Terraforming Mars: Solutions to Shield against Cosmic Radiation

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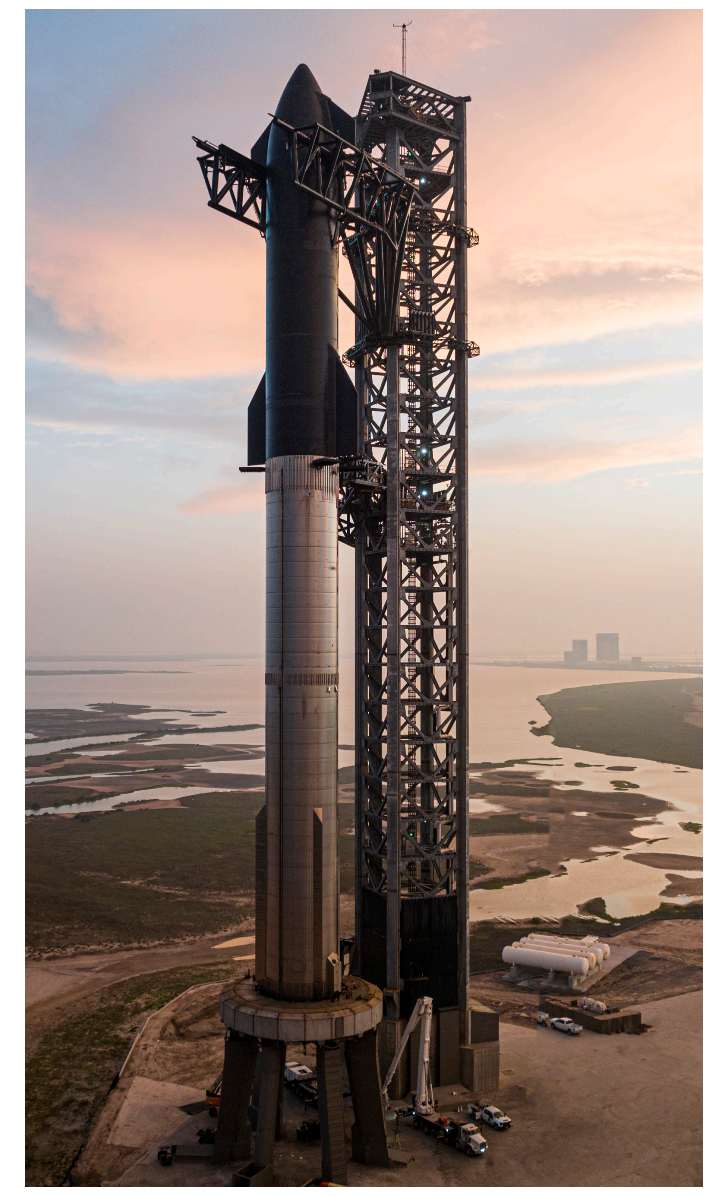

Figure 1: The first test flight of SpaceX's reusable "Starship", the most powerful rocket launch system to date. April 2023, Texas.

1 Introduction

The colonization of other planets is crucial to the long-term survival of humanity amidst existential threats like asteroid impacts, artificial intelligence, and nuclear war. Mars is at the front of these ambitions due to its proximity. Commitments to establish permanent settlements are notably pursued by SpaceX (Figure 1). Beyond the construction of habitats, the hypothetical terraforming of Mars aims to alter its hostile environment, allowing human survival without shelter. This poses many challenges, one of which is analyzed here, namely providing protection from cosmic radiation, which is harmful to our health [1] and can strip planets of their atmosphere [2].

2 Solutions

Three solutions, all generating a magnetic field around Mars to fend off radiation (Figure 2), are presented. First, heating the iron core of Mars by detonating thermonuclear bombs in order to activate the dynamo effect, mirroring the natural mechanism on Earth (Figure 3). Second, constructing a current-carrying ring of plasma around Mars, in the orbit of the moon Phobos. Third, winding a current-carrying wire around the surface of Mars. The wire can be made of either copper or a superconductor (e.g., YBCO). Superconductors have zero electrical resistance and conduct current without energy loss at low temperatures.

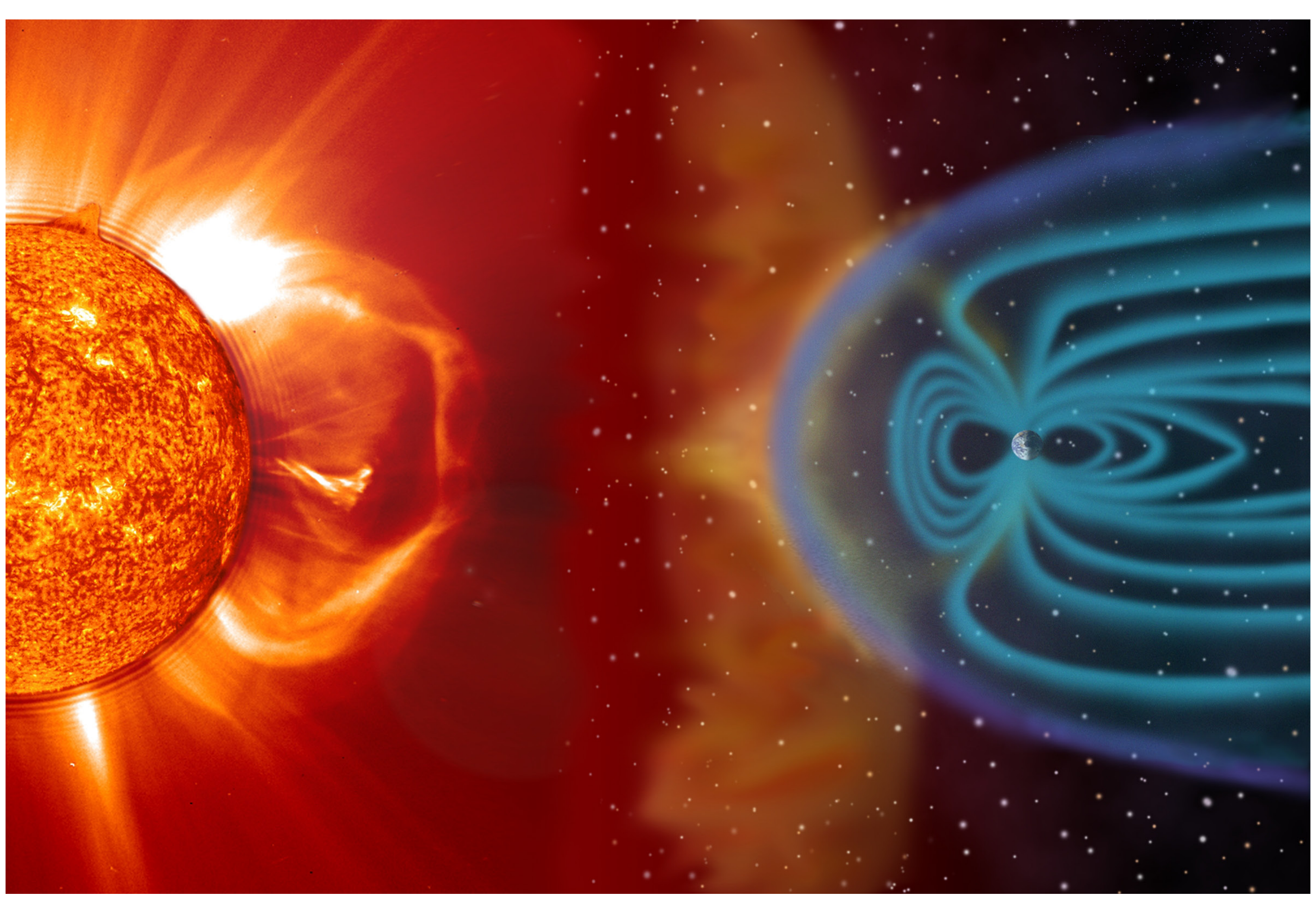

Figure 2: Artistic concept of a magnetic field (blue), like Earth has one, shielding a planet from solar wind (red).

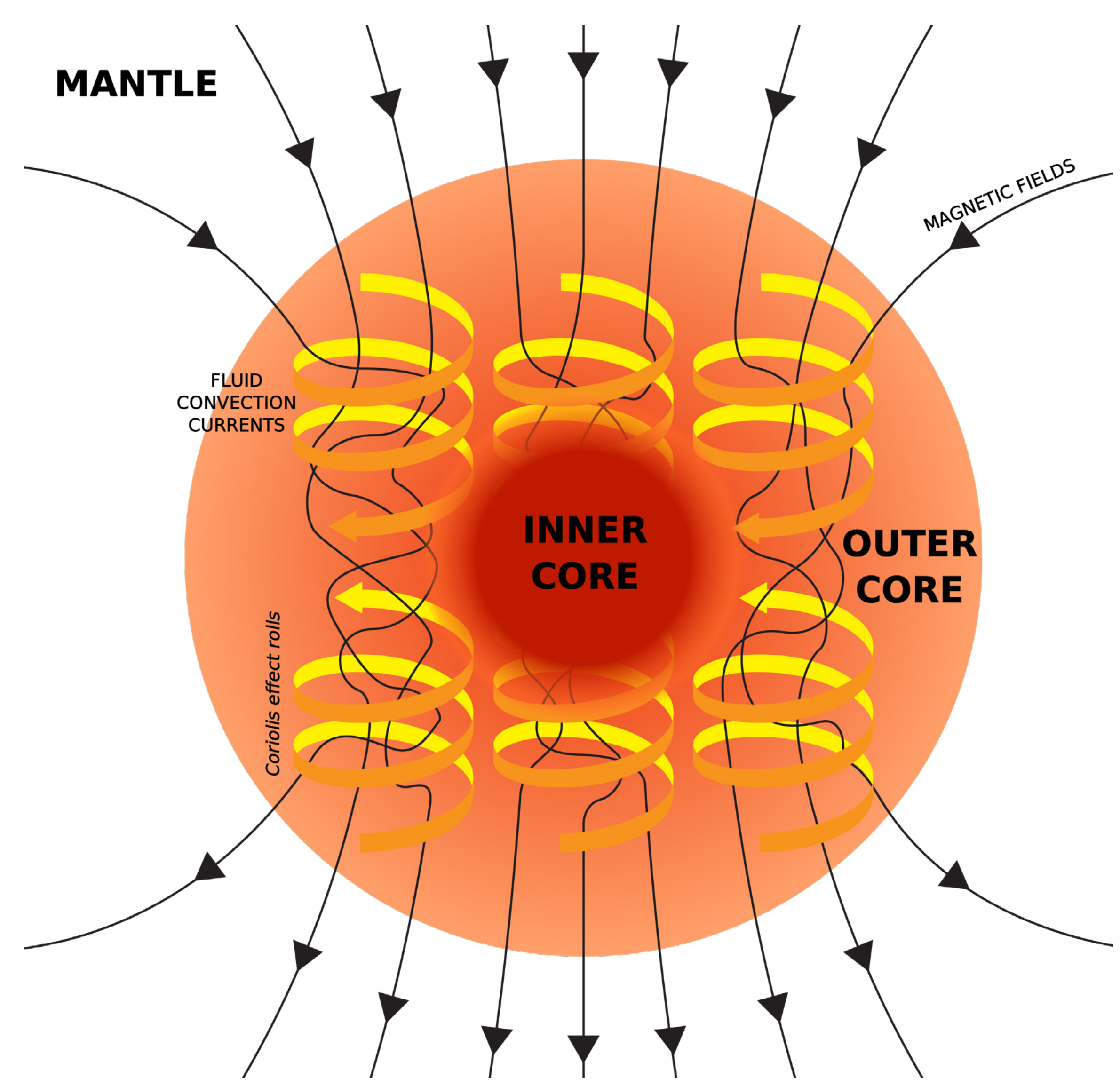

Figure 3: The dynamo effect as it occurs in Earth's liquid iron outer core. Fluid convection, powered by temperature differences, creates a magnetic field.

3 Feasibility

Heating Mars's core is most unrealistic due to the high energy demands (340 million times the annual global energy consumption) and the uncertainty of success. The plasma ring poses complex engineering challenges of containing and heating the plasma and sustaining the current inside. A more feasible solution is the wire. While a copper wire does not require cooling and is easier to manufacture and handle than a superconducting one, sustaining the current in it requires considerable power (91 times the global power consumption). This makes the superconductor the most promising solution, especially in view of the very active research in the field.

References

[1]: J.C. Chancellor, G.B. Scott, J.P. Sutton, "Space Radiation: The Number One Risk to Astronaut Health beyond Low Earth Orbit", *Life* **2014**, *4*(3), p. 491–510, doi:10.3390/life4030491

[2]: F. Leblanc, A. Martinez, J.Y. Chaufray, R. Modolo, T. Hara, J. Luhmann et al., "On Mars's atmospheric sputtering after MAVEN's first Martian year of measurements", *Geophysical Research Letters* **2018**, *45*, p. 4685–4691, doi:10.1002/2018GL077199