NEPTUNE TECHNOLOGY GROUP

AUTOMATED DATA COLLECTION FOR ANTENNAS

MECH 4240 CONCEPTS REVIEW

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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 motion of the carriage will meet or exceed the requirements set forth by the sponsor, Neptune Technology. The carriage and track design must be developed must be developed according to the systems engineering process outlined in MECH-4240, Comprehensive Design 1. The purpose of this report is to detail and illustrate the progress made towards the final design by showing the steps of a proper design analysis. Important factors to be considered in this design include weight, cost, maintenance and reliability, and a reduction of electromagnetic interference due to physical components. The merits of each concept developed are discussed and evaluated against the overall design requirements. The report covers four different working concepts, with the primary concept of a battery-powered, motor controlled, gear driven system being recommended. Further design plans for the battery powered design will be given at the conclusion of the concept review and future plans for analysis and prototyping will be presented.

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INTRODUCTION:

The Neptune Technology Group has been a major producer of water meters since 1892 and since then, they have collected over 119 years of experience in better-quality service to the water utility industry. Neptune Technology Group has been able to produce mobile data collectors such as the MRX920 that has the ability to take 5,000 readings per hour along with being wireless and weighing less than 5 pounds. Neptune Technology Group is 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 automating the data collection process for antennas under test, 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 ft. 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 the carriage is moved to various locations around the track by two technicians who manually collect data from the receiver. This set-up is time consuming, uncomfortable, and inefficient.

The design task at hand is to create an automated receiver that will go along a track of 50 feet in diameter. There are currently no designs that will be sufficient at accomplishing this task, so the goal behind the design will be to create and manufacture this automated receiver from scratch. The design of the automated receiver and its components may be based off of a battery powered roller coaster or a new design may be developed to accomplish the tasks described above.

In this concepts review, a general overview of design ideas for the automated carriage is presented. The purpose of this review is to convey the ideas of the designs considered for production and to show which design best fulfills the mission objective stated below. A cost analysis of each design will be shown as well as advantages and disadvantages of each design. In conclusion of the review, the concept chosen for further design will be determined and future plans for the chosen concept will be discussed.

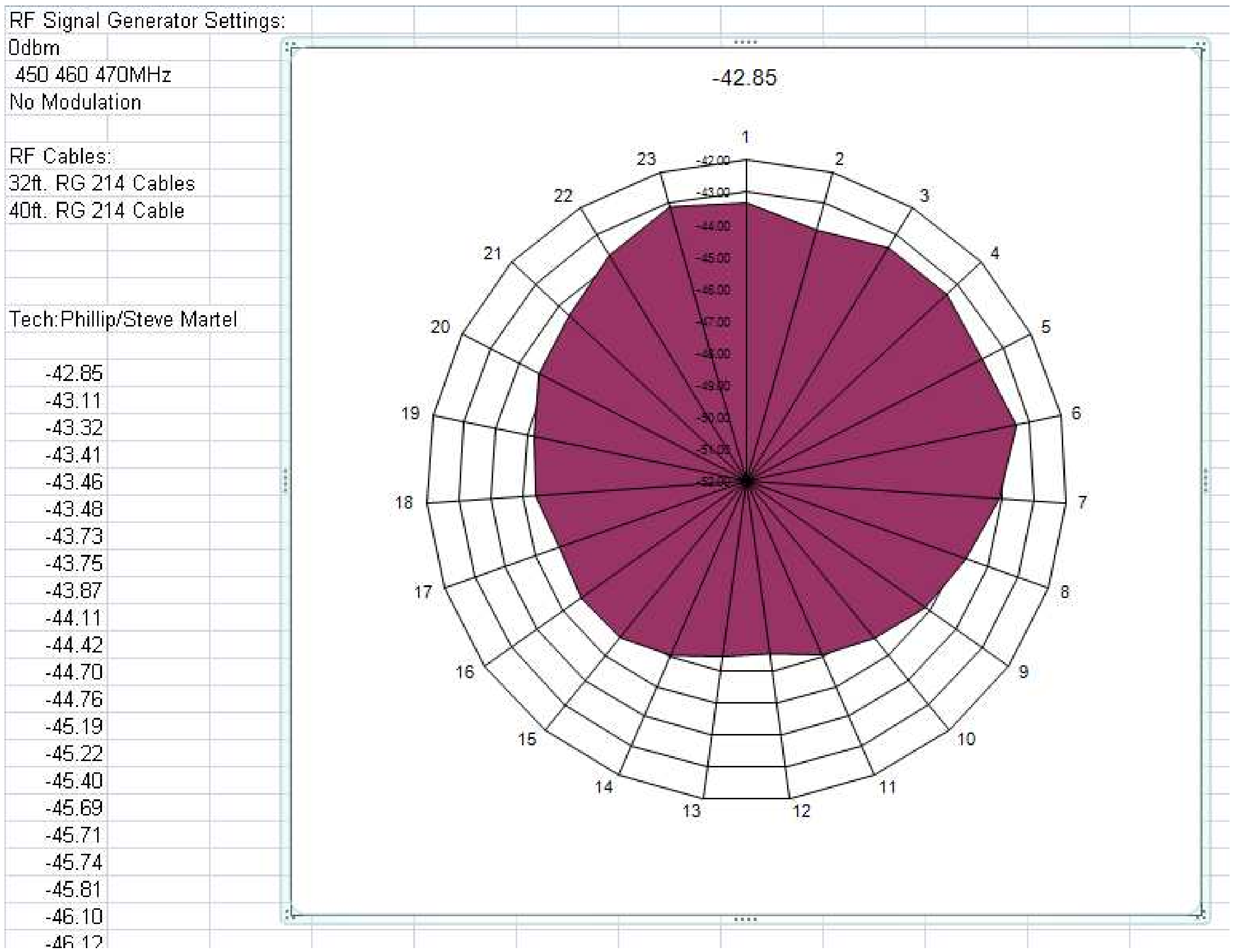

Figure 1 – Typical Signal Strength Plot

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 due to it being carried inside the base station in case of severe weather. The major use for this device will be for receiving a signal produced by a water meter in the middle of the 50 foot diameter circle and measuring the intensity of the signal; therefore the apparatus will have to be secured safely to the track.

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 in the figure below (Figure 2).

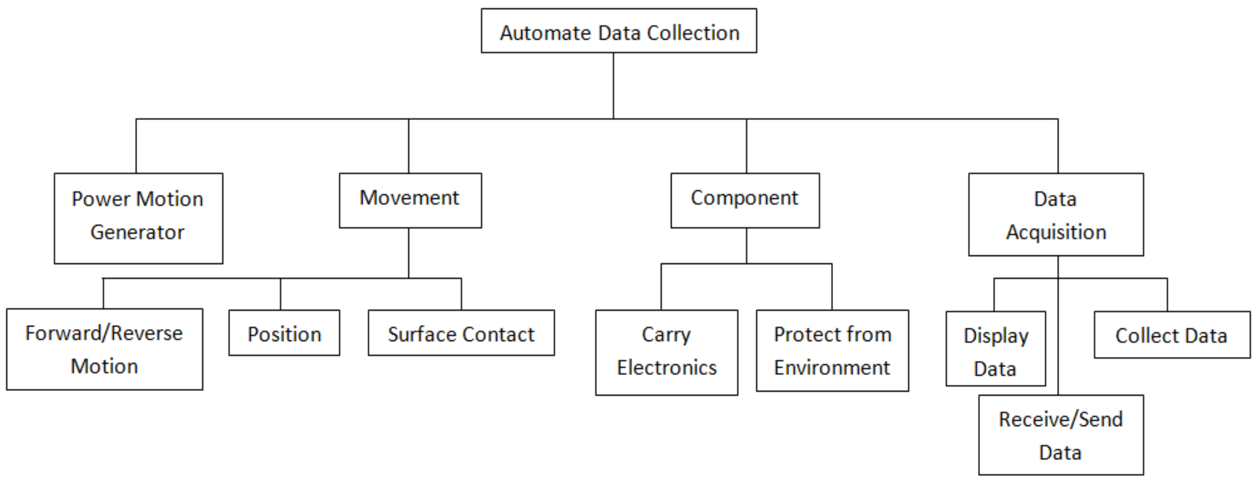

Figure 2 – Corp_4 Functional Decomposition

CONCEPT 1: BATTERY POWERED, WHEEL DRIVEN

Advantages:

- Relatively inexpensive and lightweight design
- Steel carriage can be easily shaped, cut, bent, and welded
- Constant RF interference by motor that circles the track with the test antenna reducing error in collected data
- Under heavy loads, material will bend before breaking

Disadvantages:

- Battery will have to be recharged/replaced frequently
- Possible slip between rollers and track

The battery powered/wheel driven design consists of a steel platform mounted on a set of wheels in which the front axle is being driven by the battery powered DC motor. This design will provide a constant radio frequency noise coming from the motor and will be accounted for in the frequencies experienced from the receiver. The steel platform will be covered in a material that will reduce corrosive effects since it will spend the majority of its time outside. The electronics and the battery will be removable to reduce the risk of overheating the electronics. The goal of the battery powered/wheel driven system is to reduce weight and maintenance while having fewer moving parts. An image of the battery powered/wheel driven design is shown below (Figure 1).

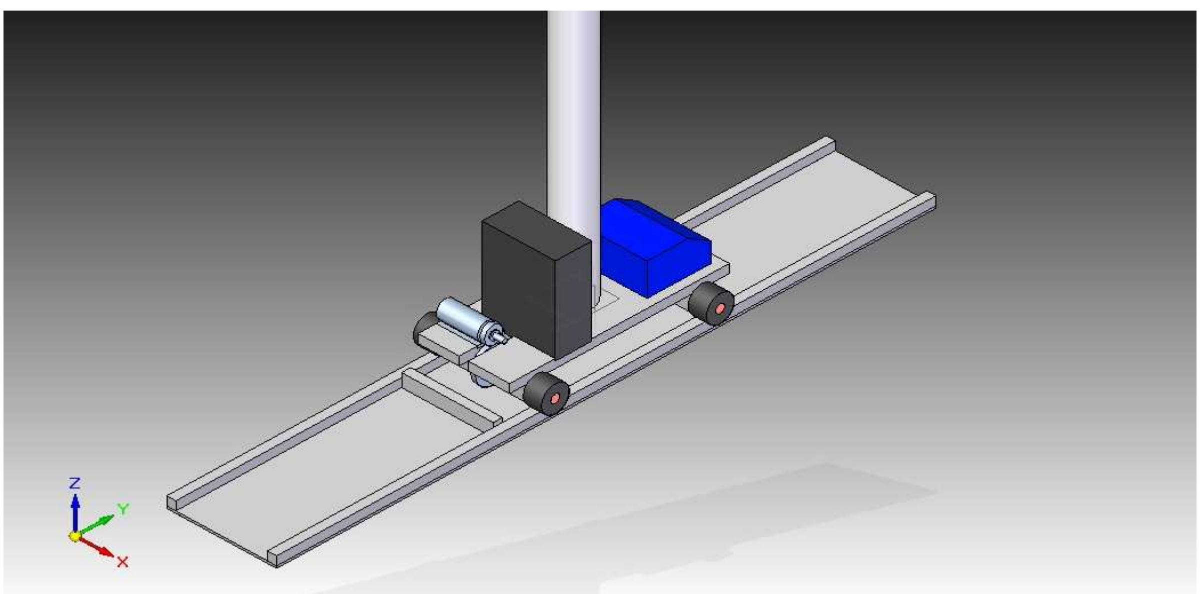

Figure 3 – Battery Operated/Wheel Driven Platform

PRODUCT HIERARCHY: Battery Powered/Wheel Driven Concept

- SUBSYSTEM 1: Power Motion
  - DC Motor
  - Battery
  - Gear Driven Wheel

- SUBSYSTEM 2: Movement
  - Forward/Reverse Motion
  - Position
  - Surface Contact

- SUBSYSTEM 3: Carriage Component
  - Carry Electronics
  - Environmental Protection

- SUBSYSTEM 4: Data Acquisition
  - Display Data
  - Collect Data
  - Send/Receive Data

FIRST-CUT BILL OF MATERIALS: Battery Powered/Wheel Driven Platform

Table 1 – Bill of Materials: Battery Powered/Wheel Driven

Manufacturer	Product	Price	Quantity	Total
Weldasprocket (Tractor Supply Co.)	Sprockets	37.99	1	37.99
Marathon Electric (Tractor Supply Co.)	Electric Motor	109.99	1	109.99
MetalsDepot.com	Stainless Steel 4'x4' 16 GA. Sheet	204	1	204
MetalsDepot.com	Stainless Steel 1'x2' 0.25" Sheet	159	1	159
Northern SPAL	4" Miniseries fan	74.74	1	74.74
Tractor Supply Company	Roller Chain, Size 40	16.99	16	271.84
Mapp Castor	U-Groove Steel Wheels	81.66	4	326.64
MetalsDepot.com	2"x1"x16 GA. Rectangular Tubing	42	2	84
MetalsDepot.com	1.5" Round Cold Drawn Tubing	250	16	4000
Battery Source	Battery	115	1	115
Total				$5,383.20

Concept 2: Monorail Concept

Advantages:

- "Unlimited" access to power supply for motor
- Motor mounted on carriage to reduce RF error in readings taken

Disadvantages:

- Safety issues
- High cost
- Problematic maintenance, difficult to service due to limited market
- Overseas market

The monorail concept consists of a motor mounted on a carriage that drives a wheel via a set of gears. The motor will receive power from the monorail that will be mounted to the existing track and will also be able to reduce the RF interference. The platform will be fixed to 3 wheels with only one being driven by the motor. The wheels will fall in line with the angle iron that will be bolted to the concrete pad keeping the carriage in its path. An image of the monorail design is shown below (Figure 4).

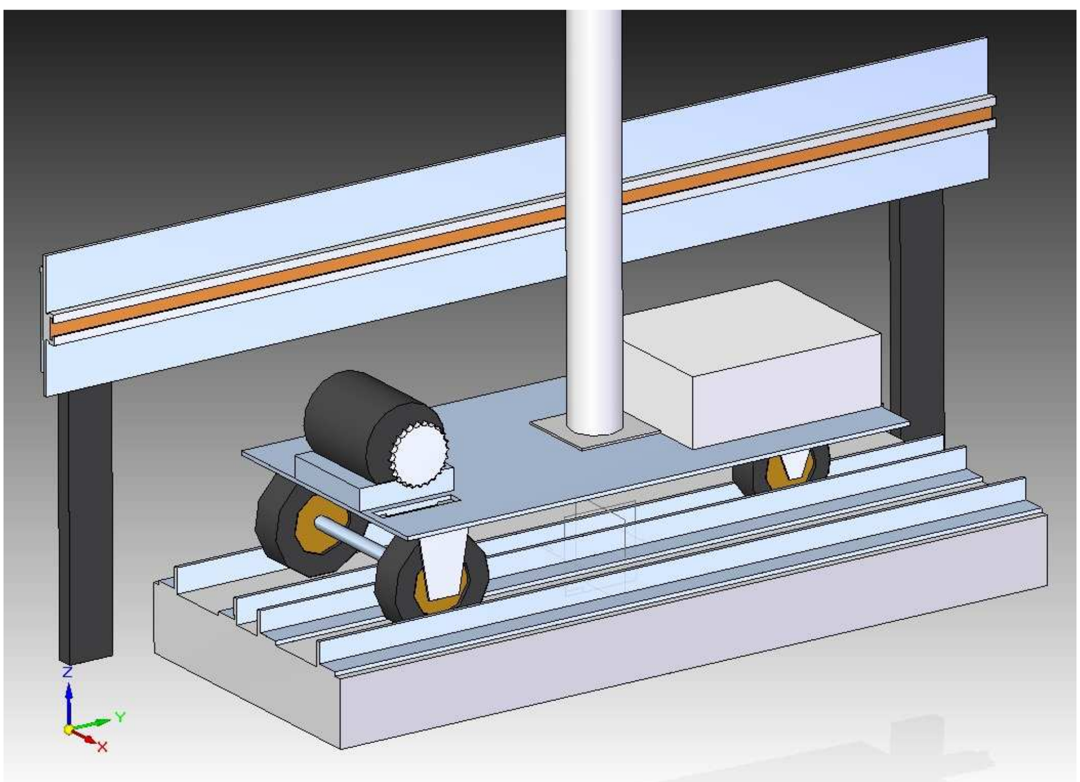

Figure 4 - Monorail Platform (Tether cable not shown)

PRODUCT HIERARCHY: Monorail Concept

- SUBSYSTEM 1: Power Motion
  - AC Motor
  - Monorail
  - Gear Driven Wheel

- SUBSYSTEM 2: Movement
  - Forward/Reverse Motion
  - Position
  - Surface Contact

- SUBSYSTEM 3: Carriage Component
  - Carry Electronics
  - Environmental Protection

- SUBSYSTEM 4: Data Acquisition
  - Display Data
  - Collect Data
  - Send/Receive Data

FIRST-CUT BILL OF MATERIALS: Monorail Platform

Table 2 – Bill of Materials: Monorail

Manufacturer	Product	Price	Quantity	Total
Northern Tool and Equipment	6 inch rubber wheel/tire	12.99	2	25.98
AngletonSalvage.com	2"x2" angle iron	32	16	512
Grizzly (Amazon)	G8165 5" Heavy-Duty Fixed Caster	10.25	1	10.25
Weldasprocket (Tractor Supply Co.)	Sprockets	37.99	4	151.96
Marathon Electric (Tractor Supply Co.)	Electric Motor	109.99	1	109.99
MetalsDepot.com	Stainless Steel 4'x4' 16 GA. Sheet	204	1	204
MetalsDepot.com	Stainless Steel 1'x2' 0.25" Sheet	159	1	159
Northern SPAL	4" Miniseries fan	74.74	1	74.74
	Concrete Pad	2000	1	2000
Gobrel	Monorail	10000	1	10000
Total				$13,247.92

CONCEPT 3: OUTLET POWERED, CHAIN DRIVEN DESIGN

Advantages:

- "Unlimited" access to power supply for motor (no recharges)
- Longer life for the electronics

Disadvantages:

- More moving parts, more friction than other concepts
- Chain stretching inevitable
- More costly compared to other designs

This design choice makes it much easier to reduce weight on the carriage itself since the motor will be place on the ground. The motor will make use of the AC outlet that is within close proximity to the track. The design features a stationary motor and sprocket driving a chain that moves throughout the guides and along the track. The carriage is attached to the chain by a small platform on rollers that guide it as it circles the track. To reduce friction the chain is guided in custom machined pieces of oil-filled UHMW plastic. The chain also features self-lubricating plastic rollers with stainless steel links so there would be a small amount of maintenance required. A slot would have to be cut out from the steel flange to allow for the sprocket to interface with the wheels. An image of the outlet powered/chain driven design is shown below (Figure 5).

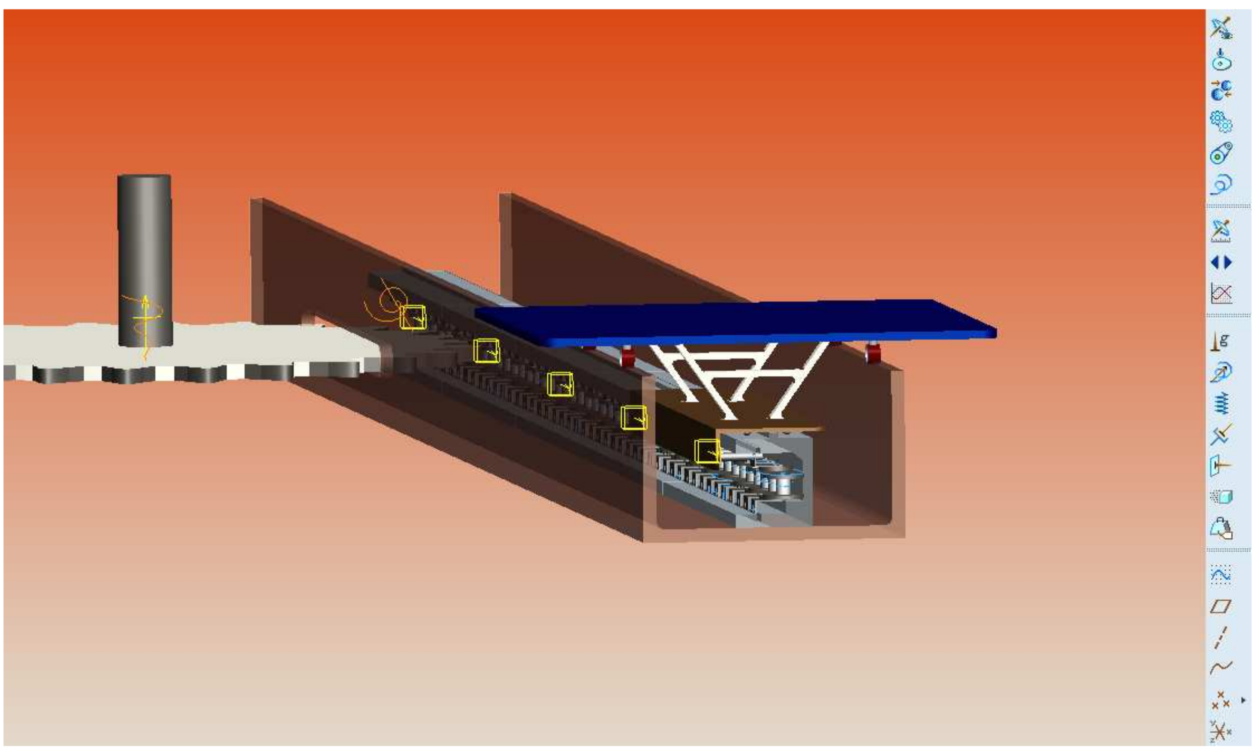

Figure 5 – Outlet Powered/Chain Driven Platform

PRODUCT HIERARCHY: Outlet Powered/Chain Driven Concept

- SUBSYSTEM 1: Power Motion
  - AC Motor
  - Gear Driven Chain

- SUBSYSTEM 2: Movement
  - Forward/Reverse Motion
  - Position
  - Surface Contact

- SUBSYSTEM 3: Carriage Component
  - Carry Electronics
  - Environmental Protection

- SUBSYSTEM 4: Data Acquisition
  - Display Data
  - Collect Data
  - Send/Receive Data

FIRST-CUT BILL OF MATERIALS: Outlet Powered/Chain Driven Platform

Table 3 – Bill of Materials: Outlet Powered/Chain Driven

Manufacturer	Product	Price	Quantity	Total
Weldasprocket (Tractor Supply Co.)	Sprockets	37.99	1	37.99
Marathon Electric (Tractor Supply Co.)	Electric Motor	109.99	1	109.99
MetalsDepot.com	Stainless Steel 4'x4' 16 GA. Sheet	204	1	204
MetalsDepot.com	Stainless Steel 1'x2' 0.25" Sheet	159	1	159
Northern SPAL	4" Miniseries fan	74.74	1	74.74
Tractor Supply Company	Roller Chain, Size 40 (10 ft)	16.99	16	271.84
WhiteFab	I-Beam	7500	1	7500
Slideways	Composite Plastic	7000	1	7000
US Tsubaki	Plastic Roller Chain	60	16	960
McMaster-Carr	Ball Bearing Transfer Plate	35	1	35
Total				$16,352.56

CONCEPT 4: BATTERY POWERED/CHAIN DRIVEN DESIGN:

Advantages:

- Motor on carriage allows for a constant RF "interference"
- Lightweight
- Fewer moving parts, lower friction and maintenance
- Gear driven
    - More accurate positioning
    - Better surface contact

Disadvantages:

- Battery will have to be recharged/replaced frequently

This design choice is very similar to the first concept with the advantage of the carriage having a sprocket and chain design. The carriage will be placed on a square or round tubing track that will be placed on the existing track. A motor will be mounted to the carriage and will drive itself via a set of gears and a chain that is fixed to the edge of the track. There will be fewer moving parts with this design but unfortunately the battery will have to be charged and replaced frequently. An image of the battery powered/chain driven design is shown below (Figure 6).

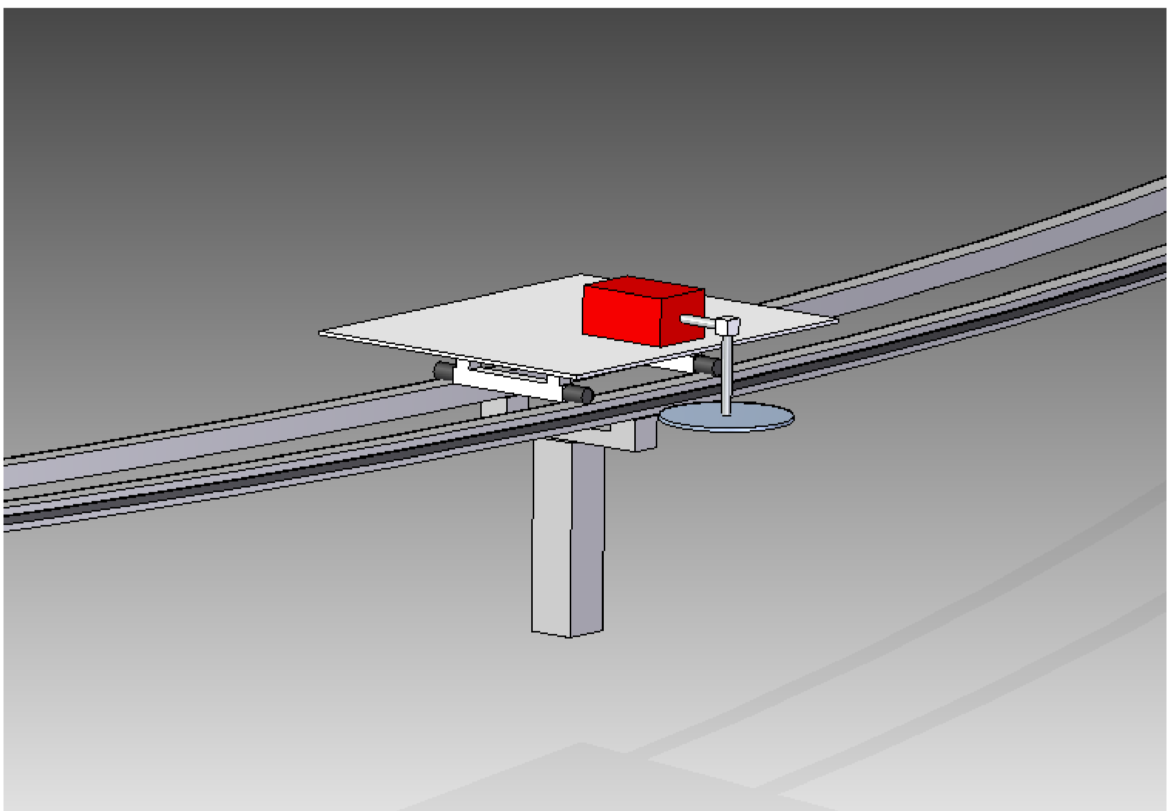

Figure 6 – Battery Powered/Chain Driven Platform

PRODUCT HIERARCHY: Battery Powered/Chain Driven Concept

- SUBSYSTEM 1: Power Motion
  - DC Motor
  - Battery
  - Chain Profile

- SUBSYSTEM 2: Movement
  - Forward/Reverse Motion
  - Position
  - Surface Contact

- SUBSYSTEM 3: Carriage Component
  - Carry Electronics
  - Environmental Protection

- SUBSYSTEM 4: Data Acquisition
  - Display Data
  - Collect Data
  - Send/Receive Data

FIRST-CUT BILL OF MATERIALS: Battery Powered/Chain Driven Platform

Table 4 – Bill of Materials: Battery Powered/Chain Driven

Manufacturer	Product	Price	Quantity	Total
Grizzly (Amazon)	G8165 5" Heavy-Duty Fixed Caster	10.25	1	10.25
Weldasprocket (Tractor Supply Co.)	Sprockets	37.99	1	37.99
Marathon Electric (Tractor Supply Co.)	Electric Motor	109.99	1	109.99
MetalsDepot.com	Stainless Steel 4'x4' 16 GA. Sheet	204	1	204
MetalsDepot.com	Stainless Steel 1'x2' 0.25" Sheet	159	1	159
Northern SPAL	4" Miniseries fan	74.74	1	74.74
Tractor Supply Company	Roller Chain, Size 40 (10 ft)	16.99	16	271.84
Mapp Castor	U-Groove Steel Wheels	81.66	4	326.64
MetalsDepot.com	2"x1"x16 GA. Rectangular Tubing	42	2	84
MetalsDepot.com	1.5" Round Cold Drawn Tubing (20 ft)	250	16	4000
Battery Source	Battery	115	1	115
Total				$5,393.45

REQUIREMENTS:

- Drive receiver around 50’ diameter track in under 4 minutes
- Weather resistant
- Removable electronics
- Cooling for the electronics
- Low RF interference
- Take readings from receiver every 15 degrees track
- Know resolution to within 1 degree

CONCEPT OF OPERATIONS:

A receiver will be mounted to a platform and a motor will drive it around a 50’ diameter track and collect data from a water meter placed in the ground in the middle of the track. The existing design is very simple and it requires a technician to push the platform around the track stopping every 15 degrees to take a reading. Neptune Technologies wanted to automate this process in order to wirelessly communicate with the base station that operates the receiver. A view of the current design is shown below (Figure 7).

Figure 7 – Current Platform and Track

Where the design will differ from the current platform design is the motor that will drive the platform around the track. Depending on the concept chosen, the motor will either be mounted to the platform and drive the carriage via a fixed chain or by wheel. The receiver will be mounted on the 3” PVC pipe as illustrated in the following picture that will eventually have the ability to move the receiver up and down the pipe (Figure 8).

Figure 8 - Current Receiver Mount

In order to make the carriage resistant to the elements, there will be a coating applied to all of the surfaces that will resist corrosion. The electronics will be coated with a special coating that resists moisture called conformal coating. This coating will be applied to the electronic circuitry to act as protection against moisture, dust, and temperature extremes that could result in damage or failure of the electronics to function. A sample of conformal coating is shown below (Figure 9).

Figure 9 – Conformal Coating

VALIDATE AND VERIFY:

A meeting with Neptune engineers was conducted on June 29, 2011 in order to present and discuss current ideas. Of the several design ideas, two were preferred over the others being presented. After discussion with the Neptune engineers, it was confirmed that the two main concepts were sound and could go forward into further design to determine a final concept. Once a final concept is decided upon and the material and system analysis has been conducted, the analysis will be reviewed by Neptune and Dr. Beale to verify the final design. From this point, initial prototyping will commence.

A few tests will need to be performed before the manufacturing stage to determine failure modes. A test will be conducted to find how much interference is caused by the electric motor. The results from this test will help reduce error by minimizing the noise that the receiver picks up from the motor. Another test planned for the future is to ensure that the motor and battery are sized correctly and that the cart can remain on the track while powered by the sprocket and chain.

Mission Environment:

The mission environment for this project deals with the heat and humidity that comes with the climate of Alabama that will severely affect the testing equipment. Along with the outside environment, the size, shape, and radio frequency will be issues to overcome as well. The humidity will be a factor in the metallic components to rust. The sun's ultraviolet rays will affect the plastic parts as well. The design will have to be lightweight for easy transportation of the carriage to the base station. A heat-resistant shield and a fan will need to be utilized for the safe operation of the electronics while they are in use. The operators need to be assured that the carriage is able to take consistent measurements around the track and be able to duplicate the results if necessary. The operators also need to be able to break the carriage down if the weather starts getting bad or if the carriage needs to be modified for any reason.

Risk Management:

The motor that drives the platform could possibly fail and one way to overcome this failure is to add a clutch mechanism to the gearing. The clutch mechanism will allow the operators to use the carriage by disengaging the sprocket connected to the drive system. The track will be assembled in sections so if it is damaged in any way, the damaged section can be easily replaced. The Monorail Concept could possibly produce an electric charge across the metal track; therefore there will be a cutoff switch at the base station when it is not in use. In addition to safety, performance and longevity of the carriage life must be considered. The carriage cannot be made so rugged that its weight would prohibit proper use, which could lead to failure due to user error. Materials used must be considered for their ability to weather adverse conditions outdoors as well. Once a final concept is decided upon and prototyped, scale models, and material samples will be available and Failure Analysis and Destructive Testing will be done.

SYSTEM DESIGN ENGINEERING:

System design engineering documents the work to date on the system design efforts using the engineering design process. The concept comparison chart was generated using the process and in it, each concept was evaluated on a scale from one to five (five being optimal). For example, the Monorail concept scored low in maintenance because there are very few people that are available to work on the monorail if it needed to be repaired or modified. Another example is the Outlet powered/chain driven concept scored exceptionally well on the power supply life because it will ultimately have an AC outlet powering a motor that will drive the carriage around the track. The concept comparison chart is shown below (Table 5).

Table 5 – 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**

PROJECT MANAGEMENT:

Project management is an important part in group design due to the necessity to maintain order and organization throughout the design process. The following measures have been taken in order to manage the design process and can be found in the appendix of this report or attached:

- Design team's schedule
- Contracts of Deliverables (Included at the end of Concepts Review)
- Preliminary Power calculations for the chosen concept

CONCLUSION:

In conclusion, after presenting the concepts to Neptune Technology Group project engineers, it was decided to pursue the battery power/chain driven design. This design will fulfill all requirements including low radio frequency noise and the ability to take measurements in under 4 minutes. This overall design will weigh less than some of the other concepts since it will be battery operated. The final costs will not be the least expensive but it will benefit from less moving parts and ease of maintenance. The two possible track options being considered for the track design are the round and square tubing. The type and size of battery to be used will be analyzed based on how much power and torque is needed to move the carriage on the track. Once the specific drive system and type of battery is chosen, prototyping of the structure may begin to test the design. By the next review, a specific drive system and battery will be analyzed and determined. Also, prototyping of the design will have commenced.

APPENDIX:

1. Design Team's Schedule

Table 6 – Design Schedule

Project Tasks	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/Manufacture Parts	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	Sept. 17, 2011
Test and Make Revisions as Necessary	Week 16, Week 17 Week 18, Week 19	Sept. 18, 2011	October 15, 2011

2. Preliminary Power Calculations

The following curves show the power, force and torque required to move the carriage to a given velocity. The motor mechanical time constant was assumed to be 10 ms, which is a reasonable assumption for an electric motor. This time constant was used to find the carriage acceleration and then the required force to move the carriage at that acceleration. The curves (Figures 10 – 12) were generated in Matlab.

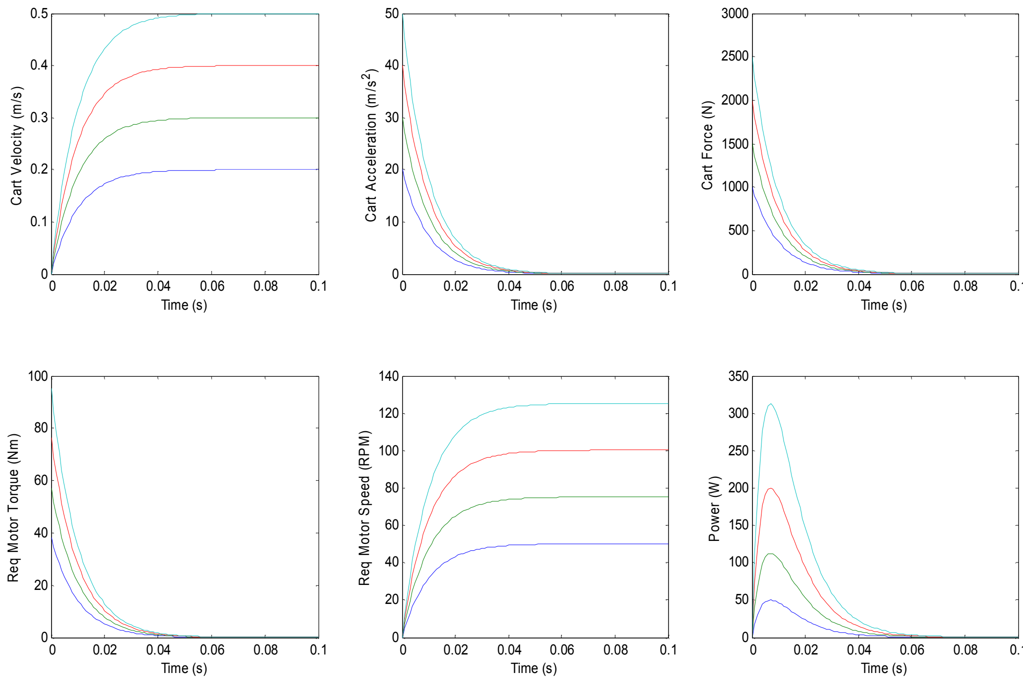

Figure 10 – Power, Torque, Velocity Curves

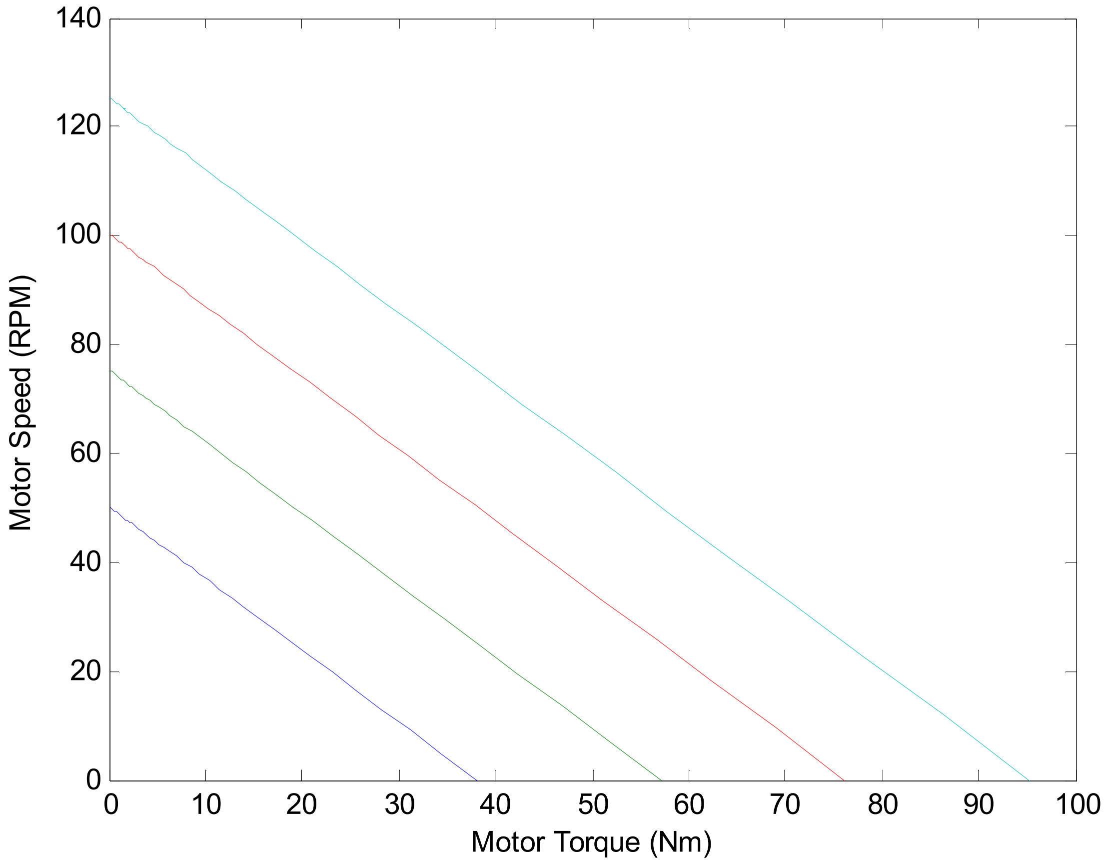

Figure 11 – Required motor speed vs. Required Motor Torque for given Carriage velocities

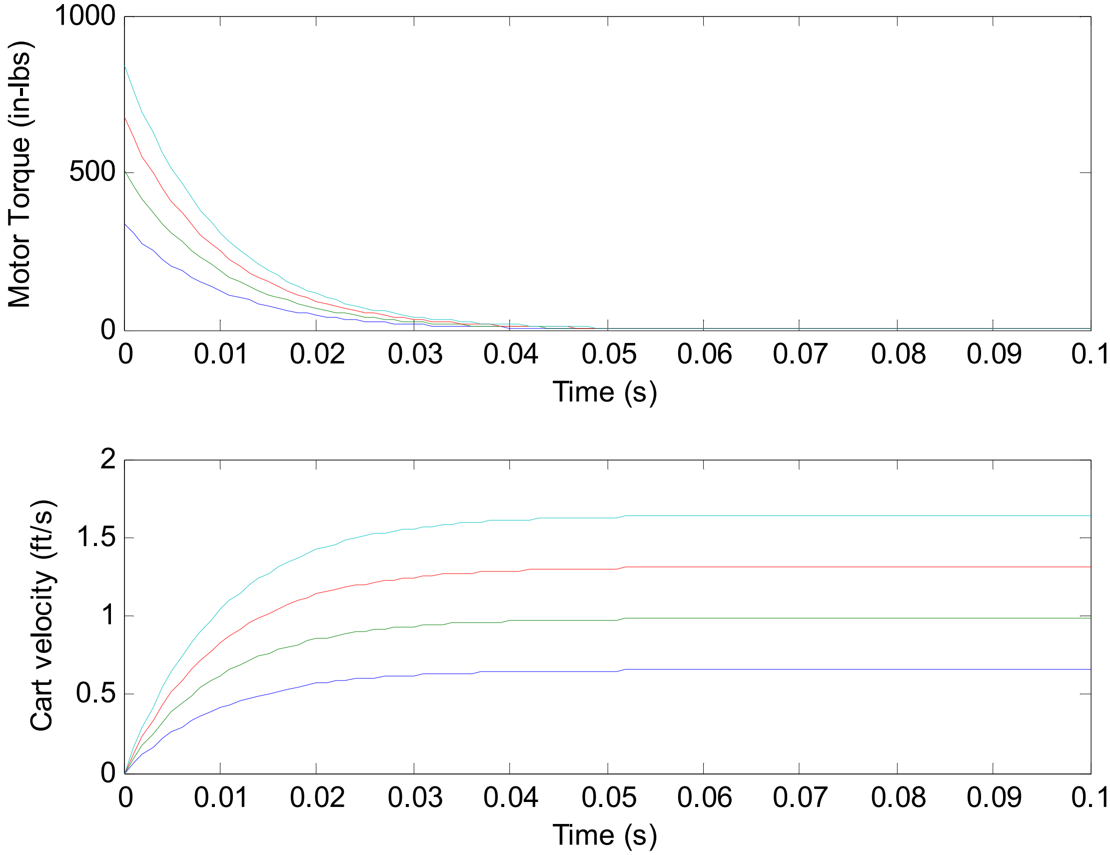

Figure 12 – Motor Torque and Cart Velocity in English Units