Magnetic Shields for Mars: A Model of Planetary Protection Against Solar Wind

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This project evaluated the ability of laboratory-scale permanent magnets and a battery-powered electromagnet to generate magnetic pressure and compared their capacity to approach the pressure-balance condition required to counteract simulated solar-wind dynamic pressure under Mars-like conditions. A permanent-magnet array and wire-coil electromagnet were constructed and tested. Magnetic field strength (B) was measured using independent application for cross-validation, and average values were calculated. Attraction and repulsion distances were also recorded for each system. Magnetic pressure was computed using P_B = B2/(2μ0) and compared to a reference Martian solar-wind dynamic pressure of P_sw ˜ 8.18×10^-9 Pa. Experimental measurements were used to estimate scaled magnetic pressure values and were further analyzed using the Magpylib simulation environment to model behavior under varying conditions, including low and high-pressure and solar wind speed scenarios. Comparison between measured and simulated data revealed consistent trends in magnetic field behavior as a function of distance and system configuration. Differences between experimental and simulated results were attributed to model simplification and measurements of limitations. Overall, the results support the use of pressure-balance modeling as a framework for evaluating artificial magnetic field systems and highlighting the dependence of magnetic pressure generation on system design and geometry.

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