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Team 513: EZ-RASSOR Transporter

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Abstract

The abstract is a concise statement of the significant contents of your project. The abstract should be one paragraph of between 150 and 500 words. The abstract is not indents.

Keywords: list 3 to 5 keywords that describe your project.

Acknowledgement

These remarks thanks those that helped you complete your senior design project. Especially those who have sponsored the project, provided mentorship advice, and materials. 4

- Paragraph 1 thank sponsor!
- Paragraph 2 thank advisors.
- Paragraph 3 thank those that provided you materials and resources.
- Paragraph 4 thank anyone else who helped you.

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Notation

A17	Steering Column Angle
A27	Pan Angle
A40	Back Angle
A42	Hip Angle
AAA	American Automobile Association
AARP	American Association of Retired Persons
AHP	Accelerator Heel Point
ANOVA	Analysis of Variance
AOTA	American Occupational Therapy Association
ASA	American Society on Aging
BA	Back Angle
BOF	Ball of Foot
BOFRP	Ball of Foot Reference Point
CAD	Computer Aided Design
CDC	Centers for Disease Control and Prevention
CU-ICAR	Clemson University - International Center for Automotive Research
DDI	Driver Death per Involvement Ratio
DIT	Driver Involvement per Vehicle Mile Traveled

	Difference between the calculated and measured
Difference	BOFRP to H-point
DRR	Death Rate Ratio
DRS	Driving Rehabilitation Specialist
EMM	Estimated Marginal Means
FARS	Fatality Analysis Reporting System
FMVSS	Federal Motor Vehicle Safety Standard
GES	General Estimates System
GHS	Greenville Health System
H13	Steering Wheel Thigh Clearance
H17	Wheel Center to Heel Pont
H30	H-point to accelerator heel point
HPD	H-point Design Tool
HPM	H-point Machine
HPM-II	H-point Machine II
HT	H-point Travel
HX	H-point to Accelerator Heel Point
HZ	H-point to Accelerator Heel Point
IIHS	Insurance Institute for Highway Safety
L6	BFRP to Steering Wheel Center

Chapter One: EML 4551C

1.1 Project Scope

Project Description

Florida Space Institute has prompted Team 513 to design a cooperative robot to lift and carry heavy items on the moon. A dedicated transporter is not viable due to the cost of transportation to the moon; therefore, the existing RE-RASSOR mining robot will be repurposed to become a transporter. This system will be used to research new ways to transport heavy payloads on the moon as a permeant human presence on the lunar surface comes closer to reality.

Project Objective

The objective of this project is to repurpose RE-RASSOR into a transport system that can lift and move heavy payloads on the moon.

Key Goals

Team 513's most important goal is to pick up and transport a payload. The two payloads our design must account for are: A long circular beam and a large cube. The long beam will be 5 meters long and 0.5 meters in diameter. The cube will be 2 meters by 2 meters and weigh 100 pounds on the moon.

The robot will be entirely 3D printed excluding motors, bearings, and screws. This robot will be used for research and having it be easily replicated to continually test and improve its systems is a major point in FSI's overarching goal for this project. In addition, having a 3D printable robot would be great for reducing transport costs to the moon. Instead of sending fully constructed robots, small, easily printable robots can be made with components found on the moon.

The last key goal is to design the robot to be cooperative with multiple versions of itself. Typical transporters use mass and size to overcome the struggles of lifting heavy payloads, these are two of the scarcest elements of space travel. Since this system will be considerably lighter than what it will be transporting, being creative with multiple robots is a necessity.

Primary Market

Florida Space Institute (FSI) is sponsoring this project to develop new ways to think about transportation on the moon.

Secondary Markets

Other companies that may be interested in a way of transporting objects on the moon are NASA and SpaceX.

Assumptions

It is assumed that no mechanism will be limited by the power source provided. The robot would have enough power to fulfill the mission on the moon. This assumption is necessary as it is our assignment to design and develop a mechanism capable of withstanding heavy loads and there would not be a way to recharge the batteries of each robot.

Another important assumption is the design of the robot would not be made of plastic. Because the robot will land on the moon, plastic will become very brittle due to the temperature drop on the moon.

Stakeholders

The main stakeholders in the EZ-RASSOR transporter include the Florida Space Grant Consortium (FSGC), Florida Space Institute (FSI), and the National Aeronautics and Space Administration (NASA). More personal stakeholders include Dr. Shayne McConomy, Michael Conroy, and Keith Larson. Other space exploration companies may become stakeholders throughout the project.

1.2 Customer Needs

Team 513 was provided with a project brief and met with Dr. Mike Conroy, Team 513's sponsor from FSI, to answer questions about the specifications of the project. The meeting took place on the discord meeting. All the questions along with his responses and engineering interpretations from the meeting are in Table #1.

Based on the interpretations of Mike Conroy's responses, the EZ-RASSOR transport system will need to: pick up and carry a 100 lbs payload, have all its structural components 3D printed with PLA, have the same body (including drivetrain and wheels) as the original RE-RASSOR, cooperate with 3 other versions of itself to achieve its goals, and have a latching mechanism for the payload and the robot. For picking up the payload, have latching mechanism will be required. The team will narrow the project scope and find ideas to satisfy the interpreted needs.

Table #1: List of questions to the customer with responses and interpretations for each question.

Questions	Response	Interpretation
1. How much weight does the EZ-RASSOR have to carry?	"600-pound moon equivalent, so about 100 lbs"	The transporter system will pick up and carry a payload of 100 pounds.
2. What kind of objects does it have to carry?	"It will carry general structural components or cargo in the form of boxes"	The transporter system is universal, capable of lifting a variety of shapes such as a long circular beam and a cube.
3. What material should the EZ-RASSOR be made of?	"The robot will have to be entirely 3d printed in PLA, with the exception of bearings, motors, and screws"	The mechanical structure of the mechanism will be 3D printed out of PLA.
4. How many robots need to cooperate?	"It is easier to upscale robot cooperation from 4 to 8 than 2 or 3 for example"	The transport system will include 4 cooperating robots.
5. How far can we stray from the RE-RASSOR design?	"To make it easier, you guys should keep the body, drive hub and wheels the same, to concentrate on the transport mechanism."	Design will keep the RE-RASSOR body without digging drums.
6. Would the transporter be controlled?	"There will be a software team available to reach out to that can help you control the transporter in whichever way you feel fits best."	The software of the transporter is done by a specific software team, whereas the hardware is developed by the team.
7. Can we change the size of the robot from the original RE-RASSOR?	"The RE-RASSOR body can be scaled up to be within reason"	The transporter will be smaller than the actual RE-RASSOR robot.
8. Is there a specific method desired to lift the object?	"The object should be universal but there is expected to me a sort of latching mechanism."	A latching mechanism is required to lift the object.

1.3 Functional Decomposition

Introduction

The functional decomposition process was utilized after the team discussed the project scope. To break down complex concepts of the project scope to smaller and simpler concepts, the process is necessary for the team to identify the targets and metrics to the project.

Data Generation

The functions of the project are determined by the team to find the important aspects of the EZ-RASSOR. These functions were found through the customer needs and the project scope. After analyzing them, the major and minor functions of the EZ-RASSOR were identified.

Flow Chart Reasoning

Shown in Figure 1, the function decomposition hierarchy chart is broken down to three major systems: connection, locomotion and control. These major systems are then broken down to minor systems.

One of the major systems, “Connection”, deals with the connection with the lifting mechanism with other objects. It is broken down into two subsystems, “Payload-Side Connector” and “Transporter-Side Connector”. The “Payload-Side Connector” is the connection between the lifting mechanism and the payload. The “Transporter-Side Connector” is the connection between the lifting mechanism and the EZ-RASSOR robot. Below the subsystems are attachment methods for the mechanism.

The “Locomotion” system deals with movement of the lifting mechanism with the payload. The subsystems are: “Rotate Payload”, “Translate Payload”, and “Stabilize Payload”. The functions for the subsystems “Rotate Payload” and “Translate Payload” are wheel motors.

The subsystem “Stabilize Payload” includes functions for dampening the perturbations and the slip compensation of the payload.

The “Control” system provides the power and control of the mechanism. The subsystems of the major system are “Human Control” and “Power System”. The subsystem “Human Control” has functions that control the adjustment of the lift mechanism and the attachment actuator with a microcontroller. The power system of the lifting mechanism has a function to distribute the power through it.

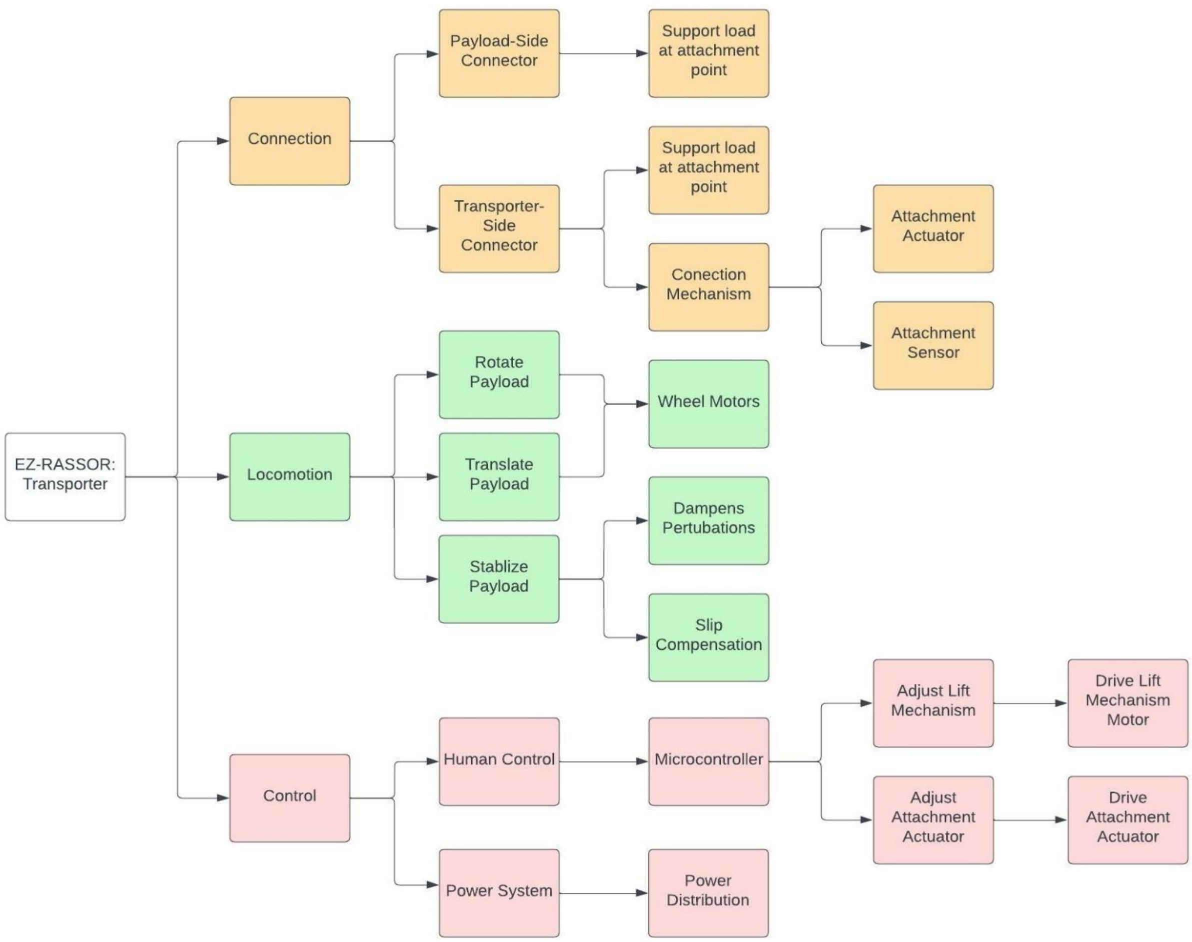

Figure 1: Functional Decomposition Hierarchy Chart

Connection to Systems

The functional decomposition cross-reference table, shown in Table #, relates the functions to the major systems of the mechanism. The "X" mark indicates the function has influence the major system. Some functions effects more than one of the major systems, for example, the function "Slip Compensation" affects the "Locomotion" and "Control" systems. From the table, the major system with the most functions is the control system. The team decided that the control system is the top priority for the lifting mechanism to carry the payload on a lunar surface.

EZ-RASSOR Functional Decomposition			
Function	Connection	Locomotion	Control
Support Load at Attachment Points	X		
Attachment Actuator	X		
Attachment Sensor	X		
Wheel Motors		X	
Dampens Perturbations		X	X
Slip Compensation		X	X
Drive Lift Mechanism Motor			X
Drive Attachment Actuator			X

Table 2: Functional Decomposition Cross-Reference Table

Integration

The functions "Dampens Perturbations" and "Slip Compensation" are part of the locomotion and control systems. Both functions correlate with the movement of payload on the lifting mechanism and the controlling system to prevent the payload to slip off the mechanism.

The perturbations of the payload from the movement of the mechanism can be limited by changing the speed of the mechanism and controlling movement errors from the mechanism. Similarly, the function to prevent slipping of the payload would need both systems to keep the payload on the lifting mechanism.

Action and Outcome

The lifting mechanism must carry heavy payloads for transport on the EZ-RASSOR transporter. The mechanism needs to have a power system and must be controlled. After creating the functional decomposition chart and systems chart, the team can identify the targets and metrics of the project scope.

1.4 Target Summary

Method of Validation and Discussion of Measurements

The project's targets will be validated after concept selection where the construction of the mechanism begins. The first step after concept selection will be to create 3D CADs of the parts and assemble them into a single file. This CAD assembly will be able to validate “Rotate payload around robot” as well as “Translation in Z-axis” by creating stand-in CAD payloads and simulating movement in the CAD program. Once the design is put to print, “Proximity Sensor Detection” can be validated by bringing an object close to the sensor and reading the output until the sensor displays 10mm and comparing that to the real-world value with a caliper. Once the parts are printed and the mechanism is assembled, “Mechanical Advantage Provided from Gearbox” can be validated by counting the number of rotations of the pinion shaft and comparing it to a single rotation of the output shaft. “Static Payload Connection Load Support” and “Static Payload Connection Load Support” will both be validated by suspending an equivalent weight on to the connection points and checking if the structure is intact, the equivalent weight will be found using a digital scale. “Supply Power to microcontroller” and “Supply Power to Stepper Motors” will be validated by measuring the voltage of the power cable in reference to ground. Finally, the “Lift the Weight of the Payload” will be validated by placing a reference weight on the connection point and then driving the motors.

Derivation of Targets and Metrics

After many meetings and discussions with Dr. Conroy, the RE-RASSOR transporter was decomposed into specific desired functions, each within a major system. The three main systems consist of control, payload motion, power, and connection. All functions of the transporter exist within one of these systems. A series of targets and metrics have been assigned to each function to test the functionality of the design. The target is the specific value in which the transporter must be designed around, while the metrics are the methods to validate each function. Applying targets and metrics to functions allows for those functions to be analyzed and measured, ensuring a successful design within the specifications, and meeting the customer needs. Designating targets and metrics to each function will also allow for competitive benchmarking.

Many functions can be quantified with specific hard values in which define the movement of the robot. For example, payload motion requires specific values to be met. On the other hand, some functions cannot be quantified, but rather require a simple check.

Control Targets and Metrics

One function under the control system is the *Human to Controller* function. The transporter must be able to control remotely by an operator. This was determined so that the transporter can function with a controller. For functions *Supply Power to the Microcontroller* and *Supply Power to the Stepper Motors*, the voltage going into the microcontroller and the stepper motor must be 5V and 12V, respectfully. This is determined for the microcontroller and the stepper motor to function properly and with decent power.

Payload Motion Targets and Metrics

Payload motion is defined by a global three-dimensional axis fixed relative to the robot. The movement and manipulation of the payload is under the system of "Payload Motion." There must be two different payloads with specified dimensions, one will be a 2x2x2m cube and one a long cylinder of 0.25m diameter and a length of 5m. In effort to make a universal payload connection, the latching mechanism will be designed the same for both cargo candidates.

The most significant target for payload motion is lifting a payload of 100 lbs. This was generated based off the customer needs and the desires of Dr. Conroy. The specific target of lift for each payload is 0.3 meters of total translation in the z direction upwards. This can be from different vertical positions or if it is buried in dirt or sand. This target was calculated based off the height of the RE-RASSOR robot. The target for the gearbox is to reach a mechanical advantage of 50:1. This will provide significant torque to allow for the lifting of the payload.

Connection Targets and Metrics

The connection between the robot and the payload is necessary for the mechanism. There is one target for the functions, *Static Payload Connection Load* Support and *Static Transporter Connection Load* Support. The load for the lifting mechanism must support 100 lb. Additionally, the mechanism must support a load of 111.2 N for a connection with the robot. These were determined based off the required weight to be lifted by the payload.

There are two targets for the *Rigid Attachment to the Payload* function. The transporter must be less than 5 degrees about the z-axis and less than 10 millimeters from the z-axis. These targets ensure that the transporter is safely attached to the payload. For the *Proximity sensor detection* function, the sensor must detect the distance of the connection with the robot of 10 millimeters. The target was determined for the mechanism to be connected to the robot without becoming loose.

Targets and Metrics Outside the Functions

A variety of targets are not as critical to the functionality of the design and therefore do not exist within any of the core systems. The design is intended to be for research and educational purposes, which makes cost a significant factor. After conversations with Dr. Conroy, the cost of replication should be less than $150 to ensure affordability across educational programs. The weight of the design is also important to consider as the base of the robot is entirely 3D printed. To maintain a lightweight and versatile design, the intended weight should be less than 50 lbs. The entirely 3D printed design forces the consideration of the tensile strength of the 3D printed material. There will be additional efforts made to increase the strength of the material, however, it must have a tensile strength of 7250 psi to match the standard of PLA.

Summary

The targets and metrics of all functions is listed on the catalog below. The critical targets of the transporter are bolded. These targets must be met to achieve the goal of the project. The targets are determined based on the requirements for the transporter. These targets are subject to change when prototyping and testing the transporter.

System	*Function*	*Target*	*Metric*
Payload Motion	**Lift the weight of the payload**	**100 lbs**	**Weight**
Payload Motion	**Rotate payload about robot**	**0-180 deg about x-axis** **0-270 deg about z-axis**	**Angle**
Payload Motion	Translation in Z Axis	0.3 m	Length
Payload Motion	Provide a Mechanical Advantage from Gearbox	50:1	Toque Ratio
Connection	**Static Payload Connection Load Support**	**100 lbs distributed evenly across attachment points**	**Weight**
Connection	**Static Transporter Connection Load Support**	**100 lbs**	**Weight**
Connection	Rigid Attachment to the Payload	< 5 [deg] about z-axis < 10mm translation about z-axis	Angle
Connection	Sensor Detects Attachment to the Robot	< 10mm	Length
Control	Human to Controller	Robot can be controlled remotely	Boolean
Control	Supply Power to the Microcontroller	5V	Voltage
Control	Supply Power to the Stepper Motors	12V	Voltage

1.5 Concept Generation

Concept generation is a vital component of the design process. Effective concept generation allows for an assortment of new ideas covering an array of potential solutions to the project scope. With proper concept generation tools, the team was able to generate 100 potential designs addressing all necessary components. Then, with conversations with Dr. Conroy and Mr. Larson focusing on the desired functions and needs of the design, all concepts were narrowed down to 5 medium fidelity concepts and 3 high fidelity concepts.

Concept Generation Tools

The team ensured that a wide range of concept generation tools were attempted to guarantee that all potential designs were discussed. These tools include but were not limited to biomimicry, crapshoot, brainwriting, and a morphological chart. Some methods generated more concepts than others, but all were effective in establishing consistent and efficient ideation. It is important to note that although each technique can consist of limitations in the number of concepts generated, simply talking through ideas permitted constant brainstorming and ideation leading to a great deal of generated concepts.

Brainwriting was the first concept generation technique utilized. This method consisted of each member brainstorming as many concepts as possible within 3 minutes, before passing on to the next member for those ideas to be built upon. This technique alleviated potential unbiased conversation due to individual bias. By ensuring all members had their ideas considered and built upon, an umbrella of potential designs was considered, and allowed for an influx of concepts to be generated. This proved as the most effective method in the pure number of concepts and was a great starting point as it sparked conversation involving all perspectives.

Biomimicry, although not generating as many hopeful concepts, served as inspiration for potential robot collaboration. The team explored natural techniques for heavy lifting as well as collaboration. Species such as bees and ants are excellent examples of collaboration in nature. Ants, for example, use chemicals to send signals to other ants to address certain needs and issues. Bees have specific roles that are utilized to work efficiently and effectively. Using these techniques as inspiration, concepts were generated in which utilize several robots that actively communicate to perform different roles to lift the desired payload. An example concept utilizes one robot with the sole intent of lifting the payload, while an additional robot provides additional support to avoid potential tipping.

Crapshoot generated the bulk of the team's concepts. In one die, six functions needed for the design were assigned to each value. The second die assigned potential mechanisms to each value in which could be used to perform such functions. The functions and mechanisms can be seen in Table # below. After each roll, the team brainstormed ways in which the mechanism could perform the desired function. Even in situations where the combination was not sensible, these forced discussions ultimately led to a variety of concepts generated.

	Functions	Mechanisms
	Vertical Lift	Rack and Pinion
	Rotation	Pulley
	Transport	Spring
	Connection	Cam and Follower
	Detaching	4-bar

	Stability	Counterweight

Table X: Crapshoot Assignments

The design of the RE-RASSOR lunar transporter consists of a variety of components that can be combined without limiting functionality. As a result, a morphological chart was created consisting of potential design ideas for all systems which will later be combined to ensure full coverage of concepts. The key systems which were explored are the lifting mechanisms and the connection capabilities.

Fidelities

After analyzing the desirability of all generated concepts, five concepts were selected as medium fidelity concepts. These concepts, although embodying many of the functional requirements of the design, did not match the team's vision. Each concept consists of desirable characteristics that will be evaluated to provide insight into the final design choice. The medium fidelity concepts selected as well as a brief description can be found below in table #.

Concept #	**Description**
Pulley Ramp (#10)	A rack and pinion are used to extend towards the payload, hooking around a "hood" on the payload, and pulling up a ramp. The robot drives towards the payload while pulling in effort to increase the mechanical advantage.
Multi Robot Ramp	Multiple robots approach the payload from different directions, wedging their base

(#11)	platform below the payload. The robots then drive toward the center of the payload while flattening their base, ultimately leaving the payload resting on top of all four robots
Counterweight (#20)	Two robots connected by one arm approach the payload and latch on using a cam lock. Once attached, the rear robot utilizes a rack and pinion to pull down, generating torque about the payload and adding stability to prevent tipping.
Robot Crusher (#19)	A robot with an attached pulley consists of an arm with a flat base that connects to the bottom of the payload. As the pulley turns, the arm moves radially, hence flipping the payload forward, where another robot is prepared to catch the payload on a ramp. This robot then adjusts its base to stabilize the payload.
Pallet (#22)	Two robots contain a rack and pinion linear elevator with a forklift type extension that lowers to the ground. The robots approach the payload from either end, sliding the

	extension beneath the connection mechanism on the payload, and driving upwards, lifting the payload. The connection point is simply a planar attachment.

Table X: Medium-Fidelity Concepts

After analyzing, three high fidelity concepts were selected. These designs not only prove to meet the needs and functionality of the design, but also match the desired direction the team plans to head in. Each of these concepts will be heavily investigated using concept selection tools to narrow down to one final design. The concepts and their descriptions selected as high-fidelity concepts can be seen in table X below.

Concept #	**Description**
Multi robot car jack (#73)	A motor-powered rack and pinion force two robots functioning as a linear actuator towards each other, driving the connection mechanism upwards, sliding into the attachment point on the payload.
Five-bar (#82)	Using the motors from the shoulder joints, a five-bar mechanism is used to drive the connection mechanism (U slot) up to the attachment point of the payload. Once attached, the motors can work independently to

	shift the payload and increase stability during locomotion.
Single carjack (#56)	A four-bar mechanism connects at the middle nodes to act as a linear actuator. The motors move the attached gears along the rack (linear actuator) which brings the nodes together, forcing the end effector, in the shape of a U, towards the connection point. The end effector slides around the extension of the payload, allowing it enough force to lift the payload.

Table X: High-Fidelity Concepts

1.6 Concept Selection

House of Quality

The customer needs, previously established through extensive conversations with Dr. Conroy, are analyzed using a binary pairwise chart, in which each need is assigned a value of 1 or 0 against its counterpart. Through direct comparisons in this manner, a ranking of the customer needs can be established. After analyzing the chart, lifting the 100 lbs payload and having payload flexibility can be considered the most important needs.

Customer Needs								o t al
1. Lift Payload								
2. Payload Flexibility								
3. Ease of Assembly								
4. Human Controlled								
5. Inexpensive								
6. Stability								
7. 3D Printed Parts								
Total								
Check: (n-1)								

Now that the customer needs are appropriately weighed, the essential engineering characteristics of the design can now be appropriately ranked. These engineering characteristics consist of the most desirable functions as well as additional predetermined criteria. Using the

House of Quality, the engineering characteristics of the design are directly compared to the designated customer needs. Analyzing the functions fixed to the calculated weight factor of the customer requirements allows for the functions to be ranked according to their ability to satisfy each customer's need. Therefore, the function that best meets the most desired customer need, lifting the 100 lbs payload, is ranked the highest. The chart used for this analysis can be seen below.

Upon completing the house of quality, the most essential engineering characteristics can be determined to be the payload to transporter connection accessibility and translating the payload. Both are necessary in lifting the payload, stabilizing the payload, and payload flexibility, which were previously found to be the three most important customer needs. The least important functions are sending, receiving, and transducing a signal, which only plays a major factor in controlling the robot. These rankings are beneficial as they allow for each concept to be judged according to its ability to complete the top priority functions.

Pugh Chart

The Pugh chart is a method in which each concept from the fidelities is directly compared to a datum, or the current market standard. Currently, there are no lunar transporters currently existing that work in cooperation with other robots. Therefore, for the data, the team will be comparing directly to a robotic forklift, as suggested by Dr. Conroy. Each concept will be directly compared to the datum based on their functions. The concept will receive a (+) if deemed better than the datum for the desired function, a (-) if it does not match the datum, and an (S) if it similarly compares to the function of the datum. The selection criteria consist mostly of the desired functions with a few additional criteria unrelated to functions such as size and weight. Functions which provided no beneficial data were excluded from the selection criteria.

The first iteration of the Pugh chart was successful in eliminating concept #11 (multi robot ramp), which was the only concept which performed worse than the datum. Due to the equal number of plusses and minuses for concept #22 (pallet), the second iteration of the Pugh chart utilized this concept as the new datum. This concept appeared to be the most comparable to the datum and serves as a good comparison for further design selection.

For the final iteration of the Pugh chart, the bottom two concepts were eliminated, and concept #19 (robot crusher) was chosen as the final datum before selection. This concept performed well throughout the selection process but had proven less effective than the final three concepts. Comparing to the datum one final time, the Pugh chart was able to successfully deem one concept superior to the rest. Concept #82 (5-bar) outperformed the datum in all but two selection criteria, performing satisfactory in the other two.

Analytical Hierarchy Process

Final Selection

The final selection for the RE-RASSOR lunar transporter will be concept #82, the five-bar mechanism using the shoulder joints. Many factors led the team to this decision, including the data found in the Pugh charts and other concept selection techniques. In a research and education robot where reusability is a major factor, reutilizing the shoulder joints will prove to be extremely beneficial. Repurposing the shoulder joints lowers the overall weight and cost of the design tremendously. Also, having two different motors grounded at the base link (shoulder joints) allows for the end effector to be manipulated in two planes. More freedom in manipulating the end effector offers an easier connection to the payload and increases the overall stability of the design. Additionally, the five-bar mechanism satisfies the more important selection criteria than the other concepts. Overall, this design best matched the customers' needs, achieved all desired functions, and outperformed all other potential concepts. A depiction of this design can be seen in the figure below.

Figure X: The 5-Bar Shoulder Lift was chosen as the final selection

1.8 Spring Project Plan

Chapter Two: EML 4552C

2.1 Spring Plan

Project Plan.

Build Plan.

Appendices

Appendix A: Code of Conduct

Mission Statement:

Design and develop a cooperative, multi-functional, transportation system based on the RE-RASSOR mining robot.

Outside Obligations:

Axcell Vargas: N/A
Carlos Sanchez: Part time job (20 hours per week)
Jared Carboy: Part time job (20 hours per week)
Kaden Lane: Part time job (20 hours per week)

Team Roles:

Axcell Vargas: Controls Engineer
Carlos Sanchez: Mechatronics Engineer
Jared Carboy: Systems Engineer
Kaden Lane: CAD designer
As more information regarding the project is acquired, amendments will be made to assign more specific team roles. A formal meeting will be held following the sponsor meet and greet to come to a decision on who serves what role. Overall, the above team roles serve as a general basis for the preferred role each team member has.

Communication:

Communication between the team members will be done using Microsoft Teams. Text messages or phone calls will be used if members are not responsive. Zoom will be used for meetings with our advisor. If there is no response within 24 hours of a message, a meeting will be held to ensure proper communication techniques.

Dress Code:

Presentations and team photos will have the team in formal business attire. Meetings with the project sponsor will be business casual. There will be no dress code for team meetings.

Attendance Policy:

If a member cannot attend a scheduled meeting, they must notify the team 24 hours before. Emergency meetings scheduled during the SD class time slot must have 100% attendance. If there are 3 unexcused or unapproved absences from a meeting, external support from TAs or Dr. McConomy will be needed.

How to notify the group:

Notification of any meeting or event will have a distinct within Microsoft Teams and will be placed on the team calendar.

How to respond to people in a meeting:

Professional language will be used, rude or demeaning language will not be tolerated. All ideas must be seriously considered, and team members must remain civil during arguments. Votes can be enacted during disagreements and the results will be respected. If an issue arises within a group, all parties prefer direct and blunt communication.

Dr. McConomy or TA intervention:

Ensure all available parties agree that all steps were taken to solve the issue prior to any intervention by Dr. McConomy or the TAs. In a case where there is obvious intervention is needed regarding a specific party, three members can agree to contact Dr. McConomy or a TA. Dr. McConomy will mediate the argument and help delegate new roles for the team members.

How to Amend:

The majority of team 513 (3 out of 4 members) must agree to the amendment before editing the code of conduct. The changes will be dated and members advocating for the amendment will sign the code of conduct again.

Statement of Understanding:

By signing this document, we agree to the contents of this code of conduct. We to be civil amongst each other and productive towards our goal of completing the project.

Signature — Date: 09/08/2022

Signature — Date: 09/08/2022

Signature — Date: 9/8/22

Signature — Date: 9/08/22

Appendix B: Functional Decomposition

Appendix C: Target Catalog

System	*Function*	*Target*	*Metric*
Payload Motion	**Lift the weight of the payload**	**100 lbs**	**Weight**
Payload Motion	**Rotate payload about robot**	**0-180 deg about x-axis** **0-270 deg about z-axis**	**Angle**
Payload Motion	Translation in Z Axis	0.3 m	Length
Payload Motion	Provide a Mechanical Advantage from Gearbox	50:1	Toque Ratio
Connection	**Static Payload Connection Load Support**	**100 lbs distributed evenly across attachment points**	**Weight**
Connection	**Static Transporter Connection Load Support**	**100 lbs**	**Weight**
Connection	Rigid Attachment to the Payload	< 5 [deg] about z-axis < 10mm translation about z-axis	Angle
Connection	Sensor Detects Attachment to the Robot	< 10mm	Length
Control	Human to Controller	Robot can be controlled remotely	Boolean
Control	Supply Power to the Microcontroller	5V	Voltage
Control	Supply Power to the Stepper Motors	12V	Voltage

Appendix D: Work Break Down Structure

EZ-RASSOR Transport	Semester	Milestone	Tasks	Team Members Involved	Date
Team 513	Fall 2022				
		Project Scope			9/23/2022
		-	Schedule Meeting	Jared Carboy	
		-	Discuss project brief with sponsor	All	
		-	Decide on market, assumptions, and stakeholders	All	
		-	Write report	All	
		-	Submit report	Carlos Sanchez-Sarmiento	
		Customer Needs			9/30/2022
		-	Schedule Meeting	Jared Carboy	
		-	Gather customer data and desires	All	
		-	Synthesize customer data	All	
		-	Establish hierarchy of each need	All	
		-	Write report	All	
		-	Submit report	Carlos Sanchez-Sarmiento	
		Functional Decomposition			10/7/2022
		-	Schedule Meeting	Jared Carboy	
		-	Reflect on project specifications	All	
		-	Break down project into defined parts	All	
		-	Describe necessary actions and desired outcomes	All	
		-	Write report	All	
		-	Submit report	Carlos Sanchez-Sarmiento	
		Targets			10/28/2022
		-	Schedule Meeting	Jared Carboy	
		-	Analyze potention targets and metrics	All	
		-	Decide on perfomance measures	All	
		-	Define specific values that must be reached	All	
		-	Write report	All	
		-	Submit report	Carlos Sanchez-Sarmiento	
		Concept Generation			11/4/2022
		-	Schedule Meeting	Jared Carboy	
		-	Perfom at least three idea generation techniques	All	
		-	Record all potential ideas	Axcell Vargas	
		-	Analyze all ideas generated	All	
		-	Write report	All	
		-	Submit report	Carlos Sanchez-Sarmiento	
		Concept Selection			11/4/2022
		-	Schedule Meeting	Jared Carboy	
		-	Choose criteria for critiquing	All	
		-	Formulate a decision matrix	All	
		-	Rate each concept and evaluate	All	
		-	Determine concept	All	
		-	Write report	All	
		-	Submit report	Carlos Sanchez-Sarmiento	
		Risk Assesment			11/18/2022
		-	Schedule Meeting	Jared Carboy	
		-	Assess potential risks involved	All	
		-	Develop methods for mitigating risk	All	
		-	Write report	All	
		-	Submit report	Carlos Sanchez-Sarmiento	
		Bill of Materials			11/28/2022
		-	Schedule Meeting	Jared Carboy	
		-	Analyze and evaluate all order needs	All	
		-	Identify vendors	All	
		-	Identify project cost	All	
		-	Identify labor and unit costs	All	
		-	Write report	All	
		-	Submit report	Carlos Sanchez-Sarmiento	
	Spring 2022				

Appendix E: Concept Generation and Selection

Biomimicry

1. One robot pushes the payload onto the back of another robot, like how ants work together to lift heavy objects.

2. Create lifting rack like deer antlers to have multiple points of contact and a distributed lifting load over payload for singular lifting robot.
3. Robot arm with low to the ground lifting point using a jaw like grabber with a beak much like a snapping turtle utilizing rubber or other soft compound to grab and secure lifting point on payload.
4. Creating a grabbing mechanism that uses a tail like counterweight similar to a monkey using its tail as a counterweight and as a balance.
5. Robot with a pad that mimics a remora's dorsal fin to adhere to the payload with payload coupling being a specified area to lift or drag.
6. Robot has a mini rover that doubles as an articulating arm as well as a stabilizer which stows away inside the robot like a kangaroo pouch
7. Robot deploys a net that hooks onto points located on the payload and pulls the payload along like a spider using silk.
8. One robot utilizes a low center of gravity mandible design that clasps and lifts like a stag beetle.
9. Robot has two separate low hanging articulating arms which act like claws that rotate and clasp onto the payload like a lobster uses each of its claws.

Brainwriting

10. Robot uses a ramp to wedge beneath the payload and utilizes a pulley to pull the payload up the ramp and onto the platform of the robot.
11. Multiple robots utilizes a ramp towards a payload at different directions and lifts it.
12. Robot uses hooks and straps connected to arms that close around hooks with actuating lifting mechanisms.
13. Robot utilizes a large arm like a bulldozer attachment to push the payload across the lunar surface.
14. Robot deploys a hook and winds around the payload until it reaches multiple windings where it hooks to the payload again and pulls the payload with a lasso type winding.
15. Robot utilizes multistage ramp that can move over regolith and bumps on the lunar surface while maintaining rigidity to push the payload.
16. Robot utilizes a bowline knot that ties to a vertical hangar and pulls tight, the payload is then lifted by four attachment points by each robot and transported.
17. Robot utilizes a 6bar lifting mechanism that is motorized to lift the vehicle.
18. Vehicle uses a wedge with wheels to position under the payload and drive the payload off with a trailer type trailing design
19. 3 robots lift the payload and drop it on a ramp from a robot.
20. Two robots work together, one acting as a counterweight and one manipulating the payload with an arm.

21. Two robots center themselves in a line and use a pulley system to translate the payload across the lunar surface making each robot drive forward with the payload in tow.
22. Robots go underneath the payload and lift vertically on horizontal underpinnings until the payload is lifted above the robots and then the payload is transported across the lunar surface using the actuating robots as suspension to keep the payload level.
23. Two robots use a winch between themselves to hook on to and then using the winch between robots to drag the payload.
24. Three robots connect with platforms attached and one robot lifts payload on top while the rest of the robots transport the payload overhead
25. Two robots connect to the payload with ropes and pull the payload while two robots push the payload from the other side with extruded flat plates.
26. Four robots combine to form an overhead four-point crane that attaches to the payload and lifts using an overhead winch
27. Robots deploy four actuators that go underneath and lift the payload while robots orient themselves underneath the payload and lower it.
28. Robots use an arm with a tracked attachment that drives itself under the payload digging regolith.
29. Robots use digging arms to make space under the payload and lift using a scissor jack.
30. Robots drive on top of each other and connect, one robot using a rack and pinon type connection and the other driving rearwards will pull the payload.
31. Robots connect horizontally and use multiple arms to pull the payload on top of the robots to be transported.
32. Robots use a multi wheeled extension that will be used to transport the payload, while two robots lift with ramps the other robots will lower the dually wheeled attachment and pull the payload.
33. Replace the front shoulder with a track attachment for added stability and the front shoulder being ground, create a mechanism that is a crane type hook with the rear shoulder being a stabilizer and counterweight.
34. Robots use the regolith miners as extra wheels. An arm attachment connects to a bar and lifts while the regolith miner attachments drive under the payload and flip it onto another robot ramp.
35. Robots use multiple linear actuators to create a crane attaching to the payload.

Morphological Chart Ideas

36. Four robots use an actuator and a flat platform to push the payload laterally across the moon surface.

37. Robots use a Two-point actuating claw to hold onto the corners of the robot holding on using rubber tips to the claws to lift the platform with an actuator.
38. Robots use an Articulating arm to attach to the corners and side of the payload to push the payload along the lunar surface, they can also arrange themselves on the side and push.
39. Four robots use hooks to hook onto the bottom of the payload using an actuator to pull the payload up and transport it.
40. Robots use a hooked mesh to hook onto the upper corners of the payload to pull and push the payload along the surface of the moon.
41. Robots drive into the payload using ramps to load and unload the payload, ramps with be actuated horizontally to provide increased loading forces.
42. Robot uses a platform to mate with a vertical open hole bracket, platform extrusion to mate and actuates the payload up to transport.
43. Robot uses a two-point claw to attach to a vertical open hole bracket and lift the payload using an actuator
44. Robot uses an articulating arm to attach to a vertical open hole bracket and a lifting actuator to transport.
45. Robot uses a hook and open hole bracket to actuate the hook and lift the payload.
46. Robot uses a hooked mesh to hook into the open hole bracket and actuate the payload vertically.
47. Robot uses a ramp to attach to a low mounted bracket and attaches using an actuator to vertically lift the ramp and payload.
48. Robot attaches to a multi-point mesh that is over the payload using a platform to wedge into the mesh and pull the payload with an actuator.
49. Robot uses a two-point claw and actuator to attach to a multi-point mesh that covers the payload. The payload is pulled after attachment.
50. Robot uses an articulating arm to grab onto a multi-point mesh and pull the payload using an actuating arm.
51. Robot hooks into loops on a multi-point mesh that covers the payload and lifts using an actuator to transport.
52. Robot uses a spherical ball to hook onto loops inside the mesh and lifts the payload from the points on the mesh.
53. Robot uses a multiple hooked mesh to connect on multiple points on the mesh on the payload acting almost like Velcro the payload is lifted with an actuator.
54. Robot uses a four bar to lift a hook that connects to a multi-point mesh lifting the payload.
55. Robot uses a spherical ball joint to connect to a multi-point mesh which is then lifted with a four bar.
56. Robots use an articulating arm to connect to a multi-point mesh that is then lifted using a four-bar design.

57. Robot uses a hooked mesh that connects to a multi-point mesh covering the payload and lifts using a four bar.
58. Robot uses an actuator and platform to lift the payload from a shoulder or extruded platform from multiple points on the payload.
59. Robot uses a two-point claw that squeezes either side of an extruded platform off the payload and an actuator to lift the payload.
60. Robot uses a scissor jack and a platform to lift an extruded plane from the shoulder.
61. Robot uses a 5 bar from shoulder joints to lift a platform that mates with an extruded plane on the shoulder.
62. Robot uses a 5 bar from shoulder joints to hook onto a vertical open hole bracket and lift the payload.
63. Robot uses a spherical ball to connect to a hollow spherical joint and a motorized worm gear to lift the payload.
64. Robot uses a rack and pinon and platform to lift the robot from an extruded shoulder plane.
65. Robot uses a Four bar mechanism to grab a pin joint linkage with a two-point claw that couples with a revolute joint.
66. Robot uses an articulating arm to connect with a twisting coupling, the robot arm articulates to a set diameter and couples, the mechanism is lifted with a rack and pinon.
67. Robot uses a scissor jack and a hook to connect to a pin joint linkage on the payload and lifts.
68. Robot uses a rack and pinon to lift a ramp that connects with a spherical hollow joint, ramp utilizes a semicircular profile to help lift from the connection.
69. Robot uses a 5 bar to connect a two-point claw to a twisting coupler and lifts the payload.
70. Robot uses a closed form slider to move an articulating arm to an extruded plane and lifts the mechanism vertically.
71. Robot uses a closed form slider to move a ramp that moves under the payload and lifts using the track on the slider.
72. Robot uses a closed from slider to move a hook to connect with a pin joint linkage and lifts on the slider track.
73. Two robots connect using a rack and pinon and create a multi robot scissor jack and lift the payload vertically from a common attachment point.
74. Robot uses a rack and pinon and connects a two-point claw to the underside of the payload and lifts the payload.
75. Robot uses a hook and an actuator to lift from an extruded shoulder that is hooked lifting the payload.
76. Robot lifts a shoulder or extruded plane using a ramp, actuation lifts the payload.

77. Robot uses a hook to connect to a hollow spherical joint and uses a scissor jack to lift the hook
78. Robot uses a two-point claw and a rack and pinon to attach to a vertical open hole bracket and lifts the payload.
79. Robot uses a rack and pinon and ramp to attach to the payload bringing the robot close to the payload and lifting it under the payload for transportation.
80. Robot uses an articulating arm attached to a closed form slider to connect to a twisting coupling and lift the payload.
81. Robot uses a 5-bar shoulder to connect a two-point claw to the underneath of the payload and lifting vertically.
82. Robot uses a 5-bar shoulder to connect an articulating arm to the edges of the payload and lift the payload.
83. Robot uses a 5bar shoulder to connect to a twisting coupling and lifts using an articulating arm.
84. Robot uses a 5bar connected to a ramp to lift the payload from underneath.
85. Robot uses a 5bar linkage to lift a ramp that connects to vertical open hole bracket and lifts.
86. Robot uses a motorized worm gear to push a platform that pushes the payload.
87. Robot uses a motorized worm gear to lift the payload from the bottom using a two-point claw
88. Robot uses a motorized worm gear to lift the payload from the bottom using an articulating arm.
89. Robot uses a motorized worm gear to lift the bottom of the payload with a hook
90. Robot uses a motorized worm gear to lift the payload with a ramp.
91. Robot uses an actuator to lift a to point claw to a twisting coupling and lifts.
92. Robot uses a rack and pinon to lift a hook to a vertical open hole bracket.
93. Robot uses a two-point claw that connects to the bottom of the payload and lifts using a closed form slider.
94. Robot uses hook that connects to a pin joint linkage and is translated with a closed from slider transporting the payload.
95. Robot uses a closed from slider and a ramp to connect to a multi-point mesh over the payload and lifting with this connection.
96. Robot connects to a pin joint linkage using an articulating arm and lifts using a motorized worm gear.
97. Robot connects to a pin joint linkage using an articulating arm and lifts using an actuator.
98. Robot uses a scissor jack that has a rounded ball joint and lifts the payload, this connects to a trailer like locking joint.
99. Robot uses a hook to connect to a multi-point mesh which is moved using a rack and pinon.

100. Robot uses a scissor jack to connect a twisting coupling with a two-point claw and lifts the payload.

References

There are no sources in the current document.