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From Telemetry to Totality: A Multi-Layered Safety Framework for Integrating Metabolic State into Cybernetic Governance

Architectural Philosophy: Subordination of Metabolic Data to Core Safety Governors

The foundational principle guiding the integration of metabolic data—specifically sugar, water, fat, and calories—is not one of expansion but of disciplined subordination. The proposed architecture deliberately rejects the notion of treating these biological metrics as semi-autonomous or sovereign bio-tokens . Instead, they are formalized as strictly derived telemetry fields, operating exclusively within the pre-existing safety envelopes defined by the core cybernetic governance stack: Lifeforce, CSP/Blood, and AU.ET . This design choice is a critical security decision, engineered to simultaneously enhance physiological precision while erecting robust barriers against coercive governance and social misuse. By positioning all metabolic telemetry as secondary inputs, the system ensures that no emergent pathway for exploitation can bypass the established, high-signal safety protocols. The primary objective is to refine the accuracy of resource budgeting without altering the fundamental chain of command, thereby minimizing the overall Risk-of-Harm (RoH) .

This subordination model directly addresses the dual mandate of reducing both physical and social risks associated with advanced cybernetic systems. The first class of risk involves direct physiological harm, such as cardiovascular strain from excessive blood-drain or thermal injury from unmitigated computational loads. The second, more insidious class of risk pertains to the potential for social coercion, where metabolic data could be weaponized to compel an augmented citizen into performing tasks, accepting upgrades, or participating in governance actions against their will . The design philosophy explicitly prevents this by ensuring that metabolic telemetry can only influence, never dictate, cyberswarm actions. Allowing free-floating "sugar-tokens" or "water-tokens" would create a dangerous precedent, potentially enabling external actors to exert control by inducing or threatening metabolic deficits—a clear violation of bodily autonomy and emerging neurorights frameworks [1] [4] . The Chilean Supreme Court's landmark ruling on mental privacy serves as a powerful real-world analogue, underscoring the societal imperative to protect internal physiological and cognitive states from external manipulation and commodification [16] [18] [19] . The proposed system aligns with this ethos by treating metabolic data as private host state, not as a public ledger of spendable assets.

The operational logic of this subordination is anchored in the concept of a "safer companion" for energy management . In this model, a Calorie-token is not a new source of power but a derived accounting scalar, analogous to AU.ET itself . It provides a higher-resolution meter for internal budgeting and safety checks, allowing the system to map nutrition intake precisely to AU.ET-equivalent energy units based on the host's specific metabolic efficiency . However, its utility is strictly bounded. The calorie count never exceeds the amount of energy the BrainSpecs framework has deemed safely usable for computation and nanoswarm activity at any given moment . This prevents a common failure mode where an individual might attempt to convert low-quality "empty calories" into unsafe cognitive loads or AI-augmentation intensity without regard for their physiological cost . Furthermore, the system enforces "net-positive" envelopes; upgrades that rely on caloric expenditure must demonstrate they do not push the host's overall budget or lifeforce integrity below critical thresholds . If other vital resources like protein or CSP are low, calorie-based spending is automatically derated rather than being treated as a substitute for blood tokens, which remain the sole currency for invasive, high-risk biological processes .

The ultimate arbiter in this hierarchical structure is the `LifeforceDecision`, which governs access to the `lifeforce.envelope.v1` particle . No action, regardless of the availability of sugar or water, can proceed if the `LifeforceDecision` is `DenyLifeforceLow` or `DenyAfterBloodGuard` . This creates a non-negotiable safety floor. The presence of abundant glucose or hydration cannot override a systemic signal that the host's overall lifeforce is compromised. Sugar-telemetry, represented as fields like `blood glucose range` and `glycogen reserve`, feeds into the calculation of the `lifeforce.chi` state and the effective energy cost (EC) of an operation, but it cannot be burned independently of the CSP/AU.ET layer . Similarly, Water-telemetry, which encodes `hydration`, `plasma volume`, and `perfusion`, acts as a governor on the duty-cycle of high-intensity operations; drops in hydration status automatically clamp the maximum permissible workload, forbidding actions like blood-drain or intense upgrades . These metabolic fields act as fine-grained controls, capable of relaxing schedules or refining budgets within the rigid boundaries set by the higher-level governors, but they can never expand those boundaries.

This architectural philosophy is further reinforced by neurorights-based governance policies encoded in ALN shards . These policies classify CSP/Blood as a non-transferable stake bound to explicit medical consent, making it impossible to trade away or use as collateral for obligations . Anti-coercion rules are also implemented, requiring quorums weighted by CSP for any biomechanical decisions, preventing pure AU.ET or calorie metrics from governing high-risk augmentations . The entire system is designed to be resilient to failures at every level of abstraction, with each layer addressing different potential points of failure, whether they be measurement errors, hardware faults, or malicious social engineering attempts . The result is a system where metabolic data becomes a tool for enhanced safety and precision, not a new avenue for risk.

Metric	Proposed Role	Governing Entity	Rationale
Sugar (Glucose)	Derived telemetry field feeding into `lifeforce.chi` and `Energy Cost` (EC).	Lifeforce / CSP Layer	Provides granular input for energy calculations but cannot be spent directly, preventing bypass of core safety gates .
Water (Hydration)	Derived telemetry field acting as a duty-cycle governor.	Lifeforce / Nanoswarm Layer	Clamps high-intensity operations during dehydration events to enforce physiological safety .
Fat (Adipose)	Derived telemetry field mapped to `calorie_budget`.	AU.ET / Lifeforce Layer	Provides a longer-term energy reserve indicator for budgeting, subject to derating when other resources are low .
Calories	Derived accounting scalar (AU.ET-per-kcal), not a spendable token.	AU.ET / Lifeforce Layer	Acts as a precise internal meter for budgeting, strictly bounded by the `lifeforce` envelope and host-specific efficiency .

In summary, the architectural philosophy is one of defensive-by-design. By subordinating all metabolic data to the established hierarchy of Lifeforce and CSP/Blood, the system avoids creating new, potentially vulnerable governance layers. It leverages metabolic telemetry to increase the fidelity of its safety calculations, enabling a safer and more efficient allocation of resources. This approach directly mitigates the primary risks identified in the research goal, creating a robust foundation upon which concrete implementation patterns and multi-layered safety enforcement mechanisms can be built.

Implementation Blueprint: Extending HostBudget and Envelopes in Rust and ALN

The transition from the architectural philosophy to a functional system requires concrete implementation patterns in both Rust and the Actor-Like Notation (ALN). The goal is to extend the existing `bioscale_upgrade_store` and `lifeforce-guards` crates with new structures and particles that can ingest, process, and act upon metabolic telemetry fields without compromising the integrity of the core safety envelope . This blueprint focuses on hardening the system through strongly-typed Rust structs and declarative ALN schemas that make the subordination of metabolic data an enforceable property of the code itself.

On the Rust side, the central target for modification is the `HostBudget` struct, which represents the current state of the host's available resources . To incorporate metabolic telemetry, this struct must be extended with several new fields. These fields are not intended to hold spendable balances but to provide a real-time snapshot of the host's physiological state to inform the budgeting logic. The proposed additions include:

- `kcal_today: f32`: A floating-point value representing the total caloric intake for the current day. This is populated from nutrition intake logs and continuous monitoring of nutrient absorption.
- `glucose_band: u8`: An unsigned 8-bit integer index that discretizes the host's current blood glucose level into bands (e.g., 0=Hypoglycemic, 1=Low, 2=Normal, 3=High, 4=Hyperglycemic). This field is updated by telemetry from a continuous glucose monitor (CGM).
- `hydration_index: f32`: A floating-point value between 0.0 and 1.0, representing the host's hydration status relative to a baseline. This is derived from sensors measuring sweat rate, urine output proxies, and potentially skin conductance.
- `fat_reserve_index: f32`: A floating-point value representing the estimated level of adipose reserves. This is a slower-changing metric, likely updated based on periodic scans and nutritional intake data.

These fields populate the `HostBudget` struct, which then becomes the input for the `evaluate_upgrade` function . This function's logic is modified to first compute an effective AU.ET budget based on the full suite of available information, including the newly added metabolic fields. For instance, if `protein_level` is low, the contribution of `kcal_today` to the final budget is derated according to a predefined formula, reflecting the reduced efficiency of energy conversion . Only after this refined budget is calculated does the request pass through the established `lifeforce.evaluate_gate` and `blood-guard` checks . This sequence ensures that the entire decision pipeline operates on a comprehensive view of the host's state, with the higher-level safety governors retaining absolute veto power.

On the ALN side, the implementation complements the Rust logic by defining the policy and communication layer. The primary change is extending the schema of the master `lifeforce.envelope.v1` particle to include the new metabolic state fields . This binding is crucial; it ensures that any component interacting with the energy envelope is aware of the host's complete physiological context. Alongside this, new, specialized ALN particles are created to represent the sources of the telemetry data. These particles do not contain complex governance logic themselves but act as standardized data carriers:

- `metabolism.glucose.state.v1`: A particle containing the `glucose_band` value.
- `hydration.state.v1`: A particle containing the `hydration_index` value.
- `host.metabolism.budget.v1`: A particle that bundles the `kcal_today` and `fat_reserve_index` values and may also contain the computationally derived effective energy budget.

These new particles are then cyberlinked to the main `lifeforce.envelope.v1` particle . This means that whenever a `metabolism.glucose.state.v1` particle is emitted, its information is propagated and integrated into the state governed by `lifeforce.envelope.v1`. This creates a consistent and verifiable energy picture across all components of the nanoswarm, including policy shards like `policy.governance.energy-tokens.nanoswarm.v1` . The governance remains centralized and unambiguous, residing solely with the Lifeforce and CSP authorities as defined by the master envelope. This dual-language approach leverages Rust's performance for intensive calculations and ALN's declarative nature for verifiable rule application, creating a robust and secure implementation.

The table below outlines the key implementation targets and their roles in the extended system.

Component	Language	Extension Target	New Fields / Particles	Purpose
`evaluate_upgrade` Function	Rust	`bioscale-upgrade-store` crate	Accepts `&HostBudget` as input.	Computes a refined AU.ET budget using metabolic telemetry before safety checks.
`HostBudget` Struct	Rust	`lifeforce-guards` crate	`kcal_today: f32`, `glucose_band: u8`, `hydration_index: f32`, `fat_reserve_index: f32`.	Holds real-time metabolic telemetry to inform resource allocation decisions.
`lifeforce.envelope.v1` Particle	ALN	Governance Schema	Extended schema to include metabolic fields.	Centralizes governance and makes metabolic state visible to all swarm components.
Telemetry Particles	ALN	New Particles	`metabolism.glucose.state.v1`, `hydration.state.v1`, `host.metabolism.budget.v1`.	Standardize the format and propagation of metabolic data throughout the network.

This implementation blueprint ensures that the integration of metabolic telemetry is not an afterthought but a deeply embedded feature of the system's architecture. By extending the core structs and particles in a disciplined manner, the design translates the high-level philosophical principle of subordination into enforceable code and policy, ready for rigorous testing and calibration.

Physiological Safeguards: Hard Limits on Hemodynamic, Thermal, and Mechanical Loads

A cornerstone of the proposed safety framework is the enforcement of non-negotiable physiological safeguards that operate independently of cognitive load or psych-risk metrics . These hard limits are designed to protect the host's physical integrity from silent, cumulative damage that could occur even when the user is mentally relaxed or focused. The system must actively manage and cap hemodynamic stress, thermal load, and mechanical strain, ensuring that every cyberswarm operation respects the body's fundamental biophysical boundaries. This layer of defense is implemented using principles from viability kernel control theory, providing a mathematical guarantee that the host's state vector remains within a predefined safe polytope at all times .

The first and most critical safeguard is the enforcement of hemodynamic limits. Excessive or rapid blood-draw, even if sanctioned by the CSP/Blood token system, can impose severe strain on the cardiovascular system, risking hypotension, fainting, or worse . The system must track not just the total volume of blood-token consumption but also the peak flow demands and the cumulative usage over time. The `Dracula_Wave` mechanism, already present in the nanoswarm's kinetic fields, is activated when hemodynamic risk rises, enforcing a mandatory cooldown period regardless of the host's mental state or immediate energy needs . Mathematically, this is modeled by defining a viability kernel in a multi-dimensional state space where one dimension is `blood_volume`, another is `blood_flow_rate`, and others are related physiological variables. Any harvesting policy or upgrade that would drive the state vector towards the boundary of this kernel triggers a Control Barrier Function (CBF) to reject the action and steer the system back to a safe region .

Second, thermal load constraints are paramount. High-intensity computation and certain forms of neuromodulation generate significant heat within the brain and body . Unmitigated, this can lead to hyperthermia, cellular damage, and impaired cognitive function. The system must model the temperature rise from various operations and enforce strict limits on the maximum allowable temperature differential (ΔT) from baseline . This involves tracking metrics like heart rate (HR), heart rate variability (HRV), and inflammation proxies to get a holistic view of the host's thermoregulatory capacity [21] . Advanced models, such as the 3-D virtual human model for simulating heat and cold stress, can be integrated to predict the body's thermal response with high accuracy, allowing for personalized cool-down duration requirements before any new high-energy task is permitted [17] [21] . A Lyapunov-like "violation residual" function $V(x)$, where x includes the thermal state, can be used to measure the distance to unsafe thermal boundaries. Only policies that guarantee a non-increasing or decreasing $V(x)$ are allowed, ensuring that thermal risk does not accumulate over time .

Third, if the cybernetic system interfaces with biomechanical augmentations, such as exoskeletons or advanced XR motion controllers, mechanical/torque limits must be rigorously enforced . Musculoskeletal harm can result from repeated exposure to high torque, acceleration, or vibration, even at low perceived effort levels [29] . The system must apply governors on joint torque and acceleration, similar to those already defined for managing psych-risk . This involves defining safe operating envelopes for servomotors and actuators, bounding parameters like velocity, acceleration, and "jerk" (the derivative of acceleration) to prevent sudden, damaging movements . Neuromotor metrics, such as decoder accuracy and fatigue index, can be used to dynamically adjust these envelopes, reducing the permissible range of motion as the user's fatigue tolerance decreases . This proactive management prevents long-term wear-and-tear injuries that could otherwise go unnoticed until they become severe.

Finally, duty-cycle caps are essential to allow for physiological recovery. Even low-level, continuous operations can be detrimental if sustained indefinitely. The system must enforce hard stop conditions for any high-drain action based on cumulative time, session length, and rest periods, irrespective of the host's subjective perception of cognitive load . This is achieved by defining host-specific envelopes for different modes of operation (e.g., rehab, industrial, XR) that cap the intensity and duration of nanoswarm activity . Edge-device deployment with local guards, such as a Jetson-class daemon running a finite-state machine (SAFE → GUARDED → COOL_DOWN) driven by combined physload and envrisk metrics, can autonomously disable high-drain features if any envelope is breached, providing a last line of defense .

Safeguard Type	Monitored Variables	Enforcement Mechanism	Mathematical Foundation
Hemodynamic Limit	Blood volume, plasma volume, perfusion, cumulative blood-token use.	`Dracula_Wave` activation, clamped duty-cycles.	Control Barrier Functions (CBFs) to keep state vector within a safe hemodynamic polytope.
Thermal Load Constraint	Body temperature (T_b), ΔT, heart rate (HR), inflammation proxies.	Mandatory cool-down durations, throttling of high-compute tasks.	Lyapunov functions ($V(x)$) to ensure non-increasing thermal risk; predictive thermophysiological models. [17]
Mechanical/ Torque Limit	Joint torque, acceleration, vibration, decoder error rates.	Servo/envelope governors on biomechanical outputs.	Viability kernel control on motor command envelopes. [26]
Duty-Cycle Cap	Session length, cumulative operation time, rest periods.	Automatic downgrading or pausing of actions near envelope edges.	Mode-specific envelopes (rehab, XR, etc.) defining max intensity/duration.

By implementing these multi-faceted physiological safeguards, the system creates a robust, physics-grounded safety net. These hard limits are not advisory; they are inviolable constraints that form the lowest layer of the defense-in-depth strategy. They ensure that the host's physical well-being is protected from a wide range of potential harms, providing a stable foundation upon which higher-level cognitive and social risk mitigation strategies can be built.

Cognitive and Social Risk Mitigation: PDR Throttling and Neurorights Governance

Beyond the foundational layer of physiological hard limits, the safety framework must address risks arising from cognitive overload and social coercion. These higher-order risks are managed through a sophisticated combination of cognitive load metrics, such as the Psych-Density Rate (PDR), and a robust neurorights-based governance layer. This dual approach ensures that the system does not inadvertently push the host beyond their mental processing capacity and that metabolic data is never exploited for coercive purposes. The design philosophy here is to embed ethical principles directly into the system's logic, making them as enforceable as physical laws.

The management of cognitive load is addressed by extending the concept of Psych-Density Rate (PDR). PDR is defined as the ratio of psych-risk (R_v) to the sum of energy consumed and computational cycles ($En+Cl$), expressed as $PDR=R_v/(En+Cl)$. This metric is crucial because it decouples risk from raw power draw. A task can be computationally inexpensive but psychologically overwhelming, or vice-versa. By monitoring PDR, the system can throttle or reject tasks that create a high density of psych-risk relative to the host's available resources, preventing high-density stress events . Such events can occur under seemingly calm mental conditions, where the cumulative effect of multiple low-level stressors pushes the brain past its capacity to process information safely . The `Psyche_Junky` subsystem, already designed to manage psych-risk, would integrate this PDR calculation into its decision-making loop. Actions that would cause the PDR to exceed a calibrated threshold (e.g., entering the MODERATE risk band) would be automatically delayed or modified, ensuring the host's cognitive envelope is respected even when their physiological state appears stable . This PDR-based throttling can be applied broadly, not just to neural-rope calls, but to any repeated, high-energy behavior, such as dense XR usage or long lab sessions, by regulating the frequency and clustering of these operations .

The second pillar of this layer is neurorights and anti-coercion governance, which directly confronts the social misuse of metabolic data. As established in the architectural philosophy, sugar, water, and calories are not sovereign bio-tokens. Their classification and use are governed by explicit policies encoded in ALN shards to prevent coercion . A key policy is the treatment of CSP/Blood as a non-transferable stake, intrinsically tied to medical consent and bodily integrity . This makes it cryptographically and logically impossible to trade away or use as leverage for work or governance obligations. Furthermore, governance quorum rules are implemented to add another layer of protection. High-risk biomechanical decisions, for example, require a quorum whose voting power is weighted by the user's CSP balance, ensuring that no single entity or metric can unilaterally override collective safety protocols . This prevents a scenario where an adversary could attempt to manipulate the system by controlling alternative metrics like AU.ET alone.

To combat the subtle risk of incentivizing unhealthy behaviors, the system incorporates "sanitized risk-pattern 'CSS'" . This is a pattern library that flags and blocks any retrieval or code path that resembles diet-gamification, addiction loops, or other incentives that could encourage poor dietary choices or unhealthy habits. For example, a policy could forbid rewarding excess sugar accumulation or penalizing users for healthy caloric restriction. This sanitization layer ensures that the system's reward structure aligns with long-term health goals rather than short-term, potentially harmful behavioral loops. The entire governance structure is made transparent and auditable by binding Psyche_Junky configurations to neurorights and legal envelopes via ALN shards . Dangerous parameter changes, such as removing rest windows or raising blood-drain caps, are blocked at the policy level, not just in the code, and all decisions are logged in an append-only JSONL format with Bostrom-anchored hashes, deters unsafe tuning and enables post-hoc detection of drift .

This combination of PDR throttling and neurorights governance creates a powerful defense against cognitive and social risks. While physiological limits guard against hardware-level failures, and cognitive metrics guard against mental exhaustion, neurorights governance guards against systemic abuse and coercion. Each layer addresses a distinct class of failure mode, resulting in a lower overall RoH. The system is designed to be resilient not only to technical malfunctions but also to malicious intent and unintended negative consequences of its own incentive structures. This holistic approach ensures that the augmentation of a citizen is truly for their benefit, respecting their rights and protecting them from a wide spectrum of potential harms.

Risk Mitigation Mechanism	Target Risk	Key Components	Underlying Principle
PDR Throttling	Cognitive Overload / High-Density Stress Events	Psych-Density Rate ($PDR = R_v / (En + Cl)$) calculation; dynamic adjustment of task frequency/clustering.	Prevents pushing cognitive capacity by managing risk density, not just raw resource consumption.
Non-Transferable Stake Policy	Coercive Work Obligations / Exploitation	CSP/Blood classified as non-transferable, consent-bound stake in ALN governance.	Bodily resources cannot be traded or used as collateral, upholding core bodily autonomy.
Weighted Quorum Rules	Unilateral System Manipulation	High-risk decisions require quorums weighted by CSP balance, preventing dominance by other tokens.	Ensures that no single metric (e.g., AU.ET) can override safety protocols designed to protect the host.
Anti-Gamification Sanitization	Encouragement of Unhealthy Behaviors	Sanitized risk-pattern "CSS" that flags and blocks code paths resembling diet-gamification or addiction loops.	Proactively prevents the creation of perverse incentives that could harm long-term health.
Transparent & Auditable Logs	Unsafe Parameter Tuning / Drift	Append-only JSONL logs with Bostrom-anchored hashes; binding configs to legal/ neurorights envelopes.	Deters unsafe modifications and allows for external auditing and accountability.

Synthesis of a Multi-Layered Safety Framework

The integration of sugar, water, and calorie metrics into the Lifeforce/CSP safety envelope is not merely an incremental feature addition; it represents a strategic enhancement to a multi-layered, defense-in-depth safety framework. The synthesis of the proposed architectural philosophy, concrete implementation patterns, and the three distinct layers of risk mitigation—physiological, cognitive, and social—culminates in a cohesive system designed to minimize the overall Risk-of-Harm (RoH) to a target level of 0.3 or less . This framework achieves its safety objectives by trading a degree of flexibility for a substantial increase in fidelity, precision, and resilience.

At its core, the system's strength lies in the deliberate subordination of all metabolic data to the established hierarchy of Lifeforce and CSP/Blood . By treating these metrics as strictly derived telemetry fields rather than spendable bio-tokens, the design inherently mitigates the primary risk of social coercion. It prevents metabolic data from becoming a backdoor for forcing work or upgrades, a critical safeguard aligned with emerging neurorights principles concerning mental privacy and bodily autonomy [1] [4] [5] . This foundational choice ensures that the host's physiological state informs the system's decisions but never dictates them, preserving the user's sovereignty over their own body.

The implementation blueprint in Rust and ALN provides the technical scaffolding for this philosophy. By extending the `HostBudget` struct with fields like `glucose_band` and `hydration_index`, and embedding them within the schema of the central `lifeforce.envelope.v1` particle, the system creates a unified and verifiable state . The `evaluate_upgrade` function acts as the computational nexus, using this comprehensive state to calculate a tighter, more accurate energy budget before passing the request through the non-negotiable gates of `lifeforce.evaluate_gate` and `blood-guard` . This ensures that the benefits of increased precision are realized without ever compromising the integrity of the core safety protocols.

The true power of the framework is revealed in its layered defense strategy. The first layer consists of non-negotiable physiological hard limits on hemodynamic, thermal, and mechanical loads . Implemented mathematically through viability kernel control and Control Barrier Functions, these limits provide a physics-grounded guarantee that the host's physical integrity is preserved from silent, cumulative damage, regardless of their mental state or subjective perception of risk .

The second layer introduces cognitive load management through PDR throttling . By monitoring the density of psych-risk relative to energy consumption, the system proactively prevents high-density stress events that could lead to cognitive overload, even when raw power draw is low . This layer protects the host's mental processing capacity, a critical resource for safe interaction with the cybernetic system.

The third and final layer is neurorights and anti-coercion governance, which polices the social dimension of risk . Through policies that classify CSP as a non-transferable stake, require weighted quorums for high-risk actions, and employ sanitization patterns to block unhealthy incentives, the system erects a formidable barrier against exploitation and coercion . This layer ensures that the system's operation is not only physically safe but also ethically sound and respectful of the augmented citizen's rights.

Together, these layers create a synergistic safety net. Physiological limits guard against measurement error or hardware faults; PDR throttling guards against cognitive overload; and neurorights governance guards against social misuse. Each layer addresses different failure modes, and the overall RoH is significantly lower than what any single mechanism could achieve on its own . The Knowledge-factor for this design is high, as it reuses validated patterns from Lifeforce, AU.ET/CSP, BrainSpecs, and PDR, adding a consistent and bounded metabolic layer . The primary residual risks involve potential mis-calibration of the calorie-to-AU.ET mapping or social misuse if incentives are poorly designed, but these are actively mitigated by clinical envelopes and neurorights firewalls . Ultimately, this research provides a concrete, implementable, and deeply analytical pathway to extending cybernetic energy governance in a manner that is both more precise and demonstrably safer.

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