Functional Decomposition

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Background

The Psyche Rover design team has been tasked with conceiving a robotic explorer to traverse potential terrains that may be encountered on the 16 Psyche asteroid. It is hypothesized that the asteroid is mainly metallic in composition, being comprised of metallic iron and nickel. Due to this composition, the asteroid is of significant interest, as scientists believe that Psyche may be the exposed core of an early planet. As the first investigation of a world of metal, the Psyche mission may provide insight on the history of planetary collisions and what may lie at the Earth's core (In Depth, 2021).

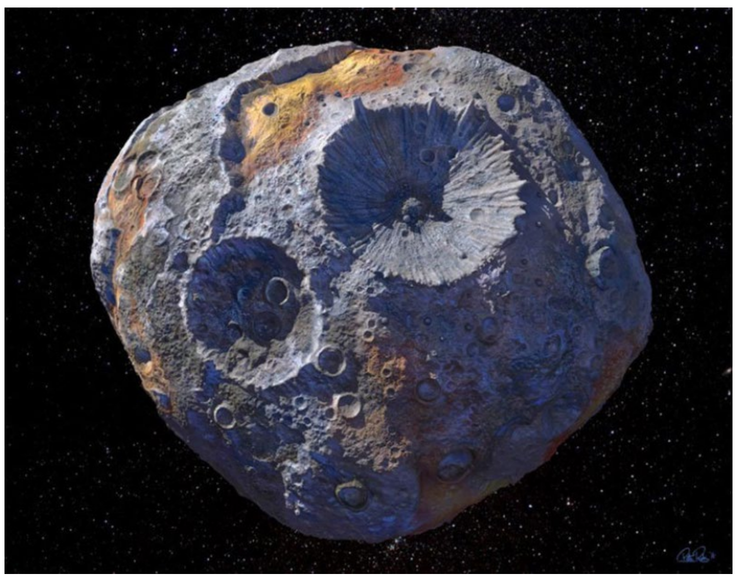

Figure 1 - Artist Concept of Psyche, Credit: Maxar/ASU/P.Rubin/NASA/JPL-Caltech

Introduction

The translation of customer needs into engineering requirements is a crucial step in the engineering design process and lays the groundwork for the next stage in design. Functional decomposition is the process of breaking down a system or product into its lowest-level functions, avoiding solution-specificity. Functions are described using verbs and integrate customer needs to give the design team the appropriate level of scope in understanding what the system must do, without being constrained by solution-specific conclusions. The functional decomposition can be represented using a chart, showing the highest-level functions at the top, with their respective sub-functions branching off until the lowest level is achieved.

Data Acquisition

The customer needs used to create the functional decomposition were obtained through meetings with Dr. Cassie Bowman, project sponsor, Dr. Damion Dunlap, faculty advisor, and through independent research performed by the design team. After this data was organized and tabulated, customer needs were translated into interpreted engineering needs. Six major functions, *power*, *communicate*, *remote control*, *sense*, *mobility*, and *support*, were identified to satisfy customer requirements.

Functional Decomposition

From the interpreted customer needs, the functional decomposition below was created, Figure 2. The six major functions were designed to fulfill one or more of the interpreted needs.

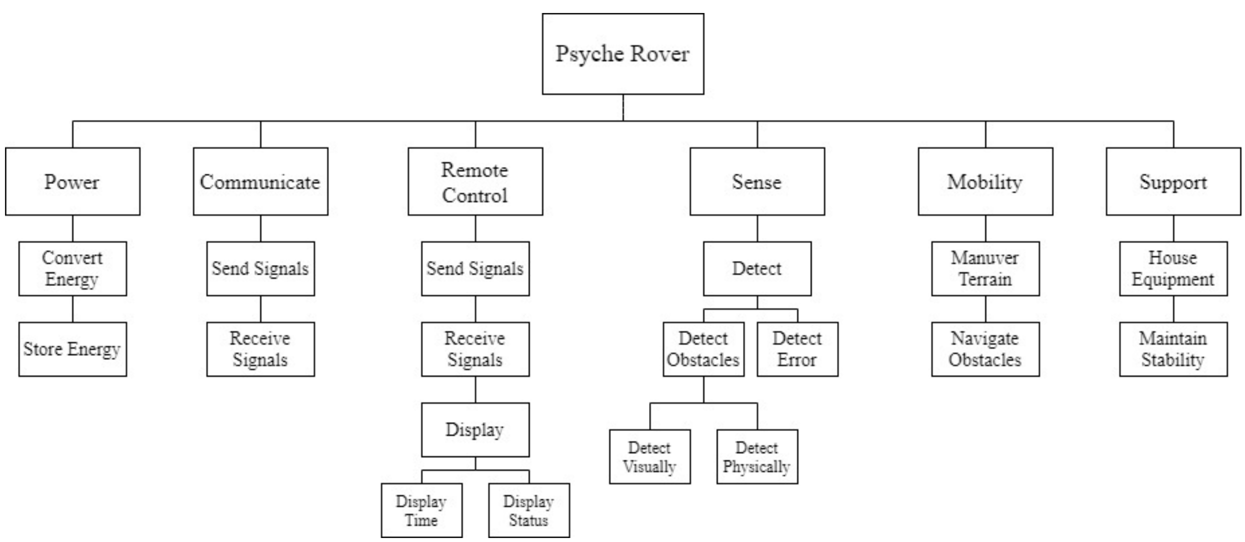

Figure 2 - Functional Decomposition

The *power* function houses the sub-functions *convert energy* and *store energy*. These functions satisfy interpreted needs by providing and storing power for an appropriate duration. An interpreted need that this function serves is “The robotic explorer functions for the duration needed to gather data samples”. The *communicate* function houses the sub-functions *send signals* and *receive signals*, allowing the rover to exchange information with other system components and the user, fulfilling various interpreted needs necessitating communication, including “The robotic explorer is capable of being operated by human personnel”.

Remote control allows for the rover to be controlled remotely and houses the sub-functions *send signals*, *receive signals*, and *display*. The *display* sub-function allows users to see relevant messages relayed by the rover and further satisfies “The robotic explorer is capable of being operated by human personnel” interpreted need. The *sense* function houses the sub-function *detect*, which branches into *detect obstacles* and *detect errors*. *Detect* addresses “The robotic explorer detects obstacles” interpreted need and is critical in the prevention of rover damage.

Mobility houses the sub-functions *maneuver terrain* and *navigate obstacles*, ensuring the rover is capable of fulfilling interpreted needs involving movement, such as “The robotic explorer maneuvers through various changes in surface topography, depression, and curvature”. The final function, *support*, is comprised of the sub-functions *house equipment* and *maintain stability*. This function is integral in ensuring the rover is capable of withstanding varying environmental conditions and supporting peripheral equipment.

Smart Integration

Detailed in the first row of the functional decomposition, Figure 2, major functions are the backbone of our system and ensure customer needs are met through the fulfillment of interpreted needs. Although sub-function branches are exclusive to their major functions, the functions included in the decomposition are intended to work harmoniously in satisfying customer needs.

Power, the first major function, specifies that the rover has the ability to *convert* and *store energy*. In the absence of this function, the rover would be incapable of *maneuvering terrain*, *sending signals*, or performing other sub-functions shown in the functional decomposition. The *sense* function is crucial for the rover's mobility, since the system needs to *detect obstacles*, whether physically or visually, and communicate back to the remote control. The user can then make appropriate adjustments for the rover to continue effective operation.

The *remote control* function impacts the outcome of several major functions, including *communication*, *sensing*, *mobility*, and *support*. The rover will be user-operated, employing a remote to influence mobility through communicated signals. *Display*, a *remote control* sub-function, will allow users to track running time and system status, integral functions in energy conversion and error detection.

Conclusion

Functional decomposition clarifies a design problem. Representing a system through various sub-functions, the design team is able to attain a comprehensive understanding of what the system must do, as well as the connectivity existing between sub-system functions. The integration of customer requirements is necessary for effective functional decomposition execution. The team developed system functions using previously gathered data on customer requirements and guidance from the faculty advisor, Dr. Dunlap. The team plans to use the developed functional decomposition chart in future steps of the design process, mainly during the concept generation phase.

References

In Depth. (2021, January 12). Retrieved January 18, 2021, from https://solarsystem.nasa.gov/asteroids-comets-and-meteors/asteroids/16-psyche/in-depth/

Appendix A – Customer Needs Table

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	Spirit and Opportunity robotic explorers were designed to operate for 90 days.	The robotic explorer functions for the duration needed to gather data samples.

need to operate at a time?	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.

Figure 3 - Customer Needs Table