SYS_ACCESS // AUTH_ENGINEERING

SYSTEM INTEGRITY: OVERCURRENT PROTECTION ON PCBs

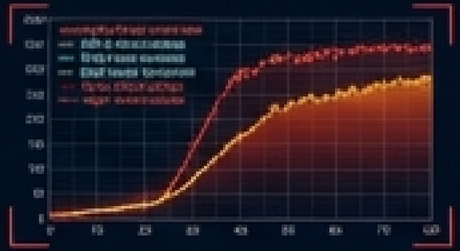
Mitigating Thermal Degradation and Substrate Failure in High-Current Architectures

DIAGNOSTIC REPORT: Analysis of trace overloading risks, carbonization physics, and 54V design protocols (100A - 1000A).

DIAGNOSTIC OVERVIEW: OCPD RESPONSE VS. SUBSTRATE ENDURANCE

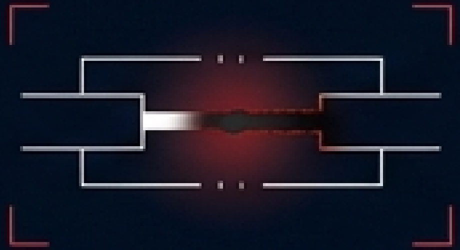
THREAT DETECTED

- **Problem:** PCB traces fuse and carbonize within milliseconds.

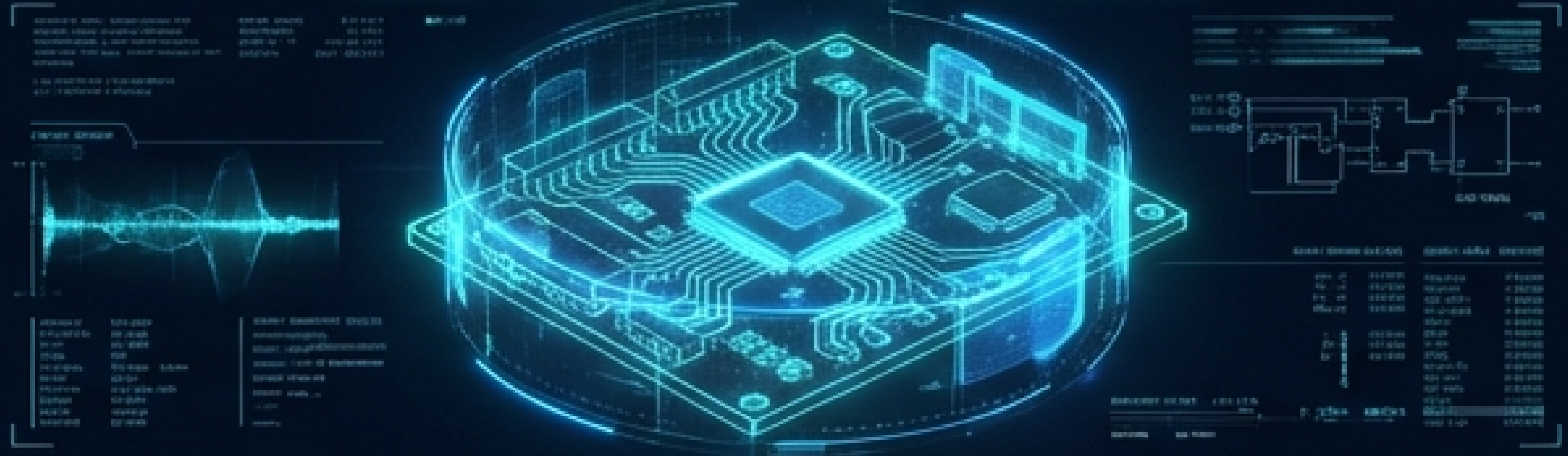


- **Risk:** Substrate degradation occurs before the fuse trips.

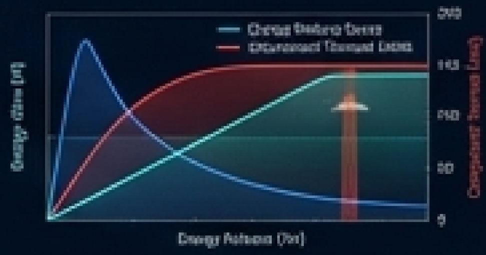
- **Outcome:** Irreversible carbonization creates a permanent conductive path.



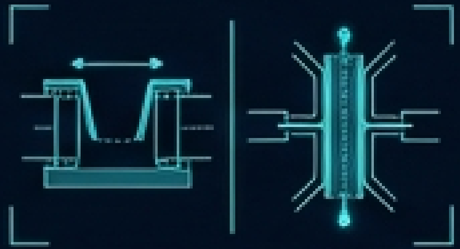
DEFENSE PROTOCOL



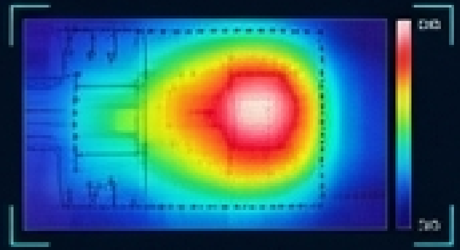
- **Solution:** Coordinate I^2t ratings (Let-through energy vs. Withstand capability).



- **Action:** Implement dynamic creepage distances and thermal barriers.



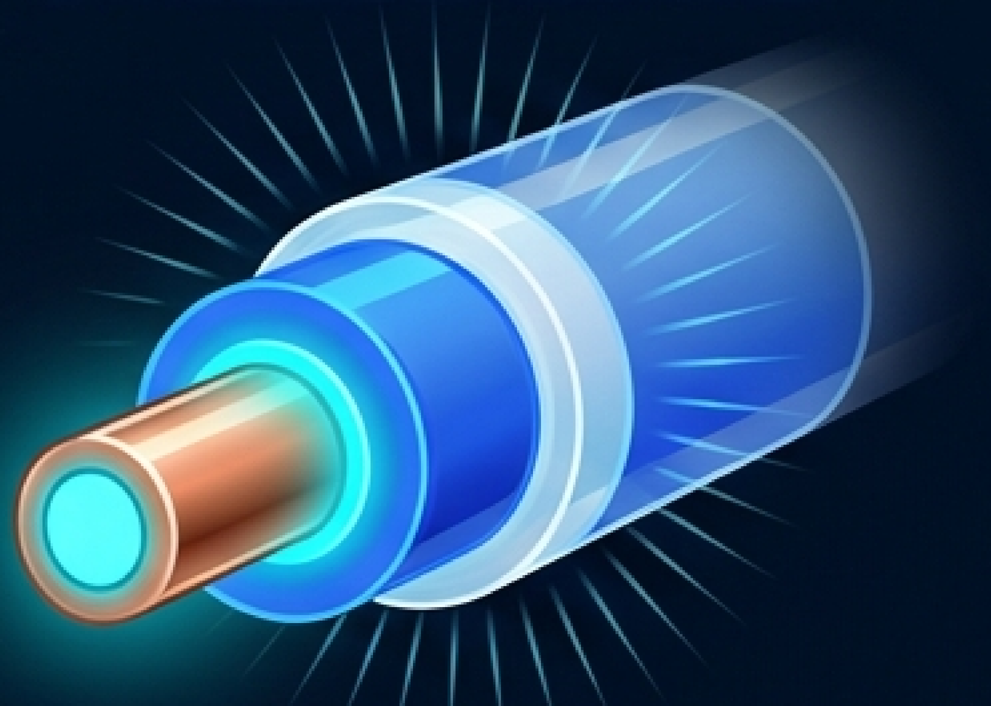
- **Goal:** Prevent Td (Decomposition Temperature) breach.



CRITICAL INSIGHT: Unlike a fused wire, a failed PCB trace leaves a "memory" of the fault—a conductive carbon path that compromises the system permanently.

ANATOMY OF A FAILURE: WIRING VS. PCB TRACES

STANDARD WIRING

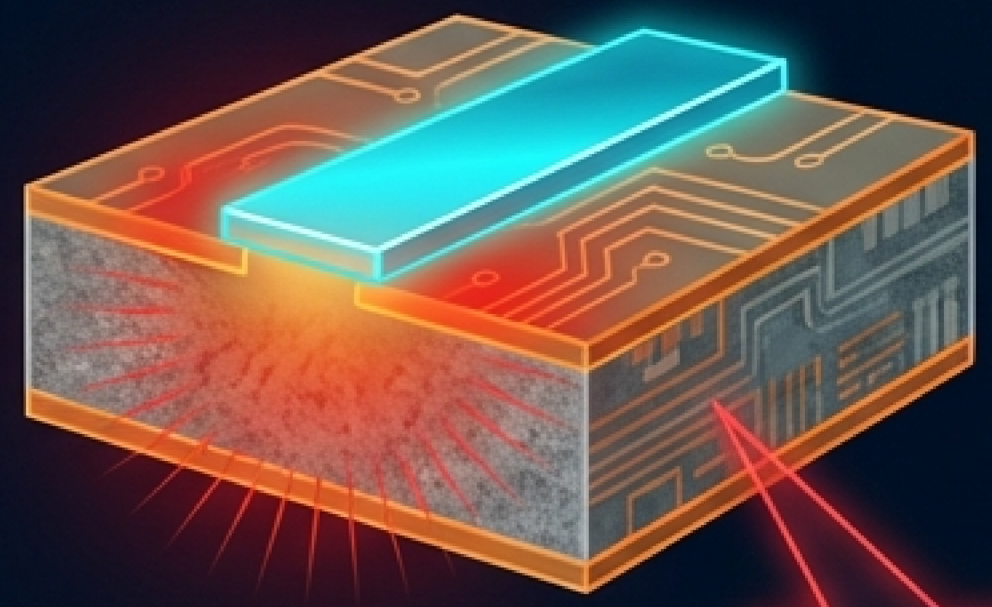


Standard Wiring:
High thermal mass. Heat dissipates into air.

Failure Mode:
Insulation melts or wire fuses (Open Circuit).

Result:
Self-clearing. Hazard removed.

PCB ARCHITECTURE



Low thermal mass.
Bonded to organic dielectric (FR-4).

Failure Mode:
Substrate decomposition (Carbonization).

Result:
Persistent Failure. Carbon residue creates short circuit.

THE INVISIBLE ENEMY: IRREVERSIBLE CARBONIZATION

HEAT GENERATION
Joule heating (I^2R) raises local temp.

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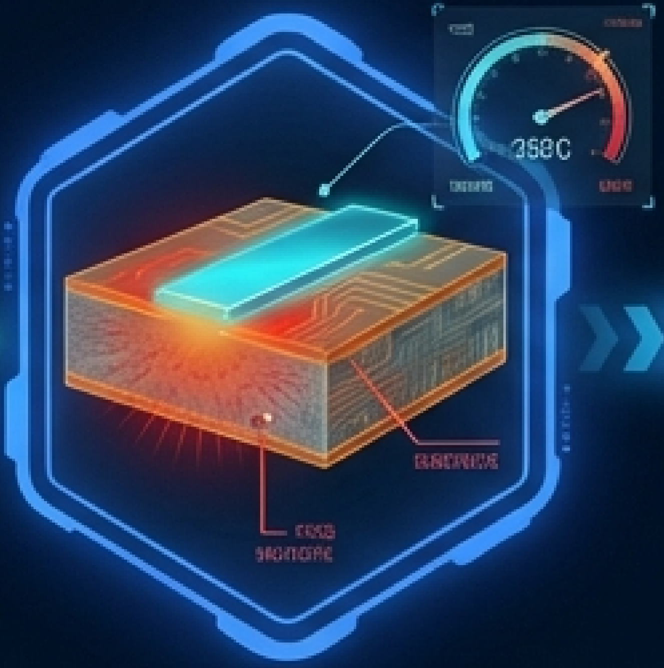
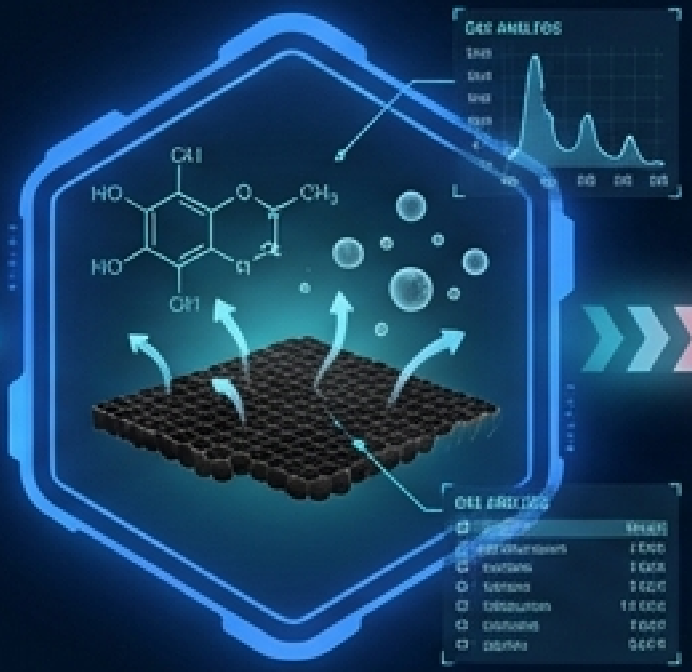
PYROLYSIS
Temp > Td (350°C). Resin breaks down.



Temp > T_d (350°C). Resin breaks down.

RESIDUE FORMATION
Volatiles release. Solid carbon remains.



Volatiles release. Solid carbon remains.

CONDUCTIVE PATH
Dielectric transforms into conductor.

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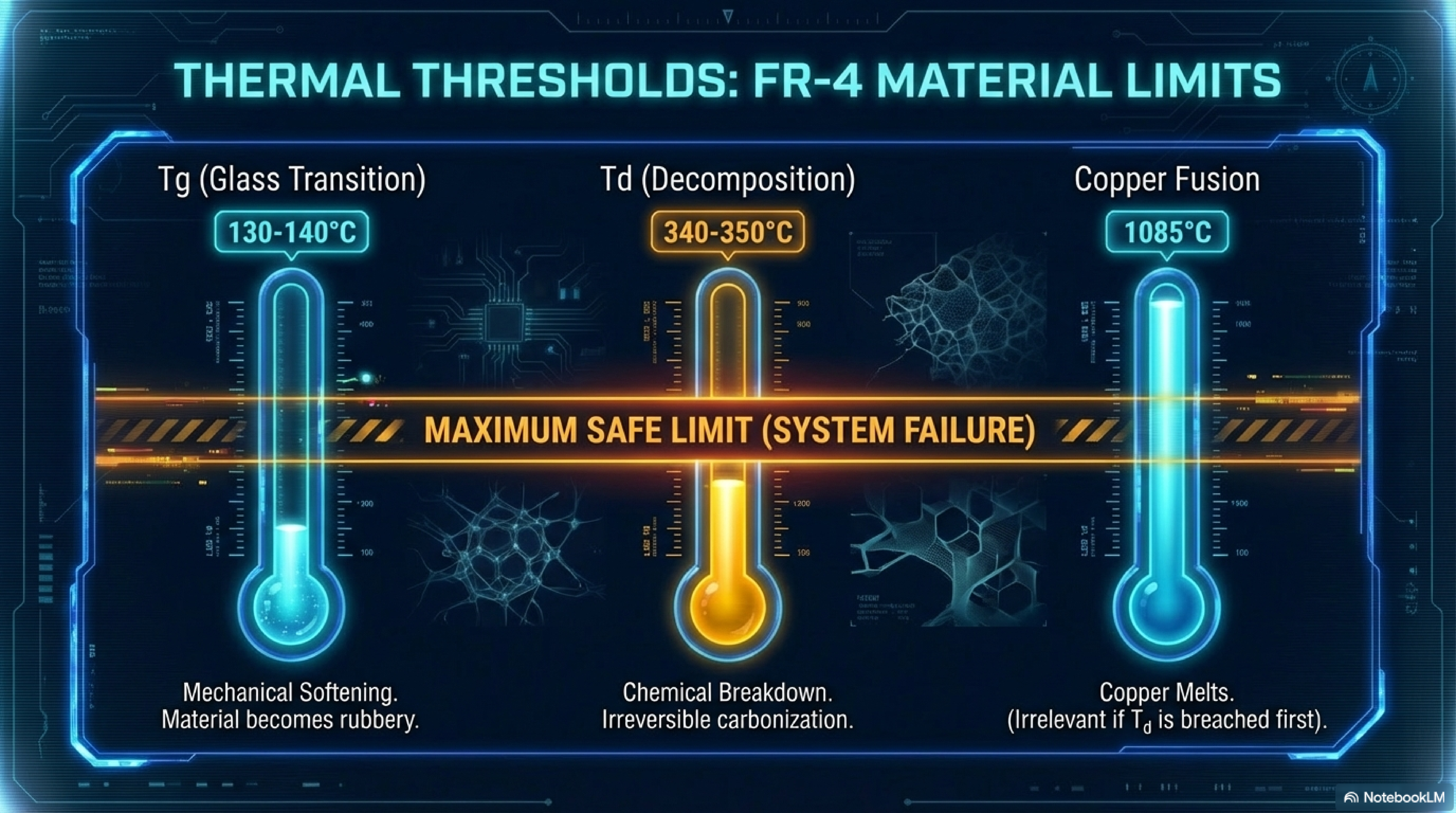
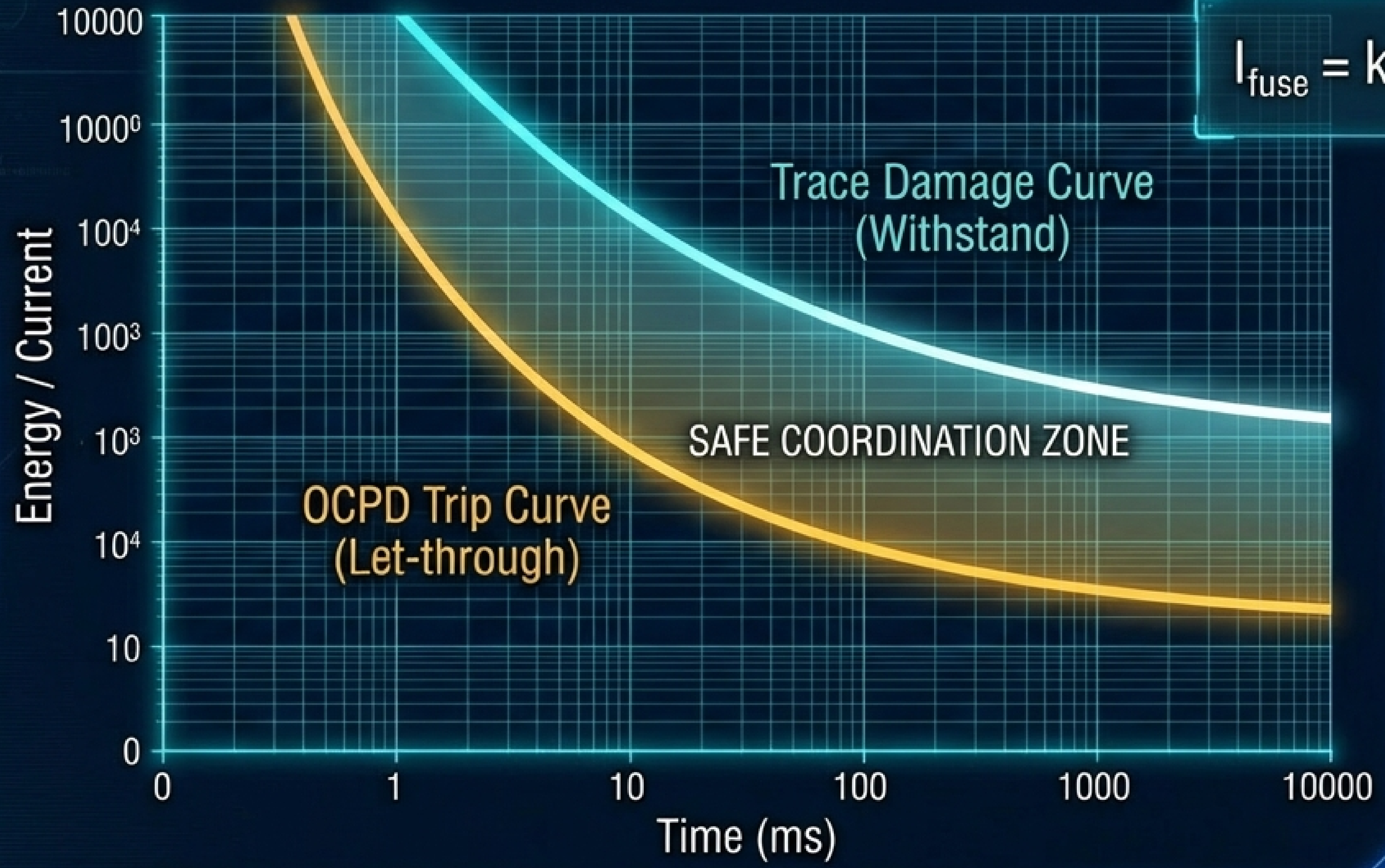
STANDARD FR-4 T_d: ~340-350°C

LATENT FAILURE RISK: Carbon path reduces dielectric strength, leading to future catastrophic re-ignition.


THERMAL THRESHOLDS: FR-4 MATERIAL LIMITS
Tg (Glass Transition)
130-140°C
Td (Decomposition)
340-350°C
Copper Fusion
1085°C
MAXIMUM SAFE LIMIT (SYSTEM FAILURE)
Mechanical Softening.
Material becomes rubbery.
Chemical Breakdown.
Irreversible carbonization.
Copper Melts.
(Irrelevant if T_d is breached first).

THE TIME FACTOR: I^2t COORDINATION



$$I_{fuse} = k \cdot A^{0.5} \cdot \log_{10}(t + 1)$$

A 100A overload can induce fusion in milliseconds. The OCPD curve must remain strictly BELOW the Trace Damage curve to prevent the board from becoming the sacrificial element.

CREEPAGE UNDER FIRE: DYNAMIC SAFETY SPACING

THE PROBLEM:
Standard creepage assumes intact surface. Overload carbonization reduces effective insulation distance.

TECH NOTE: Arc Tracking. High energy arcs vaporize dielectric material. Spacing must account for carbon propagation.

POLLUTION DEGREE:
High dust environments require 150-200+ mils.

⚠ WARNING: Spacing reduction can lead to catastrophic failure.

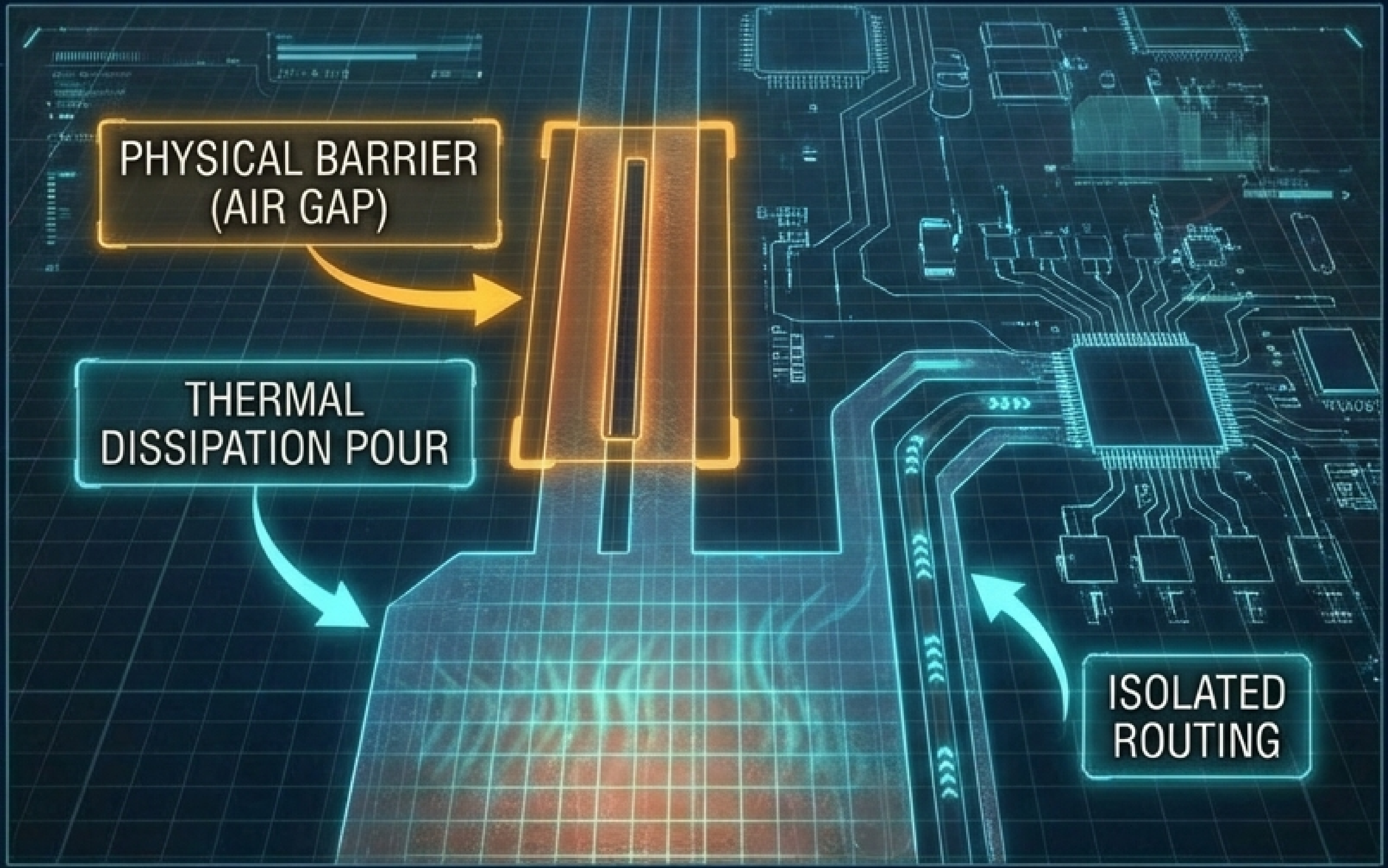
TRACE GEOMETRY: SIZING FOR SURVIVAL (54V)

LOAD CURRENT	COPPER WEIGHT	REQUIRED WIDTH (MILS)
100A	2 oz	250 - 300 mils
500A	3 oz	1000 - 1200 mils
1000A	4 oz	1800 - 2200 mils

DESIGN NOTE: For currents >100A, trace width becomes prohibitive. Consider Bus Bars or multiple parallel traces.

Internal layers require significantly wider traces due to lack of air cooling.

LAYOUT STRATEGY: CONTAINMENT & ISOLATION

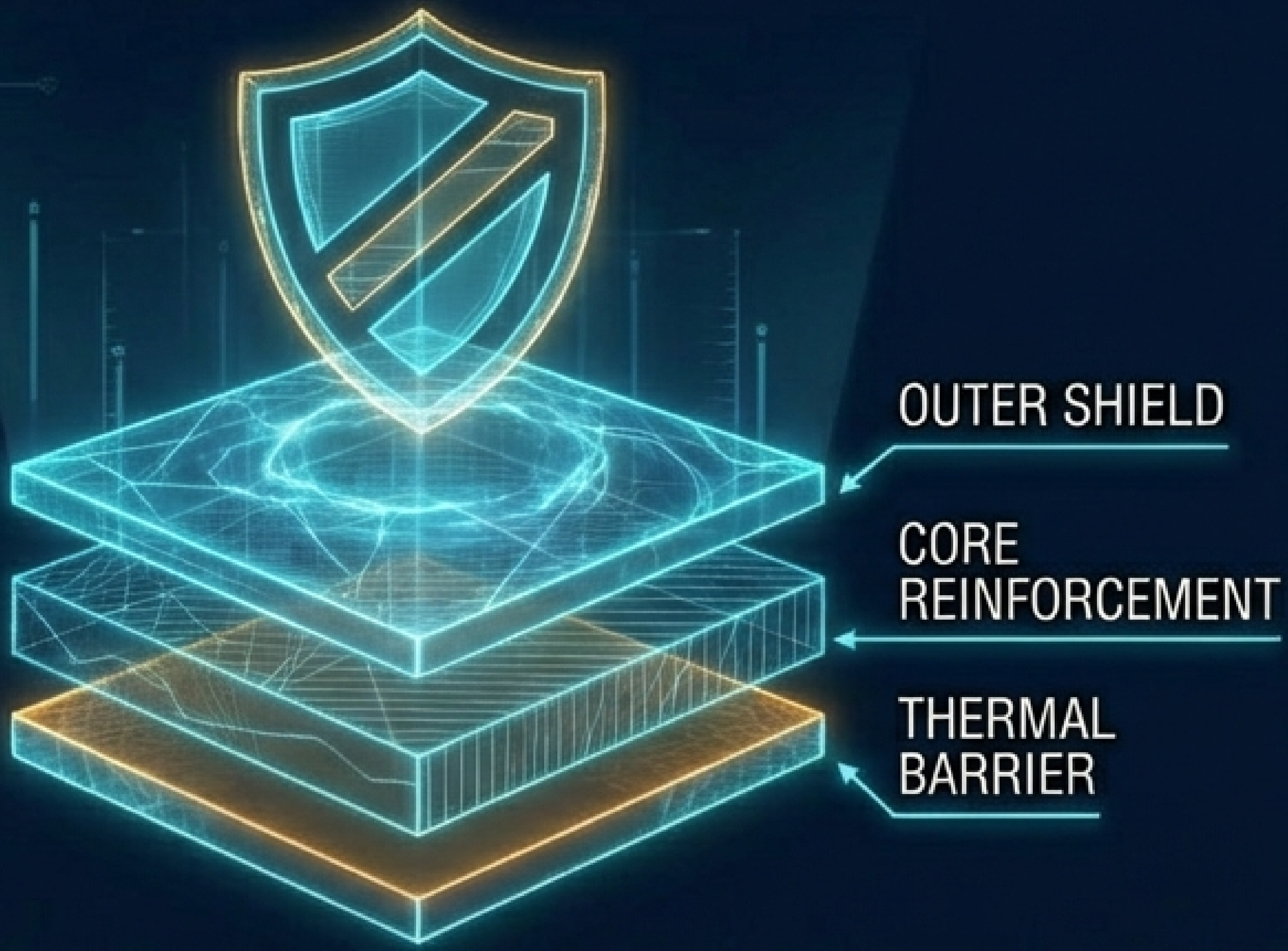


STRATEGY 1:
Slots and air gaps act as fire breaks to stop carbon propagation.

STRATEGY 2:
Route high-current traces away from sensitive control signals.

STRATEGY 3:
Utilize large copper pours as heat sinks to lower temperature density.

MATERIAL SCIENCE: REINFORCING THE SUBSTRATE



UPGRADE PARAMETERS

PARAMETER 1 High Tg (Glass Transition) **>170°C ↗**	VALUE BENEFIT Maintains mechanical stability under stress.
PARAMETER 2 High Td (Decomposition) **>350°C ↗**	VALUE BENEFIT Raises threshold for carbonization.
PARAMETER 3 High CTI (Tracking Index) **Group IIIa/b**	VALUE BENEFIT Resists formation of conductive tracks.

⚠ **ADVANCED OPTION:** Consider Metal-Core PCBs or Ceramic substrates for extreme density.

THE HOLISTIC DEFENSE PROTOCOL

A multi-layered approach ensures that if one defense is compromised, subsequent layers prevent catastrophic failure.

MISSION STATUS: FINAL TAKEAWAYS

PREVENTION IS THE ONLY CURE

Carbonization is irreversible. Once the substrate decomposes, insulation integrity is lost.

DESIGN FOR FAULT CONDITIONS

Standard creepage rules are for normal operation. Fault safety requires conservative, dynamic spacing.

THE OCPD IS NOT ENOUGH

A fuse protects the wire; the designer must protect the board. Verify I^2t coordination.

SYSTEM SECURE