2023 Executive Summary

GATEWAY ARCH NATIONAL PARK'S ENGINEERING COMPETITION

Engineered by the STL CAPS Student Associates

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stl CAPS ENGINEERING

RIVERBOATS
AT THE GATEWAY ARCH

Overview

Ever since 1964, guests from all around the surrounding St. Louis area have come to Gateway Arch Riverboats to take a scenic trip down the vast Mississippi River. With around 1.5 million visitors per year, the Gateway Arch National Park is an immensely significant reminder of St. Louis history. However, there is more that goes into operating the various different attractions housed in this great national park. One of the main challenges faced, specifically dealing with the Riverboat tours, is the rapidly fluctuating water levels of the Mississippi River. Because of this, dock operators and employees are required to manually adjust the position of their docks to stay afloat. This executive summary outlines our solution to allow dock operators to adjust the position of their docks in a fully automated way.

Problem Statement

The constantly fluctuating river levels along the Mississippi River poses a significant challenge for docks utilizing manual systems, such as Gateway Arch Riverboats, requiring regular manual adjustments to keep the docks afloat and accessible. This process requires a full team for operating the winch system, impacting various dock operators along the Mississippi River. Within a 70 mile section of St. Louis there are over 200 privately owned docks and barge terminals in the area. This makes up only a small section of the 2,340 mile long Mississippi River, and many use manual systems. Our goal is to develop an automated design applicable to various docks systems.

Existing System

Currently, the Gateway Arch Riverboat Dock utilizes a completely manual winch system to reposition the dock when necessary. When the water level changes, Kevin, the captain, must personally go down to the dock, at any given time, to operate four electric winches and one hydraulic winch, all controlled from a single control panel. These five winches move the dock in a crab-like motion, ensuring that the three ramps remain aligned with the paved pathway. Additionally, five utility lines extend from beneath the dock, along the exposed middle ramp, and under a metal plate, connecting at the top of the road.

Design Specifications

One of the first things we created in this project are establishing design specifications to create detailed descriptions of the features, functions, and performance criteria that the system we create must meet. The specifications are:

- The system must adjust the dock based on the fluctuating water levels.
- The boat must have the ability to move up and down, and back & forth
- Utilities must be able to expand or retract in correspondence with the fluctuating water levels.
- Utilities must not interfere with the ramp and other systems as it moves.
- The design needs to be automated.
- Must be able to detect the water level and how far away the ramp is from the shoreline.
- System must fit on the dimensions of current riverboat barge: 303 ft x 120 ft, Ramp length: 75 ft, Ramp to end of barge: 195 ft
- Must keep an accurate and realistic budget
- Materials must withstand the elements
- Ramps must stay on path with the cement track
- The system must be able to be manually overridden
- Prevents possible debris from taking the boat off-course
- Must be able to hold the dock in place when it’s not being adjusted
- Must adhere to all coast guard regulations
- Individuals boarding the dock must not have to trudge through water to board.
- Prevent ramps from tearing up the utility lines
- The ramp needs to be able to adjust with the dock

Our Solution

Our objective was to devise an automated solution for precise control of the dock's vertical and horizontal movements. Our solution involves four distinct components: the winch system, the track/ramp system, the cable system, and the utility system. In short, our solution revolves around the implementation of a software applicable to the winches, that interfaces with environmental sensors to automatically adjust the dock when necessary, eliminating the need for manual intervention. As the winch pulls the dock in a crab-like motion, the three ramps, fixed to a hinging joint between the dock and the ramps themselves, pivot while remaining securely guided by a track to stay aligned to the paved pathway. Simultaneously, the five utility lines are reeled in and out from a hose reel located beneath the dock. These lines run under the middle ramp, between the tracks, and into an underground utility housing trench.

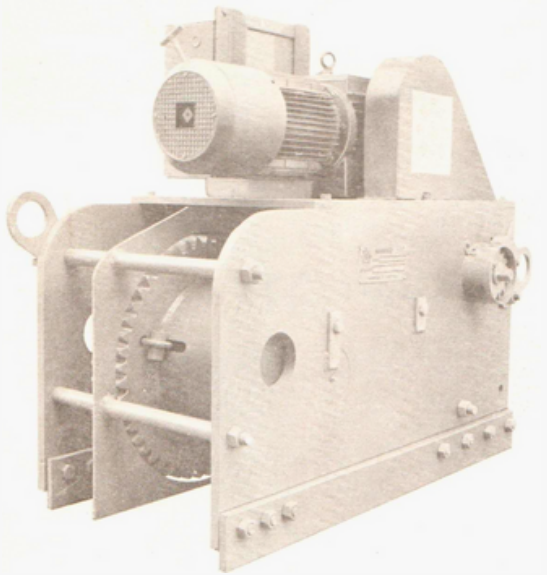
Winch System

- **Current**

Currently, four electric winches and one hydraulic winch, each holding up to 40 tons, are responsible for adjusting the position of the dock. An operator is required to manually adjust these winches using a single control panel located on the dock. This raises many issues, one of the main issues being safety as this operator could possibly have to wade through river water in order to board the dock and adjust it. Currently, there are no sensor systems on the boat that allow their system to monitor the water levels or the winch tension. The only way they're able to detect upcoming river levels is using the NOAA (National Oceanic and Atmospheric Administration) website's predicted river levels.

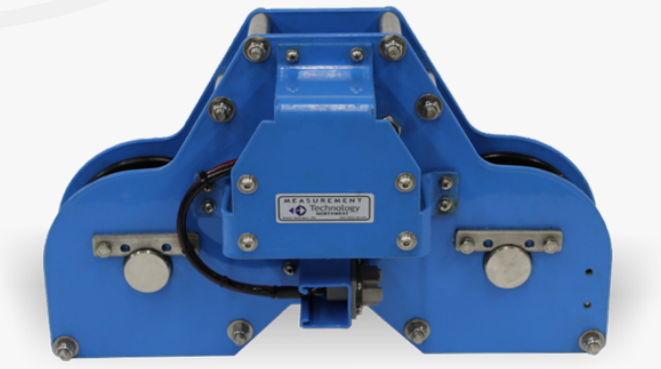
- **Solution**

We plan to use a method that is able to constantly measure the tension and speed of each of the winches, then translate that to readable data that is sent to a micro controller or computer, which then can send signals to remotely move the winches. We plan to use the Rugged Controls Running Line Tensiometers to detect winch tension. RC have created a tensiometer that attaches to a winch line that is able to detect winch tension, speed, and payout monitoring (locating where the boat is in the water). They also create a display called the LCI-90i display to read the tensiometer accurately, and is able to connect to an ethernet cable to send data to other remote devices on the network.



The best model that Rugged Controls currently sells is the RL-10, capable of attaching to a cable diameter of 1.5" with a weight capacity of 45 tons, and are able to send data to the LCI-90i display. These exceeds our needs for our current winches, which use a 1" cable line and carry 40 tons.

This software will completely automate the current winch system, ridding the dock of the need for manual labor.



Track/Ramp System

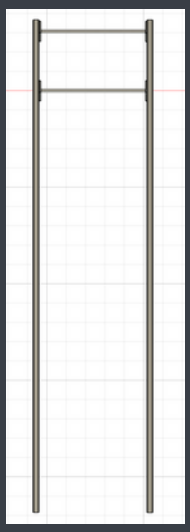
- **Current**

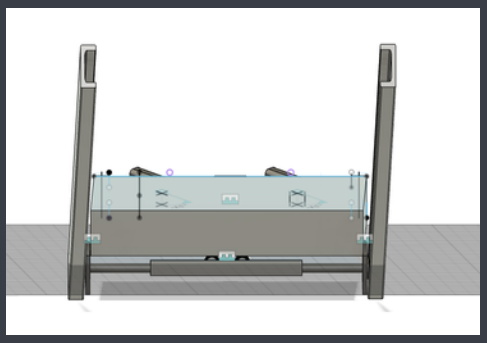
Currently, there are three ramps extending from the dock to the shore. The middle ramp is the longest of the three. The ramps sit on two tires that move along a paved path. As the dock is inched forward in a crab-like motion, the tires move back and forth up the path. However, with this, the utility lines that run along the middle ramp risk being run over and damaged.

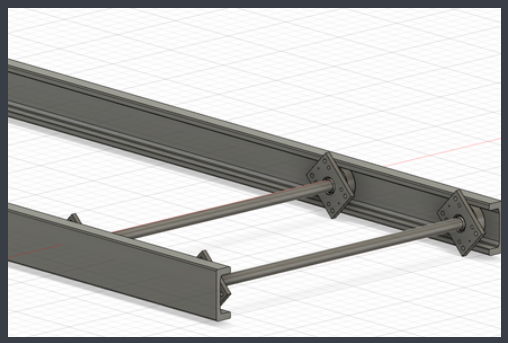
- **Solution**

Our proposed solution is to implement a track system that will need to be installed under all three of the ramps. This track will ensure that all three ramps stay aligned with the paved pathway as the winches adjust the dock. To address the crab-like motion produced by the winches, each ramp will be equipped with a hinging joint, allowing them to pivot in unison with the winches while staying aligned with the path along the tracks. To ensure safe boarding, a circular grate can be installed beneath each ramp, positioned above the hinging joint, to bridge any gaps that may emerge due to the pivoting motion of the ramps. To avoid debris affecting the path of the ramp along the track, skirt protectors found on common escalators can be accommodated to fit the track. This solution will eliminate the issue of keeping the ramps aligned with the path, as well as the worry of running over and damaging any utility lines.

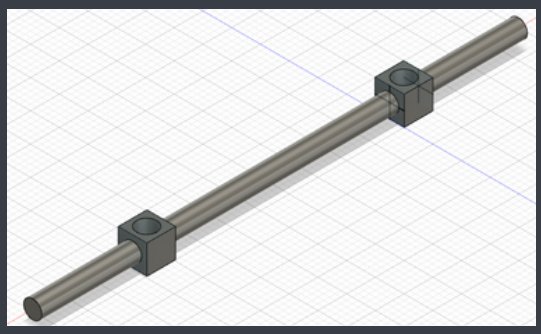
- **A rough diagram of how the ramps will slide across the track. The ramp attaches to a vertical pivot point to allow it to turn right and left. This attaches to an axle which connects to the wheels on the tracks. This allows the axle to pivot up and down, the ramp to pivot left and right, and allows the ramp to slide up and down the track.**

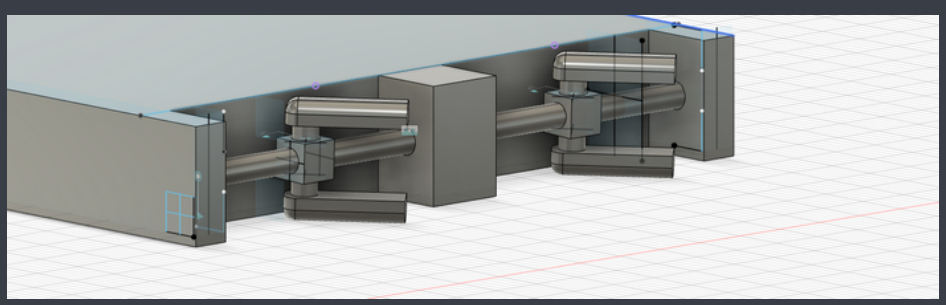


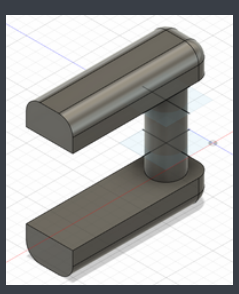




- **These diagrams show how the ramps are able to pivot with the boat when the winches use their crab-walking method to climb the shoreline.**







Cable System

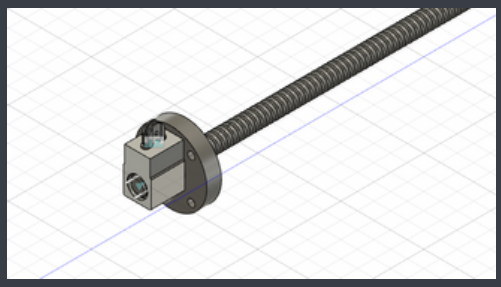
- **Current**

Currently, all five of the winch cables extend up the shoreline until they reach a mounted chain that is fixed to the bank. This chain prevents the cable from extending all the way to the road and becoming a tripping hazard. However, when the dock is raised to a certain extent, the cable must be manually detached from the chain and reattached at a higher link to allow it to be pulled further.

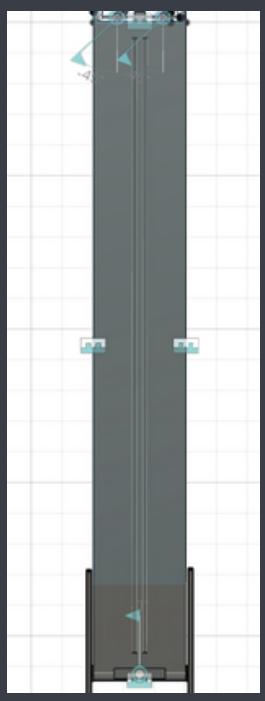
- **Solution**

Our proposed solution is to install a track that runs along the path of each winch cable. In this track, a ball screw with a pulley affixed on top will be mounted within the track. This ball screw will simultaneously move up and down the track with the pull of the winches, ensuring that the cable remains safely out of the way of pedestrians and vehicles. This eliminates any potential safety concerns associated with exposed winch cables. With this, the automated ball screw eliminates the need for manual labor in adjusting the winch cable along the chain. To further enhance safety and aesthetics, the track can be concealed within an underground trench and covered with a metal plate.

- **Cable Description. A lead screw will be mounted inside a track. A pulley is placed on top and the winch cable will run under the pulley. This will keep the cable line close to the ground and allow the cable to run up and down the bank. This will eliminate a need for the chain.**



- **A worm's eye view of the bottom of the ramp and the utility systems. These two lines will guide the utilities from the boat to the underground utility housing.**



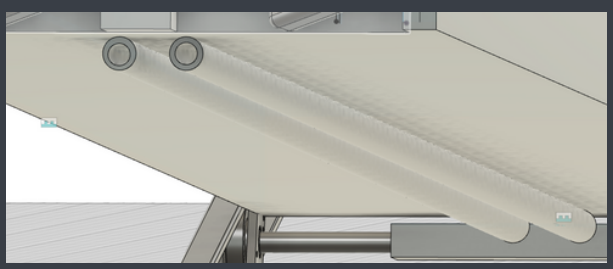
Utility System

- **Current**

Currently, the five utility lines (gas, electric, telephone, water, and sewage) extend from under the dock, along the middle ramp, and under a metal plate until they reach their designated points. As previously stated, with these utility lines being exposed, they run the risk of being run over and damaged by the wheels of the middle ramp.

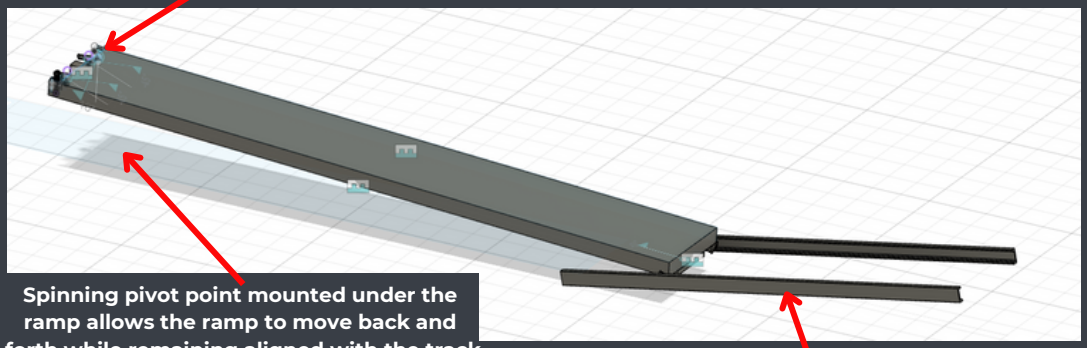
- **Solution**

Our proposed solution is to install utility retraction devices under the dock. The five utility lines will run through hose reels and into two utility tubes, separating gas and electric lines. These tubes will be secured by piping brackets under the middle ramp and between the tracks underneath. These five utility lines will then run into an underground utility housing trench, which will run in between the track, ensuring an effective and aesthetically pleasing system.

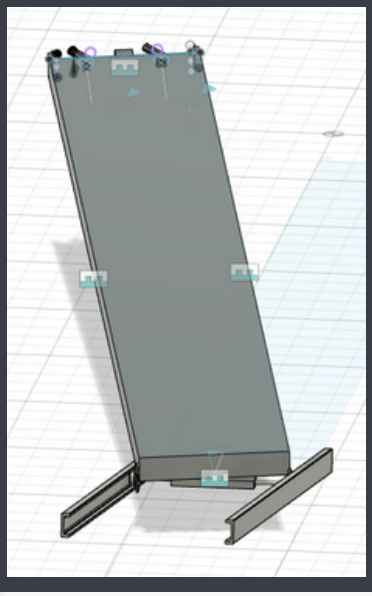


- **A closer view of the utility lines.**

Track and Ramp



- **Pivoting Ramp**



Project Timeline

Process	November				December				January				February				March				April				May			
	W 1	W2	W3	W4	W 1	W2	W3	W4	W 1	W2	W3	W4	W 1	W2	W3	W4	W 1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4
Excavation																												
Install Winch Software																												
Install Track/Ramp System																												
Install Cable System																												
Create Utility System																												
Integration of Systems																												
Testing and Quality Assurance																												
Training																												
Final Testing and Adjustments																												
Project Review and Handover																												

BUDGET PROJECTION

MANUFACTURER	PART	AMOUNT
TRACK & RAIL SYSTEM		
1. PBC Linear	6-Two-Carriage 6000 cm Hevi Rail HVB-063-HVP6	$19,935.72
2. McMASTER-CARR	6-130.31 ft Low Carbon Steel U-Channel	$9,362.77
3. Alibaba	900 ft Skirt Deflectors	$600
WINCH SENSORS		
1. ABQ Industrial	5 Straightpoint TIMH Running Line Testometer	~$100,000
CABLE SYSTEM		
1. NSK Automation	5 High Load HTF Ball Screw	~$2,500
2. McMASTER-CARR	5-150 ft Low Carbon Steel U-Channel	$8,981.25
UTILITIES SYSTEM		
1. RELINER/ Durian Inc.	2-304 SS Pipe Bracket	$157.56

MANUFACTURER	PART	AMOUNT
UTILITIES SYSTEM CONT.		
3. Home Depot	2-75 ft PVC Pipe	$673.50
4. Duro Reels	Hose Reel	$1394.45
LABOR		$71,105.40
GRAND TOTAL		$214.710.65

The prices listed are sourced directly from numerous manufacturers from their websites or via quotes. Most parts, for example the skirt deflectors and PVC pipes, are sold retail online. Some parts (the running line tenisometer & the ball screw) we were unable to secure a quote on but concluded an estimated price based on an un-modified version provided by the manufacturers. The rails sourced from Mc-MASTER CARR were sold by the foot, and the PBC Linear Hevi Rails contain track for 6000 cm and two wheel bearings per rail, totaling four wheels per ramp, and twelve wheels in all. In order to calculate the labor costs, we used the Rule of Two Method which states that a rough estimate of labor costs of construction projects will be around 40 to 50% of material cost. Using the latter we came up with a rough estimate of labor being around $71,105.40.

Conclusion

In conclusion, the Gateway Arch Riverboats are facing a formidable challenge dealing with the ever-changing water levels of the Mississippi River, which necessitates constant manual adjustments to maintain dock accessibility. To address this issue, we've envisioned a solution that incorporates several exciting advancements in the winch system, track/ramp system, cable system, and utility system. Our revamped winch system takes advantage of sensor technology to monitor tension and speed. This innovative approach enables remote control and automation, eliminating the need for arduous manual labor and significantly enhancing safety measures.

Sources

- Kevin East - Gateway Arch Riverboat Details
cell: 314-910-1804
office: 314-982-1400
- Sensor Systems
https://rugged-controls.com/sites/default/files/product_brochures/Running%20Line%20Tensiometers-2017_0.pdf
https://rugged-controls.com/sites/default/files/LCI-80x%20-%20User%20Manual_0.pdf
- Utility Systems
https://smharbor.specialdistrict.org/files/30a8bc80f/3_Anchor-QEA_May-26-2017_OCR.pdf