EATON
Powering Business Worldwide

COLLEGE OF ENGINEERING ★ THE UNIVERSITY OF TEXAS AT EL PASO ★

THE UNIVERSITY OF TEXAS AT EL PASO

Eaton Kit Cart Standardization

Industrial Partner: Eaton El Paso (P1)

Team:
Kimberly Canales
Mia Carreon
Jahzeel Quintero Villa

Faculty Mentor: Miguel Carrera

Our Team

Kimberly Canales

Mia Carreon

Jahzeel Quintero Villa

Powering Business Worldwide

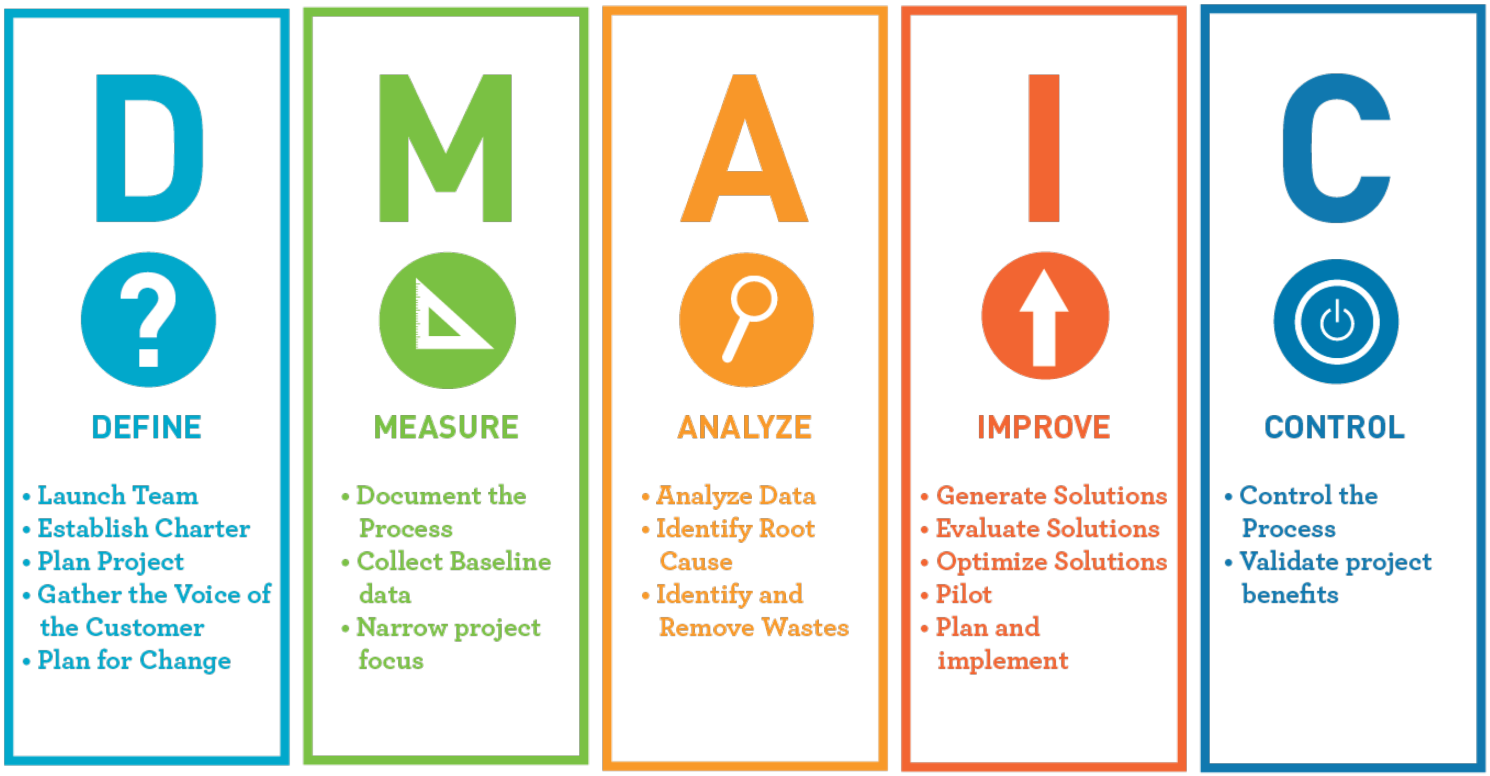
Industrial Partner Background

- Eaton Corporation is a global power management company operating in more than 160 countries, focused on delivering safe, efficient, and sustainable energy solutions. In El Paso, Eaton operates two manufacturing plants.

- This project focuses on the Trade Center Drive plant, which produces Low-Voltage Assemblies (LVAs),), or low-voltage switchgears — three-phase electrical distribution systems used in critical industries such as hospitals and data centers.

Project Methodology

This methodology was selected to ensure a structured, data-driven approach that aligns with Eaton's continuous improvement standards.



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Define

This phase identifies the problem, project objectives, and customer requirements. The team defines the scope, constraints, and key stakeholders to ensure everyone understands what needs to be improved.

Problem Definition – Kit Cart System

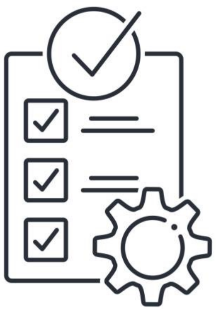
The current kit carts used on the Low-Voltage Assembly (LVA) line lack standardization design and documentation, creating structural, ergonomic, and operational inefficiencies.

Project Objectives

- Standardize a universal kit cart design that can serve at least 50% of workstations.
- Improve the structural integrity and load capacity of the kit cart.
- Enhance ergonomics and operator safety during material handling.
- Ensure compatibility with future Autonomous Mobile Robot (AMR) implementation.
- Reduce variability in material handling across workstations.
- Perform structural analyses in SolidWorks to evaluate load capacity, stress distribution
- Develop a SolidWorks digital prototype of the universal kit cart to visualize and validate the design

Project Requirements

- The universal kit cart shall serve at least 50% of workstations to be considered standardized.
- The cart structure shall support the weight of copper components without deformation.
- The cart structure shall remain fully above the AMR sensor detection zone.
- The cart shall improve operator ergonomics.
- The cart dimensions shall fit within existing workstation space constraints
- The current universal kit cart and new design shall be fully documented.
- The proposed design shall comply with Eaton’s safety standards



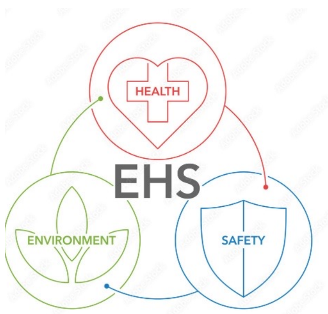
Limitations and Constraints

Timeframe:
Limited to one academic semester, restricting design iterations and testing.

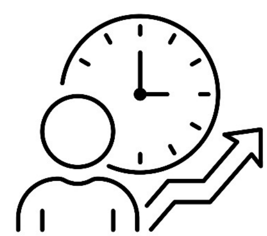
Material Adjustments
Slight changes in workstation materials due to a new customer order created minor inconsistencies in early data collection.

AMR Integration
Eaton requested AMR compatibility, requiring the cart to meet specific height, clearance, payload, and sensor detection constraints.

Plant Operations
Data collection had to occur without interrupting LVA production.



Safety Protocols
All activities required compliance with Eaton safety standards.



PROJECT CHARTER

GENERAL PROJECT INFORMATION	
Project Name:	Eaton Kit Carts Standardization
Project Sponsor:	Eaton – Manufacturing Department
Project Manager:	UTEP Senior Design Team
Email Address:	jgquinterov@miners.utep.edu, kncanales@miners.utep.edu, mcarreon4@miners.utep.edu, macarrera2@utep.edu
Phone Number:	(432)-231-2935, (915) 342-0465, (915) 262-3218, (915) 222-5286,
Organizational Unit:	Eaton Plant 1 – Low Voltage Assemblies (LVA)
Process Impacted:	Material handling and delivery of kits to workstation
Expected Start Date:	September 9th, 2025
Expected Completion Date:	December 2nd, 2025
Green Belts Assigned:	Jahzeel Quintero Villa, and Mia Carreon
Black Belts Assigned:	Miguel Carrera

PROBLEM, ISSUE, GOALS, OBJECTIVES, DELIVERABLES	
Problem or Issue:	No centralized documentation or standardization of kit cart design across Eaton's production floor. Current carts vary widely, causing inefficiencies, safety risks, and difficulty in replication.
Purpose of Project:	Develop standardized kit cart designs and documentation to improve efficiency, safety, and consistency across the production floor.
Business Case:	Standardization will simplify manufacturing, reduce safety risks, and create reusable designs with CAD models, BOMs, and simulations.
Goals/Metrics:	Standardized kit cart designs, structural analysis and ergonomic analysis.
Expected Deliverables:	3 deliverables: 1st deliverable consists of baseline documentation of existing universal carts, 2nd deliverable includes draft of CAD models of standardized cart with simulations and evaluation, and the 3rd deliverable is the final design with BOMs, validation results and implementation plan.

PROJECT SCOPE & SCHEDULE	
Within Scope	Documentation, CAD models, ergonomic/structural/safety analysis, simulations, BOM, and prototype of standardized kit carts. (Amazon)
Outside of Scope	Workstations, non-Amazon product carts, Microsoft line carts.

PROJECT RESOURCES & COSTS	
Project Team	Kimberly Canales, Mia Carreon, Jahzeel Quintero Villa, with guidance from Miguel Carrera (from TMAC)
Support Resources	Eatons Manufacturing Engineers (Antonio Aragon, Danny Gonzales, and Juan Del Real), OPEX Manager (Eduardo Quiroz), Safety & Ergonomics Specialists (Nayeli Escamilla)
Special Needs	Access to plant production floor, CAD software (SolidWorks), Eaton safety standards, PPE,

Project Charter

A Project Charter was developed and submitted to Eaton to formally define:

- The problem and business case.
- Project objectives and expected deliverables.
- Scope (in-scope and out-of-scope items).
- Stakeholders and team roles.
- Key constraints.
- Timeline and resources

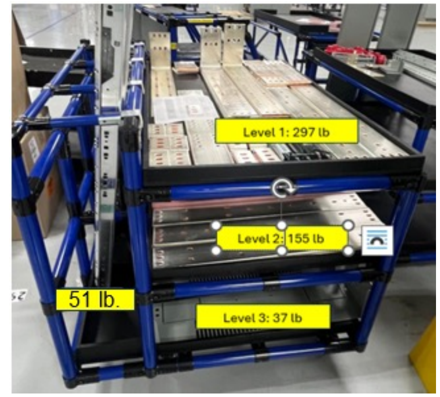
Measure

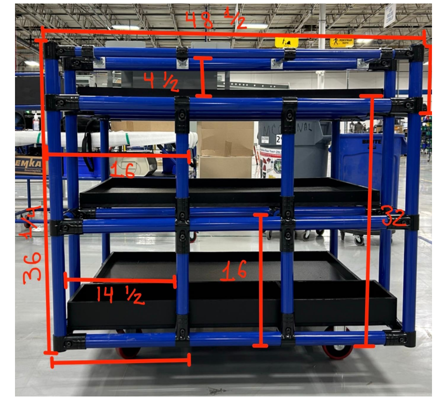
This phase establishes the baseline by collecting quantitative data and operational feedback. Physical measurements, structural evaluations, ergonomic assessments, and Voice of the Customer input are gathered to understand current performance and validate the problem with objective evidence.

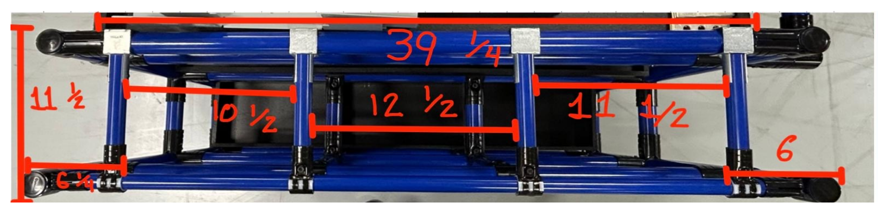
Cart Documentation:
Current Universal Kit Cart

- Collected key dimensions of the current universal cart.
- Measured total weight of the cart (empty and fully loaded).
- Recorded weight distribution stocking level (3 levels + side).
- Selected this cart because it supports Copper Layout station, one of the stations with the heaviest material demand → worst-case scenario.
- Data supports structural analysis and validation of load capacity.

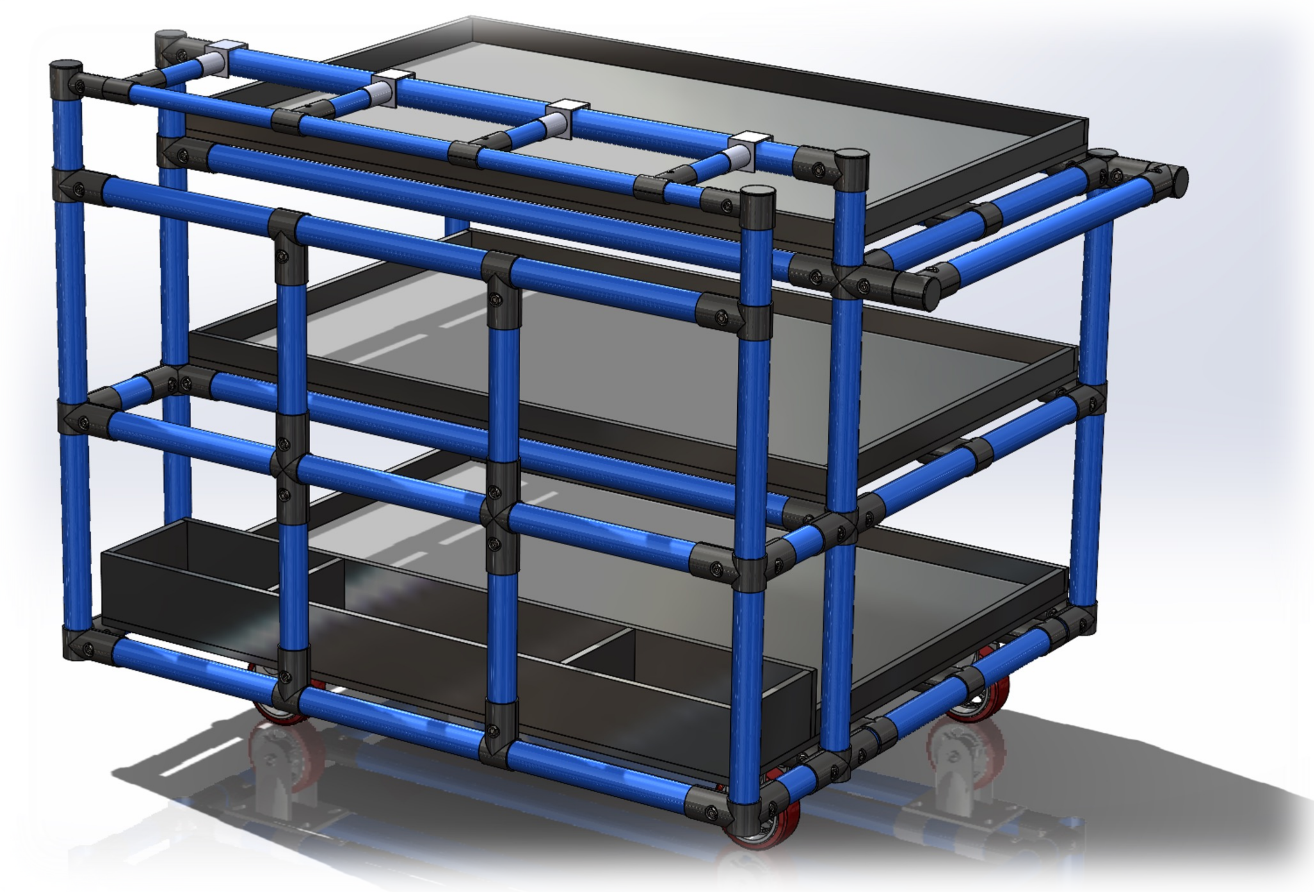
Component	Weight (Lbs.)
Car (Empty)	192 lbs.
Level 1 (Top)	297 lbs.
Level 2 (Middle)	155 lbs.
Level 3 (Bottom)	37 lbs.
Side Material	51 lbs.
Total Weight: 732 lbs.	





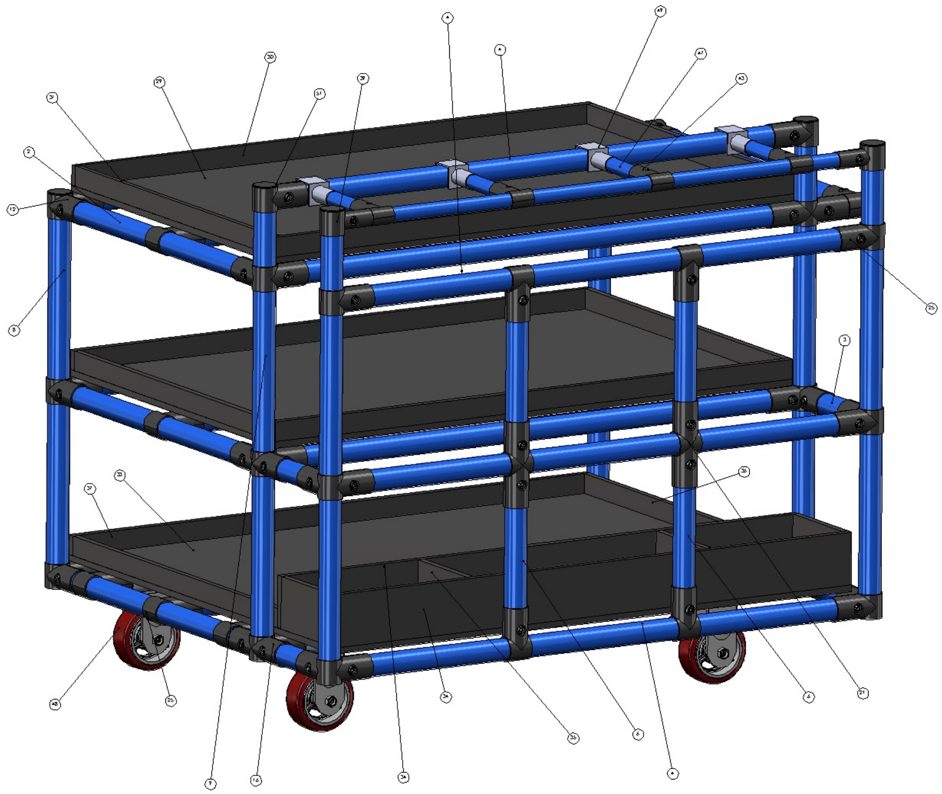


CAD Model of Current Universal Kit Cart (SolidWorks)



Bill of Materials (BOM)

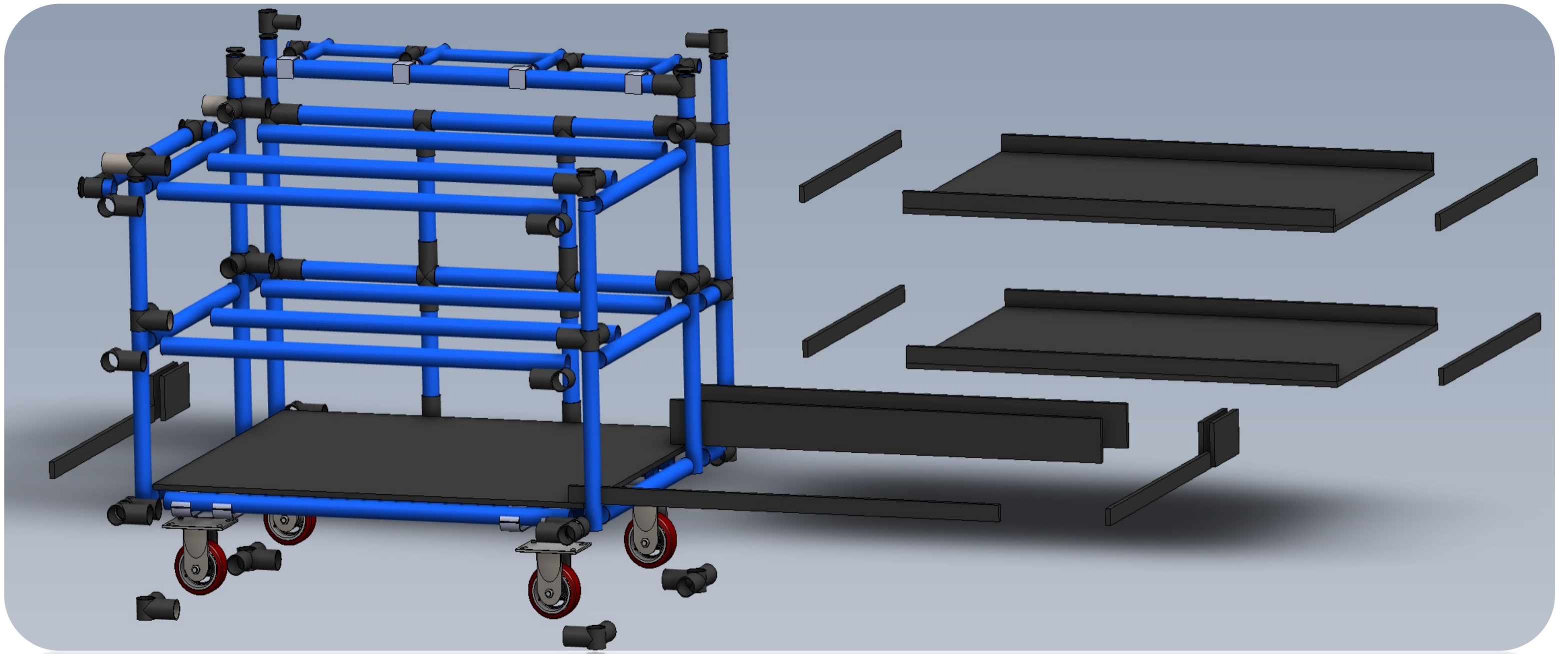
BOM Table (Restructured)	
ITEM NO.	QTY.
1	1
2	7
3	4
4	15
5	2
6	4
7	1
8	2
9	4
10	10
11	1
12	1
13	2
14	2
15	6
16	1
17	2
18	3
19	3
20	2
21	2
22	2
23	2
24	20
25	2
26	1
27	1
28	2
29	1
30	2
31	2
32	1
33	1
34	2
35	4
36	2
37	2
38	2
39	2
40	1
41	1
42	4
43	2
44	1
45	1
46	4
47	1
48	4
49	4
50	16
51	8



The Bill of Materials was created by identifying each component in the Create-Shop and matching it with the 3D model of the cart

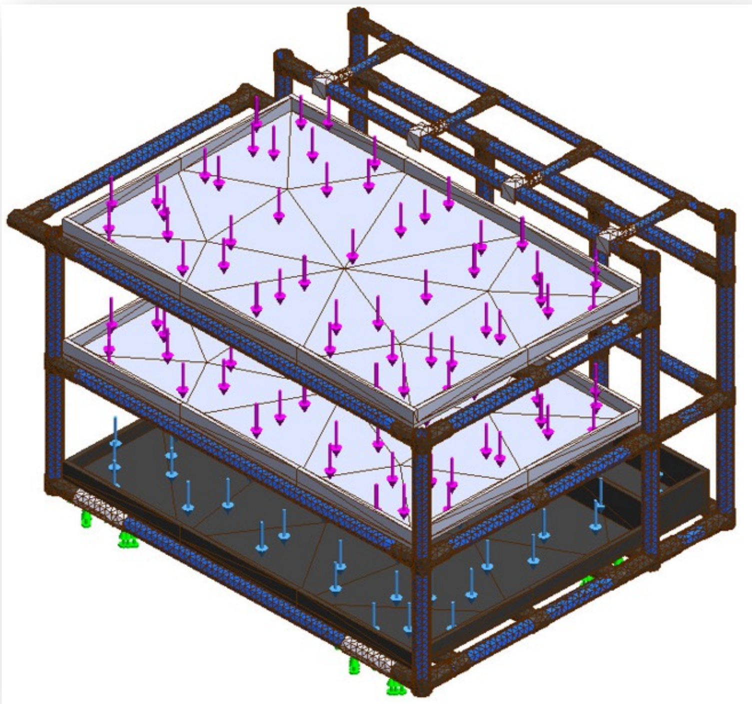
Exploded View

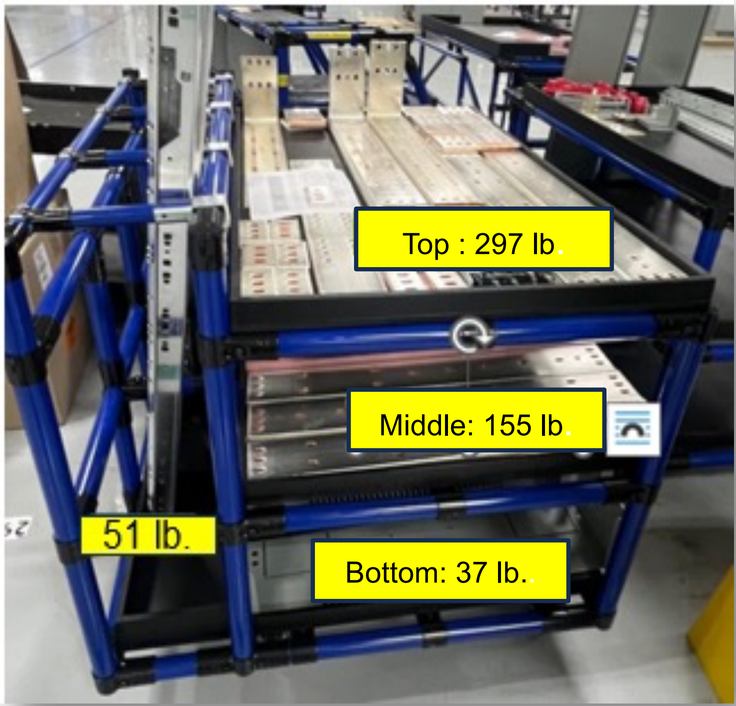
This view helps to understand the structure and the position of each part.



FEA – Static Analysis

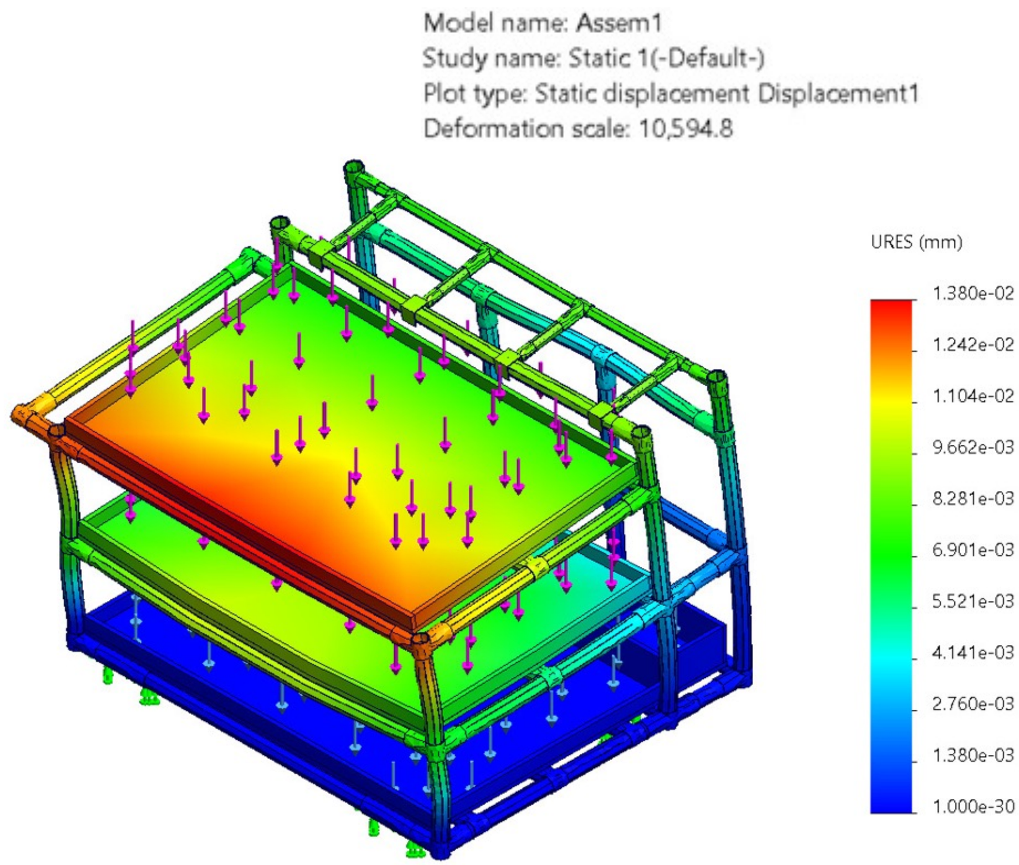
FEA, Finite Element Analysis, It is a method that divides the CAD model into small elements to simulate how the structure reacts to loads and forces





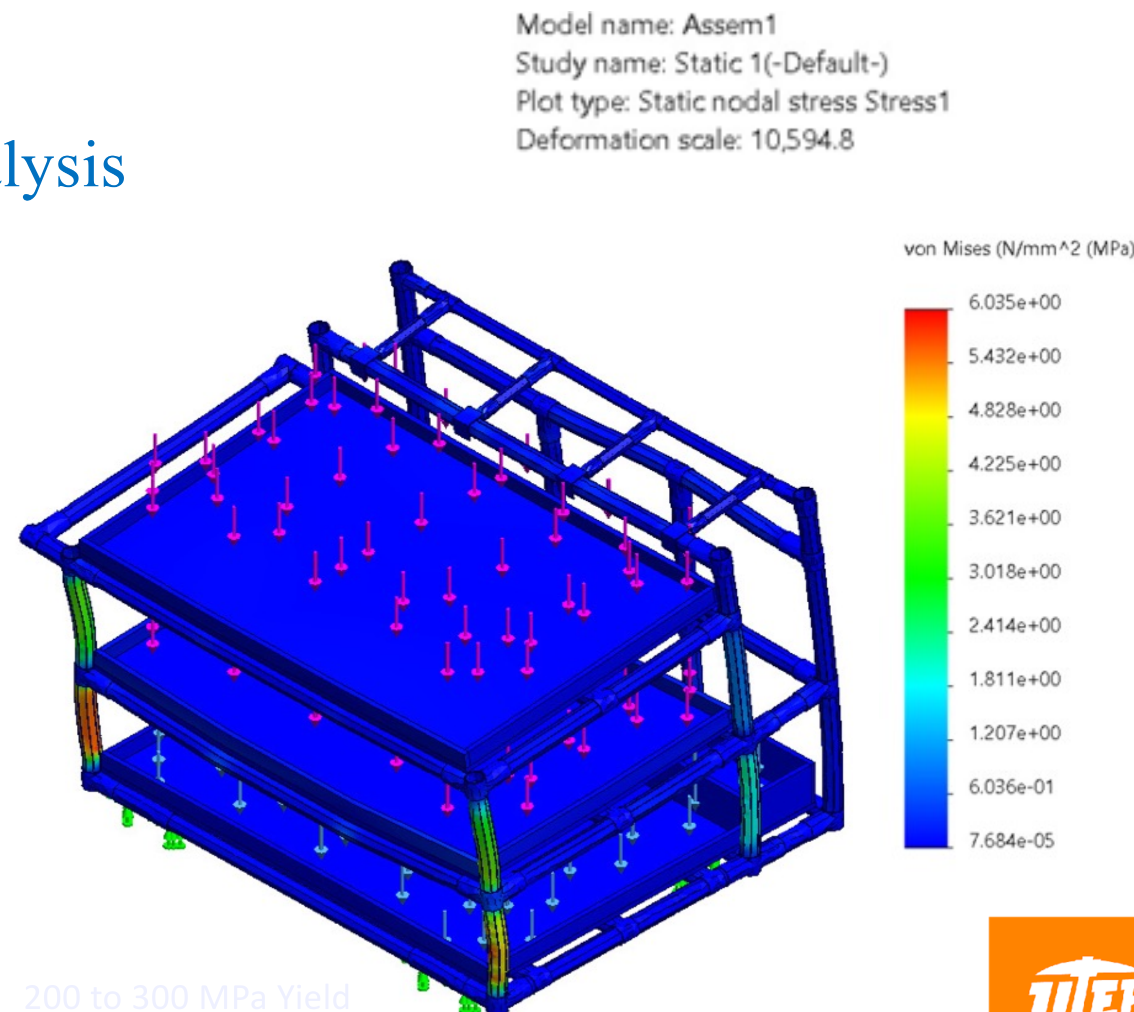
Displacement Analysis

- Software magnifies the deformation for visualization
  - ✓ Deformation scale: 10,594.8
- Maximum displacement = 0.0138 mm (almost no movement)
- Red area shows where the cart experiences the highest displacement



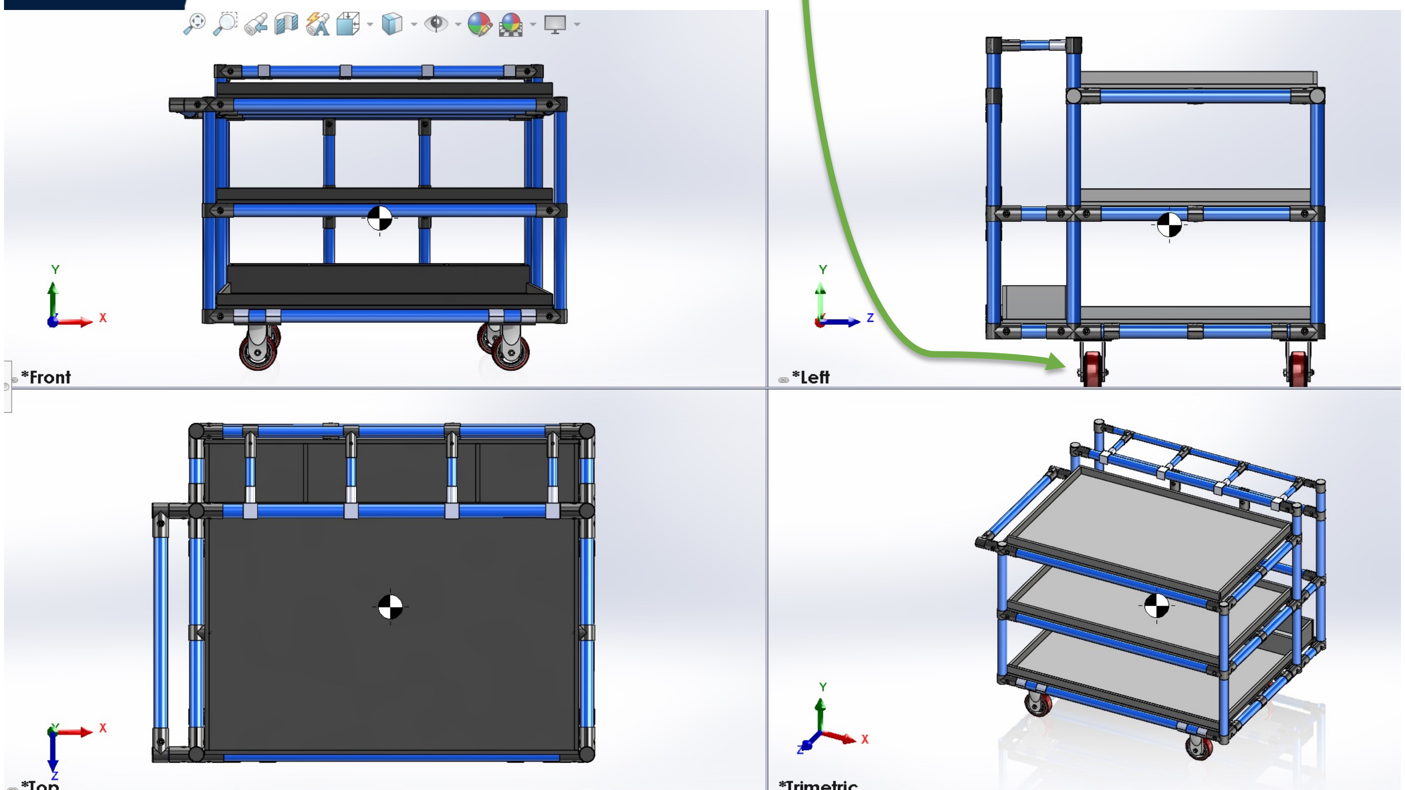
Von Mises Stress Analysis

- Von Mises = combination of compression, tension, and shear
- Red areas show highest stress concentration
- Stress values are far below material yield strength



200 to 300 MPa Yield
tensile, compressive, and shear

Relocating both wheels toward the outer edge aligns the center of gravity and significantly improves cart stability and operator safety.

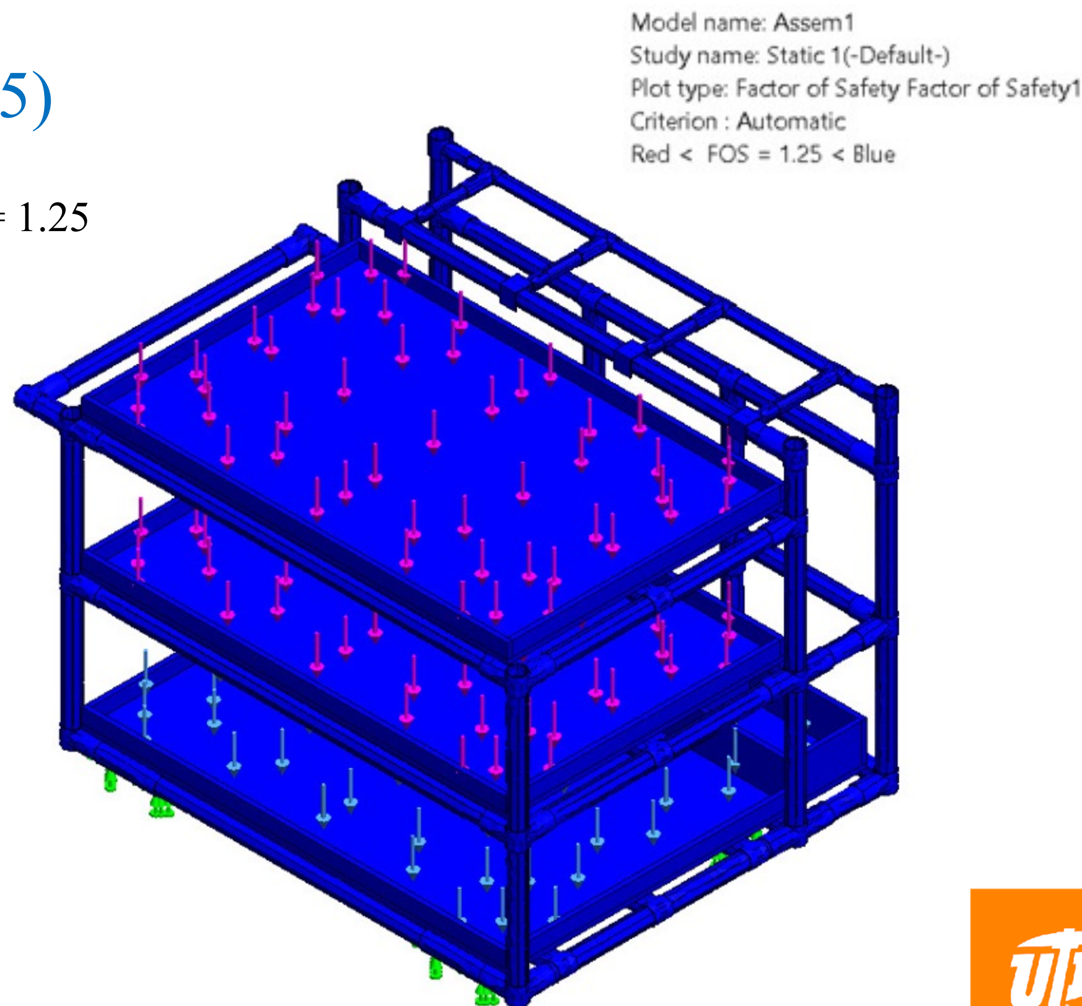


Center of Gravity

- Center of gravity not aligned with wheels → turning tendency
- Most of the weight is at the top → less stability
- Moving the wheel to the edge aligns the center of gravity and improves safety

Factor of Safety (1.25)

- Eaton standard Factor of Safety = 1.25
- Allows 25% extra load without permanent deformation
- Structure is safe under current conditions



Push Force Measurements (Start-Up & Rolling Force)

Purpose: To assess ergonomic safety, determine operator effort, and establish a baseline for improvement.

Testing Procedure:

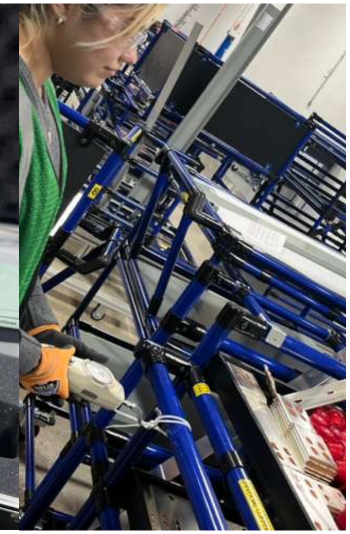
Measurements taken using Shimpo MF-50kg Force Gauge

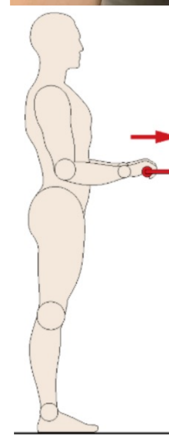
Force applied at elbow height with two hands (standard push posture)

10 trials performed for each condition:

- **Start-Up Force (static)** — peak force recorded just before movement
- **Rolling Force (dynamic)** — force required to maintain motion

Condition	Trial Results	Average Force
Start-Up Force (Static / Peak)	7 tests → 9 kgf 3 tests → 12 kgf	9.9 kgf
Rolling Force (Dynamic / Maintain Motion)	Readings fluctuated between 5–10 kgf	7.5 kgf (visual average)





Push out at elbow height, 2 hands

Frequent (≥ 2/minute)

Recommended: 11.8 lb (5.4 kg)

Acceptable: 17.7 lb (8.0 kg)

Infrequent (< 2/minute)

Recommended: 29.5 lb (13.4 kg)

Acceptable: 38.3 lb (17.4 kg)

VOICE OF THE CUSTOMER			
Verbal Feedback	**Want**	**Requirement**	**User**
The plastic chains on the kit cart frequently break during movement, causing the panels to fall.	A metal chain	Stronger, more durable chain system	Floor Operator
Panels inside the kit cart scrape against each other when the cart is in motion.	More support materials	Reinforced dividers/padding	Floor Operator
When fully loaded, the kit cart becomes too heavy, requiring two operators to move it.	Bigger tires and better distribution of weights	Heavy-duty tires, balanced frame	Floor Operator
The handle on the kit cart is non-functional, so operators resort to alternative methods to pull it.	A more ergonomic handle that works	Redesigned ergonomic handle	Floor Operator
The kit cart veers off course and doesn't travel in a straight line, making it difficult to maneuver.	A better distribution of materials	Improved axle/tire alignment	Floor Operator
Materials slide out of the kit cart because the compartment sides are too short to contain them securely.	Longer sides for the compartments	Taller compartment panels	Floor Operator
Due to the lack of a standardized material layout, operators organize contents based on personal preference, often resulting in poor fit within compartments.	Labeled layout	Standardized and labeled compartments	Floor Operator
Placing materials into the kit cart causes it to become unstable and unbalanced.	Better stability	Wider base or reinforced support	Floor Operator
The panel compartments are too tall, leading to operator instability when loading materials.	Shorter panel compartments	Adjustable or shorter compartment heights	Floor Operator
The kit cart lacks sufficient compartments, prompting operators to use cardboard inserts to create additional sections.	More compartments	Modular and flexible compartment system	Floor Operator
Heavy materials deform the kit cart compartments over time.	Stronger compartments	Use of reinforced/durable materials	Floor Operator

AMR (Autonomous Mobile Robot) Compatibility

- Eaton will use AMR to transport carts
- Carts are mounted on an aluminum base compatible with AMR
- New designs must ensure compatibility with the AMR base
- Goal: avoid operators pushing heavy carts (up to 1000 lbs.)

Analyze

In this phase, baseline data is analyzed to identify the root causes of ergonomic, structural, and operational problems. Biomechanical findings, anthropometric constraints, AMR requirements, material dimensions, and benchmarking results guide the creation of preliminary design concepts through brainstorming and affinity analysis

Ergonomics

Biomechanical Analysis Follow-up with HumanTech, Anthropometric Constraints

Introduction to humantech® — a VelocityEHS solution —

- HumanTech is a software used by Eaton to assess ergonomic conditions in the workplace, including biomechanical analyses.
- The team selected HumanTech because is a more user-friendly and better supports managing ergonomic studies in alignment with Eaton's EHS standards.
- We are using the Advanced Whole-Body Assessment feature, which:
  - ✓ Evaluates posture, force, duration, and frequency for each joint.
  - ✓ Quantifies ergonomic risk using HumanTech's internally developed scoring models tailored for manufacturing operations.
- This method was chosen instead of the Manual Whole-Body Assessment because it automates data entry and supports consistent, repeatable evaluations

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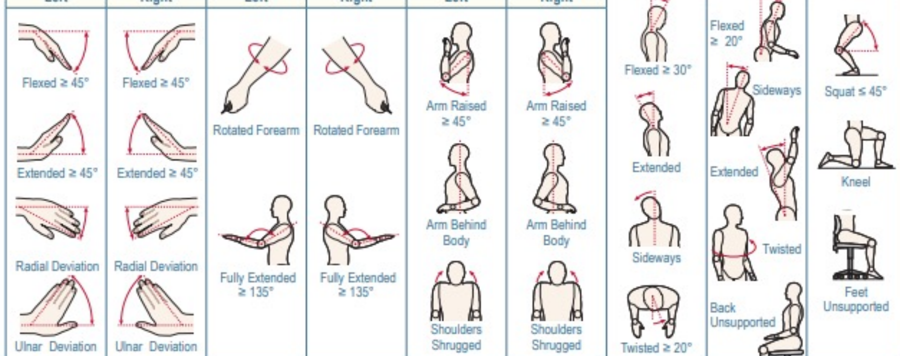
This is the view from Manual Whole-Body Assessment.

Step 2. Circle Posture and Force pictures when risk factors are observed. Mark Posture and Force boxes for each body area when thresholds are exceeded.



	Hands and Wrists		Elbows		Shoulders		Neck	Back	Legs
	Left	Right	Left	Right	Left	Right			
Posture	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Flexed ≥ 45° Extended ≥ 45° Radial Deviation Ulnar Deviation	Flexed ≥ 45° Extended ≥ 45° Radial Deviation Ulnar Deviation	Rotated Forearm Fully Extended ≥ 135°	Rotated Forearm Fully Extended ≥ 135°	Arm Raised ≥ 45° Arm Behind Body Shoulders Shrugged	Arm Raised ≥ 45° Arm Behind Body Shoulders Shrugged	Flexed ≥ 30° Extended Sideways Twisted ≥ 20°	Flexed ≥ 20° Sideways Extended Twisted Back Unsupported	Squat ≤ 45° Kneel Feet Unsupported
Force	☐	☐	☐	☐	☐	☐	☐	☐	☐
A. Pinch Grip B. Finger Press C. Power Grip	A B ≥ 2 lb (0.9 kg) C ≥ 10 lb (4.5 kg)	A B ≥ 2 lb (0.9 kg) C ≥ 10 lb (4.5 kg)	≥ 10 lb (4.5 kg)	≥ 10 lb (4.5 kg)	≥ 10 lb (4.5 kg)	≥ 10 lb (4.5 kg)	≥ 2 lb (0.9 kg)	≥ 25 lb (11.3 kg)	Foot Pedal ≥ 10 lb (4.5 kg)
			Both Elbows ≥ 15 lb (6.8 kg)		Both Shoulders ≥ 15 lb (6.8 kg)				

Step 3. For body parts with Posture or Force marked, mark Duration and/or Frequency box(es) when limits are exceeded.

Duration	☐	☐	☐	☐	☐	☐	☐	☐	☐
	≥ 10 sec.	≥ 10 sec.	≥ 10 sec.	≥ 10 sec.	≥ 10 sec.	≥ 10 sec.	≥ 10 sec.	≥ 10 sec.	≥ 30% of day
Frequency	☐	☐	☐	☐	☐	☐	☐	☐	☐
	≥ 30/min.	≥ 30/min.	≥ 2/min.	≥ 2/min.	≥ 2/min.	≥ 2/min.	≥ 2/min.	≥ 2/min.	≥ 2/min.

Step 4. Add Posture, Force, Duration and Frequency check marks (0-4) and circle Risk Rating (Low = 0 or 1, Medium = 2, High = 3 or 4).

Score (0-4)									
Risk Rating	L M H	L M H	L M H	L M H	L M H	L M H	L M H	L M H	L M H

Biomechanical Analysis – Baseline & Direct Causes

- HumanTech requires a video recording of the operator performing the pushing task to generate the biomechanical model.
- The software analyzes the video to track posture, joint angles, movement patterns, and force application, producing a color-coded skeletal model that shows low-, medium-, and high-risk movements.
- A female operator was selected for this evaluation to establish a conservative ergonomic baseline. Using a lower-strength profile ensures that the final cart design remains safe, operable, and accessible for a broad range of users.

Assessment results show high-risk scores in shoulders and elbows due to excessive push force and forward posture.

Advanced Whole-Body Assessment

Switch to Manual Whole-Body Assessment

Advanced Tool Priority Score

35

Edit

Advanced Tool Assessment

	Hands/Wrists		Elbows		Shoulders		Neck	Back	Legs
	Left	Right	Left	Right	Left	Right			
Score ▲	1	1	10	6	6	6	0	2	2
Force	0	0	4	4	4	4	0	0	0
Posture	1	1	2	1	1	1	0	1	1
Duration	0	0	3	0	0	0	0	0	0
Frequency	0	0	1	1	1	1	0	1	1
Risk Rating	Lower	Lower	Higher	High	High	High	Lower	Low	Low

Causes by Body Region

Select Body Regions

Body Region	Cause	Risk
Right Shoulder	Force	High - 4
Left Shoulder	Force	High - 4
Right Elbow	Force	High - 4
Left Elbow	Force	High - 4
Left Elbow	Posture	High - 2

Forces

Add

Name	Type	Affects	Value	Risk	
Push	Push Out	Both	742 lb	High	Edit
Start-Up Force (Static)	Push Out	Both	Estimated: 6/10	High	Edit
PPE		Neck	0.1 lb	Low	Edit

UTEP

Anthropometric Constraints (USA + Mexico)

- To ensure the handle design is ergonomically appropriate for Eaton's workforce, we considered operator anthropometrics from both U.S. and Mexican populations

- HumanTech provided U.S.-based horizontal handle height recommendations of 38 - 45 inches. Eaton's Safety Engineer provided equivalent handle height data for Mexican operators, showing a range of 35 - 44 inches.

- An inclusive design height of 40.5 inches was selected, as it falls within both populations' recommended ranges and supports accommodation across a wide span of operator statures.

Mexico

Cranks or handles		
No.	Guidelines	
1	Handles should be cylindrical, smooth, and without sharp edges. The material should be insulating and not change temperature with the environment.	
2	The height of the handles can vary between 91-112 cm	35 in- 44 in
3	The handles diameters should be between 2.5 and 4 cm. Smaller diameters make coupling more difficult.	
4	12 cm of separation should be allowed to leave the palm of the hand free and 5 cm so that the knuckles do not touch the handle and improve the fit.	4 1/2 in
5	The handles can be positioned vertically or horizontally. If they are vertical, they must be spaced 50 cm apart.	
6	The handles must have a separation from both ends of the cart by at least 10 cm to avoid entrapment.	4 in
7	Vertical handles allow users to find their optimal heights, while horizontal handles allow for optimal separation between the hands.	

USA

Hand cart/hand truck guidelines

- Vertical handles (preferred for smaller carts that turn easily):
  - Length minimum 5" (127 mm)
  - Height 36 - 49" (0.9 - 1.24 m)
  - Position 16 - 20" apart (406 - 508 mm)
- Horizontal handles (preferred for turning larger carts):
  - Length ≥ 24" (609 mm)
  - Height 38 - 45" (0.95 - 1.14 m)
- Handle diameter: 2" (51 mm)
- Handle offset for foot placement: ≥ 8" (203 mm) preferred

Defining Design Constraints

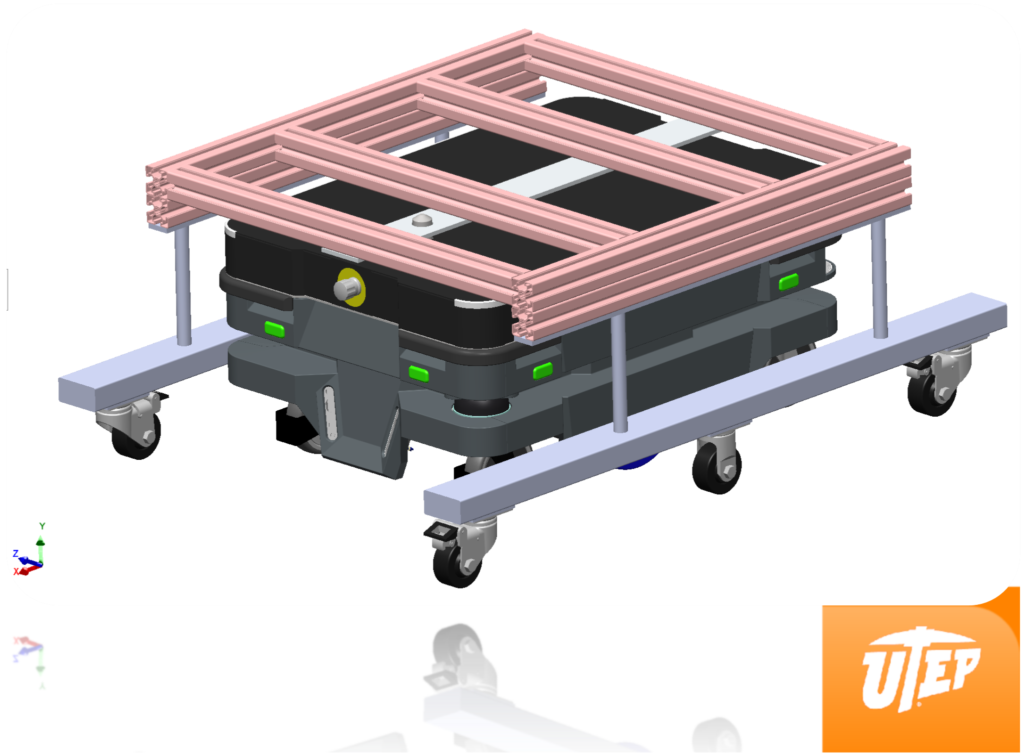
AMR Compatibility, Material Dimensions Study, Benchmarking

AMR Compatibility – Integration with MiR250 Shelf Carrier

Eaton provided the CAD base already designed to interface with their AMR.

MiR250 Key Specifications:

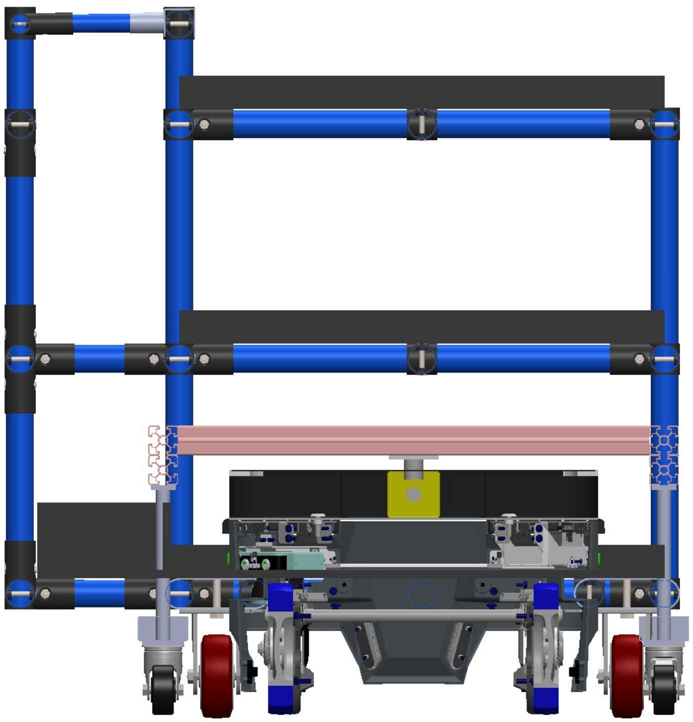
- Payload capacity: 300 kg (661 lbs.)
- Max speed: 1.2 m/s
- Run time: 10 hours
- Application: Picks up and transports carts using the Shelf Carrier module



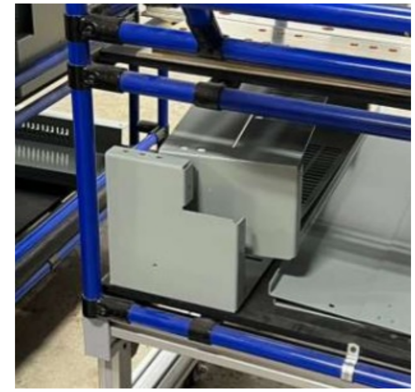
Eaton also reported that the AMR has previously transported carts weighing up to 1,200 lb. However, this exceeds the optimal recommended payload and may affect long-term performance and safety.

Current Cart Design – Not Compatible with AMR Base

- The existing cart structure does not align with the AMR
- The new design will be reconfigured to properly dock with the AMR base while maintaining ergonomic functionality.



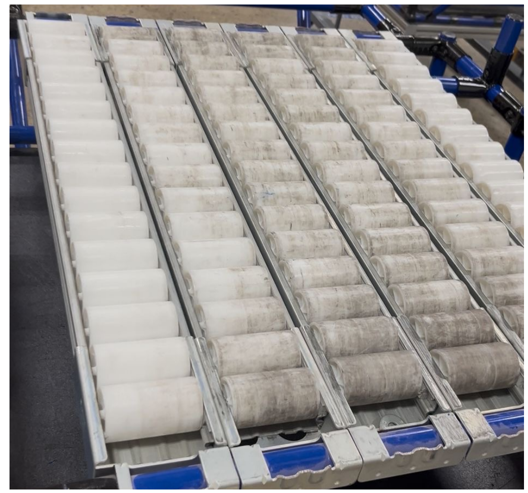
Material Dimension Study – Defining Storage Level Heights

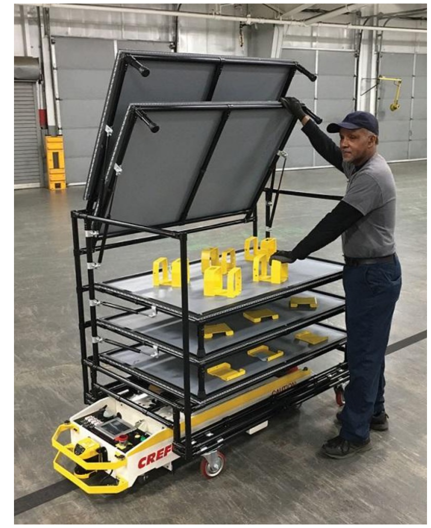


- Measured dimensions of frequently transported materials to ensure compatibility with the new cart design.
- These measurements define the height and spacing of each storage level, allowing all items to be safely loaded, transported, and accessed.

Benchmarking – Learning from Existing Solutions

- Reviewed existing Eaton carts to understand what design elements work well.
- Additional inspiration was taken from Creform's official catalog, their current material supplier, to explore configurations and ergonomic improvements for our new standard cart.





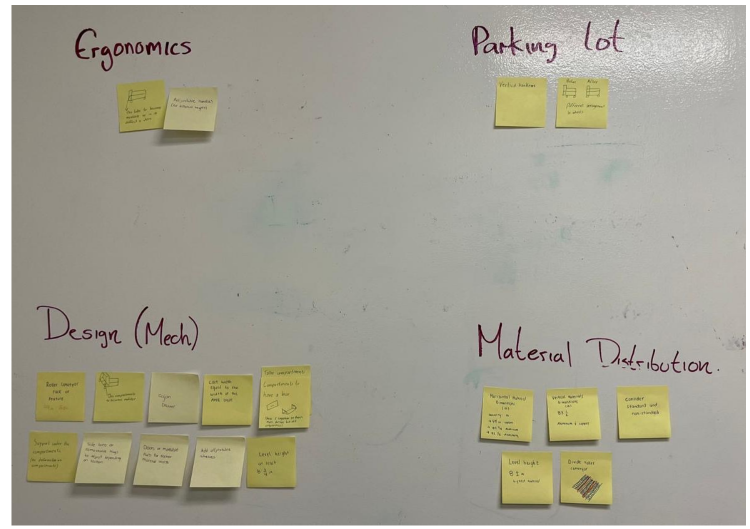
Preliminary Standardized Cart Design

Brainstorming & Affinity Diagram, Concept Sketch, Preliminary Cart Design

Brainstorming & Affinity Diagram – Organizing Improvement Ideas

- A brainstorming session was conducted based on user feedback (VOC) and our own observations from the current cart.
- Each improvement idea was written on a sticky note and then grouped into four main categories using an Affinity Diagram:
  - **Ergonomics** – Improvements related to operator comfort and safety
  - **Parking Lot** – Items pending validation or requiring further discussion
  - **Design (Mechanical)** – Structural and functional modifications
  - **Material Distribution** – Storage optimization for materials

This process helped clarify priorities and guide the direction of our new cart design.

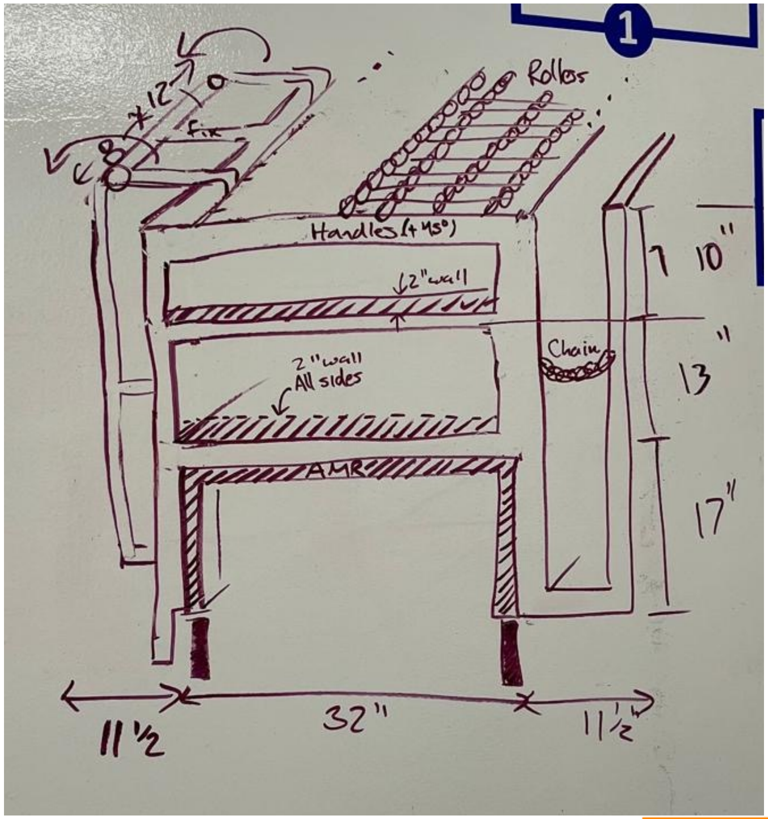


Concept Sketch – Preliminary Cart Layout

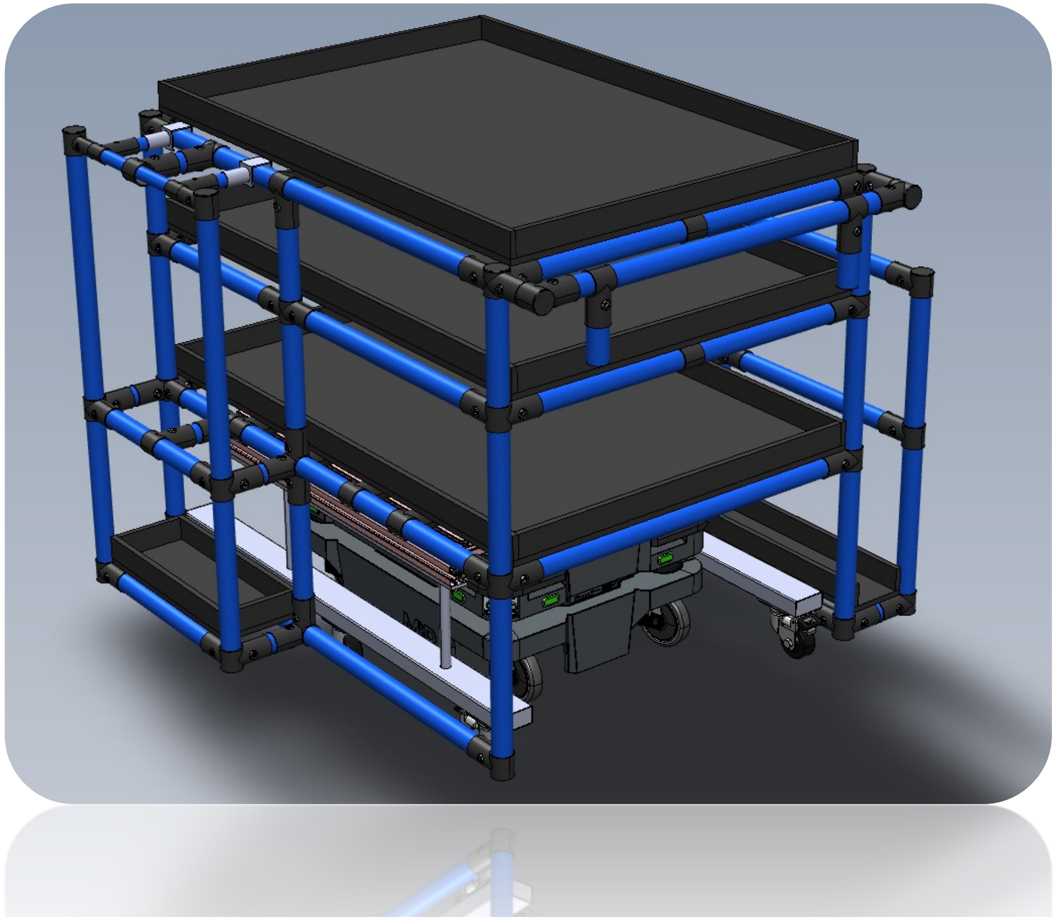
A hand-drawn concept was developed to outline the planned improvements before moving into SolidWorks. This step allowed us to:

- Visualize the new structure and shelf configuration
- Identify general dimensions (width, height, tier spacing, AMR clearance)
- Establish ergonomic elements such as handle height and access angle

By defining these parameters early, we avoided unnecessary CAD iterations and reduced design time.

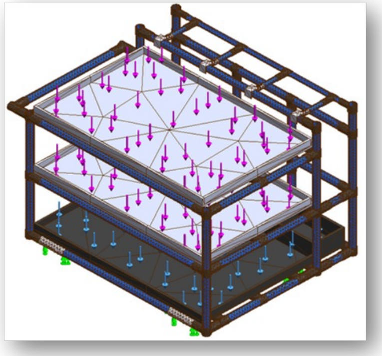


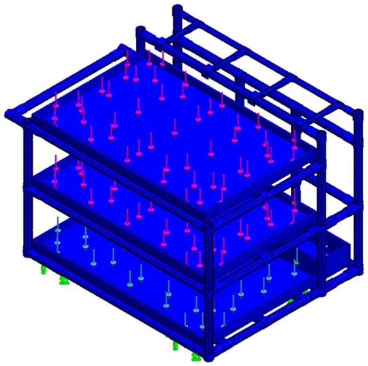
Preliminary Standardized Cart Design (SolidWorks)

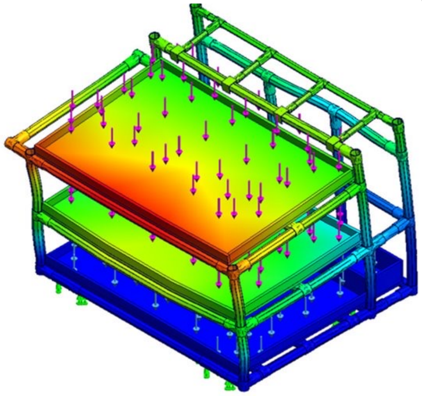


Why the New Design Has Not Been Analyzed Yet

- The current standardized cart model is only the first design iteration.
- It was created to visualize layout, dimensions, and AMR compatibility, not as a final configuration.
- Performing a full analysis at this stage would be premature and inefficient, since Eaton feedback may lead to structural changes.
- Once the design is refined and approved, we will run complete structural analyses in the Improve Phase to validate performance and safety.





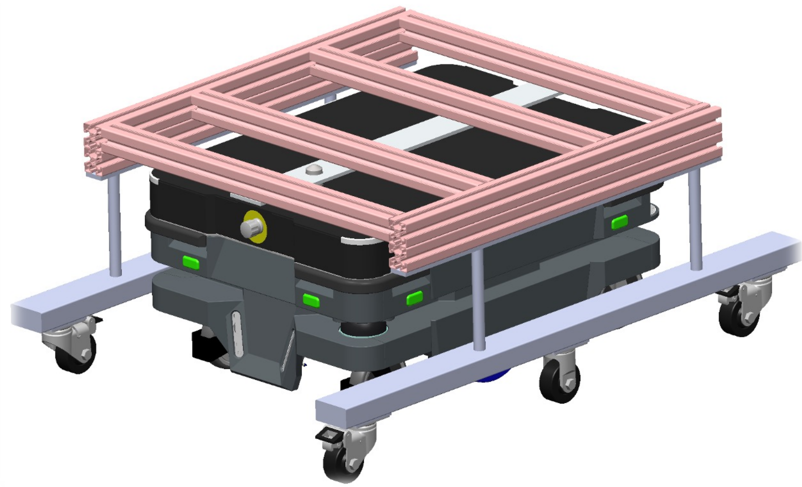


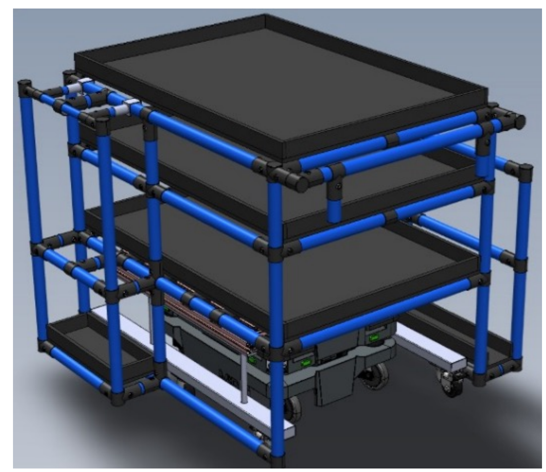
Improve

In this phase, design solutions are developed, refined, and validated to address the structural, ergonomic, and operational issues identified in the previous stages. Customer requirements and design constraints guide the creation of improved cart concepts, which are evaluated through SolidWorks modeling and analysis.

Customer Requirements – Design Constraints

- During an update meeting with Eaton team, we learned that the AMR is equipped with two corner sensors positioned diagonally, each covering 180°, which together provide 360° detection coverage.
- Any structure built beneath the top surface of the AMR's base is recognized as an obstacle, which would prevent autonomous navigation
- The light gray base color of the AMR base is intentionally used to distinguish non-obstacle areas for the sensors.
- Therefore, our design had to be modified to remain fully above the AMR's detection zone to avoid interfering with the sensors.



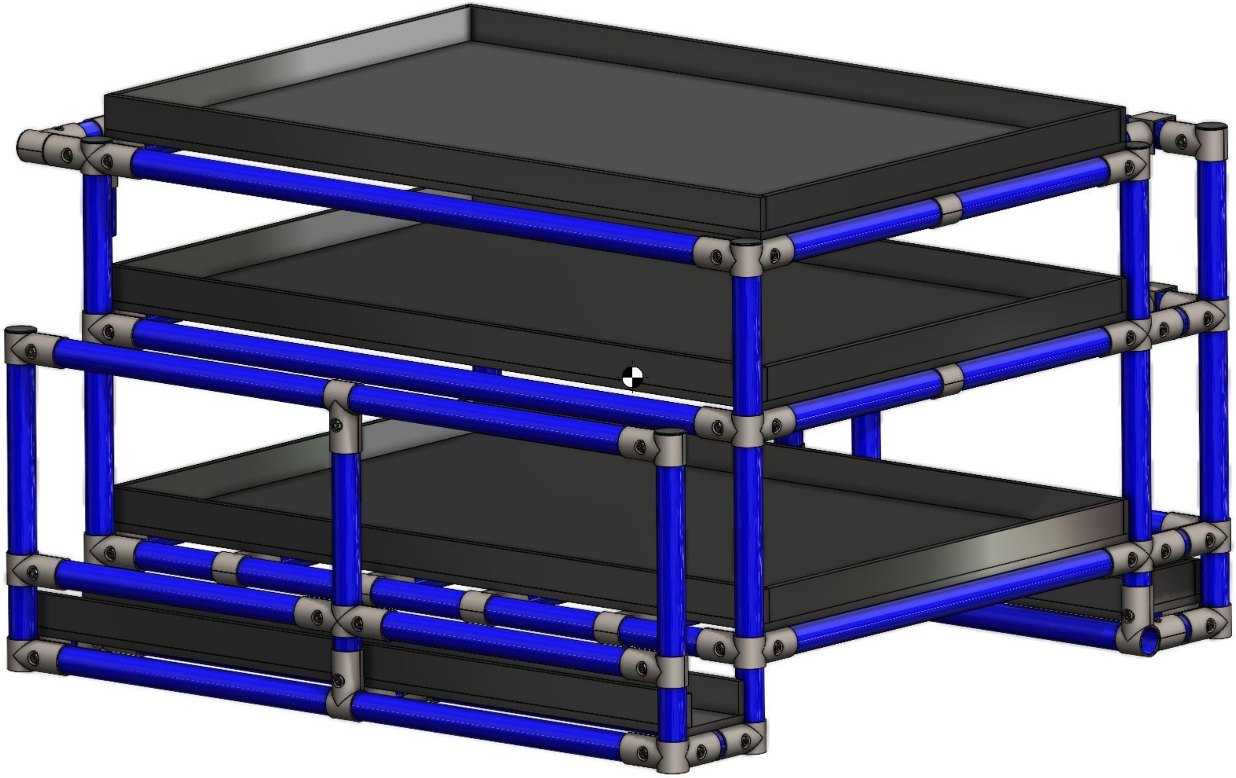


Second Design Iteration (SolidWorks)

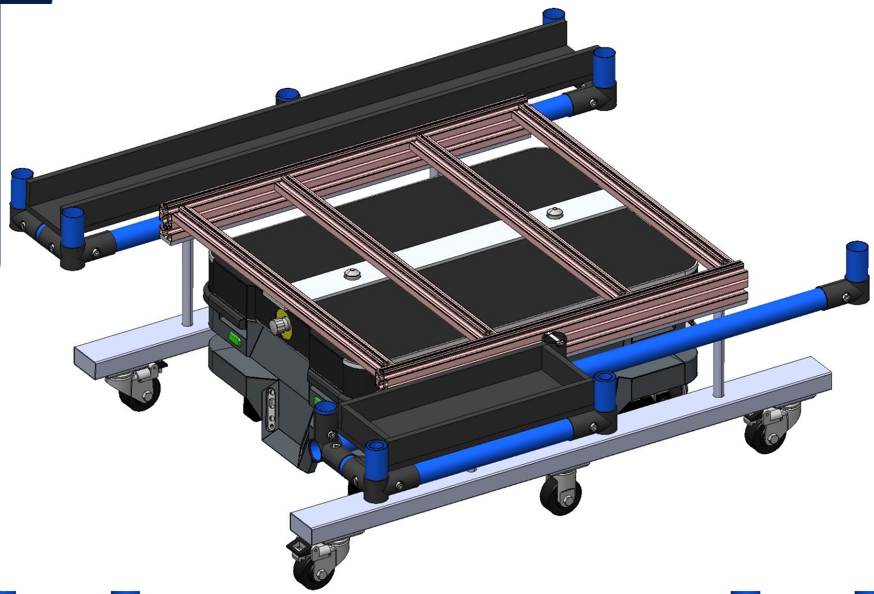
Based on the feedback from the first iteration, we developed a completely new concept. However, Eaton's team noted that this version was too long for practical use on the production floor

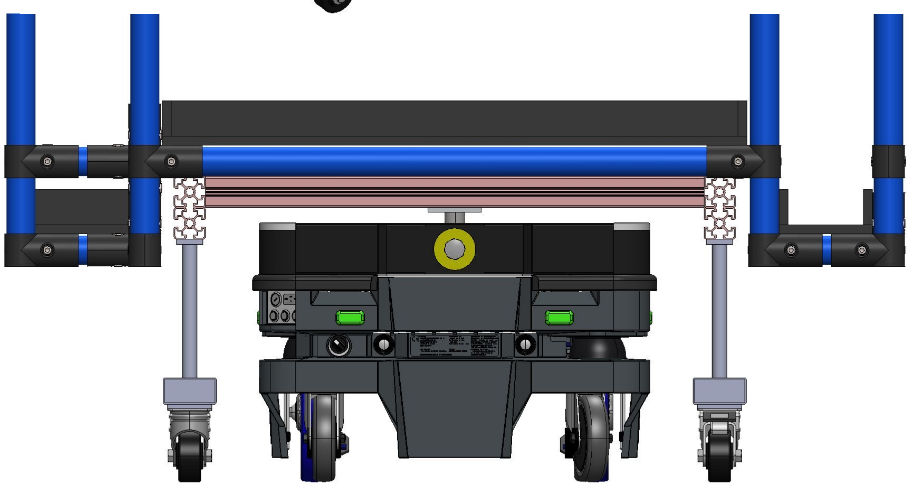
Final Design (SolidWorks)

Empty Kit Cart Structure
Mass = 286.99 lbs.



This is the final design developed as our proposed improvement. We used our first design concept as the foundation but raised the entire structure above the AMR's sensor detection, ensuring the cart is not detected as an obstacle during navigation.





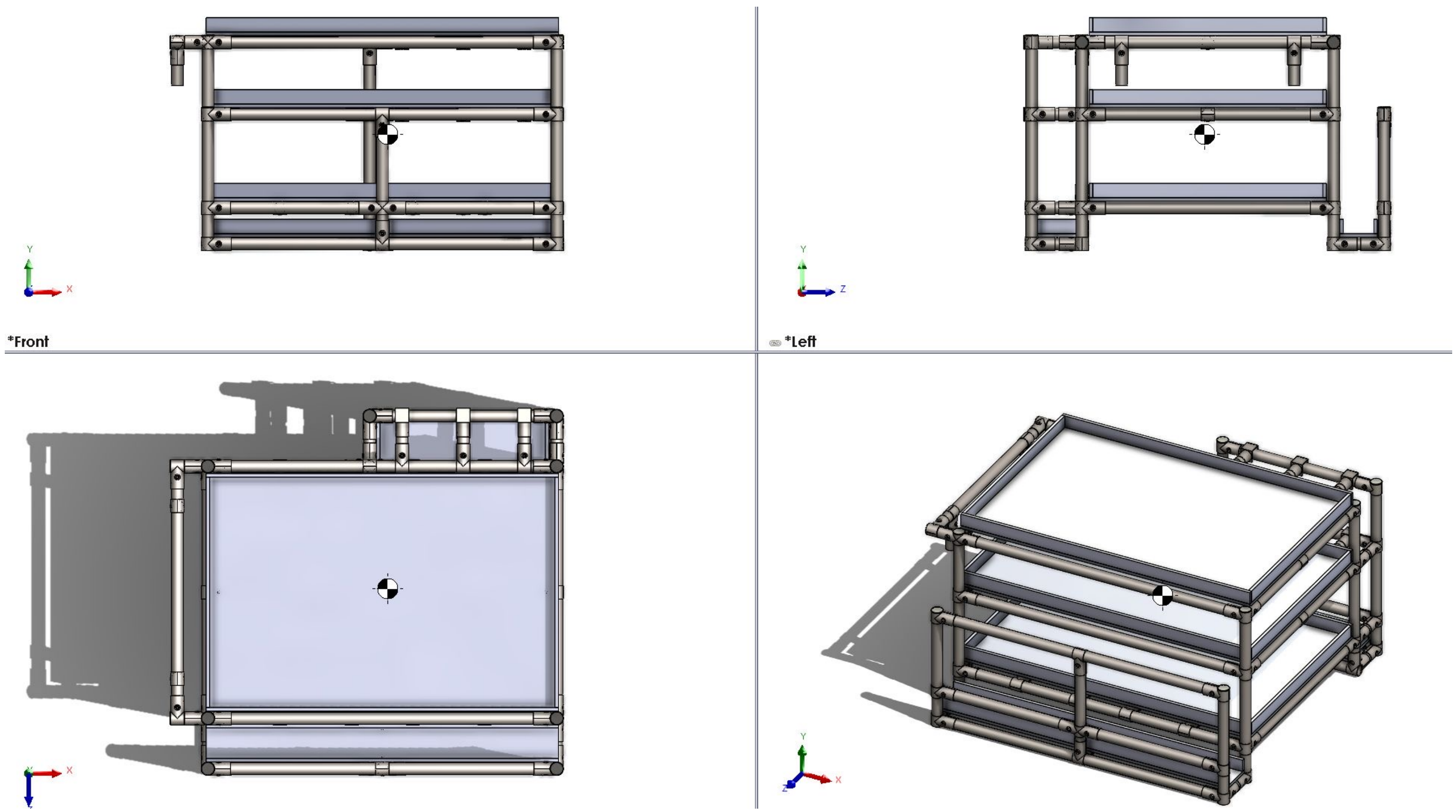
AMR Base Compatibility

This design is fully compatible with the AMR base. The structure is centered on the AMR platform to ensure better stability during transport with no components obstructing the AMR sensors.

AMR Base Weight: 41.9 Lbs. (19 kg)

Structure Center of Gravity

The center of gravity is located near the geometric center of the structure, ensuring balanced weight distribution and stable operation on the AMR base.



Picklist – Riser Workstation

Picklist used by operators to load kits. Material identification is difficult due to general descriptions; the part number identifies each item, and barcodes are used to locate materials in the warehouse.

			MAGNUM- USB						
			STRUCTURE	Rev #	Workstation			Date: / /	
			1, 2	1	Riser			Initials	
Item Typ	Stock Floor Code	Materi	Barcode	Part Number	STD	NON-STD	Description	WH	Production
		Component	*2A94296H01*	2A94296H01	4	8	PHASE TAPS		
		Component	*9251C73H01*	9251C73H01	4	0	4000A ADAPTER, AG		
		Component	*9251C73H03*	9251C73H03	4	0	4000A ADAPTER, AG		
		Component	*9251C73H05*	9251C73H05	4	0	4000A ADAPTER, AG		
		Component	*9251C73H07*	9251C73H07	4	0	4000A ADAPTER, AG		
		Component	*9251C97H01*	9251C97H01	1	1	4 POLE NEUT RISER LINK AG		
		Component	*9251C97H03*	9251C97H03	1	1	4 POLE NEUT RISER LINK AG		
		Component	*9251C97H05*	9251C97H05	1	1	4 POLE NEUT RISER LINK AG		
		Component	*9251C97H09*	9251C97H09	1	1	4P NEUT RISER LINK SPACER AG		
		Component	*9251C97H11*	9251C97H11	2	2	4P TAP PLATE SPACER AG		
		Component	*9251C97H17*	9251C97H17	1	1	4 POLE NEUT TAP AG		
		Component	*9251C97H19*	9251C97H19	1	1	4 POLE NEUT TAP AG		
		Component	*9251C97H13*	9251C97H13	1	1	4 POLE NEUT TAP AG		
		Component	*9251C97H15*	9251C97H15	1	1	4 POLE NEUT TAP AG		
		Component	*9252C02H10*	9252C02H10	14	14	RISER BUS INSULATOR 4-POLE		
		Component	*9252C02H11*	9252C02H11	14	14	RISER BUS INSULATOR SUPPORT 4P		
		Component	*9252C02H04*	9252C02H04	7	7	RISER BUS CROSS SUPPORT 30W		
		Component	*9251C04H01*	9251C04H01	14	14	TAP PLATE 2000A AG		
		Component	*9257C71G03*	9257C71G03	8	8	30" SW/DW STAB ASSY		
		Component	*9251C03H27*	9251C03H27	6	6	RISER AG B 44"		
		Component	*9251C03H29*	9251C03H29	6	6	RISER AG B 32.75"		
		Component	*87C0327G65*	87C0327G65	2	2	RISER AG B 44"		
		Component	*87C0327G67*	87C0327G67	2	2	RISER AG B 32.75"		

Material Weight Analysis

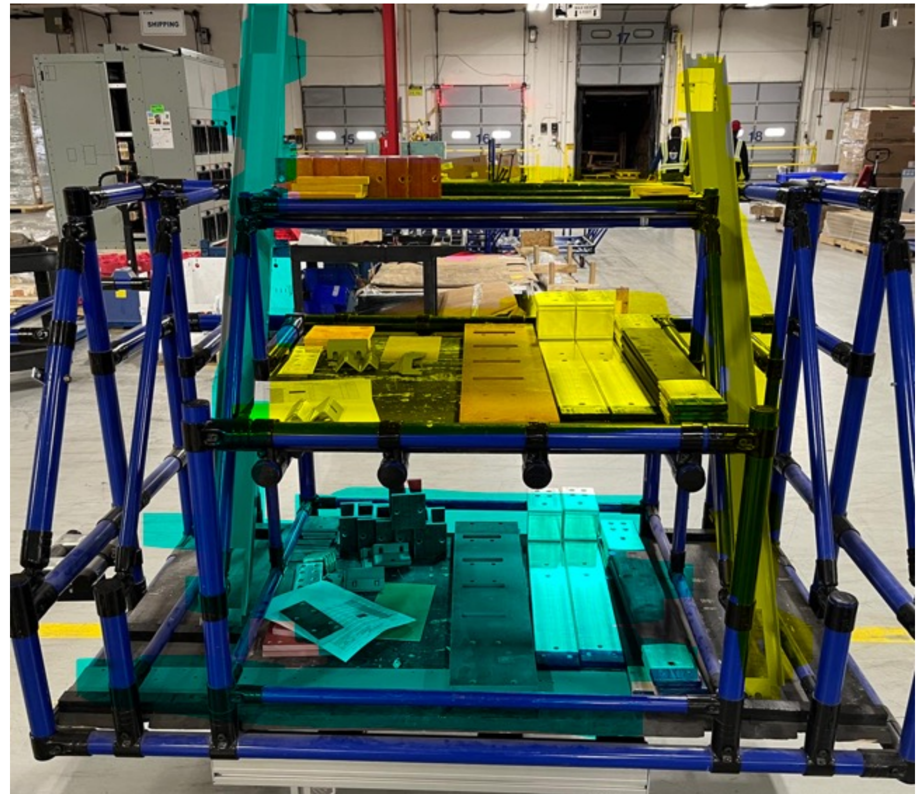
Material catalog created with barcode, part number, description, weight, and images to simplify identification. This analysis allowed us to calculate level weights and total material weight per workstation.

Material	Barcode	Part Number	Description	Weight	Image
Component	*9251C97H01*	9251C97H01	4 POLE NEUT RISER LINK AG	1 lbs	
Component	*9251C97H03*	9251C97H03	4 POLE NEUT RISER LINK AG	1 lbs	
Component	*9251C97H05*	9251C97H05	4 POLE NEUT RISER LINK AG	1 lbs	
Component	*9251C97H09*	9251C97H09	4P NEUT RISER LINK SPACER AG	1 lbs	
Component	*9251C97H11*	9251C97H11	4P TAP PLATE SPACER AG	1 lbs	
Component	*9251C97H13*	9251C97H13	4 POLE NEUT TAP AG	2 lbs	
Component	*9252C02H10*	9252C02H10	RISER BUS INSULATOR 4-POLE	1 lbs	
Component	*9252C02H11*	9252C02H11	RISER BUS INSULATOR SUPPORT 4P	2 lbs	
Component	*9251C03H27*	9251C03H27	RISER AG B	22 lbs	

Midline Mechanical Kit Cart

- Initially this station was one of the heaviest.
- Material analysis indicated that this station is not as heavy as originally expected.
- Some components could not be weighed because the scale did not register them, and the cart shown in the picture is double-loaded with two different kits.
- The blue section represents one kit. The yellow section corresponds to a second kit.

Because this station no longer represents a critical weight constraint, we removed it from our priority list for detailed design work at this stage.

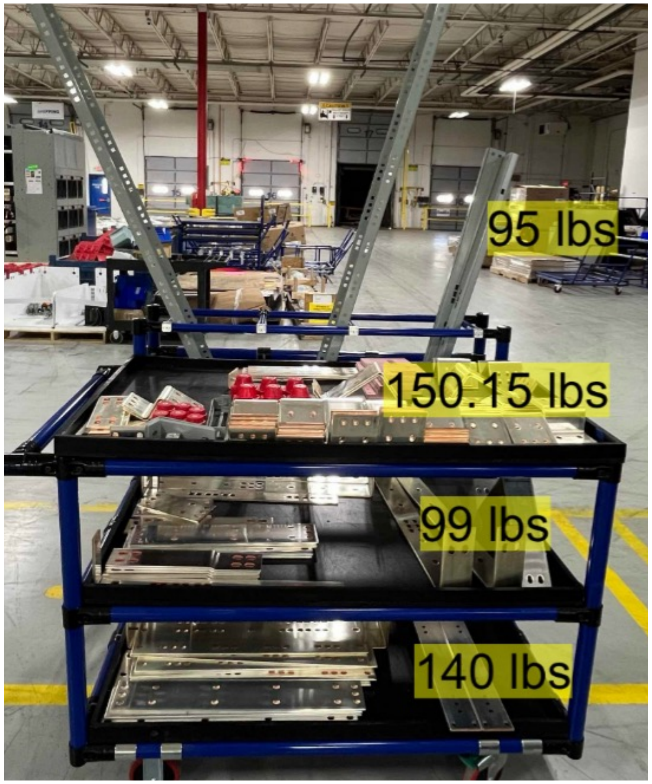


Data for Structural Analysis - Crossbus Main Station

Total Weight With AMR Base: 1,028.69 lbs.

Data for Structural Analysis - Copper Layout Main Station

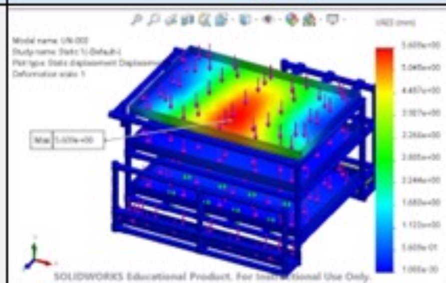
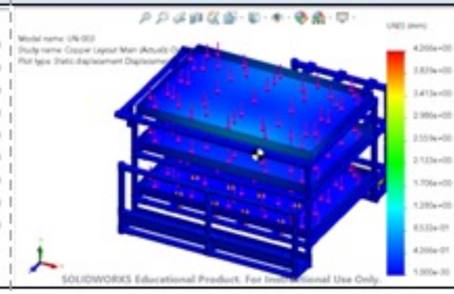
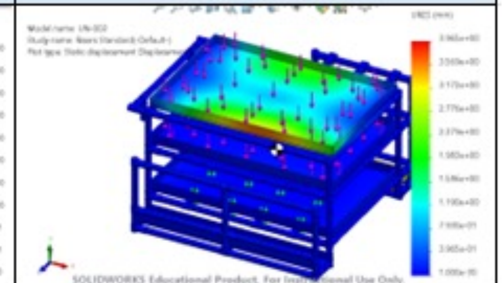
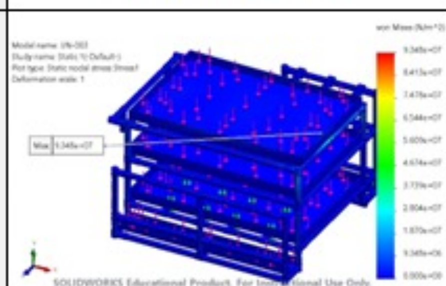
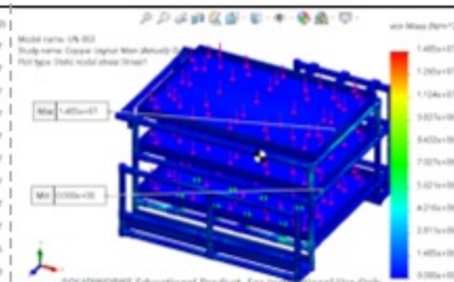
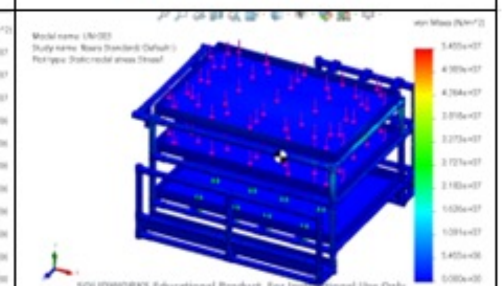
Total Weight With AMR Base: 863.04 lbs.



Data for Structural Analysis Risers Station

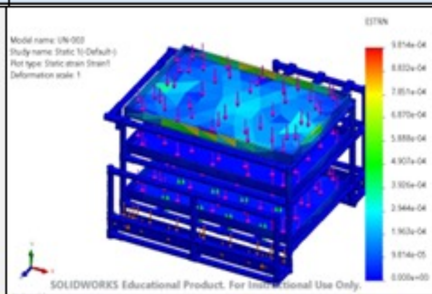
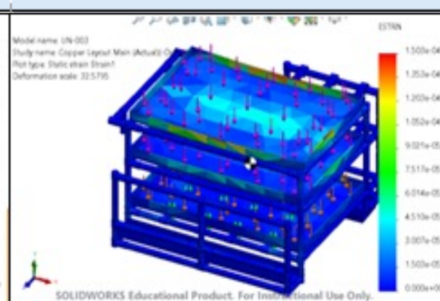
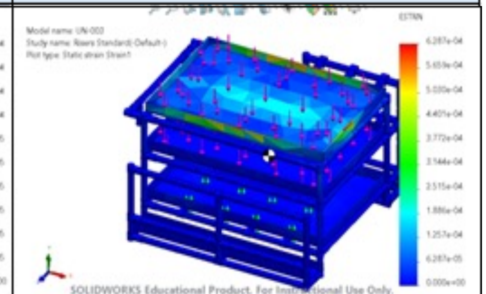
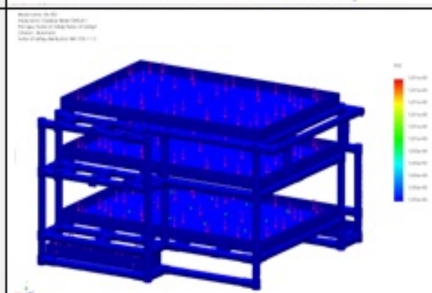
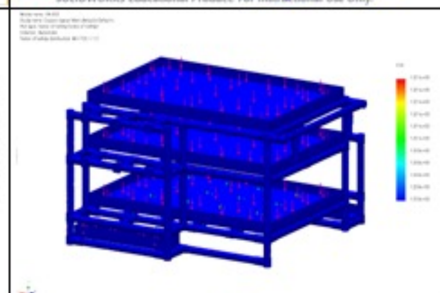
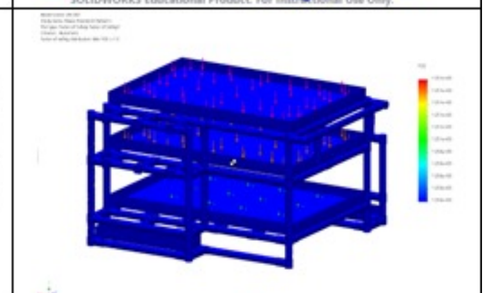
Total Weight With AMR Base: 840.89 lbs.

Finite Element Analysis (FEA) - Static

Analyis	CROSSBUS (MAIN)	COPPER LAYOUT (MAIN)	RISERS (MAIN)
Displacement			
Min / Max	0.000e+00 / 5.609e+00	0.000e+00 / 1.405e+07	0.000e+00 / 1.405e+07
Von Mises Stress			
Min / Max	0.000e+00 / 9.348e+07	0.000e+00 / 1.405e+07	0.000e+00 / 1.405e+07

This table summarizes the FEA results for the worst-case MAIN stations (Crossbus, Copper Layout, Risers), which carry larger components and heavier material loads than Feeders. Feeders are compatible by default due to their lower material requirements.

Finite Element Analysis (FEA) - Static

Analyis	CROSSBUS (MAIN)	COPPER LAYOUT (MAIN)	RISERS (MAIN)
Strain			
Safety Factor (1.25)			
Compatibility	☑	☑	☑

FEA Results Overview and Findings

Analysis Type	What It Shows / Demonstrates
Displacement (Deformation)	Indicates how much the structure bends or moves under load. Low displacement means the structure is rigid and stable.
Von Mises Stress	Shows the overall stress level in the structure. Used to determine whether the material is approaching yielding or failure. Safe if values are below yield strength.
Strain	Measures how much the material stretches or compresses. Helps determine if deformation is elastic (safe) or approaching plastic (unsafe).
Safety Factor (1.25)	Ensures the structure has at least 25% extra strength beyond expected loads. A value ≥ 1.25 means the design meets Eaton's safety requirement.
Compatibility	Confirms that the cart design remains functional and safe under each station's load.

We observed that the deformations are minimal. The small displacement is caused by a gap between the Delrin plastic sheet and the tube frame that supports it. This gap exists because the tray rests on top of the joint, and the joint has a thickness of approximately 2 mm

Recommendation: Add small spacers to remove the gap, which would reduce minimal deformation and further improve stability and load distribution.

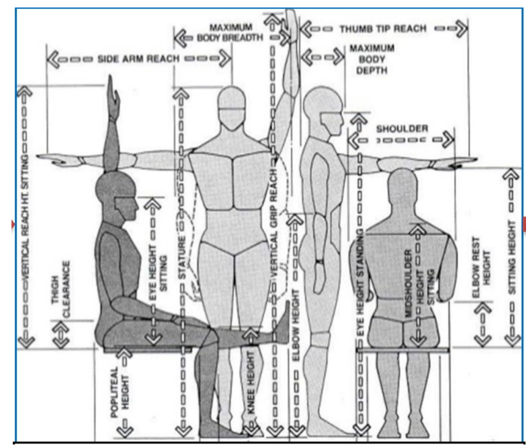
Eaton’ s Safety and Ergonomical Standard Compliance

Structural Safety Requirements

- Eaton standard Factor of Safety = 1.25
- This factor ensures the design can withstand 25% additional load beyond the expected maximum without permanent deformation or failure.
- All the previous analyses were performed considering this required safety factor.

Ergonomics

- Ergonomical criteria were evaluated using anthropometric data from both U.S. and Mexican operator populations.
- To ensure inclusivity, the horizontal handle-height ranges from both datasets were combined.
- The final handle height was set to 40.5 inches to ensure comfortable and safe operation for the full expected operators at Eaton.



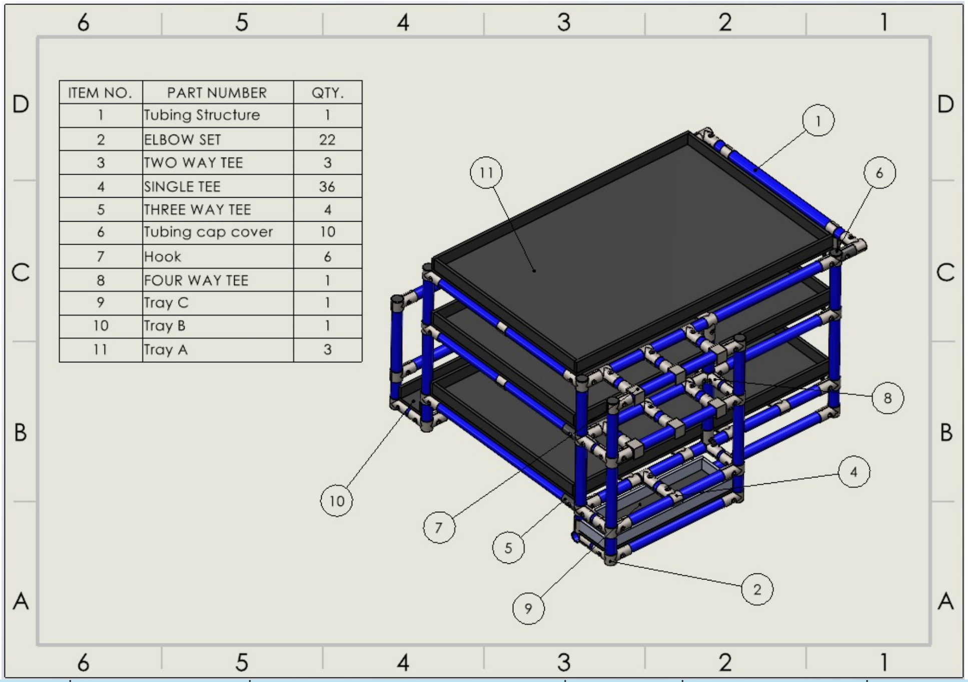
Control

In this phase, the final design and deliverables are documented to ensure repeatability. This includes the BOM with cost estimates, 2D manufacturing drawings, the final CAD and FEA package, and a Design Process Report for future replication.

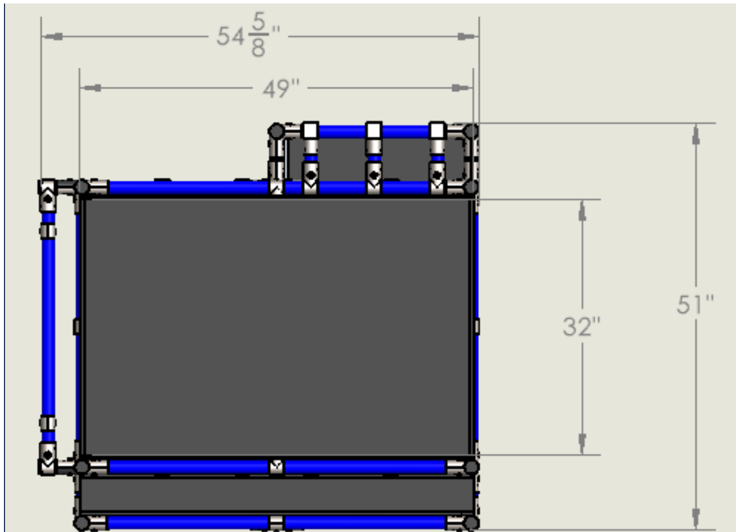
Bill of Materials & Cost Estimates

This is an estimate that was based on the latest quotes given by Eaton's provider.

Estimated Cost **$461.43**

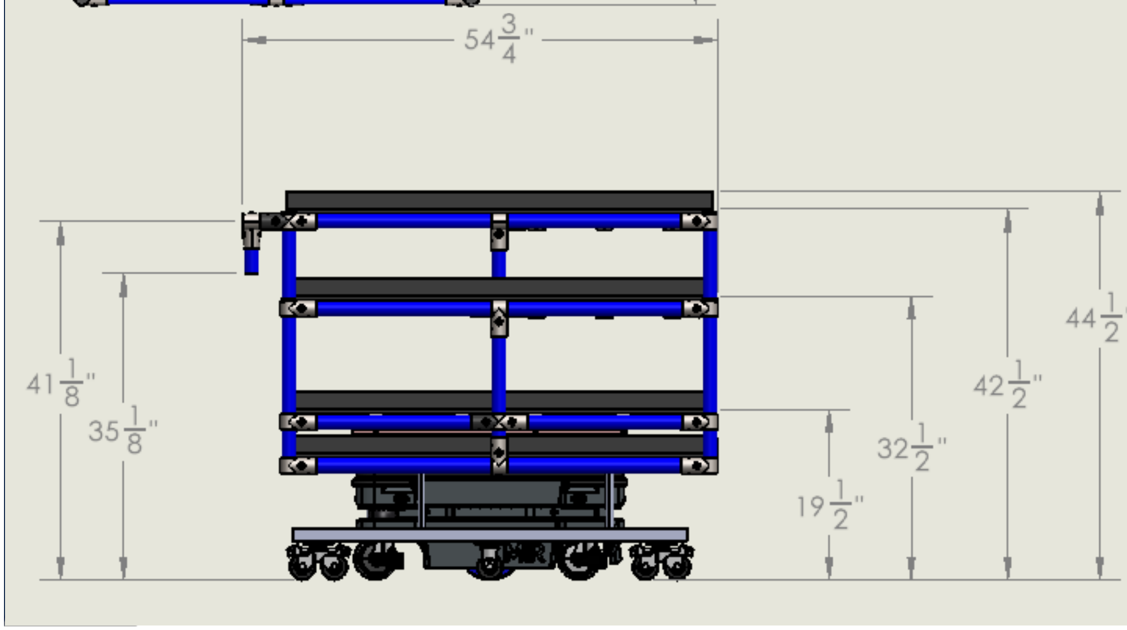


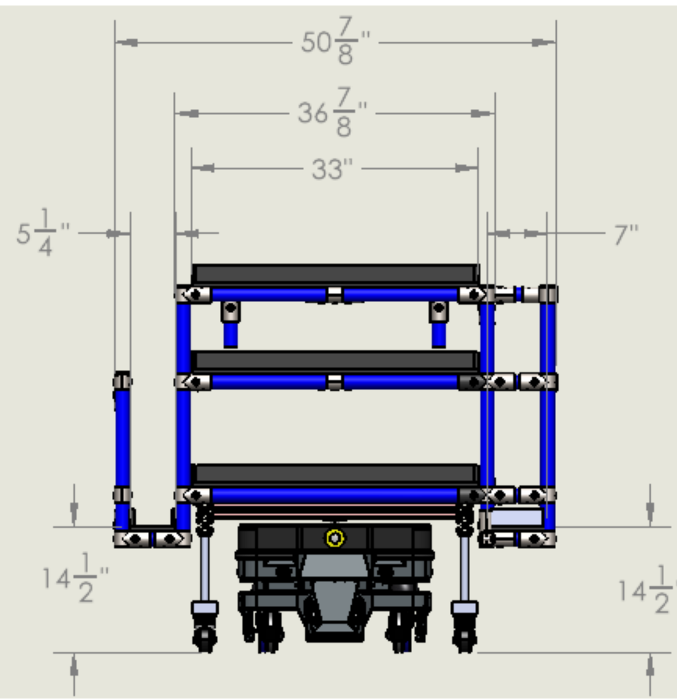
Item No.	Part ID	Part Name	Quantity	Unit Price	Total Cost
1	HK-4000-LGR-Y	Slide Pipe, Plastic Coated Steel	2	$ 16.08	$ 32.16
2	SEJ-1B	Metal Joint Set for 28mm to 32mm pipe	22	$ 6.31	$ 138.82
3	H-2	Metal Joint Set Component for 28mm Pipe	24	$ 1.99	$ 47.76
4	H-3	Metal Joint Component for 28mm Pipe	36	$ 1.99	$ 71.64
5	N/A	Tubing Cap Cover	7	$ 11.00	$ 77.00
6	TX-2061A	Slide Pipe Mount 42mm	2	$ 4.84	$ 9.68
7	N/A	Delrin Plastic	1	$ 39.53	$ 39.53
8	M-8	M8-60 Bolt, Hex Head, Zinc Plastic	118	$ 0.38	$ 44.84
Total					**$ 461.43**



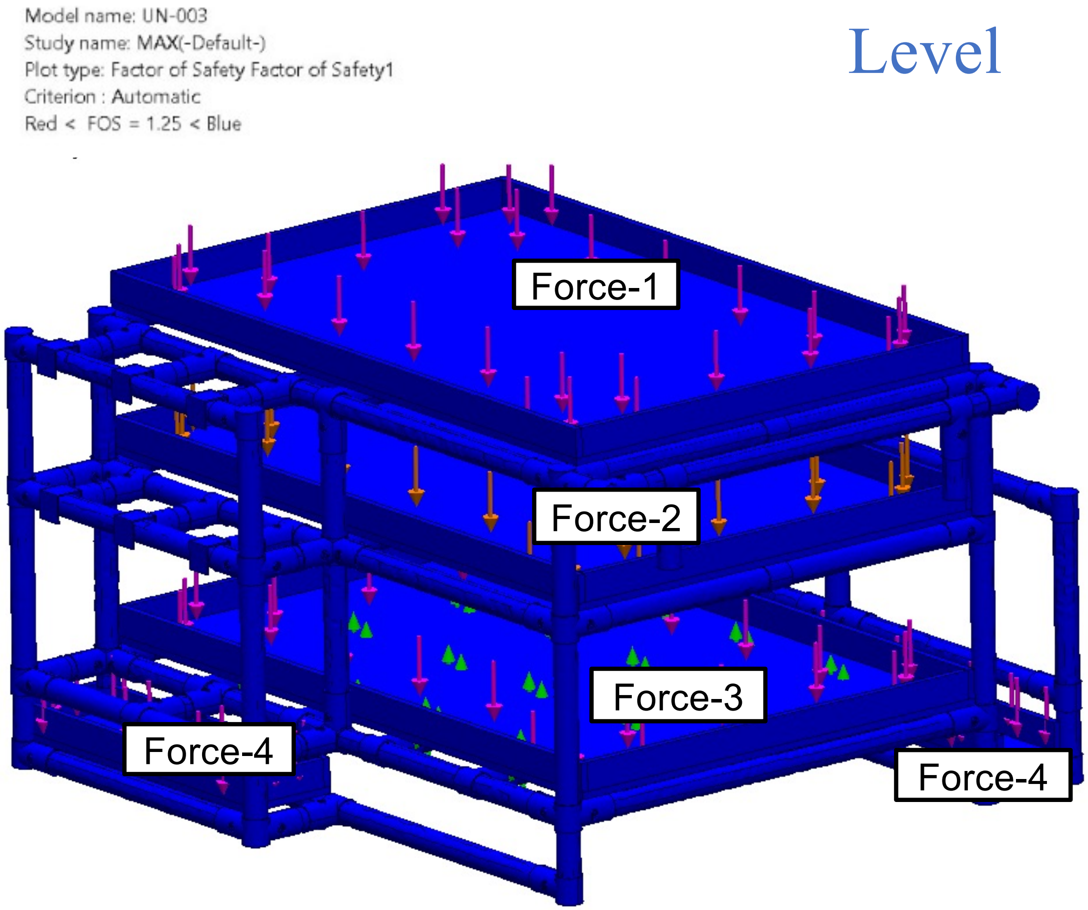
2D Manufacturing Drawings

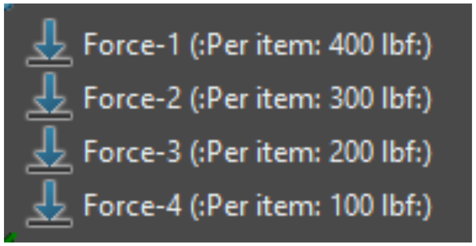
- These drawings include all the critical dimensions needed for fabrication, such as height, width, and spacing between levels.
- They allow Eaton to accurately build and replicate the cart in the future without relying only on the 3D model.





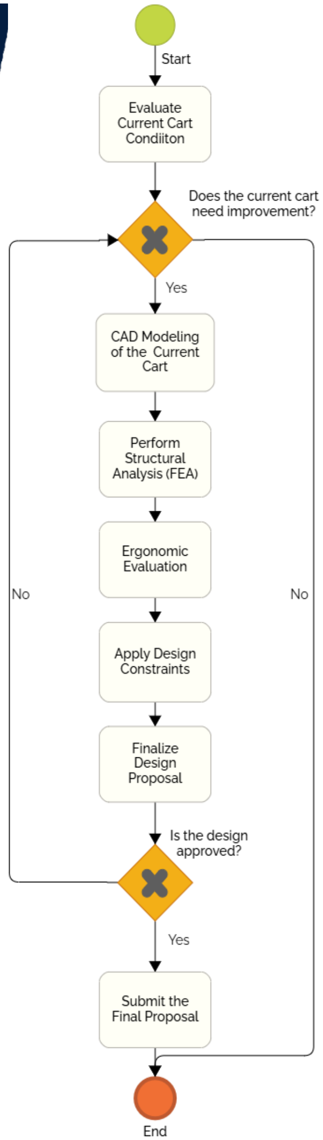
Maximum Allowable Load per Storage Level





Different forces were applied to each level to identify safe weight limits while maintaining Eaton's required factor of safety of 1.25.

This information can later be used to create visual guides for safe and ergonomic loading.



Design Process – Procedural Methodology

- This methodology outlines the step-by-step engineering workflow used to evaluate, redesign, and validate a standardized kit cart.
- The Design Process incorporated CAD modeling, FEA structural analysis, ergonomic assessment, and integration of AMR constraints. Validation confirmed compliance with Eaton's safety factor of 1.25 and ergonomic standards based on U.S. and Mexican anthropometric data. Final
- The report serves as a technical record of the design process and validation steps, enabling Eaton to replicate the methodology for future cart designs or for documenting existing carts

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THANK YOU!

Q & A