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P3 5 A Nuclear Spark for Mars

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Abstract

This speculative analysis explores the hypothetical use of high-yield thermonuclear devices, such as Tsar Bomba equivalents (50 Mt), delivered via a borehole in the thinnest crustal regions (e.g., $\sim 6 - 10$ km at Isidis Planitia), to inject energy into the planet's interior. We refine estimates for progressive rock vaporisation to deepen the shaft and calculate the energy needed to enhance core convection sufficiently for dynamo reactivation. We estimate requirements on the order of $\sim 10^{29}$ J, equating to trillions to tens of trillions of such devices - even with optimistic efficiencies - highlighting the profound impracticality.

Introduction

Sustainable Mars colonisation requires shielding from solar winds, which strip the atmosphere at $\sim 1 - 2$ kg/s [1] and pose radiation risks without a magnetic field. Mars' geodynamo ceased ~ 4.3 to 3.6 billion years ago [2] due to insufficient core convection from rapid heat loss. Restarting this dynamo requires re-establishing buoyancy-driven motions in the liquid outer core, influenced by thermal gradients, Coriolis forces, and compositional effects [3]. Unlike traditional terraforming, this paper refines a "nuclear injection" approach. It uses sequential high-yield detonations for excavation and energy delivery.

This analysis is separated into two distinct phases: excavation, where sequential 50 Mt detonations progressively vaporise mantle rock to extend a $\sim 1,506$ km shaft from the base of the crust to the core-mantle boundary (CMB), with thermal contributions to the core deemed negligible due to $> 1,500$ km propagation losses

and $< 1\%$ energy coupling; and core heating, where subsequent detonations at the CMB are modelled purely for thermal injection into the liquid outer core, neglecting further excavation.

Mars' Interior Structure and Dynamo Cessation

Mars' radius is $\sim 3,390$ km [4]. Its structure comprises a $\sim 1,830$ km radius core [4], a $\sim 1,500$ km thick mantle [4], and a $6 - 50$ km thick crust [4] (thinning to $\sim 6 - 10$ km in Isidis Planitia [5]). InSight data confirm a solid, $\sim 600 - 610$ km radius, iron-rich inner core within a liquid outer core containing light elements like sulphur (up to 16 wt% [2]) [6]. Core temperatures are $1,900 - 2,000$ K at the core-mantle boundary (CMB) [7]. The dynamo ceased as CMB heat flux dropped to ~ 20 mW/m² today (vs. Earth's $\sim 65 - 100$ mW/m² [8]), falling below the $\sim 50 - 100$ mW/m² [7] needed for supercritical convection.

Restarting it requires outer core heating to increase the CMB temperature gradient by 25 -

50% (a $\sim 10 - 50$ mW/m² flux increase), equating to a 300 – 1,000 K temperature rise for a transient superadiabatic profile [2]. Compositional adjustments, like reducing sulphur, could lower thresholds but are speculative.

Drilling and Progressive Deepening Feasibility

Penetrating the initial ~ 6 -10 km crust is conceptually feasible, drawing parallels to Earth’s Kola Superdeep Borehole of 12 km [9]. Mars’ lower gravity of 0.38 g [10] reduces overburden stress, and autonomous robotic systems could enable off-world fabrication. Beyond the crust, sequential thermonuclear detonations would vaporise mantle rock to extend the shaft from the base of the crust at depth ~ 6 km, down through the $\sim 1,500$ km mantle to the CMB, giving a total surface-to-CMB depth of $\sim 1,506$ km.

Each 50 Mt detonation yields $\sim 2.09 \times 10^{17}$ J [11], creating a cavity radius R_c (m) via the Hopkinson-Cranz, or cube-root, scaling law:

$$R_c = C \cdot W^{1/3}, \quad (1)$$

where W is yield of explosive, in kt, C is an empirical medium dependent constant [12]. For Martian mantle peridotite (average dense silicate, $\rho \approx 3.3$ g/cm³), we adopt $C \approx 10$ m/kt^{1/3} - conservatively adjusted from granite tests ($C \approx 10.7$ m/kt^{1/3}) to account for higher ductility and density reducing cavity stability by 10 – 20% under GPa pressures. Vaporising silicate rock requires ~ 10 MJ/kg [13], so with 10 – 50% energy efficiency to excavation due to shock heating and losses, each blast advances the shaft by ~ 100 m on average (effective $R_c \sim 36 - 185$ m after collapse/fracture). Thus,

$$\frac{1.5 \times 10^6 \text{ m}}{100 \text{ m/bomb}} = \boxed{15\,000 \text{ bombs}}$$

are required to reach the CMB. High-pressure effects deeper in the mantle (GPa-scale) reduce cavity formation by 50 – 90%, collapse dynamics complicate ejecta removal, and cumulative structural risks (e.g., inducing global seismicity) in-

flate realistic needs to $\sim 10^4 - 10^5$ devices-still negligible compared to heating requirements.

High-Yield Thermonuclear Devices and Energy Delivery

High-yield devices like the 1961 Tsar Bomba (50 Mt [11]) represent the pinnacle of tested designs, far exceeding modern warheads (~ 1 Mt, e.g., B83 or RS-28 [11]), limited by treaties. Detonations would propagate shock waves through the mantle, but energy attenuates rapidly due to the inverse square law and absorption, yielding $< 1\%$ efficiency to the core over 1,500 km. To enhance outer core convection, we target a 500 K average temperature increase in the outer core (mass $\sim 1.2 \times 10^{23}$ kg, specific heat $c \approx 800$ J/kg/K for Fe-S melt [2]), requiring baseline energy:

$$Q = mc\Delta T \approx 4.8 \times 10^{28} \text{ J}. \quad (2)$$

Accounting for inefficiencies and the need for sustained flux, total input escalates to $\sim 10^{29}$ J.

Required Device Quantities

For 50 Mt Tsar equivalents:

$$N \approx (10^{29} \text{ J}) / (2.09 \times 10^{17} \text{ J}) \approx 4.8 \times 10^{11} \quad (3)$$

at 100% efficiency. Scaling to 1,000 K doubles this; smaller 1 Mt devices require 50 \times more, while hypothetical 100 Mt halves it. Excavation adds $\sim 10^5$, negligible overall. These dwarf global nuclear arsenals ($\sim 13,000$ warheads, $\sim 5,000$ Mt total yield, or $\sim 0.00001\%$ of needs).

Conclusion

Incorporating the 2025 confirmation of Mars’ ~ 600 km solid inner core, this analysis refines the nuclear approach but affirms its infeasibility: trillions ($10^{12} - 10^{13}$) of Tsar-scale devices would be needed to heat the liquid outer core by 300 – 1,000 K, risking planetary destruction. This thought experiment illuminates geophysical limits in Mars geoengineering, advocating for orbital or atmospheric strategies instead. Future InSight data analyses may further constrain dynamo thresholds, but human-scale energy manipulation remains orders of magnitude short.

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