Design of a Semi-Autonomous Robot for Search and Rescue

MME 4487a Mechatronic System Design

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Abstract**—** This report reviews the design process of a semi-autonomous robot designed to extract radioactive material from a debris zone. It details the engineering considerations, including product design requirements and constraints, as well as subsequent concept design iterations, product generation and product evaluation. The report concludes that the semi-autonomous vehicle designed was successful, however can be improved by slight design changes in weight distribution, as well as enhancements to electronic communication. More detailed recommendations and future improvements are discussed for implementation in the generation of the vehicle.

I. INTRODUCTION

A scientific laboratory has collapsed during an earthquake and three metallic objects (a small sphere, a large sphere and a large iron rod) have scattered throughout the debris of the collapsed building along with a number of false metallic objects. Our team was tasked with the design and construction of a device that can move through rubble, search and gather the metal objects (a small sphere, a large sphere and a large iron rod), and deliver them safely to a separate containment unit away from the debris. A semi-autonomous robotic system is to be developed that will traverse rough terrain and explore a debris zone. This debris zone is modeled by sand and surrounded by a layer of rocks (see Figure 1).

Figure 1: Arena layout for robot demonstration. Two spheres and an iron rod are the metal objects to be collected from the sand pit surrounded by a layer of rocks.

In order to develop a solution to the above scenario, the engineering design process (preliminary, conceptual and detailed design) followed by the creation and bench testing of a working prototype was used. Our group held to a design philosophy of keeping all components and assemblies as simple as possible. Initial design requirements and constraints were provided in the project description, and further engineering targets and specifications were developed to quantify concept selection criteria. Multiple concepts for various sub-systems were generated, and the selection and evaluation of these concepts was conducted using standard design methodology (eg. decision matrix, go/no-go process). A Gantt chart was developed to ensure that design, building and testing could be completed before the demonstration date, and two design reviews were used to get feedback regarding current progress, critical problems encountered and advancement to the next design phase. Finally, a prototype based off the final selected design was developed and iterative testing was used to modify and refine said prototype to a functional and modular self-powered robot.

II. DISCUSSION

A. Product Design requirements and constraints

In preparation for the first design review, each key mechanism in the search and rescue method was identified via a block diagram showing the main function of the robot and how feedback could be implemented through a feedback loop (see adjacent Figure 2). From the visual flowchart shown below, the following subsystems required for accomplishing the target objective were identified: chassis and drive mechanism (mechanical system), sensing and detection mechanism (electrical system), collection mechanism (electromechanical system) and dispensing mechanism (electromechanical system). Feedback control could be provided in the sensing mechanism and automation could be provided in the dispensing mechanism.

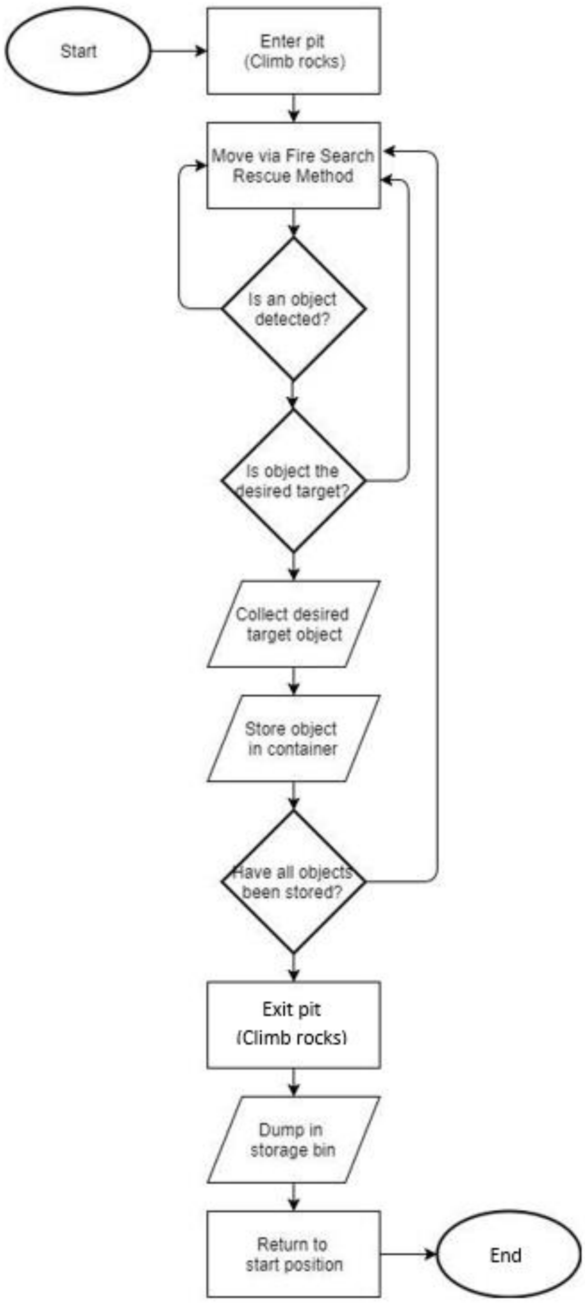

Figure 2: Block diagram of search and rescue method.

Our team was also tasked with quantifying key design constraints, engineering requirements and engineering targets/specifications to be used in the concept evaluation and selection phase. A summary of these key features is shown in point form below:

Key Design Constraints:

- Modular components (VEX components provided)
- Semi-Autonomous (requires feedback loop)
- Self-Powered (S449 LiPo battery provided in lab)

- Must fit within 40x40x40 cm^3 cube
- Must have at least one critical component 3D printed (Makerbot Replicator V5 3D printer provided)

Engineering Requirements:

- False metallic objects scattered under sand (unknown geometry/weight)
- Remote control (using PIC24H MCU and Bluetooth HC-05 modules provided)
- Must have wireless camera mounted on robot car

Engineering Specifications/Targets:

- Must retrieve three target objects in under 5 minute timeframe
- Must draw less than 181 W of electrical power provided in timeframe (see power calculations in APPENDIX)
- Bluetooth module should function without communication loss greater than 5 seconds and at a distance of 8 meters or less
- Vehicle should be able to drive over an incline of 45 degrees or less

The parameters of target objects are known and are shown in Table 1 below:

Table 1: Target object parameters

Target Object	**Material**	**Mass (g)**	**Length (mm)**	**Diameter (mm)**
Small Sphere	Stainless Steel	66.85	---	25.41
Large Sphere	Stainless Steel	225.72	---	38.06
Large Rod	Iron	316.44	177	17.83

In particular interest, the key design constraint of having the robot car self-powered was explored. Based on the S449 LiPo battery provided in the lab as well as the VEX DC motor specifications provided online ("Motors," 2017), a maximum electric power of 181W was calculated and it was determined that a maximum of 8 motors could be continuously used over a period of 5 minutes with a 20% margin (see power calculations in Appendix for further details). This meant that there would be ample power available to power additional motors (eg. for wireless camera, turntable, gripper and dispenser mechanisms), and that active sensors could be explored (eg. electromagnet, induction sensor, etc).

B. Conceptual Design Development & Evaluation

Chassis

For the chassis of the robot, VEX components were used as the main structure of the robot, as they provided enough modularity in the piece size, hole location and orientation to build the robot effectively. Additionally, VEX components also provided enough structural support as the skeleton of the robot. Before completing the build of the chassis, a preliminary test was conducted on the skeleton frame of the robot, to make sure that the components could handle the torque created by the motors as well as the overall weight of the other components including the lifting mechanism and storage mechanism. A rectangular base was used to maximize the working surface on the top of the robot, while maintaining stability during motion. To help reduce the chances of getting stuck the motor locations were set to have the flattest possible bottom of the robot. To ensure the motors were also never under any stress when driving they were covered by VEX components for added protection.

Drive Train Set up

The four-wheel design was used due to the motor limitation encountered. Having four wheels required only four motors but would allow for ease of maneuverability of the robot over the rocks as well as the sand. A track system or a third wheel on each side was concerned however they were eliminated as possible concepts. The track system had too many failure points that could result robot losing balance or getting stuck. The extra wheel with or without a motor would increase the overall size of the robot and would increase the chance of debris getting stuck between the wheels.

Collection Mechanism

Three possible concepts were discussed for how the target object would be collected. The first concept was a claw mechanism that would extend and grab the desired object. The second design was a telescoping magnet and pulley system. This design worked by having a pulley at the top of the telescoping arm what would control the extension of the system with a motor. At the bottom of the system a magnet would be aimed to attract the target object and then lifted back up using the pulley. Finally, the third concept was a rack and pinion gripping system with a push rod and magnet. This system worked by using a rack and pinion to descend a gripper near the desired object where a magnet would attract the object and then lifted. For release of the object a push rod also connected to a gear system would extend to shear the object of the magnet.

A pair wise comparison matrix was used to decide on the best concept for the robot. The second concept, the telescoping magnet and pulley was set as the datum for the matrix and each engineering requirement was evaluated closely. Modularity was the first engineering requirement and the rack and pinion mechanism was the best fit for the design since it allowed the gears and their locations to be changed easily with iterative processes. The next engineering requirement was evaluated and the most semiautonomous option from the three concepts was the claw mechanism. The claw mechanism would allow for a single programmable push button that would allow the claw to automatically clamp down on the object. Next the rack and pinion was superior to the other designs as the most self-powered. The rack and pinion design required the least amount of power to operate the system compared to the claw and the telescoping magnet. The size constraint set at 40cm^3. The best fit for this constraint was the rack and pinion mechanism since this system was the most streamlined line in design and sat very close to the actual chassis of the robot this reduced its overall footprint. Finally, the last engineering requirement was satisfied by both the the claw mechanism and the rack and pinion mechanism. Both of these designs required a minimum of one piece to be 3d printed for the system to operate as required.

In conclusion, after evaluating each concept thoroughly using a pairwise comparison matrix (see Decision Matrix in Appendix), the best concept for the lifting mechanism was the rack and pinion magnet mechanism for its alignment with the key engineering requirements.

Dispensing mechanism

Two designs were discussed for the dispensing method of the objects into the target drop off location. The first method was a simple storage method were the items would be dropped in a rectangular bucket and stored during travel. Once the robot reached the desired drop of location the lifting mechanism would then drop of each item. The second design used a dumping bucket as a dispenser. This bucket was also a rectangular bucket with a spout near the end to aim the objects. The robot would line up at the desired location and a motor would lift a rack to the necessary height for the object to slide down the spout of the bucket. After close discussion and analysis the group decided to use the dumping method for its speed. Dumping all the items at once was much quicker than moving the arm back and forth to dispense each object.

C. Product Generation

With simplicity in mind, our group's focus was to use as many standard parts as possible to minimize the requirement for custom manufacturing. This allowed the delivery of a working prototype much faster, and also allowed for multiple rapid design iterations to be made on the few custom components that were selected for focus. VEX components were available to us through the course laboratories, and thus they comprised a large part of the vehicle chassis design.

Additive manufacturing methods were used to physically develop the collection mechanism. Due to the proliferation of moving parts, our group took the approach of designing rough models, and iterating physically from that point onwards. 3D printed components were made from PLA as this material was readily available for use with the Makerbot Replicator 5 in the course laboratories. In order to attain more stiffness in certain applications with 3D printed components, our group changed infill values and designed better wall supports on certain parts. The accuracy and rapid turnaround time of the Makerbot allowed for two revisions to be made of every part on the lifting mechanism.

Collection Mechanism

BAR-001, was designed for the express purpose of pushing downwards on an object of interest once it had been collected, and using that downward force to shear it off into the container on the vehicle, or into the dispensing port on the track.

GRIP-001, the right-hand-side of the gripping mechanism, was designed when our group was still implementing the two gripper configuration; rotating on the same pinion, and closing around an object of interest. The concept was arrested in the CAD detail design stage, when it became clear that fixturing for two grippers would be difficult to implement into the vehicle chassis, and that having only one gripper would be beneficial by reducing moving components. GRIP-001 was subsequently integrated into the frame design, and ultimately became the first revision of MECHFRAME-001.

GRIP-002 was designed to add to the pulling force of the magnets on GRIP-001 (ultimately MECHFRAME-001). This was considered especially important when collecting the heaviest objects of interest. Upon dispensing, it would move laterally outwards and disengage its magnet as BAR-001 moved downwards to push the object off MECHFRAME-001. GRIP-002 was initially designed in close conjunction with BAR-001, and thus they fit together exceptionally well. MECHFRAME-001 was designed around these components for the best fit of all the components.

MECHFRAME-002 was added to constrain BAR-001 within the assembly in the x-axis (longitudinal along the vehicle). It was initially designed as a clip-on part, in order to deal with tolerancing issues.

Regarding the manufacture of these parts; GRIP-002 and BAR-001 were printed on the same bed, and had excellent tolerancing with each other. However, many printed tolerances needed to be corrected due to better match the available VEX components that were used in conjunction with this build.

MECHFRAME-001 was rapidly designed and printed, in unison with MECHFRAME-002. Lots of interference checks were done physically, with the printed part being sanded down and made to fit, before those changes were translated back to CAD and implemented into MECHFRAME-001-REVB and MECHFRAME-002-REVB. A changelog of each critical 3D printed part is shown below:

MECHFRAME-001-REVB Changelog:

- Increased magnet hole diameter
- Decreased slot thickness
- Added wall to restrict GRIP-002 on pin
- Reduced dowel depth with MECHFRAME-002
- Increased wall thickness for bottom plunging claw
- Moved pins to avoid interference with BAR-001

GRIP-002-REVB Changelog:

- Magnet hole diameter increased
- Increased depth of stubs for VEX rack insertion
- Increased diameter of VEX stub hole
- Increased indent depth for magnet cavity
- Added fillet to slot better with BAR-001

BAR-001-REVB Changelog:

- Decreased length required for bolts
- Added beams to reduce compressive stress

Ultimately, MECHFRAME-002 was discarded prior to final drive, due to its unreliability at holding BAR-001 in place, and was replaced with a VEX component that better secured BAR-001.GRIP-002 was also rejected before final drive, due to high play in the slot of the part. Future improvements towards the next revision of these parts is detailed in the Recommendations section of this report.

Magnet Pulling Force

In order to determine the best magnets to use in our gripper mechanism, on both GRIP-002 and MECHFRAME-001, various combinations of stacked magnets and spacers were used until the desired holding force was achieved. Based on our selected gripper concept, the layout of the magnets would be penetrating perpendicular to the sand layer, and thus would be attracting objects and holding them in shear, due to the force of gravity. However, due to the ferritic nature of the sand in our testing pit, an attenuating layer of small metal particles was found on the face of our magnet after the first plunge. Therefore, this additional layer of sand needed to be taken into account when deciding on the magnet configuration. Additionally, since our goal was to knock off the object of interest using a pushoff bar, it was ensured that the magnetic holding wasn't so strong that it could overcome the motor power. In this decision, object pickup was tested using the large sphere.

Because magnetic pulling force follows the inverse square law, frequently, stacking more magnets was a detriment to overall pulling force, which gave us many combinations to play with. However, there were only so many magnets that could be stacked before it was geometrically untenable to package them into our design. Table 2 below shows the experimental data and go/no-go process used to select the optimal magnet for the collection mechanism:

Table 2: Various stacked magnet configurations, and how they tested against our criteria. These were all magnet configurations that could hold the iron rod, our heaviest object, in single shear. Assuming all magnets were cylindrical, and were arranged concentric to each other.

Magnet combination	Layer of sand thickness (mm)	Object Pickup Distance after sand layer buildup (mm)	Can DC VEX Motor push off object?	Can turntable rotate without object shearing off?
Neodymium x 3	4mm	18mm	No	Yes
Neodymium x 2	2mm	12mm	Yes	Yes
Neodymium + Ceramic + 3mm PLA spacer	~ 2mm	5mm	Yes	No
Neodymium + Ceramic	3mm	7mm	Yes	Yes

Both the **Neodymium x 2** and **Neodymium + Ceramic** configurations were suitable for our application. Ultimately, the **'Neodymium x 2'** configuration (denoting two stacked neodymium magnets) was selected as they had a greater sand buildup (due to greater magnetic force), they had significantly greater object pickup distance, which would allow us to be far less precise in how well the magnets were lined up to pick up an object.

Chassis and DriveTrain

During the chassis build, setbacks were encountered and iterations were needed to resolve issues along the way. One major issue encountered was axle friction for the drive train system. Despite the VEX components lining up, our robot experienced significant axle friction, adding more stress on the axle as well as the motor. To solve this, larger holes were drilled into the VEX components to reduce the axle friction. Additionally, black plastic brackets were added to aid in axle stability. Another iteration added was the location of the lifting mechanism. The lifting mechanism was placed closer to the front and offset to the right, to allow for enough room for rotation of the arm without it contacting the bed of the robot as well as the tires. To better balance this necessary weight shift of the lifting mechanism, the storage container was put on the back of the vehicle and the opposite side (left) with respect to the lifting mechanism. This improved the vehicle's CG, however required the operator to turn the arm towards the center of the robot when traversing the track. Finally, the layout described above was necessary to allow the bread boards and cable to neatly fit into the bed of the robot without conflicting with any of the robot's motions. The driver boards were placed near the bottom breadboard on the side of the chassis. This location maintained the clearance required for the lifting mechanism to turn without interference within the internal area of the robot for dispensing and traveling actions.

Circuitry/Coding

When considering possible methods for programming the drive mechanism, the design approach of building a simple program and circuit was used with further iteration and testing towards the final design solution. Circuitry and code from course labs was used (see pin layout and circuit in Appendix) to bench test the drive mechanism, and further refinement was used to add programming logic and hardware for push buttons controlling the lifting, turntable, gripping and dispensing mechanisms. An s420 DC driver board was used for each pair of wheels on each side (left or right) and a PWM signal with varying ONTimes (between 1-2ms) was used with timer interrupts to control the speed and direction of each pair of wheels.

VEX motors used for other control mechanisms were run at a full duty cycle, in the positive and negative directions, which were controlled by input pushbuttons on the controller side. Pin testing across the two MCU modules is further explored in the Product Evaluation section of this report. Our team also implemented a shutdown function into our robots code, to allow it to reliably perform on track when communication was lost with the controller.

Dispensing

During the initial concept selection, the dumping method resulted as the better option for the robot's dispensing mechanism. However, after closer evaluation during the build and subsequent testing of the robot, our group ascertained that dispensing the object by tilting the bucket was not as simple as initially expected. Since the bucket walls needed to be high enough for the object not to fall off while driving, this made the tilting angle required for dumping the objects higher than 90°. This angle was too steep for the rack and pinion method our group was using for the dump bucket. This also dramatically reduced the accuracy of the dumping method, due to the loss of control of the objects when they fell out of the bucket. After the setbacks faced with this method, our group reverted back to the second concept of merely utilizing a simple storage container, and using the lifting mechanism as the dispensing tool. Despite the impact this would have on our group's ability to complete the task in terms of speed, this was significantly simpler to implement and far more reliable a method. However, this method also had issues with the continuously rolling objects in the bucket as the robot traveled. This issue resulted in the lifting mechanism not reaching all the object when it was time to dispense as well as disrupting the center of gravity of the robot. To resolve this issue, magnets were placed under the acrylic bucket to attract the objects closer to the range of the lifting mechanism as well as to reduce the objects from rolling in the bucket when traveling.

D. Product Evaluation

Our team developed a testing plan in order to fully ascertain the limitations of our design, and to identify potential failure modes prior to prototype build and demonstration. The plan included tests to determine chassis torsion, vehicle roll propensity, magnetic penetration in sand, and Bluetooth communication fidelity, amongst others. A detailed breakdown of our testing plan can be found in the design notebook of Sameh Khan. The following is a brief description of key tests used during prototype development:

Drivetrain & Chassis

1. Chassis Torsion test

The chassis torsion test was designed to ascertain how many loading cycles the vehicle chassis could withstand before locknuts used to fasten it would begin to come loose. To perform this, all fasteners were tightened and the chassis was placed in end-to-end torsion until nuts slipped by half a thread or more down a bolt. Upon performing this test, our group found that fastener loosening within the five-minute timeframe was not present and that our vehicle had to perform on track.

2. Three-Wheel Grip test

The three-wheel grip test was designed to ascertain whether our vehicle could continue to traverse rocks when one of its wheels had lost contact with the ground surface. This situation could occur quite frequently, given the uneven terrain the robot car would be driving on. Additionally, it could occur because the track surface constituted of loose rocks, and thus the ground could 'give way under us'. To test this, our group placed the vehicle on an upwards incline (~35°), on a rocky surface, with only the front-left, rear-left, and rear-right wheels in contact with the rocky terrain. The vehicle was also loaded to maintain equilibrium in that position. Upon initiating drive motors, if the vehicle to break into drive from rest, then the torque provided by three motors was sufficient under loaded conditions at actuating the vehicle. Our vehicle performed excellently with this test, managing to break from rest with three wheel contact at angles up to 45°. Additionally, the vehicle managed to move itself with only two wheels in case it got stuck, demonstrating that it was fully capable of traversing the rock face seen on our track.

3. Incline Pitch test

The Incline Pitch test was designed to determine whether our vehicle would pitch forward while descending an incline, due to its front heavy design. On an incline greater than 35°, our team initially tested the vehicle without the gripping mechanism attached at the front, then with the gripping mechanism attached, but unloaded. Both of these test went fine, as long as the vehicle wasn't travelling at a high velocity.

However, when the front gripping mechanism was loaded with any of the object of interest, including the small sphere, it was enough to induce forward pitch, and cause the vehicle to fall onto its front face. To counter this, our team developed a driving strategy of tucking our lifting mechanism inwards by rotating the turntable 180°. This shifted the vehicle CG back towards the center of the vehicle, and reduced the pitch propensity. This driving strategy was subsequently used to traverse high rock walls to great effect, with roll propensity being more of a concern.

4. Tilt test

The tilt test was implemented to ascertain whether the vehicle would roll while climbing an incline. Roll would be induced by having a high center of gravity, and by having a narrow track width, two features that our initial vehicle concepts had. Our group decided to test by placing our vehicle laterally on a flat plate, and then raising the plates incline up to 60° from the horizontal. 60° was chosen as a parameter because it was the highest predicted angle of the rock face that the robot car would encounter during climb, even though the selected engineering specifications state that the car must traverse a 45° rock incline. Slippage was allowed, as that would just be a grip issue, but if the vehicle rolled before 60°, it would be considered too top heavy, and changes would have to be made. Using this test, it was noticed that the vehicle was unstable when the lifting mechanism was loaded with the rod and extended fully upwards (creating the highest vehicle CG possible). Our team decided to widen our track width by 1 cm total, and adopt the driving strategy of storing our object of interest in our container to reduce CG height, and tucking our lifting mechanism inwards (as detailed in the Incline Pitch Test), before commencing to drive back out of the pit.

Dispensing Mechanism

The magnets in our dispensing mechanism were tested using the same methodology as used in our gripper design development. In this case, the magnets needed to hold the objects in the optimal position for the gripper to be able to pick them up from the container, but not be strong enough to overcome the pulling force of the gripper magnets (*Neodymium x2 configuration*). In this case, a configuration of *Neodymium + Ceramic x 2* was used. This configuration worked perfectly for all objects, including the iron rod.

Remote control and Communications system

1. Maximum Linear Distance

Our group decided to test maximum linear distance of our Bluetooth modules, before communication was lost for more than 5 seconds at a time. It was ascertained that this distance was up to 12m with certain Bluetooth modules, but as low as 7m on others. In order to reduce variables, the same breadboard and power supply lines was provided to all modules. Understanding the limitation of the Bluetooth modules allowed our group to be better prepared for demonstrating our vehicle, and to know the issues or driving the robot vehicle from a distance.

2. Bluetooth Re-pairing Distance

In order to have a contingency plan if Bluetooth communications were lost, a maximum repairing distance was tested and quantified. While in theory Bluetooth repairing distance should be the same as the maximum linear communication distance, it was found that the Bluetooth modules would not re-pair at a distance over 8m without a full power cycle on the robot side. However, while re-pairing was possible at distances under 8m, it was not of much benefit since communication losses were not frequently experienced at those distances.

3. Bluetooth Latency

In order to facilitate vehicle performance on track, Bluetooth latency was tested across distances up to 10m. Due to the fact that a Bluetooth response latency of up to 7s was experienced during bench testing, where the distance between receiver and transmitter was never more than 2m, our group found this to be an appropriate test to spend time on. Latency was frequently experienced on track immediately after a re-pairing situation, where communications were lost, and then repaired with no manual power cycling. This latency lasted on average for 3-5s. The solution that was pursued to fix this issue was to change the model of the Bluetooth device being used. However, due to the issue being relatively predictable, it was perceived to be an issue that our operator could work around when it came to track testing. The major issue with losing Bluetooth communications and having signal latency was the inability to effectively control the vehicle. In an attempt to counter this, all motors were controlled on the vehicle in short spurts, and an effort was made to minimize the amount of motor movements to those that relied on vehicular inertia or momentum, such as climbing steep rocks.

4. Input Pushbutton Testing

In order to ensure track reliability, the motor output pins were tested on the robot side with a hardwire connection to the controller MCU, and pulse width modulation response was checked upon depression of an input pushbutton. Values were not always the same, even with the values being set the same in the code, however, they were always within the 1.5-2ms range suitable for DC VEX motors. Through this testing, it was also found latency and noise in certain output pins, which led to incorporating pulldown resistors into our circuit design at every controller pushbutton input. Latency was still found on the gripper motors, but since it was not a mechanism that relied on momentum, the decision was made to keep the DC motor as opposed to swapping the motor out for a stepper or servo motor. Table 3 below shows the ONTime values received (in ms) for each programmed DC motor used on the robotic vehicle:

Table 3: Summary of tested pins across Robot and Controller MCUs, as well as output latency at the robot output pin.

	Input button on Controller MCU	Pin on Robot MCU	ONTime value received (ms)	Latency (s)
Lift	Up	7	1.92	0
	Down		1.12	0
Grip	Open	14	1.92	2
	Close		1.12	2
Dispensing	Up	10	1.83	0
	Down		1.34	0
Turntable	Left	11	1.98	0
	Right		1.05	0

III. RECOMMENDATIONS

Despite the successful build and demonstration of our robot, limitations within the group were encountered. A major limitation faced was that the vehicle's CG was too far forward and too high. This issue can be resolved by reducing weight on the front of the vehicle. The next major issue was communication loss. The Bluetooth devices provided limited the vehicles ability to perform to standard.

Some recommendations to better this project and the vehicle include:

- Initialize REV C of mechanical frame to incorporate VEX fixtures into plastic geometry, thus significantly decreasing load. Also, mount VEX motor directly to mechanical frame, thus significantly reducing slop.
- Reduce size of slot for GRIP-002 as it is now just there to hold BAR-001 in the y-axis, since GRIP-002 was removed from the design.
- Combine and pin the cables between the two robot breadboards in order to decrease chance of wire snags.
- Improve geometry of storage container to eliminate dead zones and reduce weight. Remove container if not needed for actual storage. Improve prediction path for where objects will be in container.
- Reduce needless VEX components and correct geometry from standard parts to custom (ie. reduce weight).
- Use stepper motors to automate lifting mechanism as they are much easier to program when compared with timer delays on the VEX DC motors. Automating VEX DC motors using time delays was not as predictable due to gear slipping between worm gear and worm screw used on collection mechanism. Stepper motors would remove this uncertainty.
- Consider changing the model of the Bluetooth device used, due to significant communication loss issues.

IV. CONCLUSION

In conclusion, the robotic vehicle designed by our team was able to drive, collect and dispense a known object of interest into the storage container during demonstration. The current iteration of the working prototype was successfully able to meet engineering requirements set by our design team, such as using modular components, being reliably self-powered, and fitting within the space requirements prescribed. Additionally, our team successfully progressed through a rapid prototyping process using additive manufacturing methods in the development of an integral component of the vehicle’s design. Our group has detailed further recommendations for the next design cycle of this product, which should improve drivability of the robot, and allows the team to refine the aforementioned engineering targets to more narrow design goals.

Acknowledgment

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References

[1] Motors. (2017, September 25). Retrieved December 06, 2017, from https://www.VEXrobotics.com/motors.html