Prototype Assessment Plan

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Introduction

The concept selection process utilized several analytical hierarchy methodologies to aid in clarification of the best design proposal. The next stage of the design process involves creating a physical model of the selected concept. Prototypes are often fabricated prior to the construction of the final model. The team's current design schedule allocates sufficient time for prototype assessment.

Prototype assessment is a preliminary step in prototyping used to test a proposed model, advantageous to tight-budget and time constrained projects. The process can be used to examine integral design components to minimize the occurrence of future complications and monetary losses in the actual design prototyping phase. The Psyche 525C team selected the rover's rocker-bogie suspension system, camera mount, and body for prototype assessment.

Selected components were chosen based on their importance to the overall design, the possible variability they may present, or for the purpose of gaining a greater understanding of their mechanisms and geometry in relation to one another. The prototype plan details what is to be prototyped, necessary materials, and the proposed cost. An assessment plan describes prototype testing, related key targets and metrics, necessary tools for assessment, and the relevancy of assessment results to the final design.

Prototype Plan

Camera Mount

Several materials will be used in the construction of a prototype camera mount. Nominal costs associated with the product are provided.

- PVC - $10.00
- 3-D Printing - Owned

- Stepper Motor - Owned
- Glue - Owned
- Breadboard - Owned
- Microcontroller - Owned
- Peripheral components – $5.00

Members of the design team personally possess a majority of the required prototyping components, though miscellaneous PVC fittings and peripheral electrical/mechanical components may be absent. A budget of $15.00 is anticipated to satisfy any necessary purchases.

The camera shaft will be fabricated by 3-D printing or by PVC construction and will be attached to the stepper motor to test revolving functionality. The stepper motor will provide the motion and will be controlled by the microcontroller.

Rover Body

The rover body will be constructed of similar materials:

- PVC - $10.00
- Peripheral mechanical components - Owned
- Cardboard - $20.00
- Glue – Owned

As PVC is intended to be used in varying degrees for every prototyped component, an additional allowance of $10.00 is granted. Cardboard is a unique prototype material to the rover body, with an estimated material cost of $20.00.

The rover body will be constructed primarily of cardboard, with glue being used to adhere the base and sides. PVC will be used to mount the body to the suspension system using screws, bolts, or zip-ties, which are currently possessed by design team members.

Rocker-Bogie

The rocker-bogie suspension system will be primarily constructed with previously used prototyping materials, including:

- PVC - $20.00

- Cardboard - $10.00
- Glue – Owned
- Peripheral mechanical equipment – Owned

PVC is the most integral component of the rocker-bogie prototyping, as the suspension system will be primarily constructed of various lengths and fittings, with $20.00 being estimated to cover construction cost. Wheels will be constructed of rolled cardboard and attached to the created PVC linkages. Various nuts, bolts, and washers will be required to connect the linkages, though these materials are currently possessed by design team members.

Assessment Plan

The design team will observe and evaluate the effectiveness of prototyped components after subjecting them to developed test methods.

Camera Mount

The camera mount's ability to rotate will be tested manually through design team influence and mechanically through the use of a stepper motor. A dummy camera will be secured to the mount to assess security and stability when subjected to testing. The use of external tools is not anticipated in the fabrication of this prototyped component.

Detect visually is the main function that the camera mount will support; however, the metrics of video quality and picture quantity are not relevant for this portion of the design process.

Rover Body

An appropriately scaled rover body will be constructed to house components selected for the final prototype. Footprints will be determined using vendor measurements and component weights will be considered when producing the enclosure. During the production of this prototype component, attachment of the suspension system to the main body will also be addressed, as sufficient mobility and security is critical to rover operation.

Enclosure volume and charging area are the two metrics addressed during this phase of prototyping, with targets of $0.5ft^3$ and $10in^2$, respectively. Dimensions will be verified using a tape measure, with various handheld tools, including wrenches and screwdrivers, also being required for construction.

Rocker-Bogie

The focus of this prototype component is to gain understanding of linkage application and motion to ensure maximum mobility.

The rocker-bogie suspension system will be constructed and tested manually by the design team. Integrating motorization is too advanced for this phase, so navigating various obstacles and slopes will be completed through manual propulsion.

The metrics of turn radius, obstacle size, and terrain slope will be considered, with targets of 1ft, 8in diameter and 6in length/width/height, and 20^o> incline and decline, respectively. The design team will find obstacles of appropriate dimensions to assess prototype capability in satisfying related targets and metrics.

Construction of this prototype component will require various handheld tools, such as wrenches and screwdrivers, to connect linkages and mount the suspension to the rover body. A circular saw is required to cut mounting slits, and bolt holes will be produced using a drill.

Conclusion

The rover body, camera mount, and rocker-bogie suspension system were selected for prototype assessment on the merit of their respective relevance to the final detailed design and to gain insight on their mechanisms and suitable design geometry. A prototype assessment plan was constructed for chosen components detailing necessary construction materials, budget, type of testing and necessary testing materials, related key targets and metrics, and correlation of corresponding rover parts to the resulting impact on the detailed design. Assessing integral system components through an elementary prototype design will help clarify component interactions, system mechanisms, and geometric placement, contributing to an increasingly comprehensive final design utilizing educated monetary decisions with minimized risk. The design team estimates that a budget of $75.00 will be sufficient to execute the desired prototypes.

References

Nfornavin. (2017, August 11). How to make a Mars Rover / Rocker bogie robot - stair climbing. Retrieved March 25, 2021, from https://www.youtube.com/watch?v=3Zx7tGtwF5g

Appendix A – Customer Needs

Question	Customer Statement	Interpreted Need
What types of terrains have been encountered on previous missions?	Asteroids have been shown to be covered in craters.	The robotic explorer manuevers through various changes in surface topography, depression, and curvature.
	Boulder rocks and big stones have been seen on asteroid surfaces.	The robotic explorer detects obstacles.
	Different rock types with varying characteristics have been detected.	The robotic explorer works on varying material compositions.
	Basaltic materials were expected, but surfaces similar to hard snow were encountered.	The robotic explorer can travel on surfaces with variable hardness and roughness.
	Comet terrains were mostly flat with some steep cliffs.	The robotic explorer detects and avoids sudden changes in surface elevation.
	The surfaces were non-magnetic, contrary to what was expected.	The robotic explorer functions independent of a planetary body's magnetic characteristics.
What is the budget for this project?	The school has allowed for a $2,000 budget for Senior Design projects.	The prototype for the robotic explorer is designed and implemented for $2,000 or less.
What type of environment is expected on Psyche?	Psyche is expected to have a low gravity, approximately $0.144 m/s^2$.	The robotic explorer remains on the planetary body after landing.
	Psyche has no atmosphere.	The robotic explorer operates on an airless body.
	The temperatures on Psyche are expected to be extremely cold.	The robotic explorer withstands low temperatures.
What types of terrain are expected to be encountered on Psyche?	Fractures and porous space, possibly hidden under regolith.	The robotic explorer traverses both metal and rock surfaces.
	Metal tektites and blocks, but possibly no persistent or deep metal regolith.	
How long will the robotic explorer need to operate at a time?	Spirit and Opportunity robotic explorers were designed to operate for 90 days.	The robotic explorer functions for the duration needed to gather data samples.
	MASCOT was designed to last two asteroid rotations.	The robotic explorer withstands two asteroid orbits.
How will the robotic explorer be deployed?	The robotic explorer will be deployed from the Psyche spacecraft.	The robotic explorer can be housed on the Psyche spacecraft.
Should the robotic explorer be autonomous or remote operated?	Explorers on previous missions have been hybrids.	The robotic explorer has controlled and autonomous functionality.
Who is going to operate the robotic explorer?	The robotic explorer will be operated by NASA personnel.	The robotic explorer is capable of being operated by human personnel.
Are there sizing requirements (i.e. dimensions, weight)?	The Curiosity rover was as large an as SUV.	The robotic explorer is sized to fit its deployment apparatus.
	Previous robotic explorers were sized based on the equipment needed for the mission.	The robotic explorer capably carries mission-essential equipment.

Appendix B – Targets & Metrics

Psyche Rover - Targets & Metrics Catalog				
Function	**Metric**	**Target**	**Critical**	**Notes**
Power				
Convert Energy	Percentage Converted to Useful Work	80+%	Yes	Thermal to Mechanical Electrical to Mechanical
Store Energy	Operational Longevity	60-90 days	Yes	
	Driving Duty Cycle	20%	Yes	Expected driving capacity
Communicate				
Send Signals	Wi-fi Connection	802.11 2.4 GHz or 5 GHz	Yes	
Receive Signals	Wi-fi Connection	802.11 2.4 GHz or 5 GHz	Yes	
Remote Control				
Send Signals	Output Lag	0.5 seconds	Yes	
Receive Signals	Input Lag	0.5 seconds	Yes	
Display				
Display Time	Seconds	Accurate within 2.5%	No	
Display Status	Text	Successfully display text	No	
Sense				
Detect				
Detect Obstacles	Terrain Slope	20^{o} + incline 20^{o} + decline	Yes	
	Obstacle Size	Diameter: 8 in Length/Width/Height: 6 in	Yes	
Detect Visually	Pixel Quantity	8 megapixels	No	
	Video Quality	2,500 to 4,000 kbps	No	HD Quality
Detect Physically	Detection Radius	12 in	No	
Detect Error	Sudden Acceleration or Deceleration	20% increase/s 20% decrease/s	No	
	Sudden Descent	1 in/s	No	
	Reporting Time	1 s >	No	
Mobility				
Maneuver Terrain	Velocity	0.10 ft/s	Yes	Curiosity Rover achieved 0.127 ft/s
	Turn Radius	1 ft	No	
Navigate Obstacles	Terrain Slope	20^{o} > incline 20^{o} > decline	Yes	
	Obstacle Size	Diameter: 8 in > Length/Width/Height: 6 in >	Yes	
Support				
House Equipment	Enclosure Volume	$0.5ft^3$ (8"x10"x12")	Yes	Size estimated through similar rover designs
	Charging Surface Area	$10in^2$	No	Amazon AMX3d
Maintain Stability	Center of Gravity	Low (CG < H/2)	Yes	
***Additional Non-Function Needs**				
Durable	Withstands Environmental Conditions	Yes	Yes	Gravity = 0.144 m/s^2
Economic	Budget Adherence	≤ $2,000.00	No	
Original	Locomotion Style	Distinct from Standard Rovers	No	Wheels commonly used