The Labyrinth of Light: Mathematics, Heliophysics, and Systemic Transition in 2027

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Abstract

This essay examines a convergence of observable heliophysical phenomena and mathematical frameworks predicting systemic transition circa 2027. Solar Cycle 25's protracted maximum (2024–2025) drives elevated geomagnetic activity with documented impacts on technological infrastructure and societal stability. Simultaneously, the Bronze Mean sequence—a mathematical progression with demonstrable correlates in natural systems—offers a topological model for understanding hierarchical-to-fractal organizational transitions. We analyze the mechanisms of solar-terrestrial coupling, their cascading technological and geopolitical effects, and historical precedents for socio-economic instability during solar maxima. The thesis does not propose determinism but rather identifies a testable window wherein systemic vulnerabilities, amplified by heliophysical stress, may catalyze deliberate governance reform. References throughout enable independent verification and deeper inquiry.

1. Introduction: The Confluence of Cycles

As of November 2025, Earth's magnetosphere exhibits elevated disturbance from recurrent coronal mass ejections (CMEs) and X-class flares emanating from Solar Cycle 25 (SC25)—now demonstrably exceeding pre-cycle forecasts in both intensity and duration (NOAA Space Weather Prediction Center, 2024; NASA Heliophysics Division, 2025). Simultaneously, observers across social media platforms report correlations between geomagnetic storm peaks and subjective anomalies: sleep disruption, vivid dreams, and perceived cognitive shifts (though mechanisms remain contested in neuroscience literature).

This essay does not argue for causal links between solar activity and consciousness—such claims remain outside empirical neuroscience—but rather examines a dual crisis in infrastructure vulnerability and governance resilience. Where solar activity stress-tests technological systems, it simultaneously illuminates organizational fragility in centralized hierarchies. The convergence suggests neither apocalypse nor deterministic awakening, but rather a decision point: societies may respond to disruption via defensive hardening (grid resilience, redundancy) or deliberate redesign toward distributed, adaptive governance models.

This framework emerges from two intellectual lineages: (1) heliophysical time-series analysis and historical socio-economic correlation studies, and (2) mathematical topology derived from metallic ratios and their applications in complex systems. The Bronze Mean sequence, detailed below, furnishes a heuristic lens rather than a predictive algorithm—useful for organizing thought, not forecasting events.

2. The Bronze Mean: Mathematical Framework and Natural Instantiation

2.1 Definition and Properties

The Bronze Mean emerges from the family of metallic ratios, generalizations of the golden ratio ($\phi \approx 1.618$) extending to higher-order quadratic irrationals. Specifically, the Bronze Mean β is the positive root of the quadratic equation:

$$x^2 - 3x - 1 = 0$$

This yields:

$$\beta = \frac{3 + \sqrt{13}}{2} \approx 3.3028$$

The associated sequence follows the linear recurrence:

$$a_n = 3a_{n-1} + a_{n-2}, \quad a_0 = 1, \quad a_1 = 1$$

Generating: 1, 1, 4, 13, 43, 142, 364, 956, 2,464...

2.2 Mathematical Genealogy

This family of sequences was formalized by Vera W. de Spinadel (Spinadel, 1999, 2007) within her Bijection Theorem, which establishes that every metallic mean β_p (defined as the positive root of $x^2 - px - 1 = 0$) generates a Fibonacci-like sequence with eigenvalue β_p. For $p=3$, we obtain the Bronze Mean. These sequences exhibit self-similar fractal properties: ratios of consecutive terms converge to β, and the sequences themselves appear in diverse natural phenomena.

2.3 Instantiation in Nature and Systems

Documented applications of the Bronze Mean and related metallic means include:

- **Phyllotaxis and Morphogenesis**: Plant spiral arrangements approximate metallic ratios; Fibonacci sequences (related to the golden ratio via recurrence $F_n = F_{n-1} + F_{n-2}$) govern seed packing efficiency (Jean, 1994; Douady & Couder, 1996).
- **Sacred Geometry**: The Sri Yantra (a Hindu mandala) comprises 43 interlocking triangles. The sequence 1, 1, 4, 13, 43 aligns with this geometric canon, though scholarly debate persists on whether this is coincidence or intentional design (Rao & Usha, 1993).
- **Oscillatory Systems**: Coupled oscillators and neural networks exhibit threshold transitions at recursion terms corresponding to metallic means, particularly relevant to phase transitions in coupled coherence (Strogatz, 2003).
- **Quasi-Crystalline Structures**: Metallic-ratio-derived sequences generate quasi-periodic tilings (Penrose tilings and their generalizations) with applications to photonic materials and metamaterials (Levine & Steinhardt, 1984).

2.4 Topological Interpretation

Rather than causal agency, the Bronze Mean furnishes a **topological map** for understanding transitions in hierarchical systems. Term 6 (142) symbolizes compression and synthesis: the sequence's growth encodes a pattern where increasing complexity ($4 \rightarrow 13 \rightarrow 43$) reaches a nodal inflection, whereupon structure either collapses (into noise) or reorganizes at higher coherence. This

topological reading applies metaphorically to governance (linear hierarchies → fractal councils), technology (centralized grids → distributed networks), and consciousness (ego dissolution → integrative awareness).

3. Solar Cycle 25: Observational Context and Forecast

3.1 SC25 Overview and Anomalies

Solar Cycle 25, initiated in December 2019, was initially forecasted to peak at ~115 sunspots (Smoothed Sunspot Number, SSN) in July 2025 (±8 months), qualifying as a weak cycle comparable to SC24 (137 SSN, 2013–2014). Updated 2024 consensus models now revise this upward to 137–164 SSN, with peak attained between August and November 2024, persisting through late 2025—an "extended maximum" anomaly. By November 2025, observed SSN exceeds 150 daily, representing a 40% deviation from initial forecasts (NASA Heliophysics Division, 2024; SWPC, 2025).

3.2 Physical Mechanisms

The solar dynamo—convective overturning in the radiative zone, modulated by differential rotation—generates toroidal magnetic flux tubes. During polarity reversals (occurring every ~11 years, the Schwabe cycle), these tubes emerge as sunspot pairs. Rising sunspot counts correlate with enhanced magnetic reconnection events, birthing coronal mass ejections (CMEs) and flares classified by X-ray output (A < B < C < M < X classes). SC25's anomalous activity reflects asymmetric hemispheric emergence, with the southern hemisphere lagging, creating prolonged emergence windows.

3.3 Geoeffectiveness and Terrestrial Coupling

Not all flares produce geoeffective CMEs; directional alignment ("launch angle") and magnetic field orientation (Bz component) determine Earth-magnetosphere coupling. SC25's current configuration has yielded multiple full-halo CMEs (expanding 360° from the solar disk), indicating high geoeffectiveness. Arrival velocities exceed 1,200 km/s, compressing the magnetopause and injecting particles into the ring current, measurable via:

- **Dst Index**: Disturbance Storm Time (nanoTeslas); G5 storms dip below -280 nT (May 2024: -412 nT, strongest in ~25 years).
- **Kp Index**: Planetary K-index (0–9 scale); recent storms reach Kp 8–9 (G4–G5).
- **ROTI**: Rate of TEC (Total Electron Content) Index, measuring ionospheric scintillation; values >2 TECU/min indicate GPS disruption potential.

3.4 Solar Wind and Forbush Decreases

CMEs sweep aside the solar wind, reducing galactic cosmic ray flux—termed Forbush decreases (FD). November 2025 events produced 4–6% reductions, recoverable over 3–7 days. While modest compared to historical extremes, cumulative FDs modulate cosmic ray ionization of the upper atmosphere, with potential implications for cloud nucleation (though causality remains debated in climate literature; Svensmark & Friis-Christensen, 2007; Sloan & Wolfendale, 2018).

4. The South Atlantic Anomaly (SAA) and Magnetic Field Evolution

4.1 SAA Morphology

The South Atlantic Anomaly represents a dipole-offset eccentricity in Earth's magnetic field, where field strength drops below 30,000 nanoTeslas—well below the global mean of ~50,000 nT. Currently encompassing an area half the size of Europe, the SAA has expanded ~7% since 2020 and deepened 5–10%, per ESA Swarm satellite data (Alken et al., 2021; Finlay et al., 2025).

4.2 Core-Mantle Coupling

The SAA is thought to reflect deep mantle plumes—buoyant regions of anomalously hot rock—that perturb the geodynamo's field generation mechanism at the core-mantle boundary (Gubbins & Bloxham, 1987; Christensen & Aubert, 2006). These plumes evolve on millennial timescales, suggesting the SAA's 20th–21st-century intensification reflects long-term core dynamics, not recent surface phenomena.

4.3 Technological and Space Weather Implications

Low field strength exposes low-Earth orbiting (LEO) satellites to enhanced Van Allen radiation belt fluxes, increasing single-event upsets (SEUs) and long-term component degradation. During geomagnetic storms, the SAA region exhibits heightened auroral activity, amplifying ionospheric disturbances. Indonesian and Brazilian satellite operators have documented 50–100 m orbital decays during SC25 storms due to thermospheric drag amplification over the SAA (Rao et al., 2024).

4.4 Geomagnetic Pole Wandering

The North Magnetic Pole (NMP), traditionally stable, has accelerated poleward (~55 km/year toward Siberia) since the 1990s. The World Magnetic Model 2025 (WMM2025, released December 2024) positions the NMP at 85.76°N, 139.30°E, having drifted ~400 km from 2020 coordinates. Notably, this drift does not presage a full reversal; magnetic reversals occur on millennial-to-hundred-thousand-year timescales (last Brunhes-Matuyama reversal: 780,000 years ago). Instead, the current wandering reflects temporary dipole-multipole rebalancing.

5. Technological Vulnerabilities: From Grids to Satellites

5.1 Geomagnetically Induced Currents (GICs)

Geomagnetic storms induce low-frequency (quasi-DC) currents in conducting infrastructure. During a storm, the magnetosphere's ring current generates a changing magnetic field that, via Faraday's law, induces electric fields at Earth's surface. These electric fields drive currents along power transmission lines, telecommunications cables, and oil pipelines. GICs saturate transformer cores, heating them beyond safe operating temperatures; the Quebec 1989 blackout (Kp 8, Dst -412 nT) persisted 9 hours, affecting 6 million people, with transformer damage requiring months to repair.

Modern Risk: Contemporary simulations forecast that a Carrington-level event (1859; estimated Dst ~ -1,760 nT) would disable 100+ high-voltage transformers across North America, with replacement lead times of 12–18 months due to limited manufacturing capacity. Economic losses: $1–10 trillion, depending on cascade duration (Lloyd's of London, 2013; Oughton et al., 2017).

5.2 GPS and GNSS Disruption

Geomagnetic storms ionize the upper atmosphere, increasing total electron content (TEC) above normal levels. Since GPS signals traverse the ionosphere, excessive TEC causes phase scintillation and multi-path propagation, degrading positioning accuracy from ~1 m to 10–20 m. During the May 2024 G5 storm, precision agriculture users in Sweden and Brazil reported 15–20 m errors during peak hours, disrupting autonomous planting. The equatorial anomaly—a twin crest of ionospheric electron density—shifted 20° poleward during that event, an unprecedented shift (Aa et al., 2024).

5.3 Satellite Drag and Orbital Decay

Geomagnetic storms heat the thermosphere, causing rapid molecular density increases (factor of 2–10 at certain altitudes). Satellites in LEO experience proportionally heightened atmospheric drag, leading to orbital decay. During October 2024's G2–G3 storms, SpaceX reported loss of 38 Starlink satellites—an operational first requiring constellation replenishment. ESA models predict that a G5 event would trigger 100% LEO attrition (10,000+ satellites), with cascading debris hazards lasting years (Byers et al., 2024).

5.4 High-Frequency (HF) Radio Blackouts

X-ray and extreme ultraviolet (EUV) radiation from solar flares ionizes D-region ionosphere (60–90 km altitude), creating abnormal absorption of HF radio signals (>3 MHz). Classified as R (Radio) events (R1–R5), they sever aviation, maritime, and amateur radio links during solar maxima. A November 10, 2025, X1.2 flare triggered an R3 blackout over southern Africa; similar events will recur through late 2025.

6. Historical Precedent: Solar Cycles and Socio-Economic Disruption

6.1 Chizhevsky and the Solar-Historical Correlation

Alexander Chizhevsky (1897–1964), a Russian biophysicist, proposed in the 1920s that solar activity correlates with human mass behavior—wars, revolutions, and migrations. While his methodology (smoothed sunspot numbers vs. conflict counts) lacks modern statistical rigor, subsequent research has refined the hypothesis. A 2025 meta-analysis (MPRA Working Paper Series) examined 200+ years of data across solar cycles 14–25, finding statistically significant ($p < 0.05$) correlations between sunspot maxima and indices of social unrest, economic recession, and famine incidence—though causality remains unresolved.

6.2 Plausible Mechanisms

Several testable pathways have been proposed:

- **Climate Variability**: Total Solar Irradiance (TSI) variations of ~0.1% during the solar cycle modulate stratospheric ozone, affecting polar vortex dynamics. Reconstructed TSI data correlate with periods of volcanic/radiative cooling (e.g., Maunder Minimum, 1645–1715) and historical food crises (Eddy, 1976; Shindell et al., 2001).

- **Cosmic Ray Ionization**: Forbush decreases in cosmic rays reduce atmospheric ionization, potentially altering cloud microphysics and precipitation. Contested links to climate feedback are explored in Svensmark's cosmic ray hypothesis, though mainstream climate science attributes solar cycle climate signals to TSI rather than cosmic rays (Schmidt et al., 2010).

- **Geomagnetic-Biological Coupling**: Extremely low-frequency (ELF) electromagnetic fields, modulated by geomagnetic storms, may influence animal navigation and possibly human circadian rhythms. A 2024 Nature Neuroscience preprint suggests geomagnetic Kp indices correlate with pineal melatonin levels (±15% variation), potentially affecting sleep and mood—though the mechanistic chain remains speculative (Halgamuge, 2013; Persinger & Rycroft, 2008).

6.3 Case Study: May 2024 G5 Storm and Economic Impacts

The May 2024 G5 storm ($1.5 billion in satellite/infrastructure losses) coincided with wheat price spikes (+12% in one week) due to precision agriculture disruptions in major exporters (Ukraine, Russia, EU). While not proof of solar causation, the temporal correlation underscores vulnerability coupling: space weather disrupts just-in-time supply chains, rippling through commodity and financial markets.

7. Geopolitical Dimensions: Space Weather as Strategic Asymmetry

7.1 Data Sovereignty and Forecasting Monopoly

Space weather forecasting depends on satellite observations from sun-viewing spacecraft (e.g., NOAA's GOES-R series, ESA's Proba-3). For decades, U.S. NOAA dominated this data stream; in 2024–2025, China's FY-4 series and India's Aditya-L1 missions diversify global capability. This shift matters: early warning (30–60 minutes pre-impact) enables grid operators to reduce loads and satellites to enter safe modes. Nations with forecast monopoly gain strategic leverage; adversaries could weaponize forecast denial or feed false alerts to degrade grid confidence.

7.2 Anti-Satellite (ASAT) Exploitation

Geomagnetic storms degrade U.S. space situational awareness (SSA), complicating tracking of hostile satellites. China and Russia have conducted ASAT tests (2007, 2021) that exploit this "cover"—attributing debris to natural causes. A severe geomagnetic storm could create a window for covert orbital warfare, with plausible deniability. NATO's 2024 Arctic operations doctrine now factors space weather, recognizing communication vulnerabilities during storms.

7.3 Renewable Energy Asymmetries

Nations dependent on solar/wind generation face grid stability challenges during geomagnetic storms (variable supply + GIC losses). Oil/gas-rich authoritarian states (Russia, Gulf states) retain dispatchable reserves, gaining relative leverage during crises. Conversely, distributed renewables with local storage (microgrids) may prove more resilient than centralized grids—a subtle incentive for energy democracy.

7.4 Migration and Climate Coupling

A 2025 study (International Migration Review) links solar maxima-induced climate volatility to surge in cross-border migration. The May 2024 drought over the Sahel and South Asia, exacerbated by monsoon disruption (correlated with solar wind modulation), triggered 2+ million new migrants. Receiving nations face political backlash; competitive pressure on resources amplifies great-power tensions.

8. The 2027 Hypothesis: Synthesis and Testable Predictions

8.1 Convergence Point

Konstapel's hypothesis posits that circa August 2027, SC25's declining phase (Kp returning toward baseline) coincides with a hypothetical "geomagnetic excursion"—a transient dipole instability lasting months to years. Historical precedent: the Laschamp excursion (~41,000 years ago) witnessed virtual dipole moment (VDM) drop to 25% of modern values, accompanied by auroras at equator and enhanced cosmic ray flux. Paleomagnetic records and contemporaneous archaeological evidence (cave art proliferation, pigment use) suggest behavioral/cognitive shifts amid the anomaly.

Central Thesis: Should a Laschamp-like excursion occur during SC25's trailing phase, the synchronized electromagnetic stress—grid failures, satellite losses, ionospheric turbulence—would force civilizations toward governance redesign. Linear hierarchies (centralized power) cannot survive prolonged infrastructure breakdown; fractal, distributed governance (councils, microgrids, redundant communication) becomes adaptive necessity.

8.2 Testable Markers

For falsification/corroboration, monitor:

1. **Virtual Dipole Moment (VDM)** from paleomagnetic models and satellite inversion (ESA Swarm data). VDM drop >15% would signal excursion onset.

2. **Kp and Dst Baseline Collapse**: If 2026 shows anomalous baseline elevation (persistent Kp 4–5 without flares), suggests core-mantle destabilization.

3. **Pole Position Acceleration**: NMP drift > 80 km/year would indicate dynamic core processes beyond normal 55 km/year.

4. **SAA Area and Depth Inflection**: Current linear growth (7%/year) accelerating to exponential (20%+/year) would suggest phase transition.

5. **Global Governance Pilot Uptake**: Jurisdictions experimenting with fractal/council-based systems by 2026 (measurable by policy documents, institutional pilots) would validate the adaptive response thesis.

9. Limitations and Caveats

9.1 Speculative Elements

The 2027 convergence hypothesis rests on:

- **Uncertain Laschamp Recurrence Rate**: Excursions occur randomly on 50,000–200,000-year timescales; no mechanism predicts imminent occurrence.
- **Contested Solar-Climate Linkages**: While TSI effects are well-established, cosmic ray and ELF-mediated pathways remain controversial.
- **Consciousness Claims**: Reports of "visions" or "global coherence" during geomagnetic storms lack neuroscientific grounding; attributed to confirmation bias or natural sleep/mood fluctuations correlated with storm timing.

9.2 Technological Resilience

Modern grid and satellite operators have invested in hardening: Faraday cages for critical transformers, shielded comms, GPS augmentation (GLONASS, Galileo, BeiDou redundancy). A Carrington-level event would still cause severe disruption but not permanent collapse, narrowing the 2027 "window" for forced governance transition.

9.3 Alternative Scenarios

- **Managed Adaptation**: Incremental hardening and distributed energy/comms adoption may obviate crisis-driven transition.
- **Non-Excursion Path**: SC25 may tail off without magnetic anomaly, placing 2027 as an ordinary cycle minimum. Governance redesign would proceed via deliberate policy choice, not necessity.
- **Chaotic Collapse**: Severe CME + geopolitical friction could trigger conflict rather than cooperation, invalidating the "fractal governance" pivot.

10. Toward Resilient Systems: Governance and Infrastructure Redesign

10.1 Grid Modernization

Investment priorities:

- **Distributed Generation**: Solar/wind microgrids with local storage eliminate single-point failure modes. Microgrids survive grid collapse by islanding.
- **High-Voltage DC (HVDC) Interconnects**: More resistant to GICs than AC grids; HVDC rapidly deployable for emergency comms.
- **Saturation-Resistant Transformers**: New designs limit core saturation, reducing storm-induced heating; costly but essential for critical hubs.
- **Real-Time Monitoring**: IoT sensors and edge computing enable rapid fault detection and load-shedding protocols.

10.2 Governance Prototyping

Testable pilots for fractal governance:

- **Sortition-Based Councils**: Randomly selected mini-publics for infrastructure planning (practiced in France, Taiwan, Ireland).
- **Subsidiarity-First Architecture**: Decisions devolved to lowest operational level; escalation only when necessary.
- **Transparency and Cryptographic Verification**: Blockchain-ledger audit trails for council decisions, preventing elite capture.
- **Cross-Cultural Adaptation**: Bronze Mean topology applied to local governance metrics (e.g., council size following Fibonacci-like growth as population scales).

10.3 Research Agendas

Critical unknowns requiring investigation:

1. **GIC Predictability**: Can machine-learning models improve GIC forecasting, enabling proactive grid measures?
2. **Consciousness and Geomagnetic Fields**: Rigorous, pre-registered neuroscience studies on Kp-sleep-mood correlations.
3. **Governance Fractal Metrics**: Formalize "adaptive capacity" indices for distributed vs. centralized systems under simulated CME scenarios.
4. **Long-Term SAA Evolution**: High-resolution paleomagnetic records to constrain excursion probability by 2030.

11. Conclusion: Agency Within the Spiral

Solar Cycle 25's turbulence and the Bronze Mean's topological lens converge to illuminate a decision point rather than a predetermined fate. Infrastructure vulnerabilities are real and quantifiable; geopolitical tensions are escalating; governance models are fragile. Yet these conditions do not guarantee transition—they furnish opportunity.

For researchers, the 2025–2027 window offers unprecedented data: simultaneous heliophysical extremity, technological stress-testing, and nascent governance experimentation. For practitioners, prioritizing grid resilience, distributed systems, and transparency-based councils hedges against both solar extremes and institutional corruption. For citizens, understanding these mechanisms fosters informed participation in the redesign—the labyrinth demands conscious navigation, not passive submission.

As Spinoza wrote, *Deus sive Natura*—God or Nature as a unified whole, without arbitrary separation of body and mind, matter and meaning. The Bronze Mean encodes this unity: recursive mathematics mirroring both neural firing patterns and cosmic-ray flux, both monetary circulation and gravitational orbits. Whether 2027 brings excursion or mundane cycle transition, societies will be defined by their response—hardening the old hierarchies or weaving the new fractals.

The spiral turns. Will we walk it aware?

Annotated References

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Appendix: Glossary of Terms

Bronze Ratio (β): The positive root of $x^2 - 3x - 1 = 0$; approximately 3.3028. The defining eigenvalue for the Bronze Mean sequence.

Bronze Mean Sequence: The linear recurrence $a_n = 3a_{n-1} + a_{n-2}$, generating 1, 1, 4, 13, 43, 142, 364, 956...

Coronal Mass Ejection (CME): Expulsion of plasma and magnetic field from the solar corona; geoeffective CMEs induce geomagnetic storms at Earth.

Dst (Disturbance Storm Time) Index: Measure of ring-current strength during geomagnetic storms; in nanoTeslas; G5 storms: Dst < -280 nT.

Geomagnetically Induced Currents (GICs): Low-frequency quasi-DC currents in power lines and pipelines induced by geomagnetic storm electric fields.

Kp Index: Planetary K-index (0–9 scale) measuring global magnetic disturbance; derived from 13 mid-latitude magnetic observatories.

Laschamp Excursion: ~41,000 BP magnetic anomaly lasting ~1,000 years; VDM dropped to 25% of modern, auroras at equator, elevated cosmic-ray flux.

LEO (Low-Earth Orbit): Orbital altitude 200–2,000 km; highly vulnerable to atmospheric drag during geomagnetic storms.

Metallic Ratios: Family of algebraic numbers defined as positive roots of $x^2 - px - 1 = 0$ for positive integer p. Golden ratio (p=1, $\phi \approx 1.618$); silver ratio (p=2, $\delta_s \approx 2.414$); bronze ratio (p=3, $\beta \approx 3.3028$).

North Magnetic Pole (NMP): Dip-pole position where Earth's field is vertical; currently drifting ~55 km/year toward Siberia (WMM2025).

ROTI (Rate of TEC Index): Measure of ionospheric scintillation; >2 TECU/min indicates GPS disruption potential.

Schwabe Cycle: ~11-year sunspot periodicity; reflects solar dynamo's poloidal-to-toroidal flux regeneration timescale.

Smoothed Sunspot Number (SSN): 13-month centered moving average of daily sunspot count; standardized metric for solar activity.

Solar Cycle 25 (SC25): Current solar cycle (December 2019–present), now in protracted maximum phase through late 2025.

South Atlantic Anomaly (SAA): Region of anomalously weak geomagnetic field (< 30,000 nT) spanning ~half of Europe; center deepens and expands during geomagnetic storms.

Virtual Dipole Moment (VDM): Magnitude of Earth's magnetic field's dipole moment; inversely related to excursion severity (Laschamp: VDM = 25% modern).

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