NASA Psyche: Future Power Solutions

Group 45
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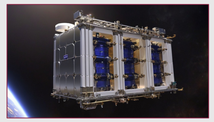
Introduction

There exists an M-type asteroid which is commonly known as asteroid Psyche. The asteroid is roughly 144 miles long and has a surface area of 64,000 square miles. Because it is so large with a possible rough terrain, a future mission must design a spacecraft that has the power to get there, successfully land, and traverse the surface of the asteroid for research. Group 45 will act as the formulation team for the Psyche Mission to design a power solution for the spacecraft that will allow it to traverse safely despite the possibly unknown hypothesized surfaces. This project will require the use of team skills from collaboration to expertise on power devices and power systems.



Previous Work

Since NASA's founding in 1958, their team of engineers and scientists have pioneered a plethora of different propulsion systems, landing systems, and rover power systems. The two main previous works that were researched for this project were NASA's Radioisotope Power System (RPS) and NASA's hydrogen fuel cells.- The Radioisotope Power System was first created by the US Navy for NASA in 1961 and since then a total of 24 NASA missions have successfully flown using it [4].

- Two of the most notable missions that utilized RPS were the Mars *Perseverance* (2020-present) and the Mars *Curiosity* (2011-present) Rovers, both sent to Mars as data collection and research probes [4].
- Hydrogen fuel cells were appealing due to their small size and reliability.
- NASA plans to implement them for interplanetary missions, because they launch as a non-toxic and low-pressure fuel source, with light energy density, and a high theoretical energy limit [7].

References

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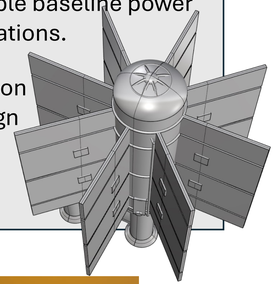
[4] "NASA RPS Missions." *NASA*, NASA, https://science.nasa.gov/planetary-science/programs/radioisotope-power-systems/missions. Accessed 09 Nov. 2024.
[5] Rep. Posey, Bill. "H.R.1508 - Space Resource Exploration and Utilization Act of 2015." *114th Congress*, Congress.gov ,https://www.congress.gov/bill/114th-congress/house-bill/1508#:~:text=Declares%20that%20any%20asteroid%20resources,law%20and%20existing%20international%20obligations. Accessed 09 Nov. 2024.
[6] "Space Nuclear Propulsion." *NASA*, NASA, https://www.nasa.gov/tdm/space-nuclear-propulsion/#history Accessed 09 Nov. 2024.
[7] "State-of-the-Art of Small Spacecraft Technology." *NASA*, NASA, https://www.nasa.gov/smallsat-institute/sst-soa/power-subsystems/#3.3.4. Accessed 09 Nov. 2024.
[8] "Systems: Thermal Radioisotope Heater Units." *NASA*, NASA, https://science.nasa.gov/planetary-science/programs/radioisotope-power-systems/thermal-radioisotope-heater-units/ Accessed 09 Nov. 2024.
[9] "What is a Radioisotope Power System." *Office of Nuclear Energy*. US Dept. of Energy, https://www.energy.gov/ne/articles/what-radioisotope-power-system#:~:text=Radioisotope%20power%20systems%20(RPS)%20convert,radioactive%20isotope%E2%80%94into%20electrical%20power. Accessed 09 Nov. 2024.

Power System Model

Group 45 designed a hybrid power system specifically for a spacecraft headed to land on Psyche. The system integrates traditional Radioisotope Power and Hydrogen Fuel cells. This offers both reliable baseline power as well as supplemental power for high-demand situations.

To gain inspiration for the design, Group 45 reflected on past NASA Radioisotope Generators. The entire design was designed using Rhino 3D 7.



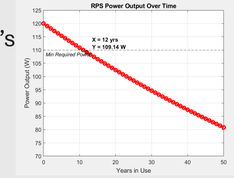
Key Components

The model's core component is the Isotope Fuel Capsule, which contains Plutonium-238 decay isotopes that generate the system's primary energy. Supporting elements include cooling tubes to prevent overheating, Hydrogen Fuel Cells for backup power, a Power Output Receptacle for energy transmission, and an exhaust system for gas release. Additional features like stabilizing fins and housing ensure structural stability and environmental protection throughout the journey.

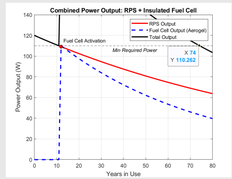
This work was created in partial fulfillment of Arizona State University Capstone Course EEE489. The work is a result of the Psyche Student Collaborations component of NASA's Psyche Mission (https://psyche.asu.edu). "Psyche: A Journey to a Metal World" [Contract number NNM16AA09C] is part of the NASA 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.

RPS Simulation

The Radioisotope Power System (RPS) begins at 120W and decreases over time following Pu-238's 87.7-year half-life. Simulations show the output drops below the mission's 110W power requirement at year 13. While the cold environment at Psyche (137K) slightly improves thermoelectric performance, the main contributors to power loss are radioactive decay and material degradation.

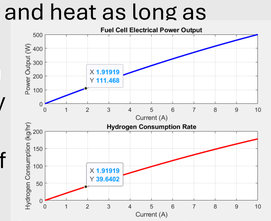


To extend mission viability, a hydrogen fuel cell is introduced as a backup, activating only after the RPS dips below threshold. With Aerogel insulation, the fuel cell degrades slowly—starting at 110W and dropping to ~70W by year 30. The combined power output remains above110W for decades, balancing RPS reliability with fuel cell flexibility in a hybrid design.



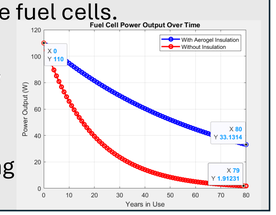
H2 Fuel Cell Simulation

Hydrogen fuel cells work very similarly to batteries but never run out of charge and continually will supply electricity and heat as long as hydrogen fuel is supplied [3].
Several simulations were completed through MATLAB, with the first showing the necessary amount of Hydrogen fuel needed to be sent on the probe to provide the baseline power of 110W.



Additionally, fuel cell power output over decades was mapped, showing the decay and functionality of the cells at the extreme temperatures encountered on Psyche, and how the implementation of Aerogel insulation prolongs the longevity of the fuel cells.

Without insulation, the output starts at the baseline value of 110W, but decreases to only 1.9W after 80 years in use. With Aerogel, this value significantly improves, holding baseline wattage for several decades, before decreasing to 33W in the same 80 year time frame.



Conclusion

In closing, the goal is to establish a design to power a probe that would land on Psyche. With a design using RPS and fuel cells, Group 45 created a sustainable and ethical power system that is capable of collecting data and exploring any terrain type with little to no refueling needed.