Targets and Metrics

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Introduction

Integration of customer needs promotes the potential success of a design. Engineering requirements that compliment customer needs are established during early stages of the design process to offer a general prerequisite guideline for future concepts. Presently, the 525-PC Psyche Rover team has gathered and translated customer needs data and organized the findings into respectively encompassing functions.

To ensure the incorporation of engineering requirements and functions into potential design concepts, a measuring system, both quantitative and qualitative, should be used. The development of targets and metrics helps in accurate fulfillment of design requirements. Metrics are used to define the measurement method for a certain function. Targets relate the optimal value, or range of values, corresponding to a metric. Targets and metrics refine the scope of future design concepts, while continuing to avoid solution specificity. They also aid in component selection and identification of any important constraints, contributing to effective concept generation in later stages of the design process.

Derivation of Targets and Metrics

The functional decomposition chart, Figure 1, was used to establish the Targets and Metrics Catalog, Appendix A. The chart is a comprehensive and simplistic translation of the customer needs to associated product functions. Upon establishing the appropriate needs, the product's critical targets and metrics were established, Table 1. The metrics were determined by market research and application and research of knowledge from past and current mechanical engineering courses.

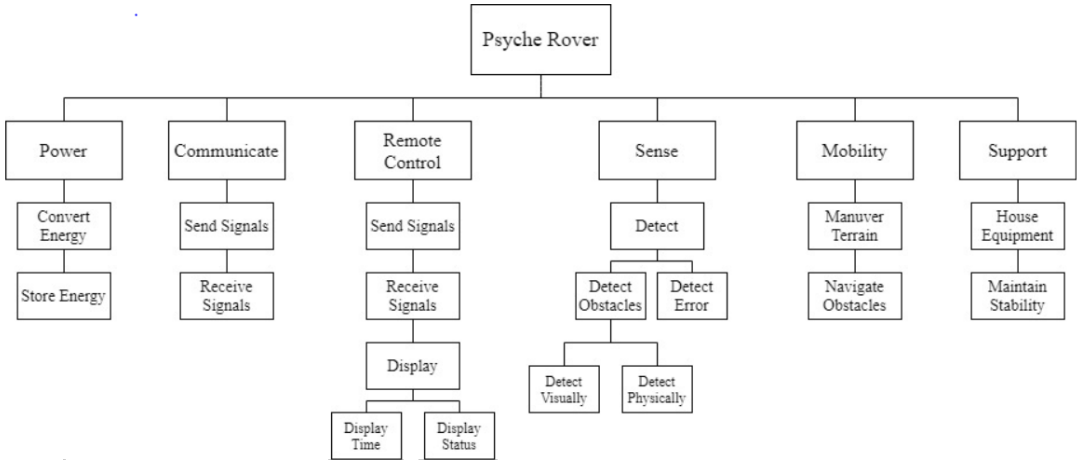

Figure 1 - Functional Decomposition

Explanation of Targets and Metrics

The following list explains the functions, bolded, and their relevant metrics and targets.

- **Power:**

- **Convert Energy:** To properly power the rover, the system must be able to convert power from a source to the rover and disperse it appropriately. The target is to convert a minimum of 80% of the provided energy into useful work.
- **Store Energy:** To function properly, the rover must store an adequate amount of energy for the allotted duty cycle as well as have the proper longevity to accomplish its mission. The target operational longevity for the rover is 60-90 days, while providing 20% of its energy explicitly for driving operations.

- **Communicate:**

- **Send Signals:** To relay information to the system, the rover must be able to successfully send data via wi-fi. The target networking is 802.11 at 2.4 GHz or 5 GHz.
- **Receive Signals:** To obtain information from the system, the rover must be able to successfully receive data via wi-fi. The target networking is 802.11 at 2.4 GHz or 5 GHz.

- **Remote Control:**

- **Send Signals:** To relay information to the rover, the system must be able to successfully send data. This data exchange should be done in less than 0.5 seconds.
- **Receive Signals:** To obtain information from the rover, the system must be able to successfully receive data. This data acquisition should be done in less than 0.5 seconds.

  - **Display:**

- **Display Time:** While collecting data from the rover, the remote control should monitor the run time of the rover. This time will be recorded and displayed in seconds with an allotted error of 2.5%.
- **Display Status:** While collecting data from the rover, the remote control should monitor the status of the rover. If the rover encounters an error, the remote control will display this error to the user via text.

  - **Sense:**

- **Detect Obstacles:** To successfully complete its mission, the rover must be capable of detecting and avoiding obstacles. The rover should detect a minimum slope of 20 degrees as well as obstacles with diameters of 8 inches or length, width, and height dimensions of 6 inches.
- **Detect Visually:** To obtain data, the rover should observe its surroundings visually for the operator to evaluate. This will be done by photo evidence at a minimum of 8 megapixels and/or video evidence at a quality range of 2,500 to 4,000 kbps.
- **Detect Physically:** To navigate properly, the rover should detect its surroundings physically and alert operators of any physical limitations within a detection radius of 12 inches.

- **Detect Error:** To operate efficiently, the rover should detect any running errors and communicate them back to the operator. These errors may include sudden acceleration or deceleration at a 20% increase or decrease per second, as well as any sudden descent of 1 inch per second, and any reporting time of less than 1 second.

  - **Mobility:**

- **Maneuver Terrain:** To operate as intended, the rover must be able to travel through a variety of terrain with minimal to no errors. To accomplish this the rover will have a velocity of 0.10 feet per second and a turn radius of 1 foot.
- **Navigate Obstacles:** To operate as intended, the rover must be able to navigate around any rough terrain and or objects in its path. To accomplish this, the rover will navigate a maximum slope of 20 degrees, as well as any obstacles of 8 inches maximum diameter and 6 inches maximum length, width, and height.

  - **Support:**

- **House Equipment:** To function properly, the rover must be able to house equipment and protect it from any damage. To accomplish this the rover will have an enclosure volume of 8”x10”x12” as well as have a charging surface area of $10in^2$.
- **Maintain Stability:** To function properly, the rover must maintain its stability. To accomplish the rover will have a low center of gravity sitting at less than half the rover's height.

Note: Addressed needs outside of function scope are listed in the targets and metrics catalog, Appendix A.

Critical Targets and Metrics

All of the targets and metrics makes a valuable contribution towards the overall successful performance of the product. However, some are more crucial than others. To decide on our critical targets and metrics, our group analyzed the functions that the product must unequivocally perform for the Psyche mission.

Critical Functions, Targets, & Metrics		
Function	**Metric**	**Target**
Convert Energy	Percentage Converted to Useful Work	80+%
Store Energy	Operational Longevity	60-90 days
	Driving Duty Cycle	20%
Send Signals	Wi-fi Connection Output Lag	802.11 2.4 GHz or 5 GHz 802.11 0.5 seconds
Receive Signals	Wi-fi Connection Input Lag	802.11 2.4 GHz or 5 GHz 0.5 seconds
Detect Obstacles	Terrain Slope	20° + incline 20° + decline
	Obstacle Size	Diameter: 8 in Length/Width/Height: 6 in
Maneuver Terrain	Velocity	0.10 ft/s
Navigate Obstacles	Terrain Slope	20° > incline 20° > decline
	Obstacle Size	Diameter: 8 in > Length/Width/Height: 6 in >
House Equipment	Enclosure Volume	$0.5ft^3$ (8"x10"x12")
Maintain Stability	Center of Gravity	Low (CG < H/2)
Durable	Withstands Environmental Conditions	Yes

Table 1 – Critical Functions, Targets, & Metrics

The rover must be able to store and convert energy to perform its mission. It must be able to detect obstacles and elevations of significance and successfully traverse obstacles and elevations of lesser, undetected magnitudes. The rover must have the volumetric capacity to carry the equipment requisite to function and achieve velocities necessary for locomotion. Lastly, it is critical that the rover be durable enough to withstand the encountered environmental conditions and successfully exchange signals with its operators.

Methods of Validation

There are a wide range of rover functions with quantifiable metrics that can be measured. The critical functions, which include convert energy, store energy, send signals, receive signals, detect obstacles, maneuver terrain, navigate obstacles, house equipment, and maintain stability can all be tangibly tested.

The system functions of converting energy and storing energy have targets that can be measured as either a percentage or a length of time. When converting energy, there are phenomena that result in losses. The design team's goal is to have a system that converts a minimum of 80% of the provided energy from the source into useful work. The losses can be determined by comparing the amount of energy input into the system to the amount of energy output by the system.

The proper storage of energy will be determined by the longevity of the battery. The battery should have a minimum lifetime of 60-90 earth days. This target is more subjective in nature; however, the longevity can be influenced through limiting the driving duty cycle of the rover. This duty cycle should not surpass 20% of the rover's overall operation. Further research will be done on operational characteristics after components are selected.

The sub functions of send signals and receive signals are included under both communicate and remote control. These targets can be measured through hertz and seconds. Sending and receiving signals from the rover to the system will be done via wi-fi connection at frequencies of 2.4 or 5.0 GHz. Communication from the remote control to the rover will be measured through lag time. A lag time of 0.5 seconds or less is the target to limit errors while operating. These criteria will be validated through sensor and software analysis.

The functions of maneuver terrain and navigate obstacles have targets that can be measured through rover velocity and detected slopes and sizes of obstacles encountered by the rover. The rover should be capable of moving at 0.10 feet per second as well as have a turn radius of 1 foot to satisfy the mobility function. These can be measured empirically, with independent verification through sensor application potentially being available. Navigating obstacles is subjective to the user, but can be tested by providing the rover with obstacles and determining if the rover has successfully traversed or navigated the target trial.

Housing equipment and maintaining stability are the last critical functions to be validated. In housing equipment, trial and error can be used to verify that components fit within the desired enclosure volume, though this will occur after component selection, and deviations from the target value of $0.5ft^3$ may be necessary. Maintaining stability is also dependent on component selection. Particular suspensions, such as tracks, are inherently more stable; therefore, conceiving specific testing methods for stability before concept selection is futile. General traversing of sloped terrains or rigid obstacles can be simulated after a prototype is produced and experiential analysis can be used to verify that this critical function is satisfied.

Discussion of Measurement

There are several tools that are required to validate the desired targets.

- A device measuring electric capacitance, such as a voltmeter, will be required to test the initial available energy. Output from the motor can then be determined and used to calculate the system’s efficiency. These calculations are also paramount in determining the rover’s longevity and operating characteristics.

- A stopwatch or digital timer will be used to measure signal delay and precision of other timekeeping targets.
- Analog measuring devices will be used to verify dimensional targets for several metrics. These measurements will be compared and verified with data from chosen sensors, such as accelerometers, if applicable.
    - Center of gravity
    - Obstacle size
    - Enclosure volume
    - Detection radius
    - Turn radius
    - Charging surface area
    - Terrain slope
- Various software and/or sensors will be required to verify that targets of several metrics are achieved. Specific software and sensor needs will be determined after a concept is selected.
    - Wi-fi connectivity
    - Signal exchange between remote control and rover
    - Assessment of picture and/or video quality
- A hardness tester to evaluate component durability.

Summary

The developed targets and metrics contributed to scope refinement and identification of design constraints. Targets and metrics were established to provide important details pertaining to concept generation and selection. Engineering requirements and functions were used to promote consistent incorporation of customer needs throughout the overall design process. Metrics were matched to select functions sourced from the functional decomposition, Figure 1. The functions were chosen based on group discretion regarding a respective function's necessity in having to be defined through a target and corresponding metric.

Metrics were defined using engineering knowledge and experience, as well as source data gathered from external research. Targets were designated in the same manner. The number of targets varied for each respective metric as needed for comprehensive metric definition. Critical targets were designated based on the extent of their contribution to the design and necessity in the overall project. Methods of validation were used to explain target and metric selection. Lastly, necessary equipment to test target values was discussed.

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Appendix A – Targets & Metrics Catalog

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

Figure 2 - Targets & Metrics Catalog