNL3040TR-ND - Tape & Reel (TR)
- Detection Range: 0–300 mm
- Interface: I2C
- Application: Detects walker module for docking alignment.
- Vendor: DigiKey/RobotShop

## B.3 Controllers

**Controller 1:** Raspberry Pi 4
- Processor: Broadcom BCM2711 (Quad-core Cortex-A72)
- RAM: 4GB
- Connectivity: WiFi/Bluetooth
- Role: ROS-based navigation, sensor fusion, and user command processing.

**Controller 2:** Arduino Uno

- Microcontroller: ATmega328P
- Clock Speed: 16 MHz
- Analog Inputs: 6
- Role: Real-time motor control, sensor polling, and electromagnet activation.

# Appendix C - Suggestions for supporting hardware and electronics

## C.1 Controllers

1. **Raspberry Pi 4**
    - **Part Number**: N/A (Standard model)
    - **Description**: Quad-core Cortex-A72 processor, 4GB RAM, Wi-Fi/Bluetooth.
    - **Purpose**: ROS-based navigation, sensor fusion, and user command processing.
    - **Supplier**: Electronics retailers (e.g., Amazon, Adafruit).
2. **Arduino Uno**
    - **Part Number**: ELEGOO UNO R3 [4]
    - **Description**: ATmega328P microcontroller, 16 MHz clock speed.
    - **Purpose**: Real-time motor control, sensor polling, and electromagnet activation.
    - **Supplier**: Amazon.

## C.2 Sensors

1. **Infrared (IR) Proximity Sensors**
    - **Part Number**: DAOKI 5-Pack IR Sensor [3]
    - **Description**: 3-wire IR reflectance sensor, 0.1–0.8 m range.
    - **Purpose**: Autonomous navigation and docking alignment.
    - **Supplier**: Amazon.
2. **Proximity Sensor (I2C Interface)**
    - **Part Number**: 751-VCNL3040TR-ND [2]
    - **Description**: IRED sensor with 0–300 mm detection range.
    - **Purpose**: Precise alignment for kitchen and bed module docking.
    - **Supplier**: DigiKey.
3. **Wheel Encoders**
    - **Part Number**: Integrated with motors (e.g., Sparkfun wheels [10]).
    - **Description**: Optical rotary encoder, 12 PPR resolution.
    - **Purpose**: Speed/distance tracking for motorized wheels.

## C.3 Actuators

1. **Double-Acting Pneumatic Cylinders**
   - **Part Number**: McMaster 6471K334 [7]
   - **Description**: 102 lbs force @ 100 psi, 0.305 m stroke.
   - **Purpose**: Walker seat/table height adjustment.
   - **Supplier**: McMaster-Carr.
2. **Electric Linear Actuators**
   - **Part Number**: McMaster 6509K56 [8]
   - **Description**: 136 kg static load capacity, 76.2 mm/s speed.
   - **Purpose**: Bed module deployment.
   - **Supplier**: McMaster-Carr.

## C.4 Motors

1. **Compact DC Motor (Kitchen Module)**
   - **Part Number**: McMaster 6331K65 [8]
   - **Description**: 4535 RPM, 0.5437 N-m starting torque.
   - **Purpose**: Drives kitchen conveyor belt via 8:1 gear ratio.
   - **Supplier**: McMaster-Carr.
2. **Wheel Motors**
   - **Part Number**: 12V 16RPM High Torque Motor [1]
   - **Description**: Worm gear reduction, dual shaft.
   - **Purpose**: Front-wheel drive for walker module.
   - **Supplier**: RobotShop.

## C.5 Power and Communication

1. **Portable Air Compressor**
   - **Part Number**: HOTTQUE Cordless Inflator [5]
   - **Description**: 100 PSI, battery-powered.
   - **Purpose**: Pneumatic cylinder actuation.
   - **Supplier**: Amazon.
2. **5V Electromagnets**
   - **Part Number**: Adafruit 3874 [2]
   - **Description**: 10 kg holding force.
   - **Purpose**: Secures walker during docking.
   - **Supplier**: DigiKey.
3. **Wi-Fi/Bluetooth Module**
   - **Description**: ESP32 or similar.
   - **Purpose**: Remote control and ROS integration.

### C.6 Safety and Miscellaneous

1. **Emergency Stop Button**
   - **Description**: Physical kill switch for immediate shutdown.
2. **Load Cells**
   - **Purpose**: Future upgrade for weight detection (e.g., kitchen module).
3. **Rubber Belts and Rollers**
   - **Part Number**: Custom (see Appendix A.2).
   - **Supplier**: McMaster-Carr/3D-printed.

## Appendix D - Bill of Materials

### D.1 Walker Module

| Component | Qty | Part Number | Description | Supplier |
|---|---|---|---|---|
| Linear Actuators | 2 | 6471K334 [7] | Double-acting pneumatic cylinders | McMaster-Carr |
| Rubber Caster Wheels | 4 | MADICO F22904 [6] | 1.5" brake wheels, 44 lbs capacity | RONA |
| IR Proximity Sensors | 4 | DAOKI 5-Pack [3] | Obstacle avoidance | Amazon |
| Arduino Uno | 1 | ELEGOO UNO R3 [4] | Microcontroller | Amazon |
| Air Compressor | 1 | HOTTQUE [5] | 100 PSI portable compressor | Amazon |
| Aluminum Frame | 1 | Custom | 6061-T6 aluminum bars | Local supplier |
| Canvas Seat | 1 | Custom | 0.4572m x 0.305m seat | Fabric supplier |

## D.2 Kitchen Module

| Component | Qty | Part Number | Description | Supplier |
|---|---|---|---|---|
| DC Motor | 1 | 6331K65 [8] | Compact round-face motor | McMaster-Carr |
| Bevel Gears | 3 | 6529K53 [A.2] | Metal miter gears for 8:1 ratio | McMaster-Carr |
| Proximity Sensor | 2 | 751-VCNL3040TR-ND [2] | I2C IR sensor for docking | DigiKey |
| Electromagnets | 2 | Adafruit 3874 [2] | 5V holding magnets | DigiKey |
| PC-ABS Frame | 1 | Custom | 3D-printed frame (⅓ infill) | Local printer |
| Rubber Belts | 2 | Custom | 0.32671m width | McMaster-Carr |

## D.3 Bed Module

| Component | Qty | Part Number | Description | Supplier |
|---|---|---|---|---|
| Electric Linear Actuators | 2 | 6509K56 [8] | 136 kg static load capacity | McMaster-Carr |
| Polyethylene Wheelbeds | 2 | Custom | 3D-printed supports | Local printer |
| Electromagnets | 2 | Adafruit 3874 [2] | 5V holding magnets | DigiKey |
| Arduino Uno | 1 | ELEGOO UNO R3 [4] | Microcontroller | Amazon |
| Aluminum Hangers | 1 | Custom | 0.381m x 0.127m frame | Local supplier |
| Proximity Sensor | 4 | 751-VCNL3040TR-ND [2] | I2C IR sensor for docking | DigiKey |