Endurance: The Self-Clean Solar Explorer Rover

Interstellar Corporation

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BACKGROUND

Mars poses extreme challenges for robotic missions, including freezing temperatures, low pressure, and frequent dust storms. Dust buildup on solar panels reduces energy intake by about 0.2% per Sol, with rovers like *Spirit* and *Opportunity* losing up to 30% efficiency in just 300 Sols, resulting in reduced mission speed. Despite this, solar power remains a lightweight, cost-effective solution for long-term exploration.

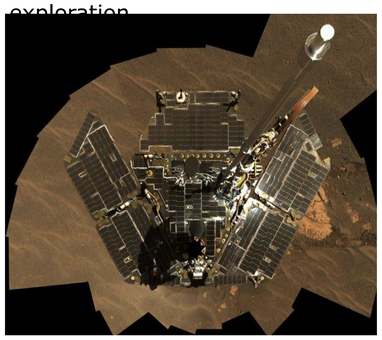


Figure 1: Opportunity Rover December 2004

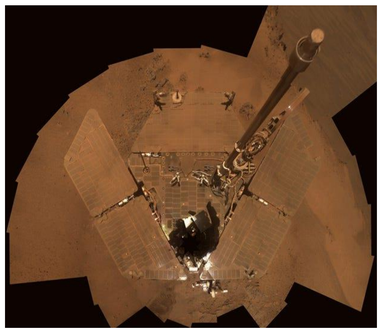


Figure 2: Opportunity Rover December 2011

PURPOSE

This self-cleaning solar panel system combats dust-related energy loss and enables reliable power generation for extended Mars missions. Integrated into a compact, solar-powered rover, it supports consistent performance in harsh, dusty environments. The goal is to extend the operational lifespan of solar-powered rovers to over 20 years while reducing reliance on costly nuclear systems. The Curiosity rover costs $3.2 billion, and Perseverance costs $2.9 billion, resulting in a combined total of $6.1 billion. In comparison, the combined cost of deploying the solar-powered Mars Exploration Rovers, Spirit and Opportunity, was only $1.2 billion [McCarthy]. Our design aims to bridge this cost gap by combining long-term mission viability with cost-effectiveness.

OBJECTIVE

DUST REMOVAL METHOD

Utilize static-repelling bristles to remove electrostatically chargged dust from the rover'solar panels

RELIABILITY

Mechanically engineered with a minimum factor of safety of 2 to ensure long-term durability under Martian conditions

POWER CONSUMPTION

Operate within a limit of 600 watt-hours per day, consuming no more than 50% of the rover's daily solar energy output

AUTONOMOUS OPERATION

Designed to function independently with minimal intervention, enabling consistent cleaning over

DESIGN

The cleaning mechanism will be integrated within the Endurance, positioned beneath the solar panels. When the rover detects a decline in solar efficiency, it will activate the cleaning system to clear accumulated dust from the panels.

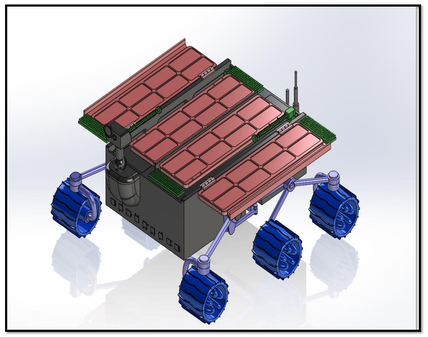


Figure 3: Full View of the Endurance

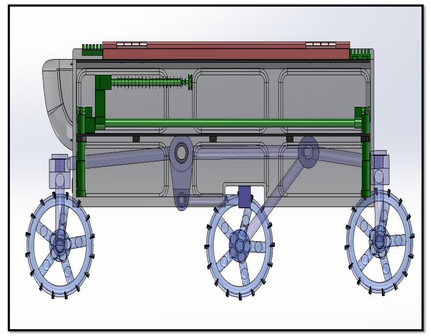


Figure 4: Internal View of Cleaning Mechanism

The cleaning mechanism arm will utilize bristles that rotate at varying speeds to efficiently clear dust from the solar panels. Made from Polyether Ether Ketone (PEEK) infused with graphene, these bristles will leverage an alternating current—shifting from positive to neutral—to attract oppositely charged dust particles. Upon reaching the edge of the panel, the brush will reverse its current, enabling self-cleaning before continuing its operation.

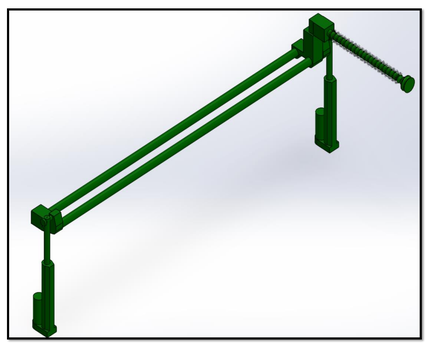


Figure 5: Full View of the Cleaning Mechanism

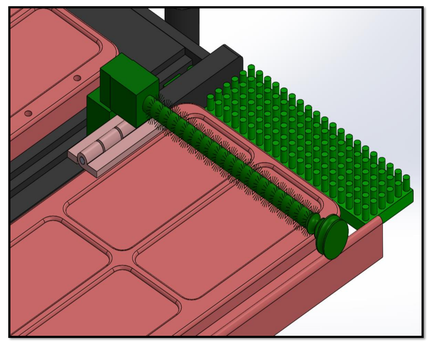
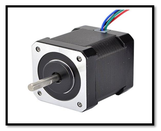


Figure 6: Internal View of Cleaning Mechanism

SYSTEM FEATURES

Actuators will regulate the linear motion of the cleaning mechanism during its activation and retraction.

PEEK will be used as the brush bristle material due to its durability and ability to endure extreme cold temperatures.



Stepper motors will regulate the rotational motion of the cleaning brush as it spins and positions the arm onto the solar panels.

Graphene coating will be applied to the bristles, leveraging its conductive properties to enable current flow, effectively attracting dust particles to the brush.

CALCULATIONS

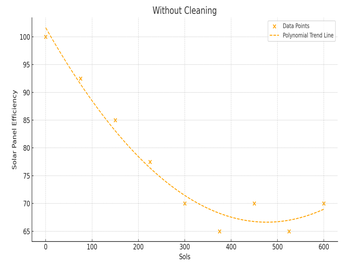


Figure 7: Solar Panel Efficiency Data from Opportunity

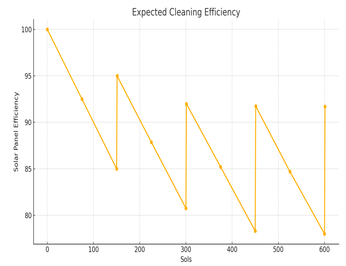
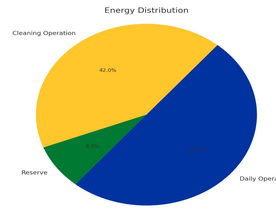


Figure 8: Expected Solar Panel Efficiency Data from Cleaning Mechanism

Over 300 sols, the Opportunity rover's solar panels experienced a gradual decline of 0.2% per sol until reaching a stable efficiency of 70%. Upon activation, the cleaning mechanism will restore the lost solar efficiency by removing accumulated dust, bringing performance back to 90% for the remainder of the mission.



This figure highlights the energy allocated to the cleaning mechanism, which requires 504 watt-hours to thoroughly clean the solar panels in one hour. This demand accounts for 42% of the rover's 1,200 watt-hour daily energy budget.

Figure 9: Energy Distribution

FUTURE WORK

- Further research must be conducted to testing on the cleaning mechanism electrostatic force objective
- Develop and evaluate the optimal brush bristle design
- Initiate the construction of the model using suitable components
- Start Coding the guide path for the cleaning mechanism

CONCLUSION

Endurance demonstrates that with innovative dust mitigation and efficient design, solar-powered rovers can operate longer, explore farther, and offer a sustainable path for future Mars missions, all at a fraction of the cost of nuclear-powered alternatives.

ACKNOWLEDGEMENTS

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QUESTIONS & REFERENCES

All questions can be sent to the team email at tsgcinterstellarcorporation@students.tamuk.edu

References can be found in the QR Code