CORP 4 OPERATIONAL READINESS REVIEW

OATS AUTOMATED CARRIAGE

DECEMBER 2, 2011

AUBURN UNIVERSITY

MECHANICAL ENGINEERING

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ABSTRACT:

The aim of this project is to design, test, and manufacture an automated moving carriage that transports a receiver around a circular track. The design of the carriage will meet or exceed the requirements set forth by the sponsor, Neptune Technology Group. The carriage and track design must be developed and manufactured according to the System's Engineering process outlined in the MECH-4240 and MECH-4250 Comprehensive Design courses. The purpose of this report is to detail the progress made towards the assembly of the final design by showing the steps of a proper design analysis and illustrate the steps taken during assembly. Important factors to be considered in this design include weight, cost, maintenance and reliability, and a reduction of radio frequency interference due to physical components. The report will detail the subsystems developed for the final concept, the functions each subsystem accomplishes, and the parts and necessary cost and labor required for each subsystem. A manufacturing plan and the steps taken in the manufacturing process will be discussed, as well as the tasks required for completion. It should be noted that, while the report summarizes the conceptual design process (i.e. developing feasible alternatives to the solution), the primary goal of this report is to detail the engineering analysis for the chosen design and discuss installation of the design and any modifications made to the design.

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INTRODUCTION:

Neptune Technology Group has been a major producer of water meters since 1892 and has over 119 years of experience in providing better-quality service to the water utility industry. They have been able to produce mobile data collectors such as the MRX920 that has the ability to take 5000 reads per hour along with being wireless and weighing less than 5 pounds. They are a well experienced and technologically advanced organization that will continue to be an aggressive competitor in the water utility industry. The projects taken on by Neptune Technology Group, such as the automated receiver, go to show that they are not slowing down anytime soon.

Neptune currently has an outdoor test setup comprised of a rolling carriage on a 50 foot diameter circular track. A test water meter is placed in the center of the track and emits a wireless signal to a test antenna designed to measure the signal strength coming from the water meter. An example of a typical signal strength measurement is shown in figure 1. The test antenna is mounted on the moving carriage and is moved to various locations around the track by two technicians who manually collect signal strength data from the receiver. This set-up is time consuming, uncomfortable, and inefficient. Since measurements are taken every 15 degrees, the current setup also has a low resolution and could be made much more accurate if automated.

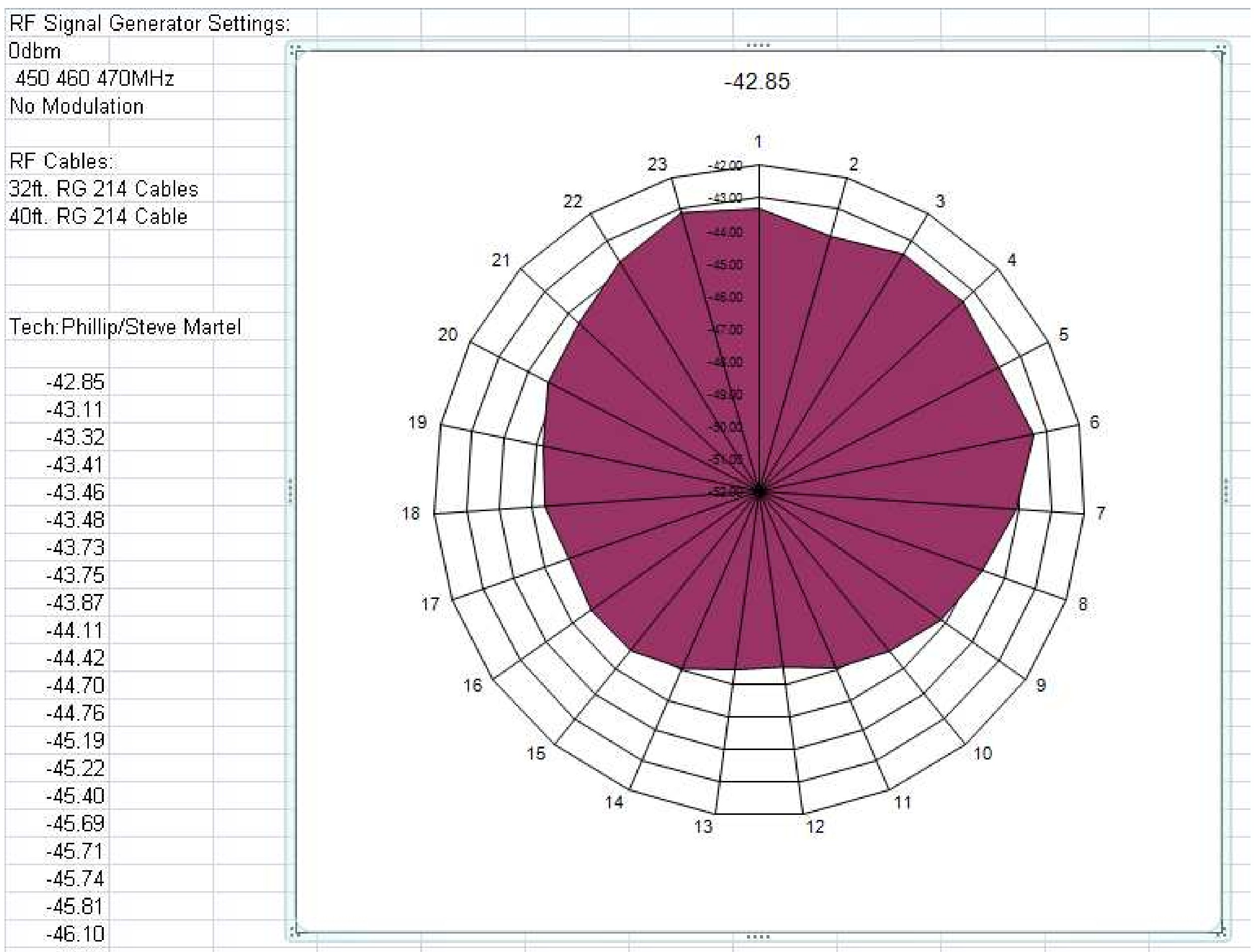


Figure 1 – Typical Signal Strength Plot

The design task at hand is to create an automated carriage that will travel on a track 50 feet in diameter. The test antenna and receiver that measures the signal strength emitted by the test water meter will be mounted to the automated carriage, which will be remotely controlled from a base station or inside the Neptune Engineering building. The receiver will wirelessly send measurements of the signal strength for review by Neptune technicians and engineers. There are not currently any designs that will be sufficient to accomplish this task, so the goal behind the design will be to create and manufacture this automated carriage from scratch. The current track design is shown below in figure 2.

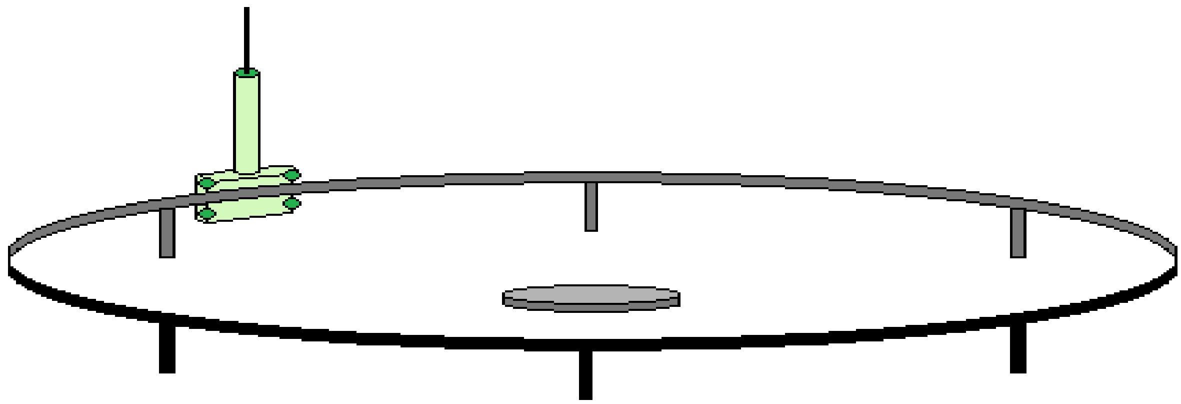


Figure 2 – Current Track Design

In this operational readiness review, a brief summary of feasible concepts for the automated carriage is presented as well as the assessment of these concepts and the selection of the final design. The development of each required subsystem is discussed as well as the integration of these subsystems and their parts into the final assembly. A description of the manufacturing and assembly of parts purchased will also be included.

MISSION OBJECTIVE:

The overall purpose of this project is to design, evaluate, and create an automated test antenna that emits a low radio frequency and is weather resistant. The target users for this project are the technicians and the engineers that will be running tests with the automated carriage. This new device will be need to be lightweight in order to reduce physical exertion and heavy lifting while transporting it to and from the base station, while at the same time providing better removability for the technicians for the purpose of carrying it indoors in case of severe weather. The major use for this device will be for transporting a test antenna used to receive a signal produced by a water meter in the middle of the 50 foot diameter circle and house the wireless receiver and electronics required for measuring the intensity of the signal; therefore the apparatus will have to be secured safely to the track. An MPCOD was created for the purpose of specifying objectives and deliverables (see figure 3).

Contract Title: MPCOD

Group Name: Corp_4 (Neptune)

Date: August 30, 2011

Task:

By the end of the semester, Corp_4 will present Neptune with an automated mechanical cart that will travel around a 25 ft radius track in under 4 min. A C-channel track that has a gear rack attached will serve as a guide that the cart will roll along the top. The electric motor located on the cart will turn the gear which is meshed with the rack, thus powering the cart. Calculations for sizing the motor, battery, and gear will be presented to show optimum performance. This prototype ensures the cart will be stable enough to remain on the track during testing and provide accurate results. The entire mechanical system has been built to protect from environmental corrosion and wear. If during testing there is a sign of mechanical failure or instability, Corp_4 will perform one iterative of redesign to correct the issue. Since we are students and at semesters end we will no longer be working on the OATs project, any further redesign will have to come from Neptune or future senior design students.

Corp_4's main focus is the mechanical aspect of this design project. If Neptune provides the necessary equipment to gather and transmit the data, then Corp_4 will collaborate with Neptune to take the design a step further to include those electrical components.

Manufacturing Schedule:

Task	Completion Date
Assemble finished chassis Prototype	September 10, 2011
Gear rack tested and fastened to prototype track section	September 10, 2011
Have specifications for electronics and select effective cooling solution	September 10, 2011
Check position of current posts to make sure track will sit well on posts	September 10, 2011
Install cooling solution on prototype and test	September 17, 2011
Assemble motor and clutch	September 17, 2011
Install mast on prototype and test stability of carriage under wind	September 24, 2011
Have programming working for motor controller and single board computer	September 24, 2011
Bulldoze existing track	September 30, 2011
Install new track	October 7, 2011
Install full gear rack	October 14, 2011
Test and Revise	November 11, 2011

Delivery Date:

Monday, December, 12, 2011

Figure 3 – MPCOD

ARCHITECTURAL DESIGN DEVELOPMENT:

One of the first steps taken in the generation of concepts for this project was to create a functional decomposition for the design. This tool enabled brainstorming ideas for the design on a sub-function and a sub-sub function level, allowing the selection of a more feasible design. Creating a functional decomposition is an important part of the Systems Engineering Process. Corp_4's functional decomposition is shown below (figure 4).

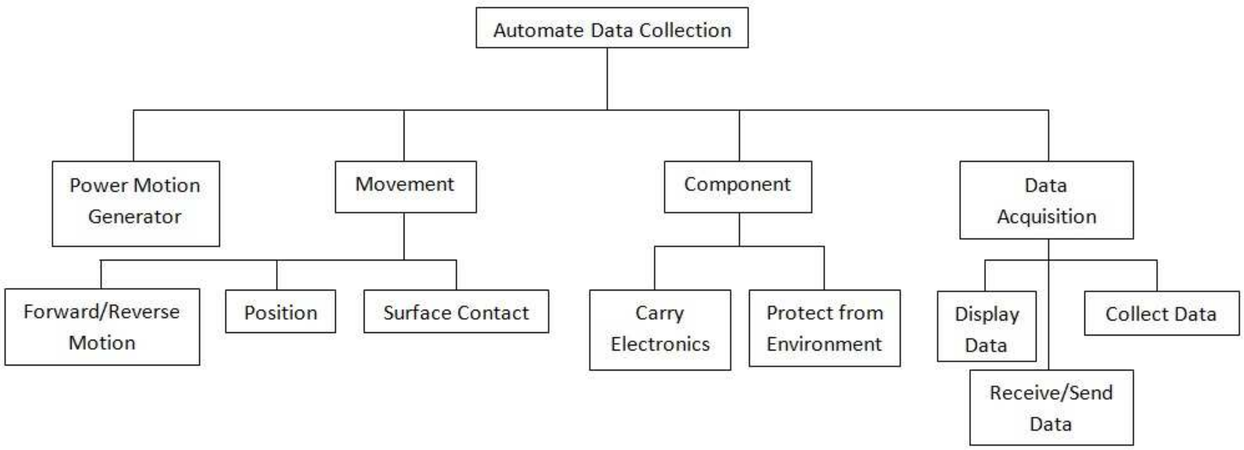


Figure 4 – Corp_4 Functional Decomposition

- **DEVELOPMENT OF FEASIBLE CARRIAGE DESIGNS**

  Using the functional decomposition and other engineering design tools such as brainstorming and morphological charts, four feasible designs were developed for the automated carriage. The first concept was battery powered and motor driven. The motor was to drive two front wheels that rested on the circular track. The second concept was powered by a conductor bar on a monorail and was also motor driven. The third concept consisted of a motor driving a long circular chain with the same radius as the track and connected to the carriage. It would be powered by a local AC outlet near the track. The final concept was also battery powered and motor driven, but instead of driving wheels in contact with the circular track, it would drive a sprocket in contact with a stationary chain. These concepts were all determined to be reasonable designs and would accomplish the mission objective.

- **CONCEPT ASSESSMENT AND DETERMINATION OF FINAL DESIGN**

Once several valid options for different designs were generated, the concepts were evaluated and compared on the basis of cost, safety, reliability and maintenance, accessibility of electronics, the ease of supplying power to the carriage, and the accuracy of carriage position control, among other criteria. The first concept, in which motion was created by wheels in contact with the track, was deemed to be easy to maintain and reliable, but lacked precision in controlling the position of the carriage. The second concept, which utilized a consistent power source via the conductor bar on the monorail system, would require less work since it would not require consistent recharging of a battery, but could be unsafe to technicians and the environment. Also, if the system were to fail, it would be difficult to fix because most of the technical knowledge for a monorail system is overseas and finding a technician who is familiar with this system may be difficult. The third concept, while providing an accurate mode of position control and having a constant power source via the local AC outlet, would require frequent maintenance to ensure reliable movement in the mobile chain and would also be very costly and difficult to manufacture. The fourth concept, although requiring somewhat frequent charging of a battery, was chosen for the accuracy of controlling the carriage position and overall ease of maintenance and manufacturability. The concepts were compared using the same criteria. See Table 1 for a detailed review of concept benefits and drawbacks.

Table 1 – Concept Comparison Chart

Concept Comparison (1-5 scale, 5 being optimal)				
	Battery Power, Wheel Driven	Monorail Powered, Wheel Driven	Outlet Powered, Chain Driven	Battery Powered, Sprocket Driven
Size	3	2	3	3
Cost	4	2	2	4
Weight	4	4	3	4
Maintenance	4	2	2	4
Manufacturability	4	2	3	4
Reliability	4	2	3	4
Simplicity	4	2	3	4
Installation Friendly	4	3	3	4
Power Supply Life	3	5	5	3
Position Control	3	3	5	5
Total	**37**	**27**	**32**	**39**

- **<u>PRODUCT HIERARCHY</u>**

For the final design, the carriage with the battery powered motor driving the platform along a gear profile was chosen. The battery powered design offered some slight advantages of using a lighter chassis that would reduce the amount of weight of the entire system along with having considerably lower maintenance overall. The final design consists of four main sub-systems. The first sub-system is the motor and battery that will power and drive the carriage around the track. The second sub-system is the mechanical drive system that will consist of the gearbox attached to the motor, the clutch, the gearing and gear profile used to propel the carriage around the track along with relaying the position to the user. The third sub-system is the chassis and platform which is the aluminum structure used to transport the carriage around the track along with providing environmental protection for the electronics carried aboard. The fourth sub-system is the data acquisition system that will collect, send/receive, and display the data collected from the receiver via a wireless card installed in the electronics box. This design has been modified from the original design to better accommodate the sponsor's requests and compensate for failures in analysis. It is shown in figure 5.

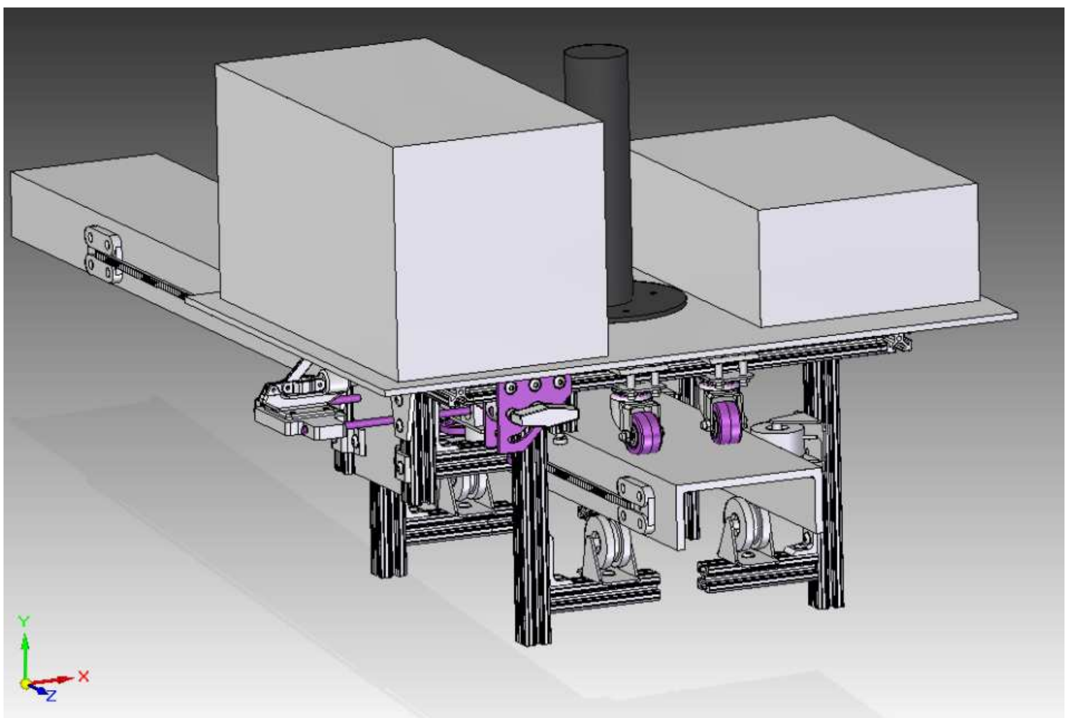


Figure 5 – Battery Powered/Gear Driven Platform

Neptune's previous design had several factors that needed to be changed. The original platform was very basic and it required the technicians to manually push the carriage around the track for testing the antenna's signals. This resulted in one of the major changes from Neptune's previous design is the addition of a motor to drive the carriage around the track with the push of a button. A gearbox will be attached to the motor shaft and will be able to control the movement of the chassis using the motor controls in the base station. The gearbox will allow variable speed along with forward and backward motion of the carriage. The motor and gearbox is shown in figure 6.

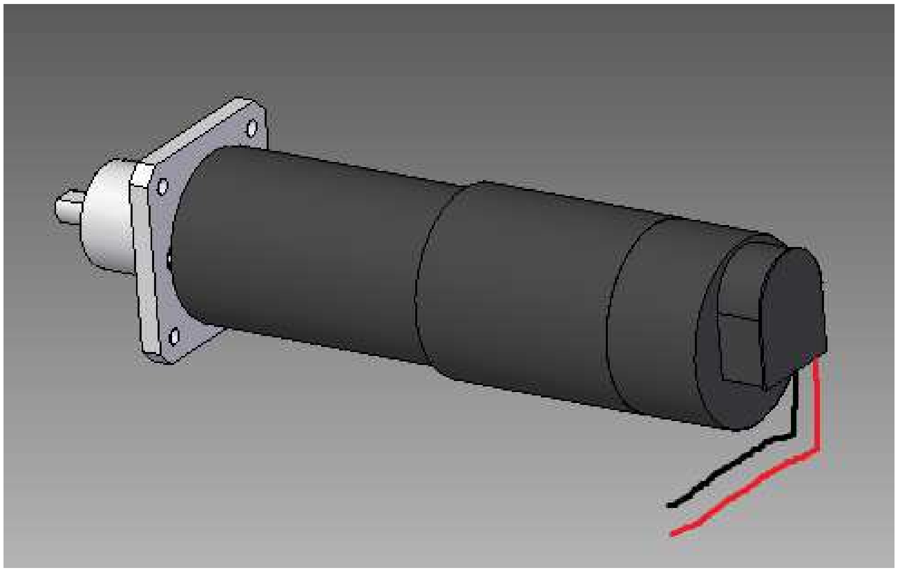


Figure 6 – Motor and Gearbox

The mechanical drive system (figure 7) has the basic components of gears and sprockets but the one thing that has changed throughout the design process is how to essentially put the power to the ground. There have been many different ideas presented including a roller chain being bolted to the channel and even a rubber wheel driving the carriage along the ground. There were many options but it was narrowed down to fastening a gear rack to the side of the track. The gear rack will be bent around the track in order to be aligned with the sprocket. The gear rack has the advantages of having precise control over the positioning system and durability for overall lower maintenance.

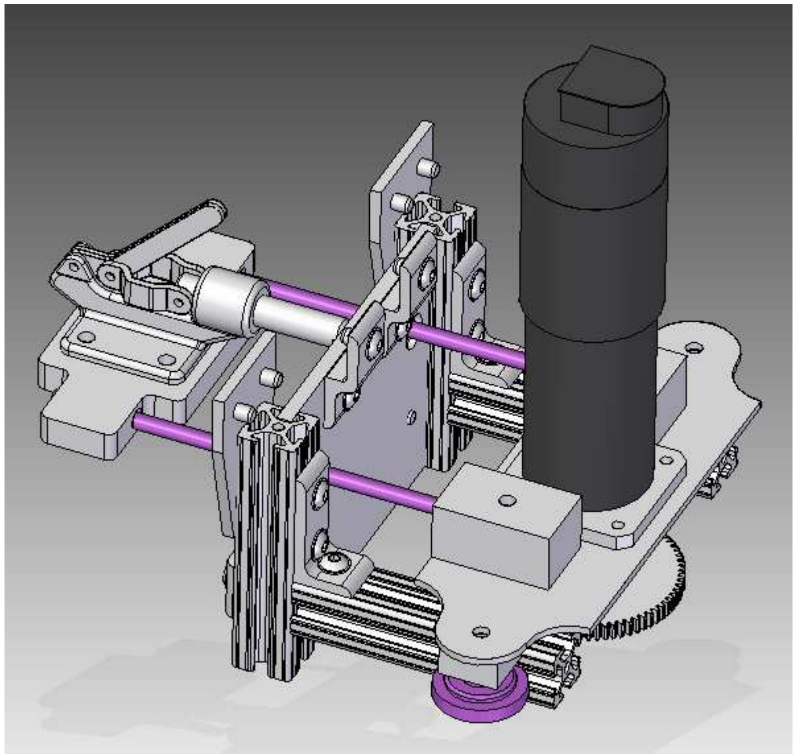


Figure 7 – Mechanical Drive System

The track design (figure 8) consists of a C-channel beam that is approximately six inches wide giving a nice clean flat surface for the casters to roll on. The channel was purchased from White Fab, Inc., a manufacturer based out of Birmingham, AL who cut and bent the track to the exact radius needed for the design. The track will be welded on to the modified studs of the existing track by Treeco, a local contractor, and painted to resist corrosion.

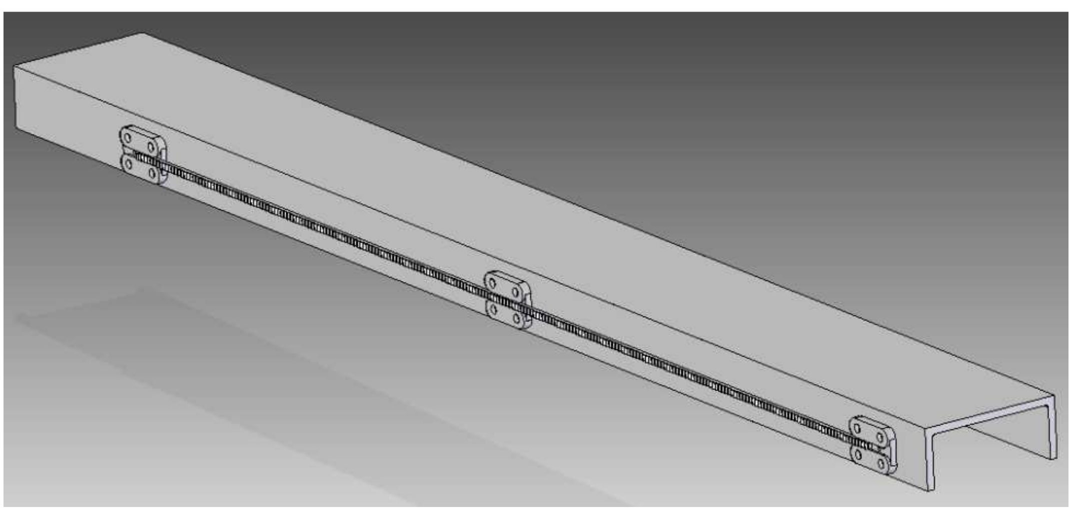


Figure 8 – Track

This design uses off-the-shelf manufactured channels already cut to length and bolted together using the manufacturer's brackets. Low profile 2" lower the center of gravity for the carriage. Bolts are used to connect the casters to the chassis. This allow the wheels to be adjusted side-to-side for idea placement on the track. The chassis is shown in figure 9.

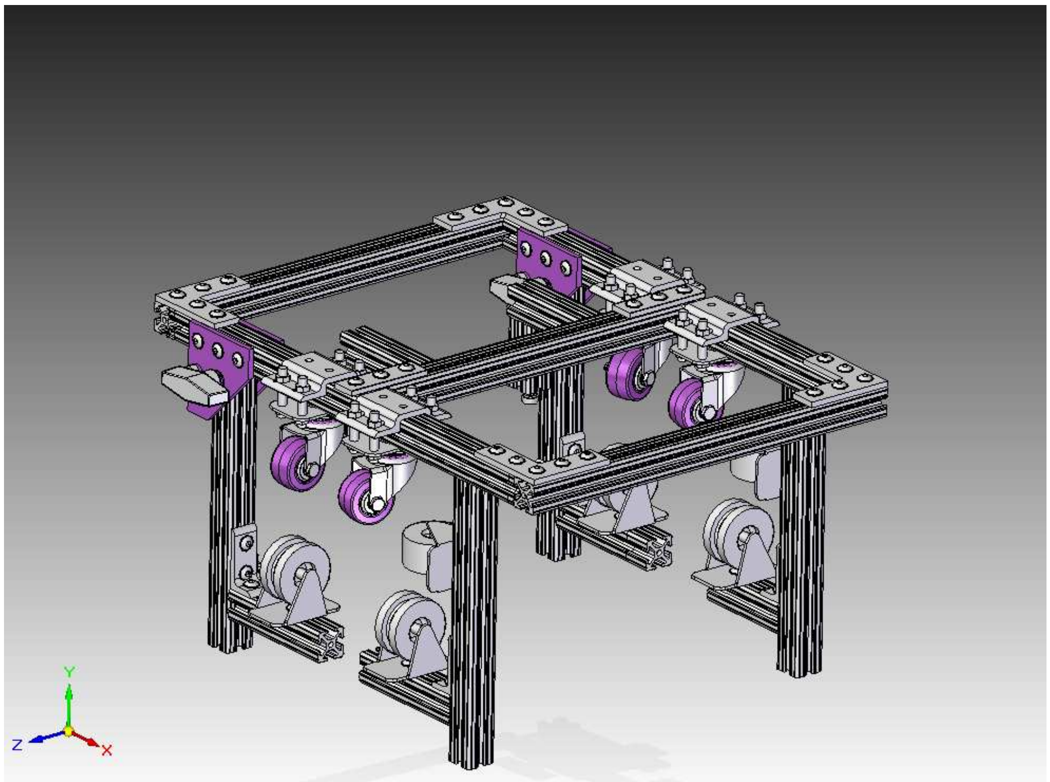


Figure 9 – Chassis with Casters

The purpose of the platform is to carry the mast, electronics, batteries, and motor around the track. The platform is made of HDPE (Marine Grade) and was chosen because it is lightweight, has low reflectivity, and is UV resistant. The platform is bolted to the carriage using bolts that connect the casters to the chassis as well as brackets on either side of the platform. A weather resistant housing for the motor and batteries was fabricated out of HDPE and attached to the platform with several screws. The platform is shown mounted to the chassis in figure 10.

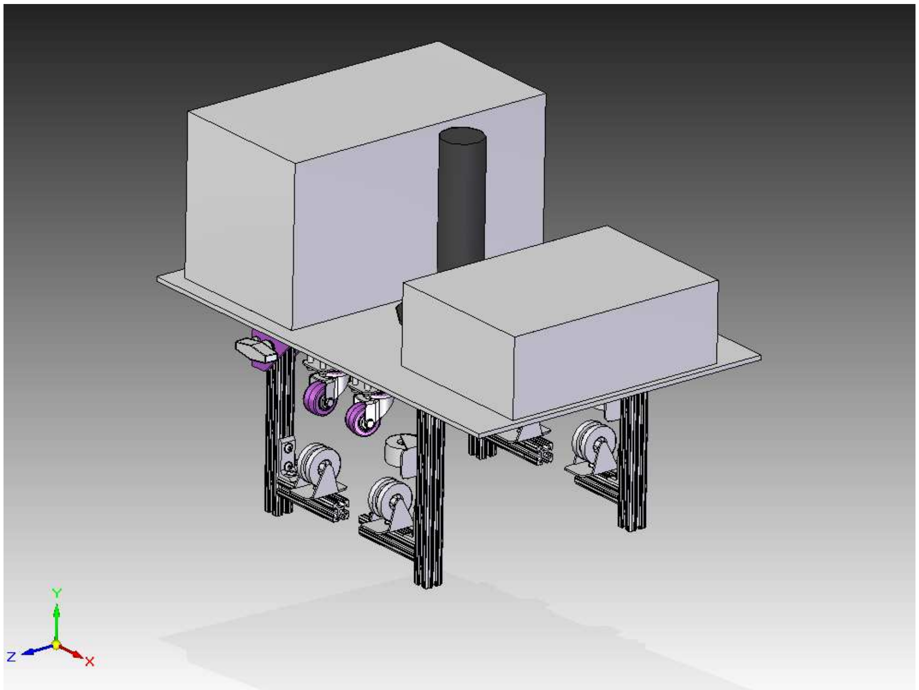


Figure 10 – Platform

The mast (figure 11) will be the same one in Neptune's previous design utilizing the 3" PVC pipe but the main difference will be how the mast is mounted to the platform. The PVC pipe will fit securely over a steel flange which is bolted to the platform. The steel flange will add extra weight to the carriage, but will supply greater rigidity to the PVC pipe to keep the mast from swaying when in motion and under high winds.

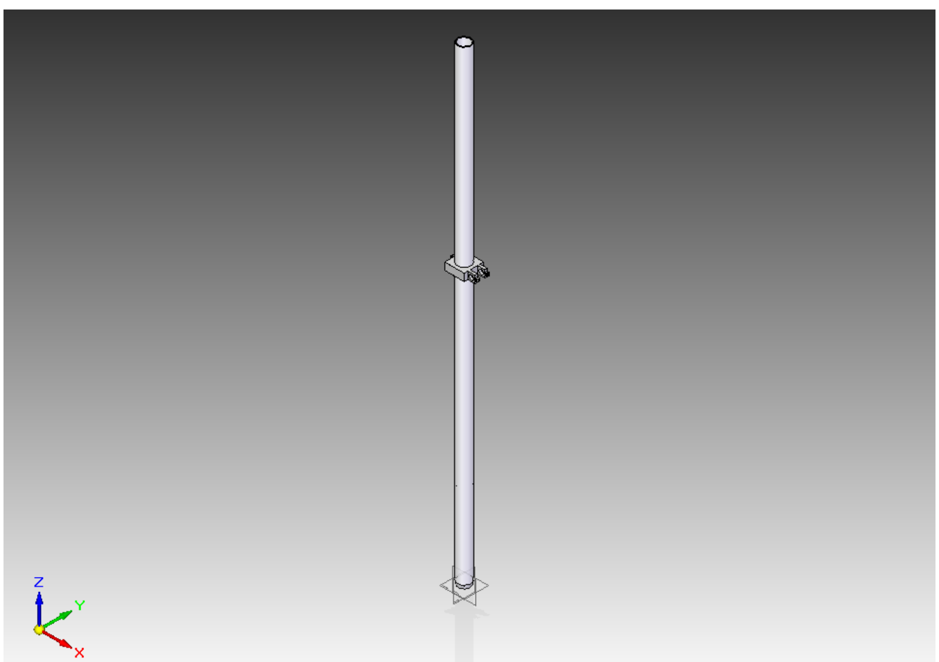


Figure 11 – Mast

The electronics box will house all of the data collecting, receiving and transmitting equipment. The signal sent out from the water meter located in the middle of the track is received by a test receiver mounted on the mast of the carriage. The receiver relays a signal that is transmitted to the base station through a wireless connection. All of the electronics will be installed by Neptune and will be located in a weather resistant box mounted on the platform.

- **<u>ECONOMIC ANALYSIS</u>**

In designing the carriage, careful attention was paid to all costs associated in the manufacturing process. Special considerations were given to ensure that all materials used were manufactured of the proper quality to ensure a high safety factor and longevity of life. Since the automated carriage is designed for use at Neptune only and is not meant to be mass produced, costs associated with the construction of the carriage were expected to be higher due to ordering a single part rather than ordering a large quantity of each part.

The most expensive part of the test setup was the track itself. The materials have extremely high strength and durability, and the horizontal surface made it an excellent choice for the design, even with its higher relative cost. The costs associated with the track were regulated by minimizing the width and depth of the legs, and going with a smaller thickness.

The rest of the materials used in the construction of the carriage were fairly simple and cost effective. Most of the costs of the automated carriage can be attributed to the motor, batteries and electronics. For this reason, extensive research and calculations were done to ensure that the chosen motor and battery were accurately sized and would not have to be redesigned. See Table 2 for a complete Bill of Materials.

Table 2 – Bill of Materials for Final Design

Manufacturer	Part Number	Part Description	Price/unit	Quantity	Subtotal
80/20	1010	T-Slotted Profile- Cut to 6.5"	$1.61	4	$6.44
80/20	1010	T-Slotted Profile- Cut to 12"	$2.76	2	$5.52
80/20	1010	T-Slotted Profile-Cut to 17"*	$3.60	2	$7.20
80/20	2523	Double Mesh Panel Retainers	$5.75	4	$23.00
80/20	3321	Mounting Hardware for 2523	$0.50	8	$4.00
80/20	4176	3 Hole Inside corner Bracket	$3.85	8	$30.80
80/20	3393	Mounting Hardware for 4176	$0.40	24	$9.60
80/20	4101	4 Hole 2.5" Inside Corner Bracket	$4.10	4	$16.40
80/20	3321	Mounting Hardware for 4101	$0.50	16	$8.00
McMaster Carr	78155T17	2" Rigid Type Casters (For Alignment)	$2.00	4	$8.00
Colson Casters	1.01652.441	1 5/8" Swivel Type Casters (For Load)	$8.00	4	$32.00
80/20	1010	T-Slotted Profile- Cut to 5"*	$1.40	2	$2.80
80/20	1010	T-Slotted Profile- Cut to 10"*	$2.50	1	$2.50
80/20	4176	3 Hole Inside corner Bracket	$3.85	3	$11.55
80/20	3393	Mounting Hardware for 4176	$0.40	3	$1.20
Midwest Motion	MMP-NE23	Nema 23 Square Flange, Motor mount	$36.00	1	$36.00
Midwest Motion	MMP D22-376H-24V	Brushed DC motor, 24 V- with encoder	$385.00	1	$385.00
SDP/SI	A 1B 2-N24072	Brass Spur Gear- 14.5 pressure angle,	$47.85	1	$47.85
80/20	2750	Roller Wheel Brackets	$6.00	2	$12.00
80/20	2281	Roller Wheels*	$4.50	4	$18.00
CarrLane	CL-150-TPC-S	SS Threaded Body Toggle Clamp	$15.55	1	$15.55
McMaster Carr	3985A42	Double Point Cable Latch w/ T-Handle	$88.84	1	$88.84
White Fab	MC 6X12	33' Section of Steel Channel	$625.15	5	$3,125.75
SDP/SI	A 1B12-N244	48" Brass gear rack, 14.5 deg pressure angle-Diametral Pitch,24	$53.02	45	$2,385.90
SDP/SI	A 1B12-N244	48" Brass gear rack, 14.5 deg pressure angle-Diametral Pitch,24	$67.60	4	$270.40
White Fab	MC 6X12	13' Section of Steel Channel	$475.00	1	$475.00
Rustolium	N/A	Spray on Primer	$3.97	2	$7.94
Pololu	RB-Pol-119	Pololu 18v7 5.5-40V, 7 A Motor Controller	$33.95	2	$67.90
Century Spring Corporation	11273	Compression Spring- .703 OD 3.5" Free Length-Closed,Ground	$3.06	3	$9.18
Century Spring Corporation	3052	Compression Spring- .703 OD 4.13" Free Length-Closed,Ground	$3.61	2	$7.22
Century Spring Corporation	10446	Compression Spring- .703 OD 4.25" Free Length-Closed, Ground	$5.31	2	$10.62
Century Spring Corporation	12283	Compression Spring- .703 OD 4.41" Free Length-Closed, Ground	$3.43	2	$6.86
Century Spring Corporation	12450	Compression Spring- .703 OD 4.13" Free Length (Stiff) -Closed,Ground	$3.49	2	$6.98
				TOTAL:	$7,146.00

REQUIREMENTS:

Neptune has several requirements for the automated carriage. The carriage needs to traverse the circumference of the track in less than four minutes. The position of the carriage must be able to be controlled to within one degree of the 360 degree track. It must also be weather resistant and removable from the track. The electronics (i.e. the mobile receiver, the wiring, the battery) must be cooled to within the specifications of each component, which will be approximately 70 degrees C. The electronic components should also be able to be removed individually from the automated carriage.

CONCEPT OF OPERATIONS:

The design that will be implemented is an automated system that will operate from a base station located all the way up to 500 feet away off of a wireless system. The system will ultimately be user controlled (i.e. by a Neptune technician or engineer). Through the use of Labview software, the user will be able to see the current position of the automated carriage and will be able to move the carriage to a new position by inputting a command. See figure 12 for a detailed description of different part interfaces.

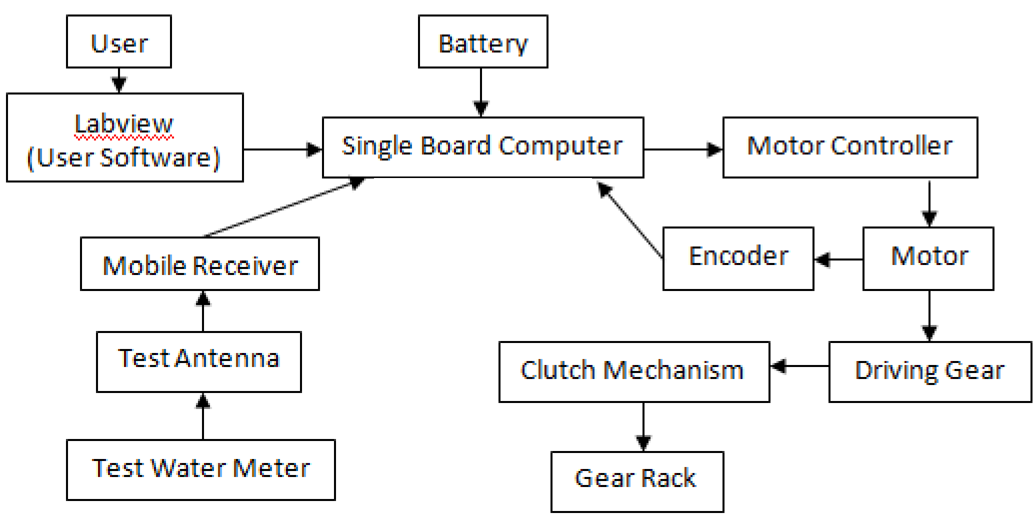


Figure 12 – Concept of Operations Detail

DATA COLLECTION AND POSITION SENSING:

As the motor travels around the track, the mobile receiver will be continually gathering data measuring the strength of the signal being emitted by the test water meter. The collected data will then be communicated to the single board computer (mounted on the carriage), which will wirelessly transmit the data back to the user in the base station. At the same time the motor is travelling around the track, an encoder mounted on the motor will communicate to the single board computer the number of motor shaft revolutions, which will be used in Labview to determine the angular position of the automated carriage with respect to the test water meter located in the center of the test set up.

CARRIAGE MOTION AND POSITION CONTROL:

When a new carriage position is desired, the user will input the desired coordinates to Labview. This software will then wirelessly communicate with the single board computer which will adjust the speed of the motor through the use of a motor controller. The motor will spin a driving gear that connects to a circular gear rack that mounts to the track on which the carriage rests.

ELECTRICAL CONSIDERATIONS:

The system will be powered by two 12 Volt batteries connected in series and will provide up to 4.6 amp-hours at 24 volts. The batteries will supply power to all of the electronics on the platform including the 24 volt motor, the motor controller, the single board computer, and the mobile receiver. The electronics box will contain the receiver, motor controller, single board computer, and the wireless card. The motor controller can be connected to the batteries and motor as seen in figures 13 and 14 below. Neptune will be responsible for installing and wiring the rest of the electronics (i.e. the receiver, the single board computer, and the wifi box).

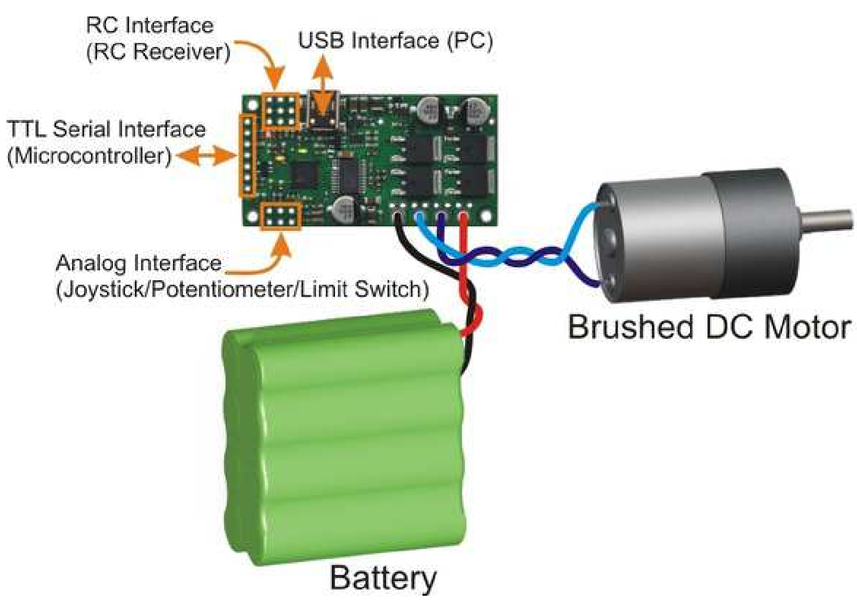


Figure 13 – Overall Motor Controller Schematic

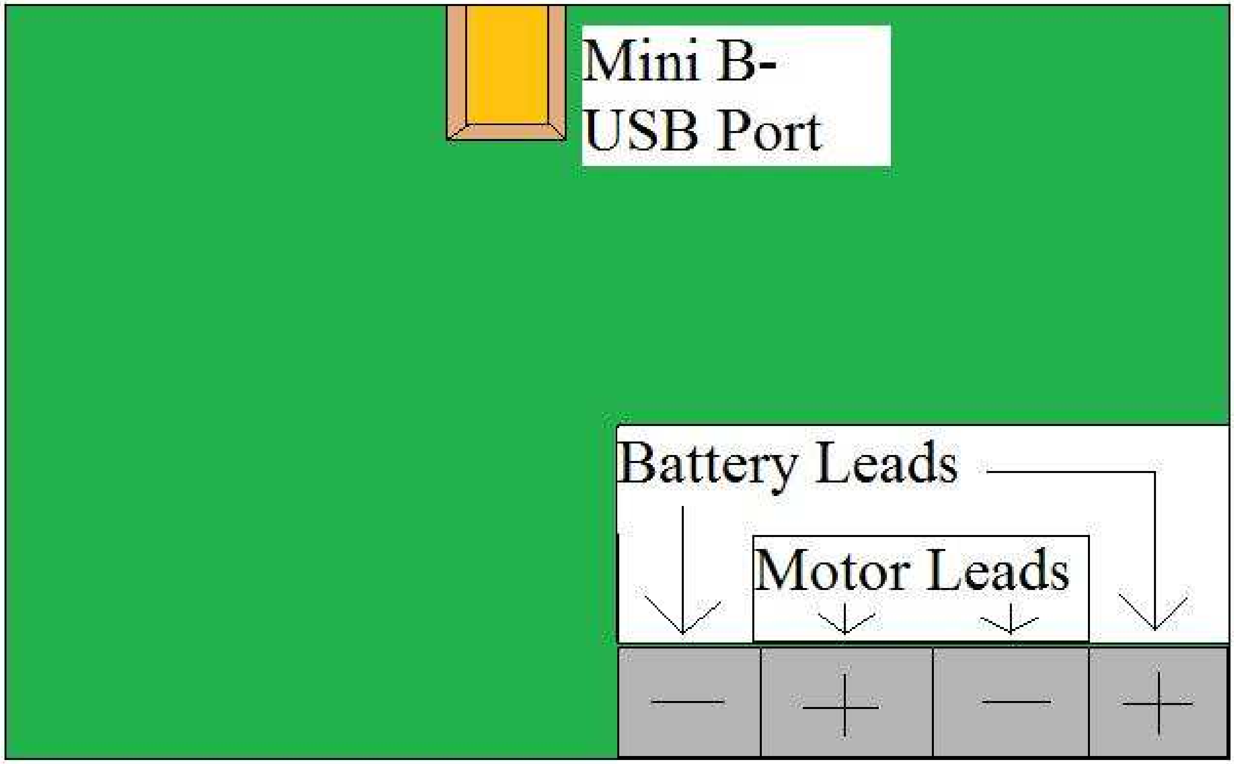


Figure 14 – Detailed Motor Controller Schematic

MANUAL CONTROL OPTION AND CHASSIS:

The driving gear will continually be in contact with the track mounted gear rack unless manually disengaged by a user at the location of the test setup. The user will be able to move the motor, shaft, and driving gear in and out to engage or disengage the gear rack by means of a manually operated clutch system. The clutch system and the motor assembly will be mounted to the chassis, which will contact the circular track at the locations of the four caster wheels that support the carriage and the four rigid wheels that provide added stability to the automated carriage.

ASSEMBLY AND INSTALLATION:

The sub assemblies that will have to be put together before operation include: chassis, motor, electronics, track, rack, and mast. The order in which these need to be put together will be mentioned in this section. First, ensure that the screws and bolts on the chassis are tightened properly. The wheels should be to the outer edge of the track to ensure that they do not swivel into each other when the cart changes directions. Second, mount the motor onto the motor mount. Third, once the metal flange has been bolted to the platform, place the platform onto the chassis. Guide the motor through the groove cut into the platform and bolt the platform down tight. Now the electronics box containing the Wi-Fi, SBC, receiver, and motor controller is ready to be placed onto its guide rods. Lastly, the mast can be slid over the metal flange that is attached to the platform.

Installing the carriage is a simple process. First loosen the four black sliding wing nuts located on one side of the carriage and lift two or all four of the legs. Now the carriage can easily slide onto the track. Make sure that the gear is in line with the rack and will properly mesh when the clutch is disengaged. Next close the legs and retighten the wing nuts. To engage the gear, pull the clutch handle upward and then push the carriage a few inches along the track to create a good mesh between the gear and rack. Now the carriage is ready to take measurements. If manual operation is preferred, just leave clutch locked in the downward position. This pushes the gear away from the track and allows for easy manual operation.

Validate and Verify:

A major concern about the design was that the battery life would be insufficient and the periodic changing of the batteries would reduce the value of the project. Therefore, a multi-meter was used to determine the current draw in order to verify that the battery life would be sufficient. In addition, the time it would take for the cart to travel around the track was a major parameter in the design. A section of six feet on the track was measured in order to determine the cart velocity.

The motor controller came with software, Pololu Simple Motor Control Center, which we were able to connect to a laptop via a USB cable. The software gave us the option of testing the cart at a user-inputted percentage of the power supply. For the experiment, the power supply was changed at 10% increments from 10% to 100%. The results of this test were recorded and can be seen in Table 3 below. At 100% power, the motor draws approximately 0.8 amps. This amount of amperage translates to an estimated 3 hours of continuous operation. The batteries used were rated at 4.6Ah. The time of 3 hours was determined by calculating the time it would take for the batteries to reach 40% of the battery life. The batteries could last longer if they were completely drained of power. However, a practice of maintaining a battery life above 40 % will prolong the life of the battery.

Also, the cart had to travel around the fifty foot diameter track in less than four minutes. At 100% power the cart travels at a velocity of 1.71 feet per second. This velocity enables the cart to travel around the track in roughly 90 seconds. This amount of time is less than half of the original parameter of four minutes.

Table 3 – Current and Speed Test Results

Max Power	26.7 V		
Distance used to measure velocity	6 ft		
Power Supplied (%)	**Current (Amps)**	**Velocity (ft/s)**	**Travel Time around Track (min)**
10	0.3	0	0
20	0.68	0.17	15.44
30	0.68	0.34	7.72
40	0.78	0.53	4.95
50	0.77	0.72	3.65
60	0.83	0.89	2.95
70	0.82	1.09	2.41
80	0.84	1.28	2.05
90	0.81	1.46	1.8
100	0.83	1.71	1.54

INTERFACES AND ICD:

There are several electrical and mechanical boundaries worth noting. The selected caster wheels have a load limit of 90 lbs. Since there are four caster wheels supporting the entire weight of the carriage, maximum weight limit of the chassis, the platform, the electrical components, and all other parts can be estimated at 360 lbs. This mechanical limit does not present a problem for carriage design because the weight of the carriage and all components is approximately 50 lbs- the lighter the carriage, the longer the battery life in between recharges.

There are also two important electrical boundaries. First, the motor runs on 24 VDC and is rated for 1.7 Amps. Also, the selected motor controller can accommodate motors that run on a DC voltage in between 5.5 Volts and 40 Volts and the motor controller can supply up to 7 Amps continuous current. The current motor and motor controller combination would work well together, but if either the motor or controller must be changed for any reason, these electrical limits must be kept in mind.

MISSION ENVIRONMENT:

Environmental concerns for this project include overcoming the heat of the Deep South and moisture from the Gulf of Mexico that will adversely affect the test equipment. Efforts to overcome these effects include the use of gray HDPE (Marine Grade) to reduce heat transfer via radiation. This will ensure that the batteries and motor will be kept in a safe environment. The electronics box is rated for outdoor use and will keep the electronics from overheating in the sun. Other environmental considerations include storms and severe weather, rain and high winds. For this reason, the electronics and even the carriage itself must be easily removed from the track and transported indoors.

TECHNICAL BUDGET AND RESOURCE TRACKING

The primary technical resource that needs to be budgeted for this design is battery power. As noted earlier, the motor draws approximately 0.8 amps at a steady velocity. The batteries being used are currently rated for 4.6 amp-hours and should last at least 3 to 4 hours in between recharges if the carriage is driven continuously. Since Neptune will probably not be driving the motor continuously for three hours, the batteries may even last up to a full day before requiring a recharge. Neptune will have to discover this parameter through trial and error out in the field when the track is completed.

RISK MANAGEMENT:

The motor that drives the platform could possibly fail and one way to overcome this failure is by using the clutch to disengage the driving gear from the gear profile. In addition to safety, performance and longevity of the carriage must be considered. The carriage is light enough so that its weight will not prohibit proper use. Materials used were considered for their ability to weather adverse conditions outdoors as well. Note that the track and gear rack will be assembled in sections so that if one section fails for any reason, it can easily be replaced with similar parts.

SUBSYSTEMS DESIGN ENGINEERING:

The first subsystem includes the motor with optical encoder and battery which was chosen based on many hand calculations including the torque, velocity, weight of the entire carriage, and acceleration. The motor was chosen based on the rated continuous current of 1.7 amperes and the rated continuous torque of 19 inch pounds. The optical encoder was an option for the motor chosen and was needed for the positioning system. The batteries were chosen based on the voltage supplied to the motor. The batteries run in series will supply 24 volts to the motor and will last from three to four hours of continuous operation. Shown below is a diagram of the motor and encoder to be used in the design.

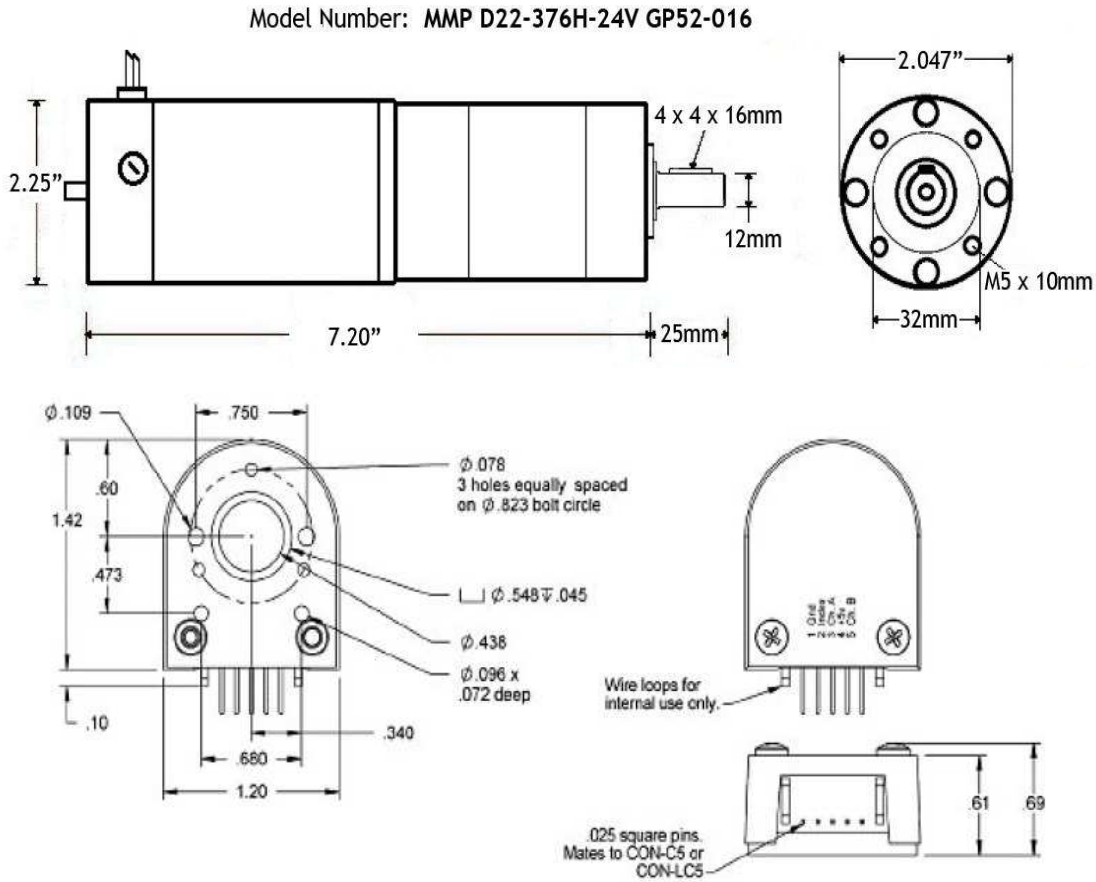


Figure 15 – Midwest Motion Motor (Top) and Encoder (Bottom)

The second subsystem consists of the entire mechanical drive system which moves the carriage forward and backward. A gear placed on the shaft of the motor aligns with the gear rack that will be placed on the outside of the track and mounted on polycarbonate brackets. The gear rack and gear was chosen for better control of the carriage along with having a precise positioning system at all times since there will a reading taken every one degree. The gear and gear rack will allow for very low maintenance, installation, and durability over many runs. The gear will come in contact with the gear rack as shown in figure 16 below.

Figure 16 – Gear and Gear Rack

The chassis utilizes a lightweight slotted frame that has much versatility along with great strength. The slotted frame has been used many times in the Neptune Technologies plant over the years and has earned a very good reputation for durability, strength, and versatility. The casters used are very inexpensive as well as having more than enough strength to be able to support the 100 pound load with ease. The main casters used are all swivel casters rated at 90 pounds each. Swivel casters were used because of the slight curve of the track. The side casters are fixed casters which will guide the carriage around the track since the casters will be rolling vertically. The casters used on the carriage are shown below. The platform used will be made of an HDPE (Marine Grade) plate of 0.25” thickness. The HDPE plate was used for the corrosion resistance to the environment. The casters are shown in figure 17.

Figure 17 – Swivel and Rigid Casters

The platform carries the motor, electronics, and mast. The clutch is connected to the chassis and enables manual and automatic operation. The electronics will be incased in a dedicated electronics box that can be easily removed from the platform. The mast will have two parts associated with it. The first part will be the steel pipe that will be welded to a plate that will be bolted to the platform. The second part of the mast will be the PVC pipe that will slide down over the steel pipe and be held in place via nuts and bolts.

The last subsystem is the data acquisition system that controls the motor and electronics. This system will consist of a motherboard that will control the velocity and position of the carriage as well as the receiver and wifi box. The motherboard will be supplied with power from the two 12 volt batteries on board and will communicate with the wireless system that will relay all of the information gathered from the receiver to the base station. The user will be able to evaluate the signal at the precise position and record all of the information gathered and to be analyzed.

Neptune Technologies will be providing several parts to the data acquisition system including the test antenna, test water meter, mobile receiver as well as the single board computer. The reason the company is supplying all of the parts is because they presently use them in the company’s testing procedures. The receiver to be used in this design is shown below.

Figure 18 – Signal Hound Receiver

Project Management:

During the first semester of this project, groups were formed and tasks were assigned to each group. This allowed for members to focus designing the parts they were assigned while following a coordination plan to integrate the parts together. This strategy was not applicable for the second semester of the project, since parts were arriving on different dates due to different lead times. Members met once enough parts had arrived to put a sub assembly together and any problems foreseen were dealt with immediately instead of ordering everything and finding out parts didn't fit together properly. A list of primary responsibilities is shown in Table 4.

Table 4 – Contribution Chart

Member	Contribution
Daniel	mounting prototyping rack, design notebook
Cody	manufacturing platform, motor shroud, track stand
Grayson	ordering parts, design clutch mechanism
Ben	organizing report, sizing motor and batteries, thermal analysis on motor
Kyle	coordinating group participation and analyzing system operation

Coordination with Neptune was a major focus this semester, since they had to disassemble their existing test track for Corp_4's design to be implemented at Neptune. In order to make an easy transition for Neptune, Corp_4 coordinated with WhiteFab to get the track delivered to Neptune so that Treeco could install and paint the track with minimal down time. Neptune's management took longer than expected to approve the order of the track and electronics, so Corp_4 was not able to test the design on the new track or with all of the electronics in the circuit. As of December 6, 2011, Treeco is still in the process of installing the new track. As for the Wi-fi, single board computer, and receiver Corp_4 has not received word whether they have arrived or not. Since Neptune will have to finish this part of the project, Corp_4 made the transition as easy as possible by informing Neptune of future ideas, plans, and tests Corp_4 had for the project.

CONCLUSION:

In conclusion, the final design meets all of Neptune's requirements. It is easy to assemble and requires low maintenance. Also it has been designed to allow for future modifications and/or upgrades in the following years. This automated data collection system will improve Neptune's overall accuracy of test results and dramatically decrease the time it takes to collect data from the test antenna.

Appendix:

1. Design Team's Schedule

Table 5 – Design Schedule

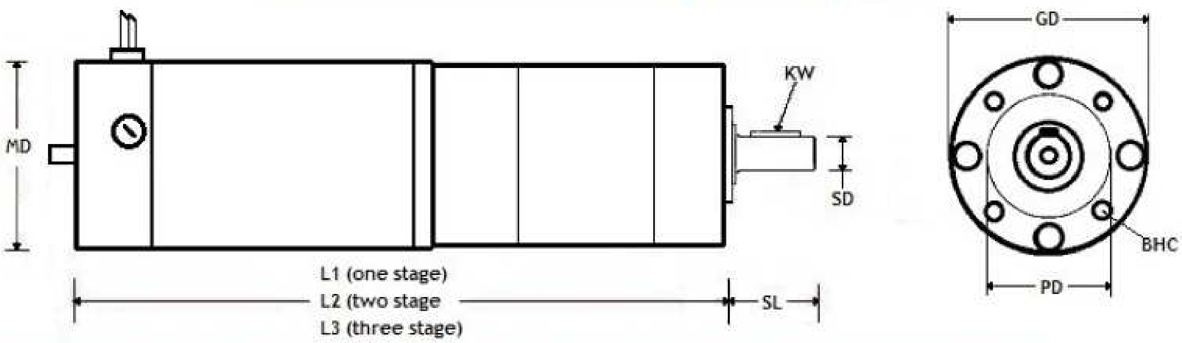
Project Task	Time Required for Task	Start Date	End Date
Define Problem Statement	Day 1	June 5, 2011	June 6, 2011
Identify Users, Needs, Values	Day 1	June 5, 2011	June 6, 2011
Conduct Research, Dom. Knowledge	Week 1	June 5, 2011	June 12, 2011
I.D. Engineering Requirements	Week 2	June 12, 2011	June 19, 2011
Refine Problem Statement	Week 2	June 12, 2011	June 19, 2011
Create Functional Decomposition	Week 2	June 12, 2011	June 19, 2011
Generate Working Concepts	Week 3	June 19, 2011	June 26, 2011
Assess Working Concepts	Week 4, Week 5	June 26, 2011	July 9, 2011
Embodiment of Final Design	Week 6, Week 7	July 10, 2011	July 23, 2011
Develop Manufacturing Plan	Week 8	July 24, 2011	July 31, 2011
Order/ Ship/ Manufacturing Plan	Week 9, Week 10, Week 11, Week 12	July 31, 2011	August 27, 2011
Assemble Working Prototype	Week 13, Week 14, Week 15	August 28, 2011	September 17, 2011
Test and Make Revisions	Week 16, Week 17, Week 18, Week 19	September 18, 2011	October 15, 2011

2. Component Specification Sheets

Midwest Motor Specifications

MMP

Date: 08 Feb, 2010 Prepared for: Production
Model Number: MMP D22-376H-24V GP52-016



INTEGRAL BRAKES AND OPTICAL ENCODER OPTIONS AVAILABLE – SEE PAGES 2 AND 3 FOR DETAILS

DIMENSIONS:	(Note: Center of output shaft contains an M-4 threaded hole)
MD = 2.25” (57mm)	SL = 25mm (21mm usable)
L2 = 7.20” (183mm)	GD = 2.047 (52mm)
KW = 4 x 4 x 16mm long	PD = 32mm, pilot length = 3mm
SD = 12mm; +0, -21µm	BHC (dia) = M5 x 10mm deep (4 ea) on a 40mmØ BC

DC MOTOR PERFORMANCE PARAMETERS:	VALUE	UNITS	TOLERANCE
Rated DC Voltage	24.0	DC VOLTS	-----
Rated Continuous Current	1.7	AMPERES	-----
No-Load Speed	2200	RPM	MAX
Rated Speed	1900	RPM	+/- 15%
Rated Continuous Power out	35	WATTS	+/- 15%
Rated Continuous Torque	25.0	OZ-IN	-----
Peak Torque (motor only)	150	OZ-IN	-----
No-Load Current	0.27	AMPERES	MAX
Back EMF Constant (Ke)	10.8	V/KRPM	+/- 10%
Torque Constant (Kt)	14.6	OZ-IN/AMP	+/- 10%
DC Armature Resistance (@1.5 amps)	3.8	OHMS	+/- 15%
Armature temperature	155	DEG. C	MAX

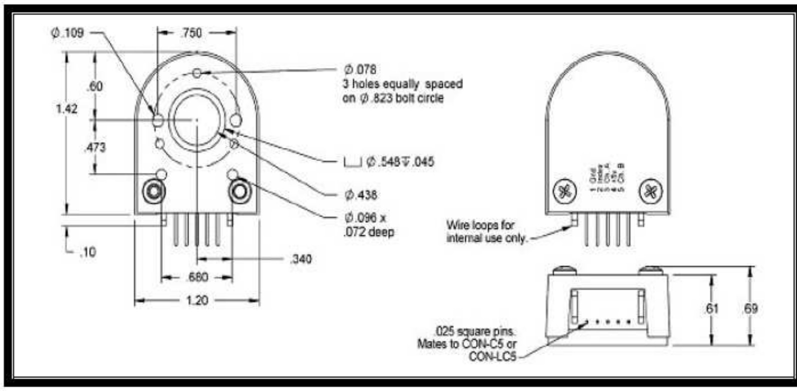
PLANETARY GEARMOTOR OUTPUT PARAMETERS:	VALUE	UNITS	TOLERANCE
Gearhead Ratio (exact)	15.88 : 1		
Gearmotor Rated Continuous Torque	19	IN-LBS	MAX
Gearmotor Rated Peak Torque	212++	IN-LBS	MAX
Gearhead Shaft Output Speed (at full-load)	120	RPM	-----
Gearhead Standard Backlash	45	ARC MINUTES	MAX
Gearhead Efficiency	75%	-----	-----
Gearmotor Total Weight	58	OZ	MAX

++ All Peak Torque Values are dependent upon duty. Consult our Sales Offices for details.

Figure 19 – Motor Specifications

MIDWEST MOTION ENCODER SPECIFICATIONS

Option 1: Optical Encoder **Consult our Sales Office for Pricing**



Interconnects / Functions

Pin Number	Function	Color
Pin 1	Ground	Brown
Pin 2	Index	Violet
Pin 3	Channel A	Blue
Pin 4	+ 5 Volts	Orange
Pin 5	Channel B	Yellow

****Encoder resolutions available: 32 PPR, 100 PPR, 250 PPR, 500 PPR, 1024 PPR**

(Use suffix "EU-xxx" after model # to designate the encoder and its resolution)

The standard modular encoder option, mounted integrally to the back of the motor,
includes an index pulse, and 12" long flying leads with connector - mounted and tested before shipping.

Figure 20 – Encoder Specifications

POLOLU MOTOR CONTROLLER

Figure 21 – Polulu Motor Controller

Key Features

- Simple bidirectional control of one DC brush motor.
- 5.5 V to 30 V (18v7, 18v15, and 18v25) or 40 V (24v12 and 24v23) operating supply range.
- 7 A to 25 A maximum continuous current output without a heat sink, depending on controller model
- Four communication or control options:
- USB interface for direct connection to a PC.
- Logic-level (TTL) serial interface for direct connection to microcontrollers or other embedded controllers.
- Hobby radio control (RC) pulse width interface for direct connection to an RC receiver or RC servo controller.
- 0–3.3 V analog voltage interface for direct connection to potentiometers and analog joysticks.
- Simple configuration and calibration over USB with free configuration program (Windows 7, Vista, Windows XP, and Linux compatible).

Additional Features

- Adjustable maximum acceleration and deceleration to limit electrical and mechanical stress on the system.
- Adjustable starting speed, maximum speed, and amount of braking when speed is zero.
- Optional safety controls to avoid unexpectedly powering the motor.
- Input calibration (learning) and adjustable scaling degree for analog and RC signals.
- Under-voltage shutoff with hysteresis for use with batteries vulnerable to over-discharging (e.g. LiPo cells).
- Adjustable over-temperature threshold and response.
- Adjustable PWM frequency from 1 kHz to 22 kHz (maximum frequency is ultrasonic, eliminating switching-induced audible motor shaft vibration).
- Error LED linked to a digital ERR output, and connecting the error outputs of multiple controllers together optionally causes all connected controllers to shut down when any one of them experiences an error.
- Field-upgradeable firmware.

USB/Serial features:

- Controllable from a computer with native USB, via serial commands sent to the device's virtual serial (COM) port, or via TTL serial through the device's RX/TX pins.
- Example code in C#, Visual Basic .NET, and Visual C++ is available in the Pololu USB Software Development Kit
- Optional CRC error detection to eliminate communication errors caused by noise or software faults.
- Optional command timeout (shut off motors if communication ceases).
- Supports automatic baud rate detection from 1200 bps to 500 kbps, or can be configured to run at a fixed baud rate.
- Supports standard compact and Pololu protocols as well as the Scott Edwards Mini SSC protocol and an ASCII protocol for simple serial control from a terminal program.
- Optional serial response delay for communicating with half-duplex controllers such as the Basic Stamp.
- Controllers can be easily chained together and to other Pololu serial motor and servo controllers to control hundreds of motors using a single serial line.