Summer 2023

JME 4110: Automated Railway Decoupler, Optimized

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Joint Engineering Program

University of Missouri–St. Louis ▪ Washington University in St. Louis

ELEVATE YOUR FUTURE.
ELEVATE ST. LOUIS.

Disconnecting freight cars from one another in trains that may be many thousands of feet long involves the dangerous and inefficient operation of manual decoupling. We have produced a system that enables freight cars to disconnect remotely, streamlining rail operations and boosting efficiency.

JME 4110
Mechanical Engineering
Design Project

Remotely Actuated Railway Decoupling

Gracer Stonner
Matt Stokes
Adam Young
Robert Murphy

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1 Introduction

1.1 Value proposition / project suggestion

Our design project focuses on a remote decoupling device for freight cars. Currently, freight cars require a person on the ground to walk up and manually throw a lever to decouple each pair of cars, which is dangerous and time consuming. Our user-friendly solution will increase safety, reduce downtime, and contribute to a more streamlined and sustainable freight industry.

1.2 List of team members

Matt Stokes- Project Manager, Codes and Standards

Grace Stonner- Design, Sketching, Quality Assurance

Adam Young- Design, Fabrication, Sourcing

Robert Murphy - Documentation, Analysis

2 Background Information Study

2.1 Design Brief

The product produced by this project is a remote decoupling device for railway freight cars. The device shall be self powered, decoupling the cars remotely using existing couplers. The device produced shall also allow the car to retain the use of the manual cut-bar, which in an emergency may be used to decouple the cars.

2.2 Background summary

Decoupling of freight cars involves a person manually raising the "cut bar", which then acts on the coupler allowing it to unlock and decouple the cars. The project seeks to create a remote electro-mechanical solution for coupling release. A relevant concept, Scharfenberg’s "CargoFlex" integrates mechanical coupling and airline functions (A.M Sontag). The Federal Railroad Association (FRA) funded Sharma and Associates' study in 2008, resulting in a functional model using a solenoid valve and on-board air for coupler lock release (US Department of Transportation, Monique Stewart).

Regulatory approval, given FRA's strict safety oversight ([3] Federal Railroad Association), presents a challenge. Design compliance requires adherence to CFR Title 49 subtitle B Chapter 2 part

231, 229, and specific coupling rules (ecfr.gov). The solution must withstand coupling forces, operate in diverse environments, and harmonize with existing railcar equipment, minimizing alterations and ensuring coupler pin security.

3 Concept Design and Specification

3.1 User Needs and Metrics

3.1.1 Record of the user needs interview

Paraphrased answers from a conversation with Dr. Luchini at Intramotev world headquarters, June 23, 2023.

1. What is the maximum range this device will need to function? Do we want to consider the infrastructure required for long range communication with the device?

   As this is a mechanical design project, focus on the mechanical components and treat the controller as a black box.

2. Do we want it to function only at designated points (i.e. humpyards)? Are there any other permissives the device might check automatically prior to uncoupling?

   As this is a mechanical design project, focus on the mechanical components and treat the controller as a black box.

3. Do we want to be able to retrofit any car, not just the electric ones?

   Yes. The more compatibility you can design in, the better.

4. Does the device need its own power source?

   Yes. Typical rail cars do not have available sources of power for your device.

5. Is the user physically present at or near the car during uncoupling?

   Ideally, no.

6. How would you like the device to communicate with the user?

   As this is a mechanical design project, focus on the mechanical components and treat the controller as a black box.

7. Would LEDs on the device be sufficient for 3 way communication? Is an audible alarm appropriate?

   As this is a mechanical design project, focus on the mechanical components and treat the controller as a black box.

8. For what time duration would you like the device to hold open the coupling?

Indefinitely.

9. How much force/torque to lift the coupling pin?

You're welcome to come back later and test that. (tested 7/7/23: 40 ft-lbs)

10. What acceleration is expected for likely mounting locations of a device?

50g

11. What mounting hardware is deemed acceptable? What mounting hardware has Intramotev used previously for similar tasks?

Ideally- no drilling or welding to the car. Welding was done in the past with mixed results.

12. For which type(s) of coupler is compatibility desired?

Whichever coupling you think works best- they can be changed out.

13. Can you provide us with models or drawings for compatible rolling stock?

We will try. (Hand drawings of a coupler later provided. Trinity provided an under-constrained 3d model of limited use).

14. Does the device need to do anything during coupling?

No.

15. Are there any areas, besides those restricted by railroad regulation, where we should not mount hardware (i.e. areas reserved for other Intramotev hardware)?

Treat this uncoupler as independent of Intramotev's other hardware. Follow FRA guidelines.

3.1.2 List of identified metrics

Table 1: Table of identified needs

Metric Number	Associated Need	Metric	Units	Minimum Number	Maximum Value
1	1,9,11	Length	inches	N/A	24
2	1,9,11	Width	inches	N/A	24
3	3	Power	Amperage	0	8
4	3	Power	Voltage	0	12
5	3,5	Force	lbs	40	330
6	5,6,8	waterproof	IPX rating	4	7

7	1,5,6,7,8	Shock	g	0	50
8	6,7,8,9	Material Strength	percentage	0	100

RCD: Remote Coupling Device

Table 2: List of Identified Metrics

Need Number	Need	Importance
1	RCD fits within allotted area	1
2	RCD is robust	1
3	RCD unlocks coupler	1
4	RCD operates within reasonable timeframe	2
5	RCD has power source	1
6	RCD is likely to meet regulations	1
7	RCD is attached rigidly	1
8	RCD is modular	1
9	RCD allows for manual use of cut-bar	1
10	RCD does not require modification of surrounding area	2

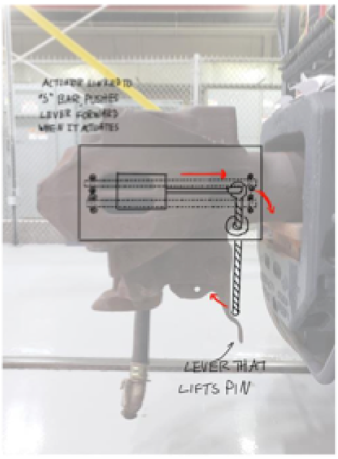
3.1.3 Table/list of quantified needs equations

Table 3: Quantified Needs Equations

Example Template		Metric															
		Number of locations	Distance (feet)	Number of power sources	% total	cubic feet	Yes/No	Metric 7	Metric 8	Metric 9	Metric 10	Metric 11	Metric 12	Metric 13	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13			
1	Compatible with any coupler system	0.2			0.8										0.74	0.1	0.074
2	Wireless capability		50												2.5	0.1	0.25
3	Device has power source			1											0.5	0.1	0.05
4	Device visually indicates activity	0.5			0.5										0.65	0.05	0.0325
5	Retains manual cutbar operation						1								0.75	0.1	0.075
6	Maintains system reliability				1										0.8	0.1	0.08
7	Mounting location	1													0.5	0.05	0.025
8	Device is robust				1										0.8	0.1	0.08
9	Must not prevent coupling						1								0.75	0.1	0.075
10	Must not decouple incorrectly						1								0.75	0.1	0.075
11	Device fits within operating area	0.5					0.5								0.625	0.1	0.0625
12															0	0	0
13															0	0	0
Units		Integer	Feet	Integer	%	Integer	Binary	Unit 7	Unit 8	Unit 9	Unit 10	Unit 11	Unit 12	Unit 13	Total Happiness		0.879
Best Value		4	1000	2	1	1	1										
Worst Value		0	0	0	0	3	0										
Actual Value		2	50	1	0.8	2	0.75										
Normalized Metric Happiness		0.5	0.05	0.5	0.8	0.5	0.75										

3.2 CONCEPT DRAWINGS

Figure 1: Concept Design 1



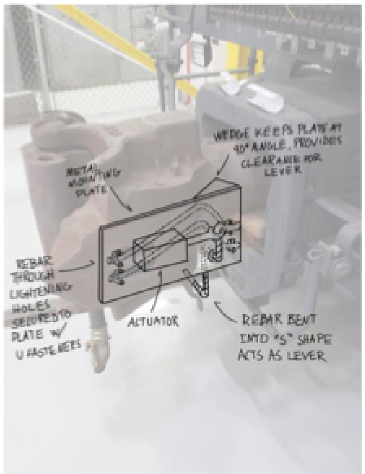


Figure 2: Concept Design 2

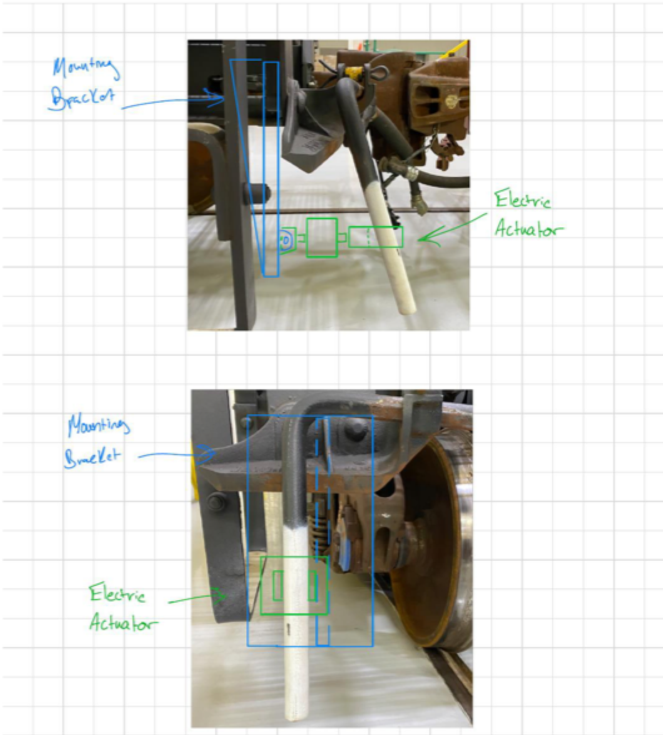


Figure 3: Concept Design 3

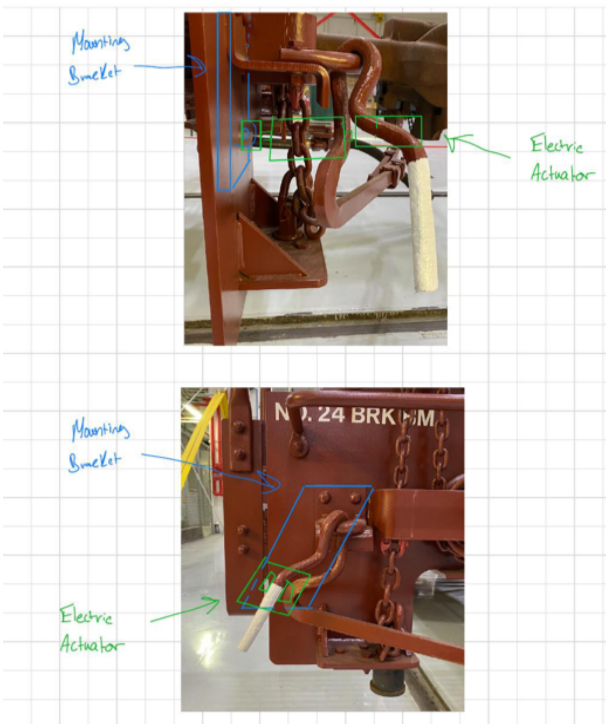
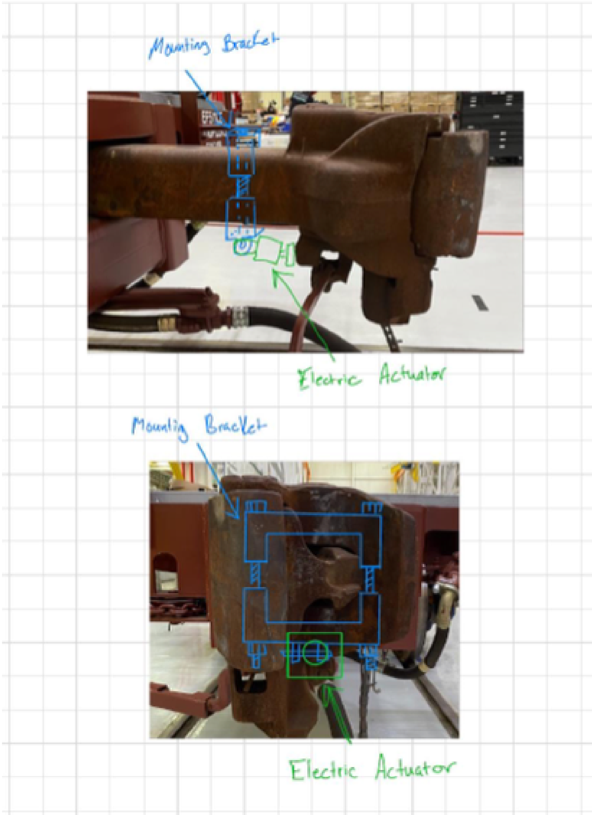


Figure 4: Concept Design 4



3.3 A CONCEPT SELECTION PROCESS.

3.3.1 Concept scoring (not screening)

Below are the user needs metrics spreadsheets used for each of the designs and their overall happiness scores.

Design 1- lightening hole mounting on coupler neck, actuator moves rotational lever through mounting plate. This ended up being our final design produced.

Design 2- A front ladder mounted electric winch that uses the existing cut-bar to unlock the coupler.

Design 3- Mounting an actuator to the existing plate under and behind (inboard) the coupler. We made this design as well, it worked but met less user requirements than Design 1.

Design 4- Two “C” shaped plates to be installed around the coupler neck to be used as a base for an actuator.

Table 4: Design 1

		Metric															
Design 1		Number of locations	Distance (feet)	Number of power sources	% total	cubic feet	Yes/No	Metric 7	Metric 8	Metric 9	Metric 10	Metric 11	Metric 12	Metric 13	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13			
1	Compatible with any coupler system	0.2			0.8										0.74	0.1	0.074
2	Wireless capability		50												2.5	0.1	0.25
3	Device has power source			1											0.5	0.1	0.05
4	Device visually indicates activity	0.5			0.5										0.65	0.05	0.0325
5	Retains manual cutbar operation						1								0.75	0.1	0.075
6	Maintains system reliability				1										0.8	0.1	0.08
7	Mounting location	1													0.5	0.05	0.025
8	Device is robust				1										0.8	0.1	0.08
9	Must not prevent coupling						1								0.75	0.1	0.075
10	Must not decouple incorrectly						1								0.75	0.1	0.075
11	Device fits within operating area	0.5					0.5								0.625	0.1	0.0625
12															0	0	0
13															0	0	0
Units		Integer	Feet	Integer	%	Integer	Binary	Unit 7	Unit 8	Unit 9	Unit 10	Unit 11	Unit 12	Unit 13	Total Happiness		0.879
Best Value		4	1000	2	1	1	1										
Worst Value		0	0	0	0	3	0										
Actual Value		2	50	1	0.8	2	0.75										
Normalized Metric Happiness		0.5	0.05	0.5	0.8	0.5	0.75										

Table 5 : Design 2

		Metric															
Design 2		Number of locations	Distance (feet)	Number of power sources	% total	cubic feet	Yes/No	Metric 7	Metric 8	Metric 9	Metric 10	Metric 11	Metric 12	Metric 13	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13			
1	Compatible with any coupler system	0.2			0.2										0.26	0.1	0.026
2	Wireless capability		50												2.5	0.1	0.25
3	Device has power source			1											0.5	0.1	0.05
4	Device visually indicates activity	0.5			0.5										0.65	0.05	0.0325
5	Retains manual cutbar operation						0								0	0.1	0
6	Maintains system reliability				1										0.8	0.1	0.08
7	Mounting location	1			0.1										0.58	0.05	0.029
8	Device is robust				1										0.8	0.1	0.08
9	Must not prevent coupling						0.5								0.375	0.1	0.0375
10	Must not decouple incorrectly						1								0.75	0.1	0.075
11	Device fits within operating area	0.5					0								0.25	0.1	0.025
12															0	0	0
13															0	0	0
Units		Integer	Feet	Integer	%	Integer	Binary	Unit 7	Unit 8	Unit 9	Unit 10	Unit 11	Unit 12	Unit 13	Total Happiness		0.685
Best Value		4	1000	2	1	1	1										
Worst Value		0	0	0	0	3	0										
Actual Value		2	50	1	0.8	2	0.75										
Normalized Metric Happiness		0.5	0.05	0.5	0.8	0.5	0.75										

Table 6: Design 3

Design 3		Metric															
		Number of locations	Distance (feet)	Number of power sources	% total	cubic feet	Yes/No	Metric 7	Metric 8	Metric 9	Metric 10	Metric 11	Metric 12	Metric 13	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13			
1	Compatible with any coupler system	0.2			0.2										0.26	0.1	0.026
2	Wireless capability		50												2.5	0.1	0.25
3	Device has power source			1											0.5	0.1	0.05
4	Device visually indicates activity	0.5			0.5										0.65	0.05	0.0325
5	Retains manual cutbar operation						1								0.75	0.1	0.075
6	Maintains system reliability				1										0.8	0.1	0.08
7	Mounting location	1			1										1.3	0.05	0.065
8	Device is robust				1										0.8	0.1	0.08
9	Must not prevent coupling						0.5								0.375	0.1	0.0375
10	Must not decouple incorrectly						1								0.75	0.1	0.075
11	Device fits within operating area	0.5					0								0.25	0.1	0.025
12															0	0	0
13															0	0	0
Units		Integer	Feet	Integer	%	Integer	Binary	Unit 7	Unit 8	Unit 9	Unit 10	Unit 11	Unit 12	Unit 13	Total Happiness		0.796
Best Value		4	1000	2	1	1	1										
Worst Value		0	0	0	0	3	0										
Actual Value		2	50	1	0.8	2	0.75										
Normalized Metric Happiness		0.5	0.05	0.5	0.8	0.5	0.75										

Table 7: Design 4

Design 4		Metric															
		Number of locations	Distance (feet)	Number of power sources	% total	cubic feet	Yes/No	Metric 7	Metric 8	Metric 9	Metric 10	Metric 11	Metric 12	Metric 13	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13			
1	Compatible with any coupler system				0.1										0.08	0.1	0.008
2	Wireless capability		50												2.5	0.1	0.25
3	Device has power source			1											0.5	0.1	0.05
4	Device visually indicates activity	0.5			0.5										0.65	0.05	0.0325
5	Retains manual cutbar operation						0								0	0.1	0
6	Maintains system reliability				0.5										0.4	0.1	0.04
7	Mounting location	1			1										1.3	0.05	0.065
8	Device is robust				0.75										0.6	0.1	0.06
9	Must not prevent coupling						0.5								0.375	0.1	0.0375
10	Must not decouple incorrectly						1								0.75	0.1	0.075
11	Device fits within operating area	0.5					0								0.25	0.1	0.025
12															0	0	0
13															0	0	0
Units		Integer	Feet	Integer	%	Integer	Binary	Unit 7	Unit 8	Unit 9	Unit 10	Unit 11	Unit 12	Unit 13	Total Happiness		0.643
Best Value		4	1000	2	1	1	1										
Worst Value		0	0	0	0	3	0										
Actual Value		2	50	1	0.8	2	0.75										
Normalized Metric Happiness		0.5	0.05	0.5	0.8	0.5	0.75										

3.3.2 Preliminary analysis of each concept's physical feasibility

Design 1- lightening hole mounting on coupler neck, actuator moves rotational lever through mounting plate

This design uses the shortest actuator arm throw, and all components would be able to be mounted in close proximity to each other. Less force to actuate the coupler lever may be required in this design than the others being considered due to the additional lever involved.

Design 2- A front ladder mounted electric winch that uses the existing cut-bar to unlock the coupler.

A winch fitting the specs needed to lift the cut-bar could be easily sourced for a low cost. Mounting solutions are less than ideal, tensioned wires add complexity, reduce safety. The ladder exists for a reason, mounting a winch on it would cause issues.

Design 3- Mounting an actuator to the existing plate under and behind (inboard) the coupler.

This design uses a longer movement of the actuator, but is the simplest overall design. The path of travel of the arm may be the easiest to control. Rigid mounting options available, within plate clearance.

Design 4- Two "C" shaped plates to be installed around the coupler neck to be used as a base for an actuator.

We are unsure of rigidity of the "C" shaped mounting plates, or how the two plates themselves would be joined in such a way that would allow for mounting of an actuator and battery on the inboard side.

3.3.3 Final summary statement

Our team decided to parallel path two designs on the initial phase of this project. Designs 1 and 3 will have prototypes produced simultaneously, while designs 2 and 4 will not be built initially. Design 1 was chosen as the best design overall, the combination of a short actuator arm movement requirement and the fact that this design is using a lever to trade force for distance through a mounting plate is an efficient seeming solution. No special materials required to build this design upon initial inspection, but mounting may be difficult and cause a need for alternate mounting solutions to be found. Design 3 was chosen as the simplest design, and the most likely to work with the least amount of time. Design 3 requires that the actuator move through a longer distance but has an easier mounting location with more options for rigidity depending on how invasive of a mounting solution is decided upon.

For designs 2 and 4, both met less user needs requirements. In Design 2, a winch is mounted on the front plane of the car, on the bottom of the ladder. We guessed this design may work to rotate the cut-bar if the bar was initially oriented suitably for rotating by being pulled up vertically. The mounting location is suboptimal and would need to further be strengthened and enlarged to support the device. Between these two negatives, Design 2 was removed from the selection process. Design 4 was cut from the selection process after Dr. Luchini informed us that this idea would not work during our brainstorming session with him. He informed us that the space where the mounting plate would be located will also be occupied by the proximal end of the coupler as the neck of the coupler recedes into the receiver when the train cars are coupled. There is a shock absorbing system behind the front and rear couplers (inboard) that absorbs horizontal movement the coupler receives when coupling which was not accounted for in that design.

3.4 Proposed performance measures for the design

The Automated Railway Decoupler, Optimized (ARDO) must decouple by unlocking the coupler, without preventing the coupler from subsequent recoupling after performing the function. This device must be robust enough to withstand the environment in which it will be operating. The device must retain the full use of the manual cut-bar. The likelihood of regulatory approval must be maximized in each instance possible, including compatibility of the device across all freight coupler types currently in use, materials used being similar to those already approved for use (in the final product).

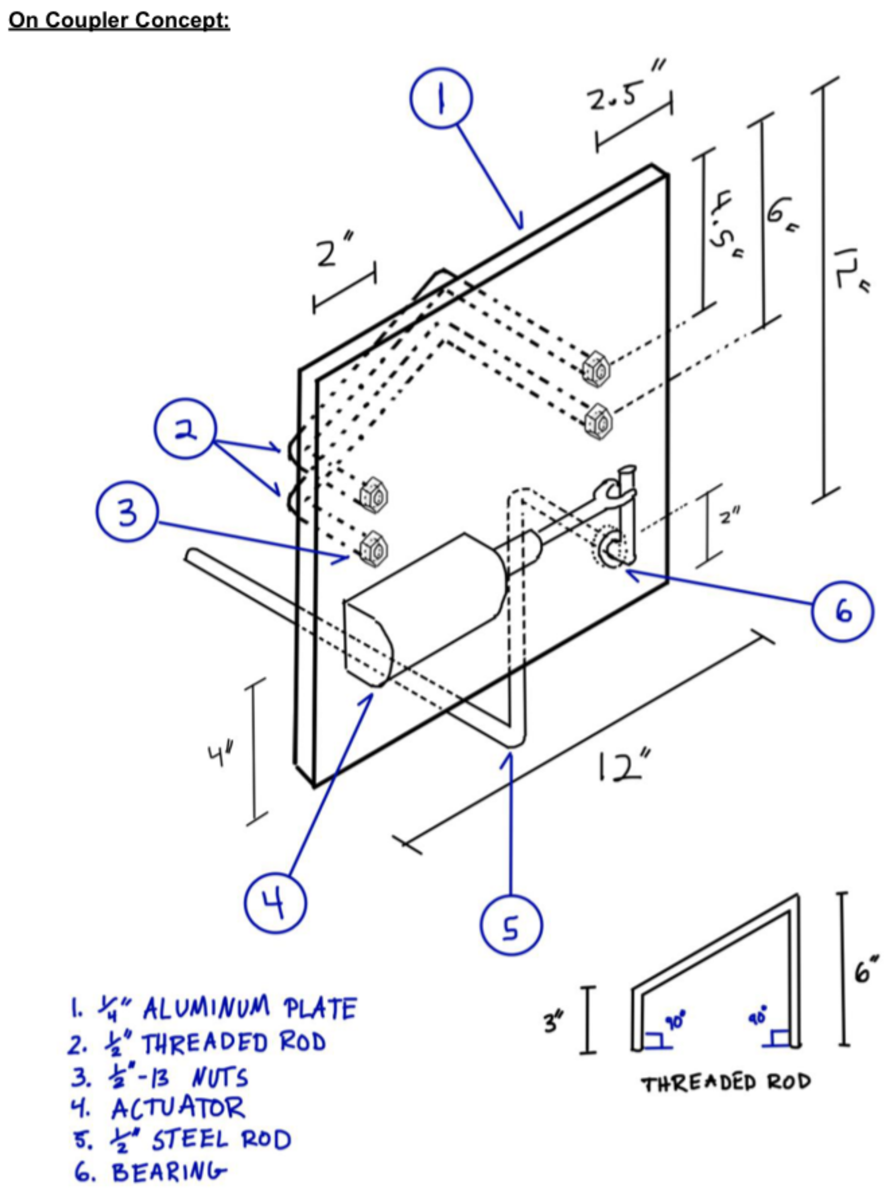
3.5 Revision of specifications after concept selection

Concepts 1 and 3 were selected for the initial build. It was decided that regulatory approval was the largest hurdle for this device to be successful as a commercial product. We thought both designs selected would have a very good chance of decoupling, and that FRA, AAR, USDOT and other related regulations would be critical to meet if the device were to be implemented. Specifications for this project that were updated to increased priority are the retention of the manual cut-bar, and resistance to environmental factors because of the heavy regulation involved in such devices.

4 Embodiment and fabrication plan

4.1 Embodiment/Assembly drawing

Figure 5: Embodiment Drawing



4.2 Parts List

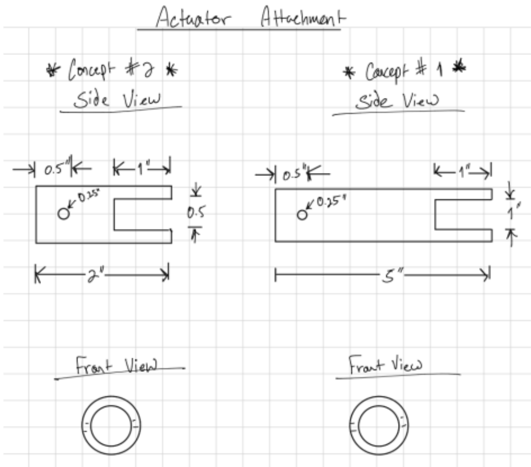
See Table 8: Parts List

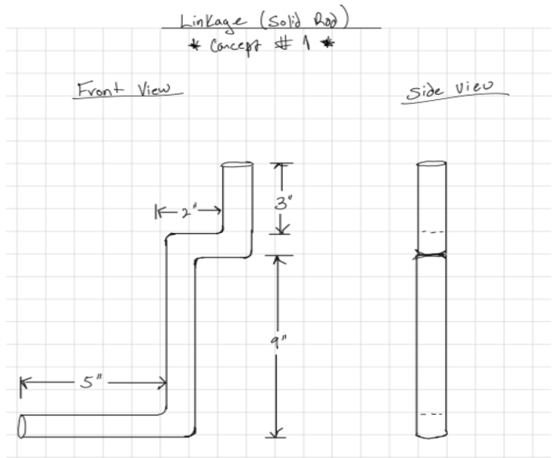
4.3 Draft detail drawings for each manufactured part

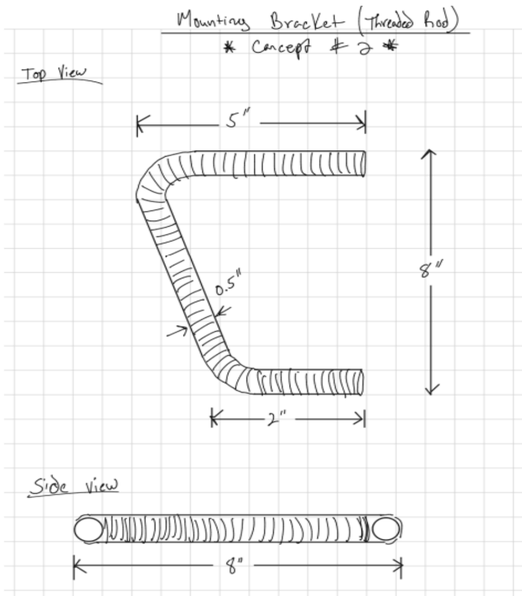
Figure 6: Actuator Attachment

Figure 7: Linkage

Figure 8: Mounting Bracket (Threaded Rod)







4.4 Description of the design rationale

Description of the design rationale for the choice/size/shape of each part

● Aluminum Mounting Plate - Most things on a railcar are either steel or cast iron but we chose an aluminum plate because it would be easiest to modify when we needed to. We understand that if this would go into production, this would be replaced with steel for durability.

● Actuator - We have two concepts which require different size actuators. Concept one requires a longer push rod, and concept two will only work with a short push rod. Both were chosen by the mounting area and actuation needs.

● ½ inch Steel Linkage and Mounting Bracket - We chose this size and material because it was easy to bend but strong enough to withstand the forces of the actuation arms. Ideally this would be thicker and stronger if this concept would go in production.

● C-clamps and other mounting hardware - The mounting challenge is that we can't drill holes in any parts that are on the railcar. So, we used C-clamps and mounting plates to get around this issue. We chose hardware sizes that would stand up to potential loads on the assembly.

● Actuator attachment - We chose aluminum tubing to make this out of because we didn't feel we had time to machine anything and it was easy to work with. The sizing was chosen by our actuator and linkage shaft size. Ideally this would be a machined part made from steel to withstand years of use.

5 Engineering analysis

5.1 Engineering analysis proposal

5.1.1 Signed engineering analysis contract

Figure 9: Engineering Analysis Contract

MEMS 411 / JME 4110
MECHANICAL ENGINEERING DESIGN PROJECT

ASSIGNMENT 5: Engineering analysis task agreement

ANALYSIS TASKS AGREEMENT

PROJECT: Coupler NAMES: Grace Stoner INSTRUCTOR: Prof Jakiela
Adam Young Prof Geismann
Matt Stokes
Robert Murphy

The following engineering analysis tasks will be performed:

Precise measurement of mounting locations.
Bolt shear calculations
Bolt tensile calculations
Force needed: at cut-bar operation point
at cut-bar / actuator interface point
to lift lock bar
Actuator power source and amount of power needed

The work will be divided among the group members in the following way:

Form given to prof Jakiela 7/24/23 in class, emailed to both professors as well.

Instructor signature: ___________________; Print instructor name: Jakiela, Geismann

(Group members should initial near their name above.)

5.2 Engineering analysis results

Table 9: Engineering Analysis Pre Build

Analysis Tasks Before Building the Prototype:

Analysis Task	Description	Results/Measurements

Measurement of coupler area	Measure dimensions of the coupler and surrounding area	See Figure 23, in Annotated Bibliography measurements verified manually
Measurement of arc length for design #1	Design 1, the side mounted design needs an arc length measurement in order to produce the correct lever arm length	4-6" depending on where the cut-bar is picked up by the actuator
Measurement of arc length for design #3	Design 3, the under coupler design needs an arc length measurement to determine the size of the actuator arm.	Approx. 9'', though the arc this design moves through is more curved due to the actuator arm moving through the distance, rather than a lever arm as in design #1
Design #1 Through rod shear strength calculation	Calculation of the shear stress on the ½" threaded rod through the mounting plate of design #1	Shear Stress (τ) = Force (F) / Area (A) Force (F) = Shear Stress (τ) * Area (A) F=(55 ksi) * (0.1419 in^2) F= 7804.5 lbs
Actuator mounting bolts (shear)	Calculation of shear strength for the bolts through the plate	Force (F) = Shear Stress (τ) * Area (A) F=(55 ksi) * (0.1419 in^2) >F= 7804.5 lbs NOTE: ¼" bolts and ½" threaded rods have same 55 ksi shear rating
Actuator mounting bolts (tensile)	Calculation of torque load for the bolts through the plate.	Clamping Force (F) = Torque (T) / (Coefficient of Friction (μ) * Radius (r)) 723 lbs= T/ (.30)*(.125) >T= 27.14 lb-in
Environmental Analysis	Range of temperatures and possible conditions seen by coupler area	Estimated annual temperature range: (140 F) - (-40 F)
Environmental Analysis	Weather resistance rating	Electronics and batteries need at least: IPX-6 (Protection from high pressure water) because of the high speeds involved in trains of up to 80 MPH.
Vibration/Shock Loads	Quantification of vibration	Known 50g shock load during coupling operations
Regulatory compliance	Assessment of compliance with applicable regulations	See *Codes and Standards*, p25
Torque Needed for "rotational" coupler type	Using a torque wrench to determine force needed to rotate "rotary" coupler	Approx. 40 lbs, difficult to measure
Force needed to lift cut-bar	Force measured at operation point	Cut bar force: 20lbs at contact point Cut bar force: 45 lbs at peak of arc

		*estimated, difficult to measure while in motion
Friction/Force reduction	Locate areas of high friction	Interface between actuator arm bracket and lever rod, plate bushing, cut-bar capture bracket. To be lubricated for increased performance.

Table 10: Engineering Analysis After Beginning Build

Analysis Task	Description	Results/Measurements
Actuator arm speed	Verify manufacturer specs	10mm/sec listed, verified without loading (10 mm is approx .40 in)
Actuator noise	Measure the sound produced by device while under load	NIOSH iPhone app is difficult to use given constant transformer background noise at location. <50 Db listed in specs, unable to verify
Calculate AWG diameter	AWG to inches diameter	.005*92^(36-AWG)/39= dia .005*92(36-18)/39= 0.0403 in
Correct sizing of power wires	Initial wires too small diameter, began heating and produced smoke after 1 actuation	AWG = (K * (V / I))^(1/2) Where: K = Constant for copper wire (approximately 21.2 for copper wire at room temperature) V = Maximum allowable voltage drop I = Maximum current (5 A) AWG = (21.2 * (0.03 / 5))^(1/2) AWG = (0.636 / 5)^(1/2) AWG = (0.1272)^(1/2) AWG ≈ 0.357
Actuator Force Produced	The force produced by the actuator used	330 lbs force generation through arm length per listed specs
Actuator stroke length selection	Based on measurements taken of arc length and mounting location, down select from actuator list	See Figure 24 in Annotated Bibliography
Friction/Force reduction	Reduce load on actuator	Bracket/lever arm interface lubricated with on hand lubrication, reshaped to reduce friction. Bushing lubricated. Actuator noise reduced with updates.

5.3

5.3.1 Motivation

In this section, we restate the engineering analysis tasks selected for our Remote Decoupling Device project and emphasize their significance in guiding our design process. These analyses are crucial for ensuring the successful development of our remotely actuated railway coupling system. Analysis tasks before building the prototype include measuring the coupler area and determining arc lengths for two design variations. Actuators, linear motion devices, and on-board power systems were researched. Additionally, shear strength calculations for critical components verified the structural integrity of selected materials for at least prototype demonstration. Environmental analysis assessed the prototype's ability to withstand varying temperatures and weather conditions that it may encounter.

Fatigue analysis, both before and after building part of the prototype, helped assess the long-term durability of our system as well as can be managed in the short time period. No long-term testing was completed in the time frame allowed for the project, though some analysis was done. Through these engineering analyses, we aim to gain comprehensive insights into various design aspects, make informed decisions, and develop a robust and reliable device that decouples two coupled freight cars through a powered cycle unlocking the coupler using the on board cut-bar and then returns to a position such that subsequent coupling may take place without further action.

5.3.2 Summary statement of analysis done

This section presents a summary of the engineering analyses performed for our Remote Decoupling Device project. We have successfully completed measurements of the coupler area and arc lengths for both design variations, providing accurate dimensional data necessary for the prototype's proper fitment. Shear strength calculations for the through rod and actuator mounting bolts verified the structural integrity of selected materials. Our environmental analysis evaluated the prototype's capability to withstand temperatures and weather conditions, ensuring its reliability during operations. We conducted a preliminary safety analysis to identify potential hazards and enhance safety, mainly looking at potential clearance and stoppage issues. The limited fatigue analysis performed, both pre and post building, involved some cycle testing and optimizing the load on the actuator through positioning of various components. Further work is needed to ensure long-term reliability of this design. Although this portion will be critical to the regulatory approval for this project, minimal if any long term testing will be performed during the time allotment. These analyses will significantly contribute to improving the design's reliability and durability.

5.3.3 Methodology

The engineering analyses were conducted using a methodology that combined some experimental testing with numerical calculations based on product and material specs. The group cohesively worked on different aspects of the project concurrently, allowing for rapid progress. Experimental testing was conducted using initial prototypes, which were modified into the current prototypes. Much of the testing was adjustment of the actuator mounting location, the actuator arm bracket (distal end) shape and style, and modification of the controller to accept a breadboard such that an over-travel switch may be added. Hands-on testing was performed at the time of installation of the lever arm, evaluating clearances and modifying the design as needed to produce the force required to unlock the coupler while maintaining a short actuator cycle length.

5.3.4 Results

The engineering analysis study yielded significant findings. Measurement data for the coupler area and arc lengths provided precise dimensional data for our prototype, directly informing the first versions of both prototypes. Shear strength calculations confirmed the structural integrity of selected materials. Environmental analysis data ensured the prototype's estimated reliability under current conditions with current hardware selections, noting that prototype hardware was purchased for low cost, availability, and ease of use. Fatigue analysis results will guide us in selecting suitable materials for long-term use and enhancing the prototype's theoretical durability.

5.3.5 Significance

The engineering analysis results hold immense significance in shaping the final design of our Remote Decoupling Device. The dimensional data obtained directly impacted the product selection, the overall layout and compatibility of components, and influenced all subsequent work on this project. Shear strength calculations confirm the structural integrity of selected materials, noting that the materials selected are more than strong enough for the loads applied at this time up to coupling shock loads of 50g, which were not tested due to time constraints. Environmental analysis ensures the prototype's reliability during freight operations. Overall, the engineering analysis outcomes optimized the final prototype, streamlining its dimensions and performance characteristics, leading to a successful implementation of the Remote Decoupling Device.

6 Risk Assessment

6.1 Risk Identification

Below are the risks identified by the group:

1. Components delivered late
2. Issues with construction or configuration of design
3. Scheduling
4. Safety
5. Lack of resource/tool
6. Over budget

6.2 Risk Analysis

1. Risk: Components delivered late

Performance Specification: Late component delivery could impede prototype construction, affecting technical performance.

Cost: Indirect costs could rise due to delays in the project timeline such as purchases of components at full retail locally.

Schedule: Late components may extend fabrication, impacting the overall schedule.

Causes: Causes might include material constraints, stock unavailability, or shipping delays. We chose specific sources such as Amazon to reduce factors that may cause delays.

Potential Effects: Delays in prototype construction could affect subsequent phases.

2. Risk: Issues with construction or configuration of design

Performance Specification: Design issues may necessitate a prototype redesign, impacting technical performance.

Cost: Rework and additional parts would escalate costs.

Schedule: Addressing design issues may extend construction and overall schedule.

Causes: Causes could be incorrect parts, inadequate build quality, or assembly challenges.

Potential Effects: Redesign and rework could lead to delays and increase cost.

3. Risk: Scheduling

Performance Specification: Disrupted schedules could delay planned build or testing and impact technical performance.

Cost: Delays might indirectly increase costs.

Schedule: Scheduling conflicts with team members or build location could lead to delays and timeline extensions.

Causes: Causes include team member schedules, the build car being used or moved for other purposes, site limitations, or site scheduling conflicts.

Potential Effects: Delayed testing and potential project setbacks.

4. Risk: Safety

Performance Specification: Inadequate safety precautions might lead to team injuries.

Cost: Medical costs and project disruptions could escalate costs.

Schedule: Team injuries could lead to schedule setbacks.

Causes: Causes involve failure to follow safety protocols.

Potential Effects: Reduced workforce, project interruptions, and potential delays.

5.Risk: Lack of resource/tool

Performance Specification: Unavailable resources/tools could compromise technical performance, particularly in fabrication.

Cost: Redesign to tools available or tool procurement will raise costs.

Schedule: Waiting for tools or redesign could prolong the project timeline.

Causes: Causes include tool oversight or inadequate planning.

Potential Effects: Delays, increased costs, and possible prototype compromises.

6.Risk: Over budget

Performance Specification: Budget constraints might limit desired components, affecting technical performance.

Cost: Exceeding the budget could result in higher costs than initially allocated.

Schedule: Budgetary limits could cause procurement delays or necessitate redesign delaying the project.

Causes: Inaccurate cost estimation or unexpected expenses.

Potential Effects: Procurement delays, potential component substitutions, and project setbacks.

6.3 Risk Prioritization

Our project team utilized a systematic approach to prioritize risks for our Automatic Railcar Decoupler project. We established a comprehensive Risk Management Register Spreadsheet that categorized risks based on their potential impact and associated response strategies. The process involved the following key steps:

1. Risk Identification: We began by brainstorming and identifying potential risks across different aspects of the project, including fabrication, scheduling, safety, and planning/budgeting.These risks were documented in the register with detailed descriptions.

2. Risk Categorization: Risks were categorized based on their potential impact on technical performance, schedule, cost, and safety. This allowed us to gain a holistic view of the potential consequences each risk could have on the project.

3. Impact and Probability Assessment: Each risk was assessed for its potential impact and probability of occurrence. Impact assessment considered factors such as project delay, additional costs, and safety concerns, while probability assessment evaluated the likelihood of the risk materializing.

4. Risk Scoring and Ranking: Risks were scored based on their impact and probability assessments, resulting in a risk ranking that quantified their relative importance. This ranking helped us focus on the risks with the highest potential impact.

5. Response Strategy Development: For each identified risk, a clear and actionable response strategy was formulated. These strategies outlined specific steps to mitigate, avoid, or manage the risk. Response strategies were tailored to address the unique characteristics of each risk.

6. Triggers and Indicators: Triggers or indicators that could signify the potential occurrence of a risk were established. These indicators helped us recognize when a risk was about to materialize, allowing us to implement the appropriate response strategy in a timely manner.

7. Exposure Assessment: The potential exposure of each risk was estimated, taking into account both the maximum and estimated exposure. This helped us allocate contingency funds effectively and plan for potential impacts.

8. Action Ownership: Each risk was assigned to a specific team member who would take ownership of monitoring and implementing the corresponding response strategy. This ensured accountability and timely action.

9. Regular Review and Update: The Risk Management Register was continuously reviewed and updated as the project progressed. Closed risks were documented, and new risks were added as they emerged.

10. Overall Project Risk Indicator: An overall risk indicator was calculated to provide a quick snapshot of the project's current risk level. This indicator helped us gauge the project's overall risk posture and make informed decisions.

By following this systematic approach, we were able to effectively identify, assess, and prioritize risks. This allowed us to proactively manage and mitigate potential challenges throughout the build of the Automated Railway Decoupling, Optimized (ARDO). We were to exceed expectations both in terms of budgetary concerns and our timeline.

Table 11: Risk Management Register

Risk Management Register

0	Open Red Risks
0	Open Yellow Risks
0	Open Green Risks
0	Risks w/ no Response Strategy
2	Closed risks

Project Name: Automatic Railcar De-coupler
Project Manager: Adam Young
Start Date: 6/12/2023

Location: Intramotev
Add'l Info:
Updated On: 7/28/2023
Overall Project Risk Indicator: 14

Risk Level (Probability × Impact):

Probability					
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5
Impact	1	2	3	4	5

Legend:
Impact: 1 - Negligible, 2 - Marginal, 3 - Significant, 4 - Critical, 5 - Catastrophic
Probability: 1 - Rare, 2 - Unlikely, 3 - Possible, 4 - Likely, 5 - Certain

Item	Project/ Phase	Risk Status	Risk	Potential Impact (Cause and Effect)	Risk Response Strategy	Triggers (Indicators that the risk will occur)
0	Fabrication	Closed	Components delivered late	Prototype construction delayed	Order early, have an alternate source for each part.	Intended vendors out of stock, notice of shipping delay
1	Fabrication	Accepted	Issues with construction or configuration of design	May require redesign of prototype, additional parts	Start prototype construction early in order to give ourselves time to determine and deal with any issues our initial design may have.	Mis-sized parts, parts interfere with operation of the mechanism or eachother, parts are not sturdy enough and fail, assembly is difficult or impossible
2	All	Accepted	Scheduling	Unable to access necessary equipment or work on the railcar on location	Discuss with employees at Intramotev about the testing schedule for the railcars and when would be a good time to work on them. Schedule group meetings during off-work hours.	Railcar the coupler is mounted to is being actively tested
3	All	Accepted	Safety	Injury of a teammember could cause significant delays	Follow all necessary safety precautions and use protective gear while working in the shop and with power tools.	High power saws and drills will be required to fabricate the prototype out of aluminum, not using safety equipment/procedures increses chance of injury
4	Fabrication	Accepted	Lack of resource/tool	If a tool we need for fabrication is not available, we may need to ask for permission to obtain it or redesign the prototype so the tool isn't needed	Determine method of fabrication ahead of time, walk thorugh it and note each tool that will be required. Take inentory of which tools are available.	A tool is not available during fabricaiton/fabrication requires a specialized tool
6	Planning/Budgeting	Closed	Over budget	Have to request additional budget, redesign prototype to use cheaper parts	Have a well planned budget to present before buying parts, include incidental funding in budget to use in case additional purchases are required.	Incorrect components or improperly sized components are ordered, components break during construction or testing

Item	Estimated Schedule Impact (Days)	Maximum Exposure ($000)	Estimated Exposure (Contingency) ($000) $39	Risk Category	Risk Sub Category	Action Owner	Start Exposure	End Exposure
0	5	$100	$0	Schedule	Material Constraints	Adam Y.	07/27/23	08/07/23
1	7	$100	$33	Construction	Layout and Constructability	Robert M.	07/27/23	08/07/23
2	3	$0	$0	Schedule	Weather, Site Conditions, Essential Services	Grace S	06/12/23	08/04/23
3	3	$0	$0	Schedule	Labor Availability	Matt S.	06/20/23	08/07/23
4	7	$50	$1	Schedule	Material Constraints	Robert M.	07/27/23	08/07/23
6	4	$200	$5	Financial/Regulatory	Cost, Budget, Forecast in Alignment	Adam Y.	07/12/23	08/07/23

Item	Baseline Risk Scoring						Current Risk Score					
	Impact						Impact					
	Tech Perf	Schedule	Cost	Safety	Probability	Risk Ranking	Tech Perf	Schedule	Cost	Safety	Probability	Risk Ranking
0	4	4	3	0	3	12	4	4	3	0	1	4
1	4	5	3	1	5	25	4	5	3	1	3	15
2	3	4	1	0	2	8	3	4	1	0	1	4
3	4	2	1	5	1	5	4	2	1	5	1	5
4	3	3	4	1	4	16	3	3	4	1	1	4
6	2	0	5	0	1	5	2	0	5	0	1	5

7 Codes and Standards

7.1 Identification

Most codes and standards relevant to our design are laid out by The Federal Railroad Administration, a sub-department of the Department of Transportation and AAR (Association of American Railroads). Access to these codes is pricey and outside of our limited budget. As our product is a prototype and many of Intramotev's customers operate on private lines, some or all of the regulations do not apply, or exceptions may be granted.

7.2 Justification

Hazard area classification is used to describe the hazards that a device poses when a combustible or explosive atmosphere is present. The freight rail industry is frequently exposed to combustible dusts such as grain and coal, as well as vapors and liquids such as propane and oil. NFPA 70 is a code which can be purchased from the National Fire Protection Agency, unfortunately not in the current budget. Guidance is available from the National Electric Code (NEC) which uses NFPA 70 to categorize hazard areas, so that a device can claim safety in one or more conditions [1]. Note that a device that is safe for one type of hazard may not be safe in another. The hazard area classifications relevant to typical freight rail are as follows [1]:

- Class I concerns combustible vapors (petroleum, solvents)
- Class II concerns combustible dusts (grain, coal, metals)
- Div 1 means the hazard is always present.
- Div 2 means the hazard is only present in abnormal operation.

The rating is a combination of class and div. For example, a device rated to be safe in environments where grain dust is always present would be rated for *class II, div 1* [1]. *Intrinsically Safe* means a device poses no ignition hazard in any environment.

7.3 Design Constraints

7.3.1 Functional

Association of American Railroads (AAR) is the standards organization for North American railroads . AAR Plate F regards the freight rolling stock that Intramotev works with. We were able to view relevant parts of this proprietary document to confirm that our design does not extend outside of the 2d envelope described. The envelope exists to guarantee rolling stock will have clearance at bridges, tunnels, and other rail-side objects. This envelope is enforced by rail-side sensors. Relevant dimensions include height and width of rolling stock, which our design cannot and does not exceed. Rolling stock which does not fit into the specified envelope will not be allowed on main lines, not a problem for our design.

7.3.2 Safety

The components used in our final product should be Intrinsically Safe, or Class I/II Div 1 rated so that the product poses no ignition hazard in hazardous environments typical of freight rail. This will restrict our possible suppliers OR restrict the applications for the product. We believe that if our prototype is successful that budget will be made available to purchase or custom-order safe hardware. If our device cannot be rated for safe operation in hazard areas frequented by freight rail it will not enjoy widespread adoption among freight companies which use their hardware in both hazard and non-hazard locations.

7.3.3 Manufacturing

Manufacturability is a key consideration throughout this design project. We planned our design to optimize manufacturability, aiming to streamline production processes and minimize complexities. By selecting readily available materials and components, we added feasibility and cost-effectiveness in the manufacturing phase. Additionally, our design's modular nature facilitates efficient assembly and minimizes production challenges. This manufacturing-centric approach underscores our dedication to creating a design that seamlessly translates into a practical and viable product, ready for large-scale production.

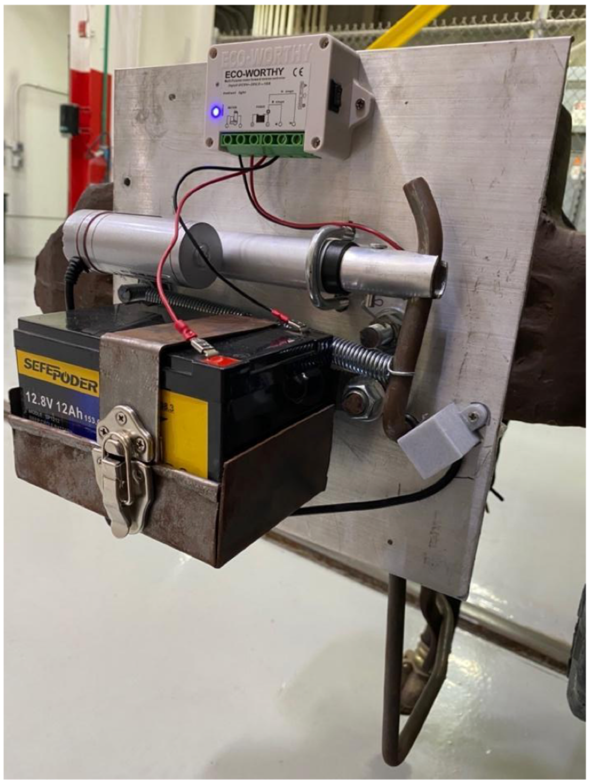
7.4 Significance

By adhering to industry standards and functional specifications both listed and anticipated, we have crafted a solution that not only addresses a critical operational need in the freight rail industry but also showcases our team's ingenuity and dedication to innovation. Our design's compliance with relevant codes and regulations, coupled with its commitment to safety, quality, and manufacturability, solidifies its potential to revolutionize railcar decoupling processes. The successful alignment of our prototype with stringent constraints and its embodiment of best practices sets the stage for widespread adoption and improved efficiency in rail operations.

8 Working prototype

8.1 prototype Photos

Figures 10 and 11: Prototype Photos



The main components of this assembly consists of a battery, actuator, micro controller with remote, mounting plate, and linkage. The sub-components of the assembly consist of battery box, linkage return spring, linkage bushing, limit switch, and mounting hardware. The aluminum mounting plate is mounted to the coupler through two lightening holes with custom made U-bolts, made from threaded rod. Some other custom-made components include the Sheet Metal battery box, steel rod for the linkage arm, actuator attachment, and 3D printed limit switch box.

8.2 Working Prototype Video

https://www.youtube.com/shorts/j3wRC5ivBdI

https://www.youtube.com/shorts/l2owUC2-YFs

https://www.youtube.com/shorts/WVlFShcKTeA

8.3 Prototype components

At least four additional digital photographs and their explanations

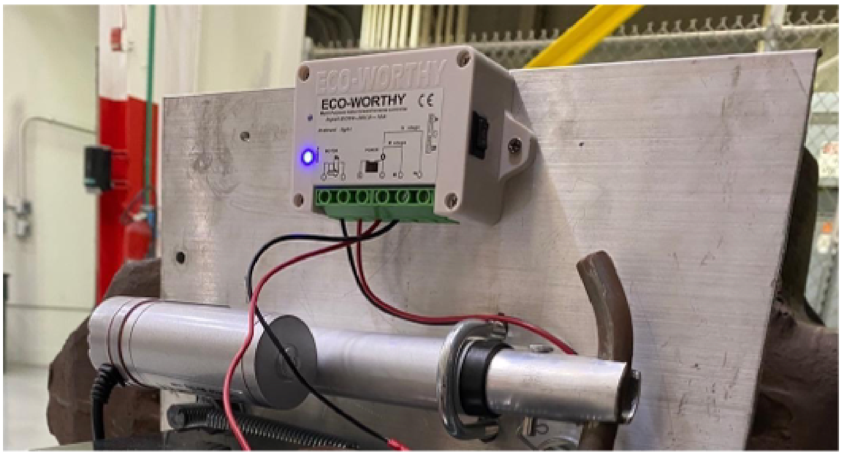
Figure 12: Overhead View of Prototype

Our initial hurdle involved determining the optimal method and location for attaching the mounting plate. The couplers weren't designed to have anything mounted due to their shape and function, but they do have two lightening holes. We were able to utilize the lightening holes with two custom U-bolts and attach an aluminum plate. To ensure precise linkage functionality, a carefully contoured piece of wood was employed to mirror the coupler's profile and align the mounting plate accurately.

Figure 13: Additive Manufacturing Component

The limit switch and 3d printed box was one of the last features we added to the design concept. Our micro controller came with a remote with a fully extend button that kept getting pressed accidently and would extend the actuator farther than it was designed to. To fix this, a limit switch and a diode was added to the power circuit of the system

Figure 14: Actuator and Microcontroller



We were fortunate to have access to both the actuator and microcontroller, which facilitated our project's needs. On Amazon we found Eco-Worthy makes several sizes to meet any electrical actuator needs for very little cost. We chose a 4 inch actuator (8 inches in total length), but we believe a 2 inch actuator would have worked better because of space constraints. We made modifications to the rear mounting bracket of the actuators in order to address the space constraints. Additionally, we planned to replace the actuator attachment with a roller bearing arrangement to effectively distribute the applied forces.

Figure 15: Battery Box

While the battery box wasn't an essential component, it added a valuable aspect to the setup. The battery box is attached to the mounting plate U-bolt, is made from 16 gauge sheet metal, and features a hinge and a latch. Like most items in the design, the battery box would have to be a lot more robust with the ability to withstand the force up to 50 G's from a car coupling. But, with limited tools and time constraints, this functions well enough to meet the current needs.

9 Design documentation

9.1 Final Drawings and Documentation

9.1.1 Engineering Drawings

See Appendix C for the individual CAD models.

9.1.2 Sourcing instructions

Table 12: Sourcing Instructions

Part #	Name	Amount	Description	Source	Estimated Cost
801177	Everbilt 1/2 in. x 72 in. Zinc Threaded Rod	2	Will be bent to create a bracket to attach the base plate to the coupler	Home Depot	$22.02
804716	Everbilt 1/2 in. x 72 in. Zinc Plated Hex Nut	8	Holds components on threaded rods	Home Depot	$2.08
802334	Everbilt 1/2 in. Zinc-Plated Flat Washer	1	Placed between components and nuts	Home Depot	$7.33
194354	4 in. x 4 in. x 8 ft. #2 Ground Contact Pressure-Treated Southern Yellow Pine Timber	1	Used to create a wedge that holds the base plate parallel to the coupler. You could probably use a smaller piece of scavenged wood instead of buying an entire beam.	Fabricated/Home Depot	$12.88
800606	Everbilt 1/4 in.-20 x 1-1/2 in. Zinc Plated Hex Bolt	1	Holds the actuator bracket onto ont base plate, may need to be cut to 1/2" length to avoid interfering with the coupler	Home Depot	$0.25
58365K85	Self-Adjusting Spring Bushings	1	Used in the through-hole for the throw rod to allow it	McMaster-Carr	$13.52
8975K135	Back Plate (12" x 12" x 0.5" Multipurpose 6061 Aluminum sheet)	1	Used as the mounting plate for other components	McMaster-Carr	$29.99
-	**Actuator Assembly:**				

Mtf220429xt1427	Actuator Collar (METALLIXITY 6063 Aluminum Tube (25mm OD x 20mm ID x 300mm L), Aluminum Round Tubing)	1	Cut down to make the actuator collar to interface with the throw rod	Fabricated/Amazon	$11.49
-	1/4" Clevis Pin/cotter pins	2	Hold bracket and collar to actuator	Provided with actuator	
-	Actuator Bracket	1	Cut down and drill additional hole for clevis pin in the bracket included with the actuator	Fabricated/Provided with actuator	
N222-125	National Hardware N222-125 2190 U Bolts in Zinc, #512-5/16"x1-3/8"x2-1/2"	1	Holds linear actuator in place	Amazon	$4.87
CA-L11ZFCDC-1	ECO-WORTHY Lin.Act. Motor Remote Controller	1	Control for linear actuator	Amazon	$32.99
-	**Battery Box:**				
-	12 35Ah Deep Cycle battery, Lead-Acid	1	Power for actuator and controller. We used a similar battery that was sitting around the shop, not this exact model. This is an example/suggestion.	Amazon	$113.99
29107	2-3/4 in. x 1-1/2 in. Satin Nickel Chest Door Latches	1	Latch for battery box	Home Depot	$3.47
56038	12 in. x 12 in. 16-Gauge Weldable Sheet	1	Cut into shape and folded to make the parts for the battery box	Fabricated/Home Depot	$16.93
29277	1 in. Zinc Plated Non-Removable Pin Narrow Utility Hinges	1	Hinge for battery box lid	Home Depot	$2.27
801617	1/2 in. x 48 in. Plain Steel Round Rod	1	Bent into shape to make throw rod	Home Depot	$14.47
16089	5/8 in. x 2-1/2 in. and 5/8 in. x 3-1/4 in. Zinc-Plated Extension Spring	2	Pulls throw rod back into place during retraction	Home Depot	$5.58

-	Limit Switch Box	1	Housing for limit switch that stops actuator at max throw bar distance. Custom modeled then 3D printed in PLA	Fabricated	$1.00
B07MW2RPJY	Limit Switch	1	Stops actuator at max throw bar distance. Had on hand, can be obtained through other suppliers. An example is provided	Amazon	$5.76
B07Q5H1SLY	Schottky Diode	1	Allows Actuator to return to recieve the retraction signal but stops forward motion when limit switch is flipped. Had on hand, can be obtained through other suppliers. An example is provided	Amazon	$5.99
90107A029	1/4" Stainless Steel Washer	1	Used as a spacer for bracket bolt. Had on hand, can be obtained through other suppliers. An example is provided	McMaster-Carr	$8.51
92146a621	1/4" Split Lock Washer	1	Used as a spacer for bracket bolt. Had on hand, can be obtained through other suppliers. An example is provided	McMaster-Carr	$6.22

7.2 Final Presentation

https://youtu.be/Qbuap3FIOwQ

8 Teardown

The device and remainder of materials will be left to Intramotev. It will be left installed on the car where it resides currently.

9 Appendix A - Parts List

Table 8: Initial Parts List

Under Car Concept

Item #	Supplier	Part #	Describtion	Quantity	Price	
1	Amazon	AM-TGF12V200-T-1	ECO-WORTHY Heavy Duty 330lbs Solar Tracker L	1	42.99	
2	Amazon	N222-125	National Hardware N222-125 2190 U Bolts in Zir	2	4.87	
3	Amazon	210520	6061 T651 Aluminum Sheet Metal 12 x 12 x 1/4	1	29.99	
4	Amazon	220912-FA	6061 Aluminum Sheet Metal 8 x 12 x 1/4 Inch, H	1	19.99	
5	Amazon	ZX07-20MM-T10	10 Pcs Malleable Iron Universal Beam Clamp Ma	1	18.99	
6	Amazon	a19111800ux1219	uxcell 6063 Aluminum Round Tube, 30mm OD 2	1	12.49	
7	Home Depot	800856	Everbilt 3/8 in.-16 x 2-1/2 in. Zinc Plated Hex Bol	10	5	
8	Home Depot	801756	Everbilt 3/8 in.-16 Zinc Plated Hex Nut	10	1.6	
9	Home Depot	812170	Everbilt 3/8 in. Stainless Steel Flat Washer (25-Pa	1	7.49	
10	Home Depot	800606	Everbilt 1/4 in.-20 x 1-1/2 in. Zinc Plated Hex Bol	1	0.25	
11	Home Depot	800131	Everbilt 1/4 in.-20 Stainless Steel Nylon Lock Nut	1	1.38	
12	Amazon	-	[12 35Ah Deep Cycle battery, Lead-Acid]()	1	113.99	
13	Amazon	-	[20W 12V solar car battery trickle charger]()	1	49.99	
					46.35	Est. Buffer
					355.37	Total

On Coupler Concept

1	Home Depot	801177	Everbilt 1/2 in. x 72 in. Zinc Threaded Rod	1	11.51	
2	Home Depot	804716	Everbilt 1/2 in. x 72 in. Zinc Plated Hex Nut	4	1.04	
3	Home Depot	802334	Everbilt 1/2 in. Zinc-Plated Flat Washer (25-Pack	1	7.33	
4	Home Depot	194354	4 in. x 4 in. x 8 ft. #2 Ground Contact Pressure-Tr	1	12.88	
5	Home Depot	800606	Everbilt 1/4 in.-20 x 1-1/2 in. Zinc Plated Hex Bol	1	0.25	
6	McMaster-Carr	58365K85	Self-Adjusting Spring Bushings	1	13.52	
7	McMaster-Carr	8975K135	12" x 12" x 0.5" Multipurpose 6061 Aluminum sl	1	29.99	
8	Amazon	Mtf220429xt1427	METALLIXITY 6063 Aluminum Tube (25mm OD x	1	11.49	
9	Amazon	AM-TGF12V100-T-1	ECO-WORTHY Heavy Duty 330lbs Solar Tracker L	1	41.99	
10	Amazon	N222-125	National Hardware N222-125 2190 U Bolts in Zir	2	9.74	
11	Amazon	N222-380	National Hardware N222-380 2192BC Square U	1	5.38	
12	Amazon		[ECO-WORTHY Lin.Act. Motor Remote Controller]()	1	32.99	
13	Amazon	-	[12 35Ah Deep Cycle battery, Lead-Acid]()	1	113.99	
14	Amazon	-	[20W 12V solar car battery trickle charger]()	1	49.99	
					51.31	Est. Buffer
					393.4	Total
					748.77	Total Cost For Both

10 Appendix B - Bill of Materials

Table 13: Bill of Materials

Part #	Name	Amount	Description	Source	Estimated Cost
801177	Everbilt 1/2 in. x 72 in. Zinc Threaded Rod	2	Will be bent to create a bracket to attach the base plate to the coupler	Home Depot	$22.02
804716	Everbilt 1/2 in. x 72 in. Zinc Plated Hex Nut	8	Holds components on threaded rods	Home Depot	$2.08
802334	Everbilt 1/2 in. Zinc-Plated	1	Placed between	Home	$7.33

	Flat Washer		components and nuts	Depot	
194354	4 in. x 4 in. x 8 ft. #2 Ground Contact Pressure-Treated Southern Yellow Pine Timber	1	Used to create a wedge that holds the base plate parallel to the coupler. You could probably use a smaller piece of scavenged wood instead of buying an entire beam.	Fabricated/Home Depot	$12.88
800606	Everbilt 1/4 in.-20 x 1-1/2 in. Zinc Plated Hex Bolt	1	Holds the actuator bracket onto ont base plate, may need to be cut to 1/2" length to avoid interfering with the coupler	Home Depot	$0.25
58365K85	Self-Adjusting Spring Bushings	1	Used in the through-hole for the throw rod to allow it	McMaster-Carr	$13.52
8975K135	Back Plate (12" x 12" x 0.5" Multipurpose 6061 Aluminum sheet)	1	Used as the mounting plate for other components	McMaster-Carr	$29.99
-	**Actuator Assembly:**				
Mtf220429xt1427	Actuator Collar (METALLIXITY 6063 Aluminum Tube (25mm OD x 20mm ID x 300mm L), Aluminum Round Tubing)	1	Cut down to make the actuator collar to interface with the throw rod	Fabricated/Amazon	$11.49
-	1/4" Clevis Pin/cotter pins	2	Hold bracket and collar to actuator	Provided with actuator	
-	Actuator Bracket	1	Cut down and drill additional hole for clevis pin in the bracket included with the actuator	Fabricated/Provided with actuator	
N222-125	National Hardware N222-125 2190 U Bolts in Zinc, #512-5/16"x1-3/8"x2-1/2"	1	Holds linear actuator in place	Amazon	$4.87
CA-L11ZFCDC-1	ECO-WORTHY Lin.Act. Motor Remote Controller	1	Control for linear actuator	Amazon	$32.99
-	**Battery Box:**				

-	12 35Ah Deep Cycle battery, Lead-Acid	1	Power for actuator and controller. We used a similar battery that was sitting around the shop, not this exact model. This is an example/suggestion.	Amazon	$113.99
29107	2-3/4 in. x 1-1/2 in. Satin Nickel Chest Door Latches	1	Latch for battery box	Home Depot	$3.47
56038	12 in. x 12 in. 16-Gauge Weldable Sheet	1	Cut into shape and folded to make the parts for the battery box	Fabricated/Home Depot	$16.93
29277	1 in. Zinc Plated Non-Removable Pin Narrow Utility Hinges	1	Hinge for battery box lid	Home Depot	$2.27
801617	1/2 in. x 48 in. Plain Steel Round Rod	1	Bent into shape to make throw rod	Home Depot	$14.47
16089	5/8 in. x 2-1/2 in. and 5/8 in. x 3-1/4 in. Zinc-Plated Extension Spring	2	Pulls throw rod back into place during retraction	Home Depot	$5.58
-	Limit Switch Box	1	Housing for limit switch that stops actuator at max throw bar distance. Custom modeled then 3D printed in PLA	Fabricated	$1.00
B07MW2RPJY	Limit Switch	1	Stops actuator at max throw bar distance. Had on hand, can be obtained through other suppliers. An example is provided	Amazon	$5.76
B07Q5H1SLY	Schottky Diode	1	Allows Actuator to return to recieve the retraction signal but stops forward motion when limit switch is flipped. Had on hand, can be obtained through other suppliers. An example is provided	Amazon	$5.99
90107A029	1/4" Stainless Steel Washer	1	Used as a spacer for bracket bolt. Had on hand, can be obtained through other suppliers. An	McMaster-Carr	$8.51

			example is provided		
92146a621	1/4" Split Lock Washer	1	Used as a spacer for bracket bolt. Had on hand, can be obtained through other suppliers. An example is provided	McMaster-Carr	$6.22

11 Appendix C – Complete List of Engineering Drawings

Figure 16: Automatic Decoupler Throw Bar

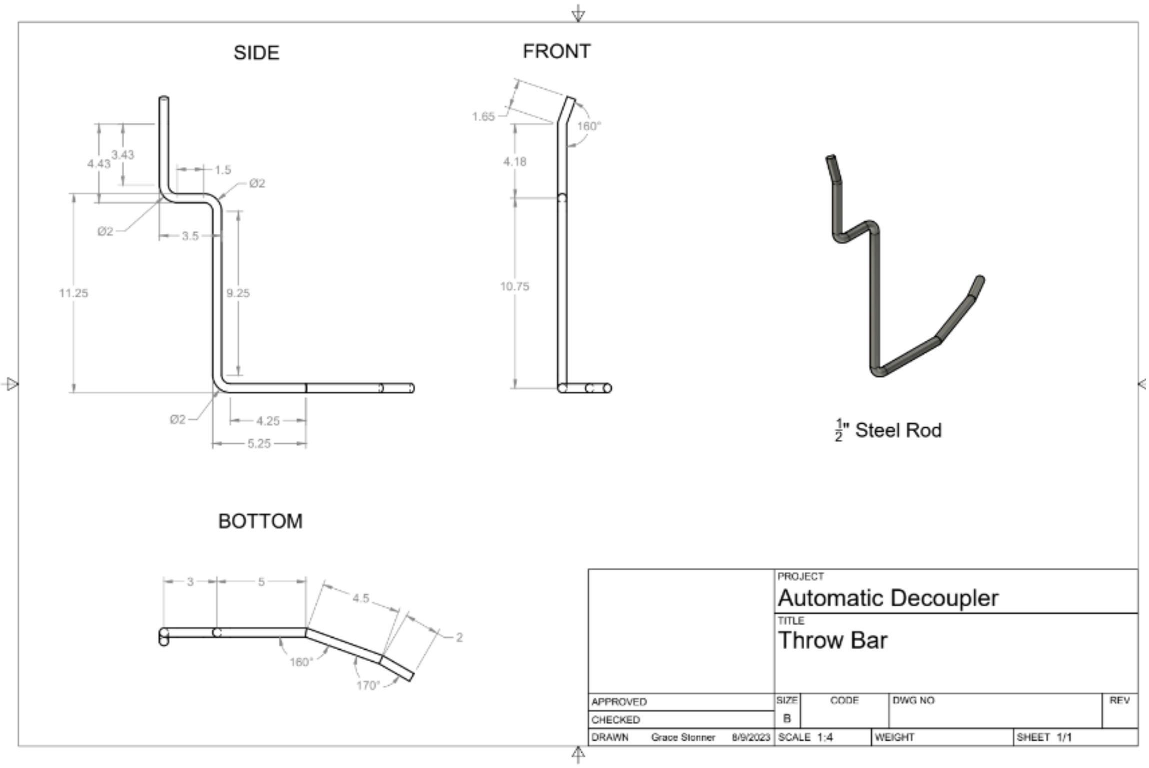


Figure 17: Automatic Decoupler Threaded Rod

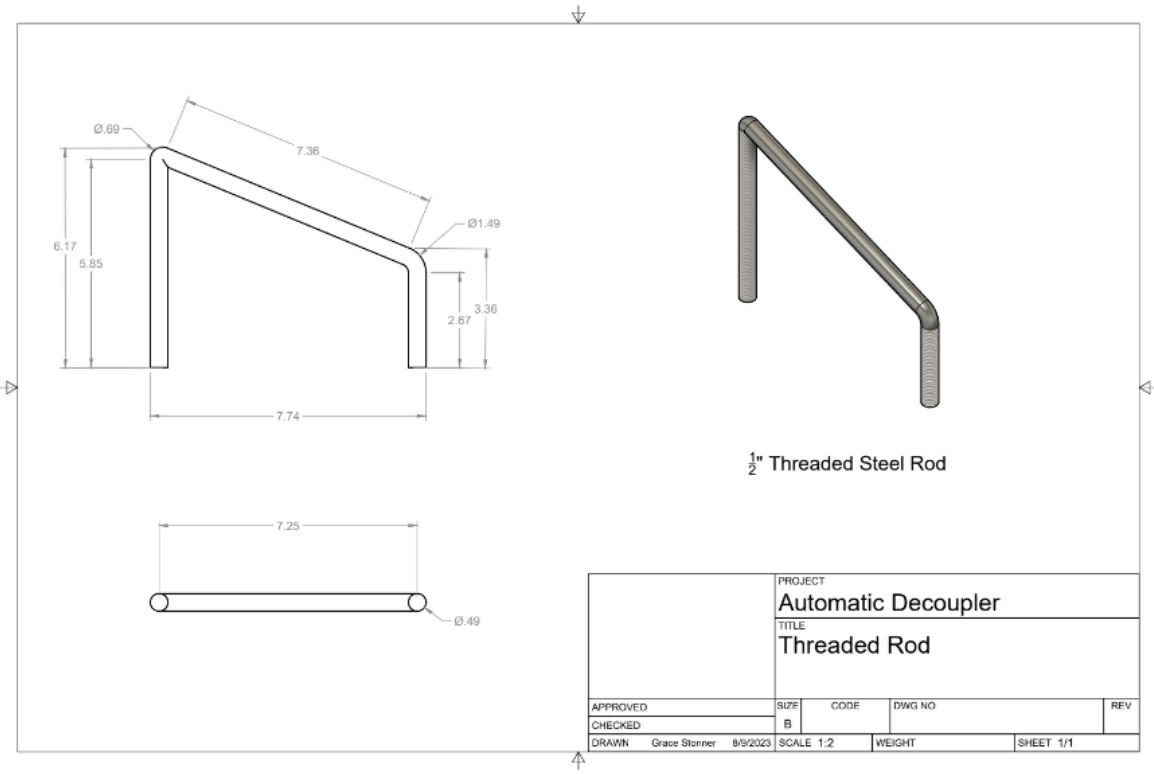


Figure 18:Automatic Decoupler Limit Switch Box

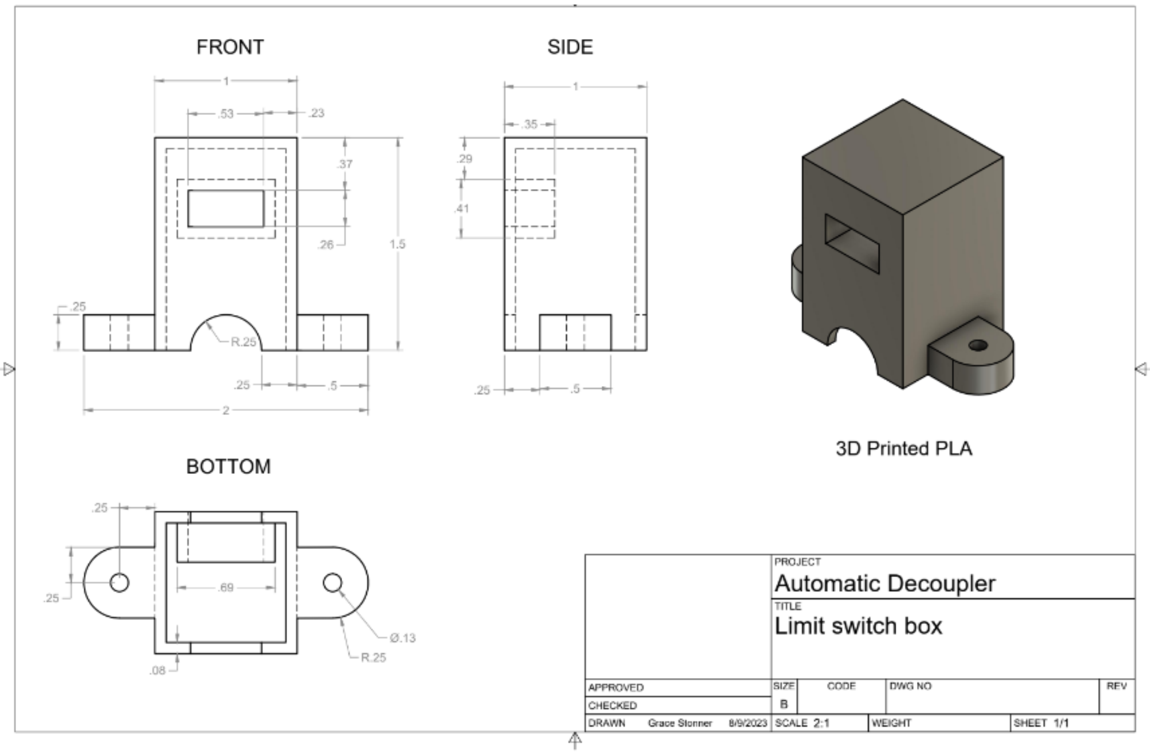


Figure 19: Automatic Decoupler Battery Box

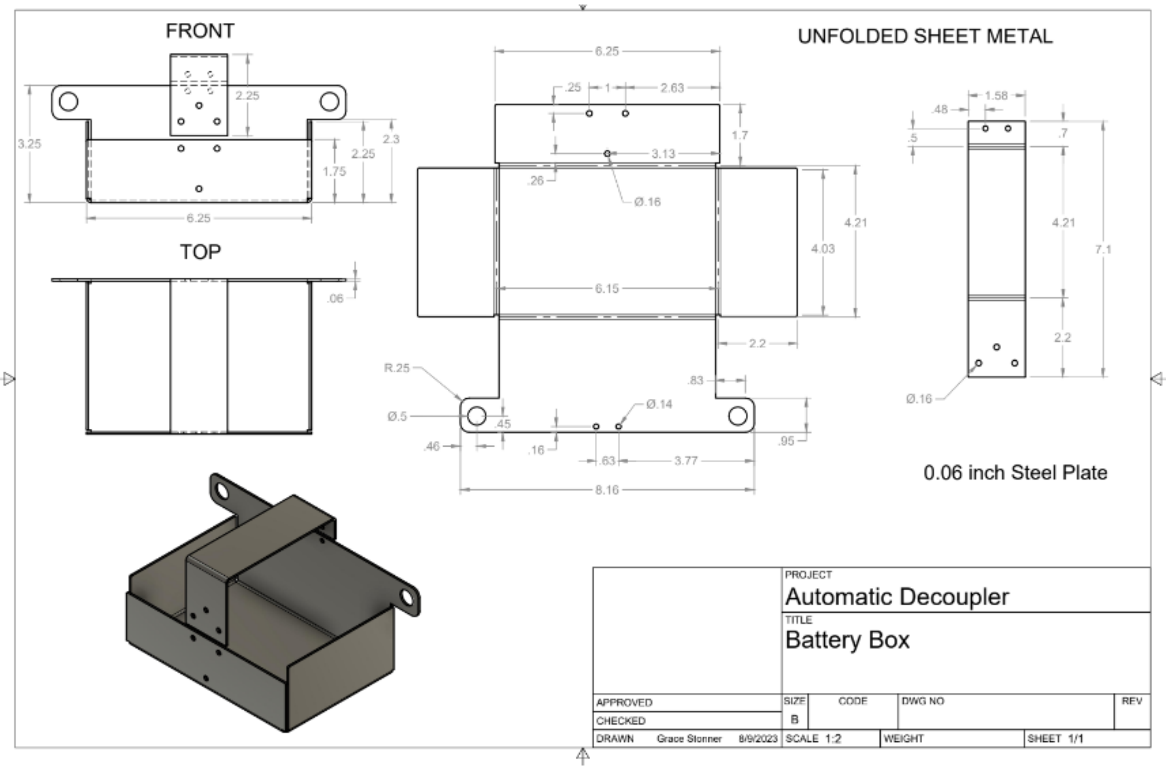


Figure 20: Automatic Decoupler Bracket

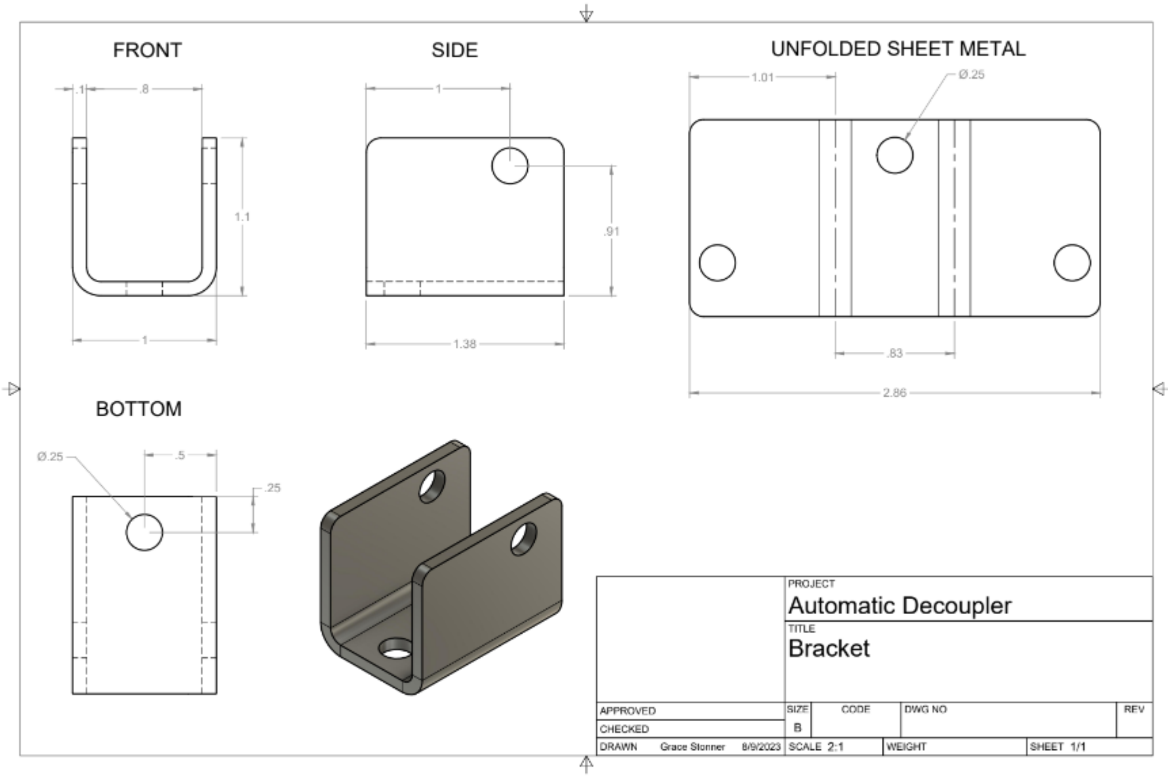


Figure 21: Automatic Decoupler Actuator Collar

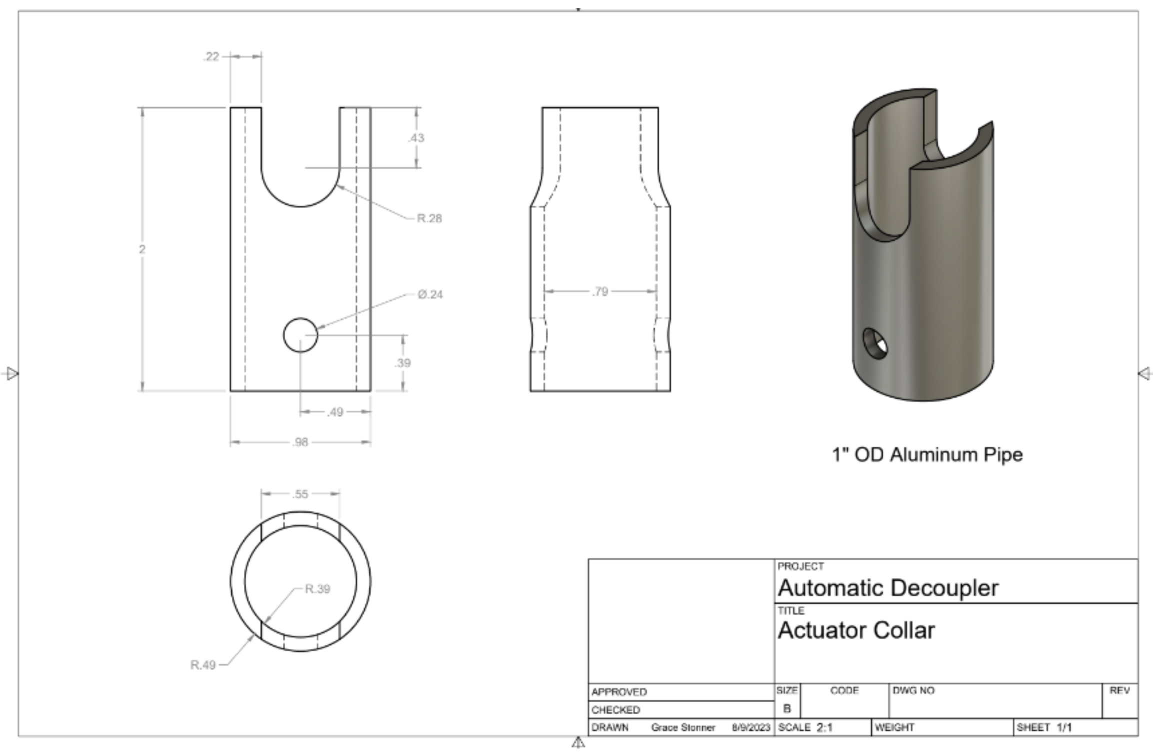


Figure 22: Automatic Decoupler Assembly

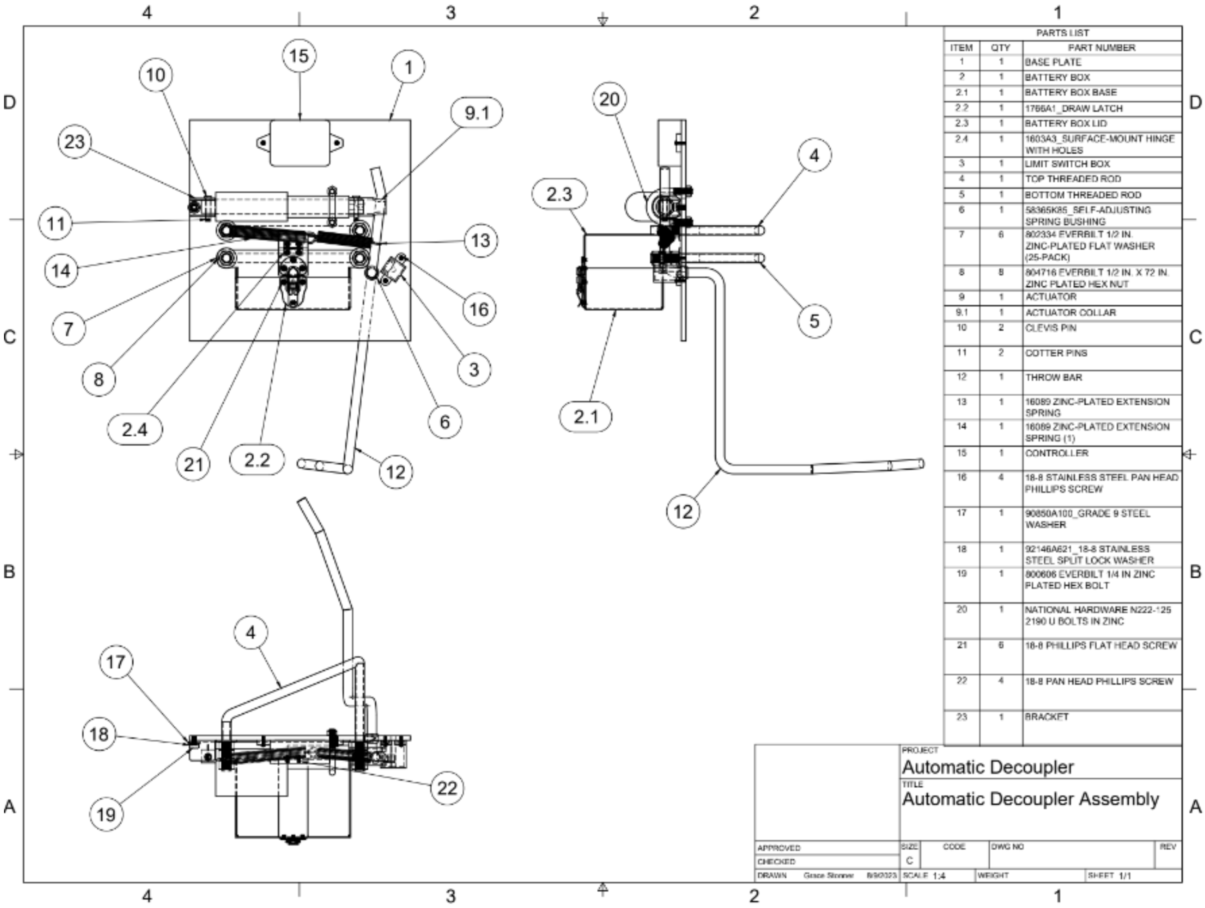
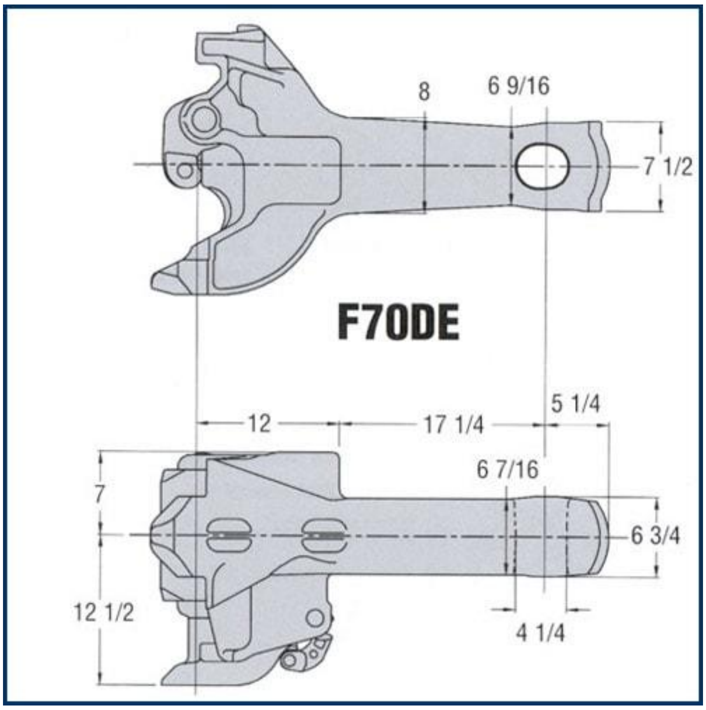
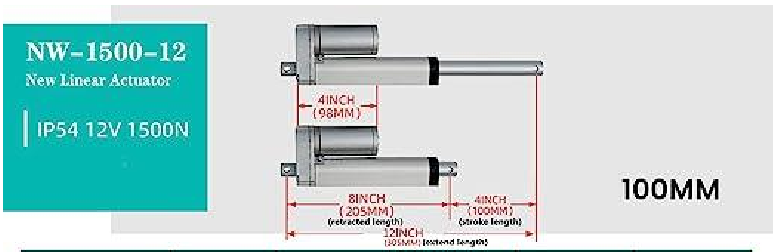


Figure 23: Freight Coupler Dimensions for F70DE



“Freight Couplers.” McConway & Torley. Accessed July 21, 2023. https://mcconway.com/catalog/freight-couplers/.

Figure 24: Actuator Selection Table



RATED LOADS (LBS) N	STROKE LENGTH (MM)	TYPE	VOLT	RETRACTED LENGTH (MM)	EXTENDED LENGTH (MM)
330 lbs (1500N)	50	NW-1500-12	12V	155	205
	100	NW-1500-12	12V	205	305
	150	NW-1500-12	12V	260	410
	200	NW-1500-12	12V	320	520
	250	NW-1500-12	12V	370	620
	300	NW-1500-12	12V	420	720
	350	NW-1500-12	12V	470	820
	400	NW-1500-12	12V	550	950
	450	NW-1500-12	12V	600	1050

12 Annotated Bibliography

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7. Electronic Code of Federal Regulations. "Title 49 - Transportation: Subtitle B - Other Regulations Relating to Transportation (Continued): Chapter II - FEDERAL RAILROAD ADMINISTRATION, DEPARTMENT OF TRANSPORTATION: Part 229 - Railroad Locomotive Safety Standards: SEC. 229.61 - Locomotive Couplers." https://www.ecfr.gov/current/title-49/subtitle-B/chapter-II/part-229#p-229.61(a)

8. Eco-worthy 12V 2 inch stroke linear actuator Max 330lbs ... - amazon.com. Accessed July 23, 2023. https://www.amazon.com/ECO-WORTHY-Actuator-Maximum-Electroic-Medical/dp/B08DX9JDMY.

Measuring 4” for Design #1, 4 inches * 25.4 mm/inch = 101.6 mm

Measuring 8” for Design #2, 8 inches * 25.4mm/ inch = 203.2 mm

This implies our selections should be 150mm and 250mm stroke lengths.

9. Association of American Railroads. (2023). *AAR Manual of Recommended Practices Car Construction Fundamentals and Details: Clearance Plate Diagrams for Interchange Service* (S-2056). https://www.aar.org/