Future Power Solutions for Exploring Hypothesized Surfaces

NASA Psyche Mission

ME 481 Spring 2025, DG8 – Mallory Brooks, Renee Kinsler, Daniel Krahn, Chase Marcath, Ari Mustafaraj

PROJECT INTRODUCTION

Project Objective: Design a power system for a hypothetical surface mission to the asteroid 16 Psyche to learn about its composition and formation. Psyche:

- Is 3.3 AU from the sun, with a shorter day and a longer year than on Earth
- Is theorized to have a rough, mostly metal surface
- Has no atmosphere and experiences extreme temperature swings

System Parameters: To be successful, our system must:

- Power the duration of the mission
- Withstand the harsh extraterrestrial conditions
- Be of a reasonable size/scale to put on the probe

We assumed that the probe would be mobile and would have a path designed to stay mostly in sunlit areas.

INITIAL DESIGN PROCESS

The first step in the process was to choose our methods of power generations. We settled on a system that included:

Solar Power: Used in many other successful NASA missions and requires no external fuel

Thermoelectric Power: Has precedence in the use of MMRGs, requires little to no external fuel

Lithium-ion Battery: Used in other successful NASA missions, can sustain a long mission

To ensure our system designs would provide the hypothetical probe with enough power, we estimated the power usage based on the instruments included in similar past NASA missions such as NEAR-Shoemaker and the MER Opportunity (table 1). Taking 110% of this power usage to account for small system defects, we found the required solar panel area for XTJ cells on Psyche to be:

$$A = \frac{\dot{W}}{\eta_{PV} G"} = \frac{182.6}{0.2670(108.22)} = 6.03\ m^2$$

This work was created in partial fulfillment of Michigan State University's Capstone Course ME 481. The work is a result of the Psyche Student Collaborations component of NASA's Psyche Mission (https://psyche.asu.edu). "Psyche: A Journey to a Metal World" [Contract number NNM16AA09C] is part of the NASA Discovery Program mission to solar system targets. Trade names and trademarks of ASU and NASA are used in this work for identification only. Their usage does not constitute an official endorsement, either expressed or implied, by Arizona State University or National Aeronautics and Space Administration. The content is solely the responsibility of the authors and does not necessarily represent the official views of ASU or NASA.

***Table 1:** Summary of Instruments/Power Use on a Hypothetical Psyche Probe*

Name of Device	Purpose	Avg. Power Usage (W)	
		Motion/Nativation	*Data Collection*
CAMERAS			
Panoramic Camera (Pancam)	Taking colored, panaramic photos of the asteriod's surface	-	6.5
Microscopic Imager	Taking B&W small, detailed images of the asteriod's surface	-	4.8
A pair of stero cameras	Mapping the asteriod's surface for navigation	6	-
SPECTROMETERS			
Alpha Particle X-Ray Spectrometer	Determining elements that make up the ground via alpha particle x-rays	-	1.5
Gamma Ray Spectrometer	Determining elements that make up the ground via chracteristic gamma rays	-	24
Miniature Thermal Emission Spectrometer	Determining elements that make up the ground via signature thermal emsssions	-	5.6
Mössbauer Spectrometer	Determining elements, specifically identifying FE materials	-	2
OTHER INSTRUMENTS			
Magnetometer	Search for a magnetic field	-	1.5
MOTORS			
Maxom RE25 10V Motor	6 motors to drive wheels	60	-
	6 motors to steer wheels	60	-
	8 motors to pan/tilt cameras (2 motors per camera)	40	40
	ESTIMATED TOTAL POWER USEAGE (Watts):	166	85.9

DESIGN CONCEPT 1 – SOLAR FAN

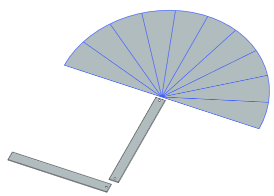

***Figure 1:** Initial CAD Model of Fan Concept*

- Motion based on a foldable hand fan
- 4 semi-circles (1.5075 m^2 each) made of triangular solar cells, joined by hinge connectors, attached to probe by jointed arm
- Fan can fold to take up less space, arm folds in towards body
- TEGs incorporated under fan segments

DESIGN CONCEPT 2 – SOLAR SCROLL

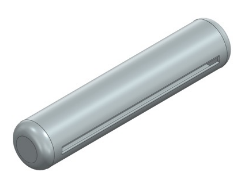

***Figure 2:** Initial CAD Model of Scroll Concept*

- Motion based on roll-out solar arrays used on ISS
- Capsule is used to protect the rolled spiral of solar cells inside
- 4 sheets of solar cells, 0.75m by 2m (1.5075 m^2 each)
- Panels supported via telescoping track on each side of the capsule, extending parallel to probe
- TEGs incorporated with data-collection devices on main body of probe

THERMOELECTRIC POWER POTENTIAL

Thermoelectric generators function via the temperature difference across the device. In our design concepts:

- We used ten 30mm TEGs, with Lead Telluride n-type legs and Bismuth Telluride p-type legs
- The heat source is devices on the probe, either solar panels or data collection instruments

Based on the operating temp. range of solar panels and the surface temp. range of Psyche we found that there is potential to generate between **7 and 110 W** of additional power.

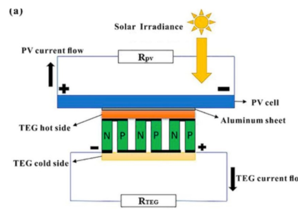

***Figure 3:** A basic hybrid PV-TEG configuration [1]*

However, we also discovered that a heat sink sized for the TEGs isn't cannot dissipate all the heat generated during operation, so future work needs to be done in designing a better heat sink suitable for space environment.

POWER STORAGE

Lithium-ion batteries were used to power the Mars rovers that informed our hypothetical probe makeup. To allow the probe travel up to 4 hours before recharging, we recommend that it hold up to 1 kWh of energy.

***Figure 3:** An Example of a Lithium-Ion Battery [2]*

CONCLUSIONS & RECOMMENDATIONS

Our design concepts, which include solar and thermoelectric power, have a maximum potential to produce **~293 watt**s of power. To implement these designs effectively, we recommend:

- Developing a more effective heat sink for TEGs
- Further design work to protect solar system joints from debris
- More research into TE materials effective at low temps

REFERENCES & ACKNOWLEDGEMENTS

[1] J. He, K. Li, L. Jia, Y. Zhu, H. Zhang, and J. Linghu, "Advances in the applications of thermoelectric generators," *Applied Thermal Engineering*, vol. 236, p. 121813, Jan. 2024, doi: https://doi.org/10.1016/j.applthermaleng.2023.121813.

[2] "SAR-10211 Aerospace Battery." Accessed: Apr. 15, 2025. [Online]. Available: https://www.eaglepicher.com/sites/default/files/SAR-10211%201023.pdf

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