AI SAFETY · EXPORT CONTROLS · SEMICONDUCTOR POLICY · CONSTRAINT-DRIVEN INNOVATION · DEEPSEEK · U.S.-CHINA AI COMPETITION · INTERPRETABILITY · SAFETY ENGINEERING

FORGED IN FIRE

How artificial constraints breed technological dominance, and why the only winning strategy in the AI race is safety

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Gilly, T. (2026). Forged in Fire: How Artificial Constraints Breed Technological Dominance and Why the Only Winning Strategy in the AI Race Is Safety. Real Safety AI Foundation. White Paper, February 2026.

The chip bans accelerated the thing they were built to stop.

In October 2022, the United States issued sweeping export controls to deny China frontier compute. Within three years, every major policy institution that studied the results reached a version of the same conclusion. **DeepSeek trained a GPT-4-class model at a fraction of the cost, on chips the regulations had deliberately capped.**

SOURCES MacCarthy & Villasenor, Brookings Institution (Feb. 11, 2025) [1] · Allen, Center for Strategic and International Studies (Mar. 11, 2025) [2] · RAND Commentary (Aug. 7, 2025) [4] · Rest of World (Oct. 16, 2025) [11] · MIT Technology Review (Jan. 24, 2025) [12] · Gilly, sec. 1

Safety engineering is a chosen constraint, and it pays the same dividend the forced ones do.

The pattern of artificial constraints breeding accelerated innovation is among the most thoroughly documented dynamics in military, economic, and industrial history. Entities forced to do more with less develop engineering cultures, institutional knowledge, and optimization reflexes that persist as permanent advantages long after the constraint is removed.

This paper traces that pattern across five historical cases, maps it onto the U.S.-China AI dynamic, and asks the question the policy literature has largely avoided: if constraints breed better engineering, what does that imply for AI safety? Chosen constraints come without the geopolitical risk of teaching your competitor to thrive on adversity.

SOURCES Gilly, Forged in Fire, abstract & secs. 1–2

PART I OF III

THE PATTERN

The mechanism of constraint-driven innovation, and five times history ran the experiment

Gilly, T. (2026). Forged in Fire. Real Safety AI Foundation. White Paper, February 2026, secs. 2–3.

The efficiency culture does not vanish when the constraint does.

01

REDIRECT

Facing resource limits, engineering effort moves from brute force to efficiency optimization.

→

02

EMBED

The gains harden into institutional culture, training pipelines, and engineering doctrine.

→

03

COMPOUND

The constraint lifts; efficiency discipline applied to better resources **exceeds what either could achieve alone.**

The critical insight is phase three. The question this paper poses: does the same dynamic hold when the constraint is *chosen* rather than imposed?

SOURCES Gilly, Forged in Fire, sec. 2, The Theory of Constraint-Driven Innovation

Toyota did not build a worse Ford factory. It invented a different philosophy.

Post-war Japan had limited raw materials, constrained factory space, and insufficient capital for American-scale mass production. The Toyota Production System, just-in-time inventory, continuous improvement (kaizen), and elimination of waste (muda), emerged directly from the constraint of having to produce competitive vehicles without American-scale resources.

When the 1973 oil crisis shifted demand toward fuel-efficient vehicles, Japanese manufacturers had spent two decades building an efficiency culture that American manufacturers could not replicate overnight. By the 1980s, lean manufacturing born from scarcity was the global benchmark. Japan did not revert to wasteful production when it could afford to. The constraint had changed the culture.

SOURCES Womack, Jones & Roos (1990), The Machine That Changed the World, Free Press [17] · Gilly, sec. 3.1

A fault-tolerant network beat centralized brute force.

CENTRALIZED · BRITTLE

Air bases, carrier groups, B-52 sorties from fixed positions with massive logistical footprints. Expensive to maintain, catastrophic when disrupted. The structure of massive GPU clusters running unoptimized code.

DISTRIBUTED · RESILIENT

Tunnel networks running hundreds of kilometers, materiel moved by bicycle and foot, and the Ho Chi Minh trail: any single node destroyed without collapsing the system. The parallel to computing is structural, not figurative.

When Soviet and Chinese hardware did flow in greater quantities, the Vietnamese combined guerrilla doctrine with conventional capability. The constraint-bred culture compounded rather than dissolved.

SOURCES Gilly, Forged in Fire, sec. 3.2, Vietnam and Guerrilla Warfare (1955–1975)

The embargo did not produce inferior industries. It produced exporters.

Israel · Defense, 1948–present

Arms embargoes, including from France after the 1967 Six-Day War, forced domestic capability: Iron Dome, the Merkava tank, the Lavi program (later contributing to the F-35), and world-class signals intelligence. The constrained defense sector seeded the highest startup density per capita of any nation. Israel is now one of the world's leading arms exporters.

Cuba · Biotech, 1960–present

Cut off from pharmaceutical imports, Cuba built domestic biotech that produced CIMAvax, a lung cancer vaccine, and exports vaccines to dozens of countries across Latin America and Africa, with physicians deployed to over 60 countries. When you cannot import the medicine, you learn to make it, efficiently enough to export.

SOURCES Senor & Singer (2009), Start-up Nation, Twelve [18] · Feinsilver (2010), Fifty Years of Cuba's Medical Diplomacy, Latin American Perspectives, 37(4) [19] · Gilly, secs. 3.3–3.4

24mo

FROM CONSTRAINT TO IRRELEVANCE

Japan's leverage evaporated precisely because it was exercised

In July 2019, Japan restricted exports of fluorinated polyimide, photoresists, and hydrogen fluoride, all critical to semiconductor manufacturing. Samsung and SK Hynix, initially dependent on Japanese suppliers, developed domestic sources and alternative relationships within two years, and emerged more resilient than before the restrictions. The attempt to create dependency instead created independence.

SOURCES Choe (2020), How South Korea's Chipmakers Are Reducing Reliance on Japan, New York Times [20] · Gilly, sec. 3.5

PART II OF III

THE CURRENT CASE

China, chip bans, and the DeepSeek phenomenon

Gilly, T. (2026). Forged in Fire. Real Safety AI Foundation. White Paper, February 2026, sec. 4.

Capped chips forced an optimization most teams never attempt.

$6M
Reported cost to train DeepSeek-V3, against over **$100M** for GPT-4

H800
The chip it was trained on, performance-capped by design to comply with export regulations

20/132
Processing units per chip reprogrammed for cross-chip communication, below Nvidia's CUDA abstractions

This is precisely the deep optimization that emerges from constraint. It requires understanding the hardware at a level that well-resourced teams rarely bother to explore, because they do not need to.

SOURCES Centre for International Governance Innovation (2025) [13] · MIT Technology Review (Jan. 24, 2025) [12] · Allen, Center for Strategic and International Studies (Mar. 11, 2025) [2] · Gilly, sec. 4

The efficiency advantage is compounding into a hardware advantage.

CloudMatrix 384 > GB200

Huawei's system, on domestic Ascend 910C chips, outperforms Nvidia's GB200 NVL72 on compute power, memory bandwidth, and integrated networking

40% faster than TSMC's best

Peking University's 2D transistor architecture, at lower power; Alibaba's RISC-V CPU is fundamentally immune to U.S. export controls

18 months behind, closing

One architectural innovation could close the gap entirely: 20% of all algorithmic progress since 2017 traces to the transformer alone

Brookings stated it plainly: scarcity fosters innovation, and when China produces its own leading-edge chips it will possess both computing capacity and efficient algorithms.

SOURCES RAND Commentary (Aug. 7, 2025) [4] · TechSoda (Nov. 25, 2025) [10] · Fedasiuk et al., TechPolicy.Press (Jan. 10, 2025) [6] · MacCarthy & Villasenor, Brookings Institution (Feb. 11, 2025) [1] · Gilly, sec. 4

THE FORK

Three branches for China's trajectory, one conclusion for U.S. strategy, and safety as the chosen constraint

However China's AI turns out, the optimal U.S. strategy is the same.

BRANCH A

China builds safe AI

Then safety and speed were never in tension. **Safety was never the bottleneck.**

BRANCH B

Unsafe AI, and it fails

Fast but fragile. **Safety is the advantage:** you do not lose a race to a vehicle that explodes before the finish line.

BRANCH C

China weaponizes AI

Defense requires predictable, bounded systems. **Safety is a national-security requirement.** An unsafely built system is a weapon you cannot aim.

CONVERGENCE *There is no scenario in which abandoning safety for speed is optimal. An unpredictable system is not a competitor; it is a hazard, including to its own operators.*

SOURCES Gilly, Forged in Fire, secs. 5.1–5.4 · Sun Tzu, The Art of War (c. 5th century BCE) [21]

The explosion is not contained to the competitor's lane.

In a globally interconnected digital economy, a catastrophic failure in a Chinese frontier model deployed across critical infrastructure, financial systems, or communications networks would produce contagion effects that damage every connected economy. Unsafe Chinese AI is not merely a competitor crashing their car; it is a competitor crashing a vehicle on a shared highway.

The externality strengthens the case for safety rather than weakening it. Even in the scenario where China's AI ambitions fail on their own terms, the United States still bears costs from that failure, costs that would be mitigated by a global norm of safety engineering rather than a race to the bottom.

SOURCES Gilly, Forged in Fire, sec. 5.2

Safety is not a tax on compute. It is an optimization function on the architecture.

BE SAFE	→	UNDERSTAND	→	STRUCTURE	→	OPTIMIZE
you cannot bound harm you do not understand		interpretability requires structure to inspect		modular designs expose their reasoning		understood components tune at every level

The result is not a weaker system constrained by caution; it is a leaner system whose caution eliminated the waste that unconstrained systems carry as dead weight. Methodologies that require systematic stakeholder harm analysis at development checkpoints, such as the Harm Blindness Framework, validated against over 300 historical cases, are one approach to embedding this discipline.

SOURCES Gilly, Forged in Fire, sec. 6, Safety as Chosen Constraint

The choice was never between safety and competitiveness.

The United States constrains China's hardware, and accelerates it. It resists its own safety constraints, and forgoes the same advantage. **If forced constraints produce permanent advantages, chosen safety constraints will too.** The logic is the same; only the application differs. Those forged in fire, by imposition or by discipline, dominate when the fire subsides.

SOURCES Gilly, Forged in Fire, sec. 7, Conclusion

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