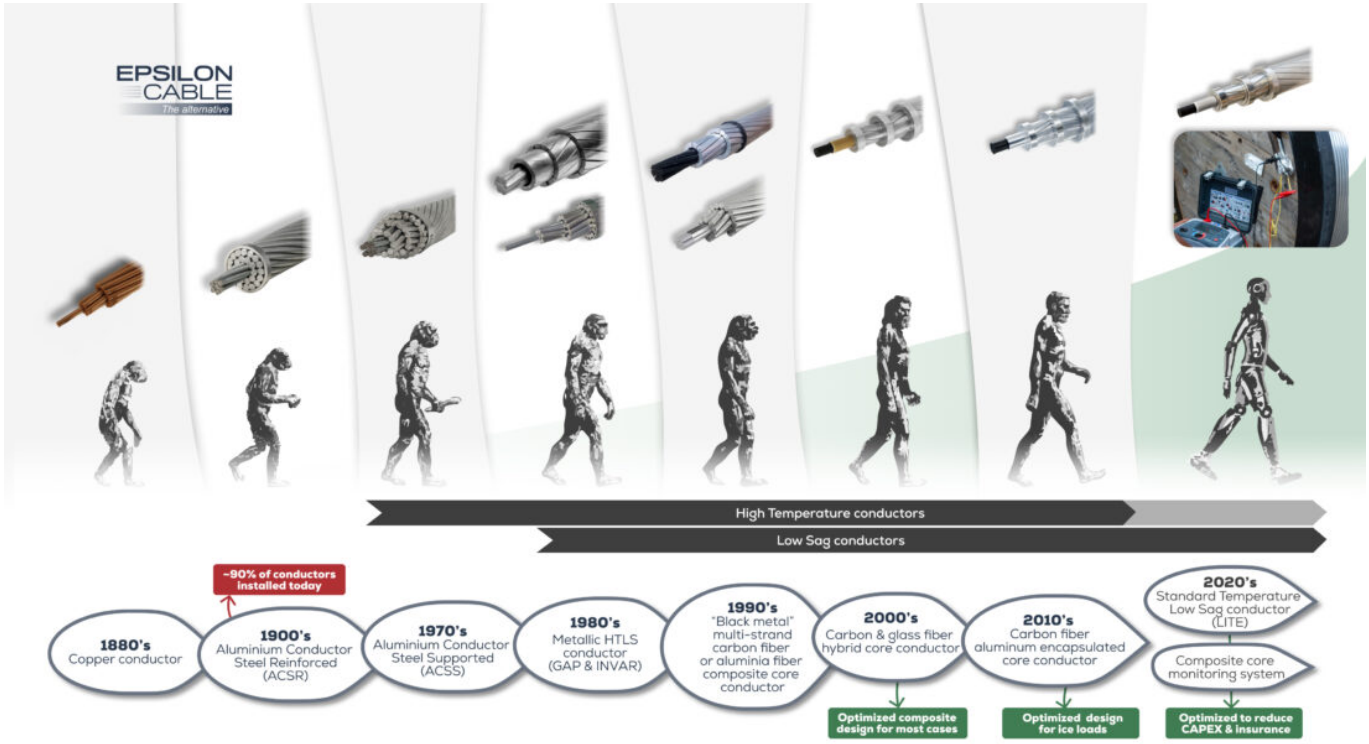


Historical shift: from copper to ACSR and the rise of high-temperature conductors

The evolution of overhead conductors follows a familiar arc: start with what is practical, then refine, optimize, and instrument. Early OHL conductors were all copper. The Panic of 1907 exposed copper's price volatility and supply risk, accelerating the move to Aluminum Conductor Steel Reinforced (ACSR) designs. ACSR paired a steel strength member with hard-drawn aluminum and enabled the first great grid buildout. It was the right tool for the time, but modern requirements around thermal behavior, clearance control, and lifecycle assurance demand more than a century-old baseline.

In the 1970s, ACSS advanced the idea of separating roles by letting aluminum run fully annealed at elevated temperature while steel carried much of the mechanical load. The first High Temperature conductors were born. Capacity rose without new corridors, yet steel's fundamentals remained: it is heavy, it elongates with heat, it corrodes, and asset owners must trade losses against mass.

The 1980s pushed further with Invar and GAP designs, the first true HTLS conductors. Invar offered lower thermal elongation, but achieving that benefit in service required much higher

initial stringing tensions, which significantly increased mechanical loads on structures and reduced compliance during dynamic events such as galloping or ice shedding. Invar conductors also carry a substantially higher material and manufacturing cost (typically several times that of comparable ACSR designs) further limiting their suitability mainly to new corridors engineered for these elevated tensions.

GAP conductors introduced a greased annulus separating the strength member from the conductive layers, enabling higher operating temperatures while maintaining aluminum properties. However, the design brought notable drawbacks: specialized and more complex terminations, demanding installation procedures, sensitivity to handling, grease migration, and limited inspectability once in service.

As with Invar, GAP conductors found their place in specific applications, but each came with meaningful operational trade-offs.

Carbon fiber and CORECHECK verification

Composites opened the next chapter by enabling real High Temperature Low Sag conductors, with recorded thermal elongation approximately one-tenth that of steel. Early 1990s programs first trialed open-mold, multi-strand carbon composite (as well as alumina fiber composite) while preserving “black metal” geometry for perceived redundancy. Such geometry is not ideal for fiber-reinforced systems, where performance improves as load paths are consolidated and filaments are fully engaged. The step change arrived in the early 2000s with pultruded, monolithic, filament-rich composite core; most commonly carbon-glass fiber hybrids with the glass fiber layer providing integral galvanic separation from the aluminum. **This type of composite core** is also available as an extra high stiffness variant (also called ultra-low sag / ULS), made from carbon fibers with a higher modulus of elasticity, which is more suitable for long crossings and heavy ice loads. More than a hundred thousand miles of this core type have been energized worldwide, delivering low mass, high strength, thermal capability, and much better clearance control than steel, with useful compliance after ice shedding.



Ten years later, Epsilon and Nexans co-developed and commercially deployed the world's first all-carbon, aluminum-encapsulated composite core. By fully enclosing the carbon in a sealed aluminum encapsulation, electrolytes cannot reach the fibers and galvanic concerns are removed. In addition, axial/bending stiffness rises without adding weight, which is a valuable benefit in severe radial-ice climates and in high-ice regions where clearance control and peak-to-peak events drive specification.

A critical design note: because the composite is enclosed, the conductor is intentionally limited to ~165°C; above this regime resin volatilization can generate off-gases with no escape path, risking internal "aneurysm" bulges, local composite damage, or thermally accelerated aging within the encapsulation. In practice, that limitation aligns with many cold-climate corridors (lines that see three inches of radial ice rarely require 180°C capability) so the encapsulated design remains a strong fit where stiffness and ice performance dominate. Additives that alter resin stoichiometry or offgassing behavior to push these limits are generally cost-prohibitive for this application, so testing is imperative (including DSC/TGA and Arrhenius-based aging) to confirm ratings and set operating practice.

As composite cores moved from early deployment in the 2010s into broader use, emphasis in the 2020s has shifted toward two questions: how to improve resin systems to right-size thermal capability, and how to verify structural integrity so performance is demonstrated rather than assumed.

The market for resin is moving beyond a single "premium" matrix aimed at continuous 180°C

and 200°C emergency service for 2× capacity versus 90°C ACSR. Asset owners can now choose from a calibrated ladder of chemistries. At the top are higher-temperature formulations for persistently overloaded corridors where ampacity is the primary driver. At the other end are standard-temperature systems tuned around ~100°C operation (Epsilon **LITE**) that deliver the mechanical advantages of a composite core at roughly 1.5× ACSR wire cost rather than the historical ~2.5–3×. This tiering allows engineers and planners to match matrix capability to operational performance and capital plan instead of buying ampacity they do not need, especially for greenfield projects. If a corridor's constraint is thermal, a higher-temperature resin unlocks ratings without re-tensioning structures. If the main constraint is initial cost, topology, or clearances rather than load, a standard-temperature resin paired with a low-CTE composite core can meet the mechanical need at a far lower material premium. The result is a cleaner business case: fewer tons in steel and concrete where spans or heights can be optimized, and the option to invest saved mass into more aluminum when loss reduction pays back.

The second advance is **CORECHECK**, a dielectric, binary field test that turns the core from a passive strength member into a verifiable asset. The method applies a controlled electrical stimulus between the aluminum and the carbon path and reads the interlayer as an insulator. An intact barrier yields a pass; a damaged barrier yields a failure. Crews get an unambiguous result in minutes, with geo-stamped and time-stamped records that can flow into commissioning files, compliance packets, and post-event diagnostic reporting. Because the toolchain uses established dielectric practice with conservative limits, it fits utility safety culture and can be trained quickly. Testing can be leveraged at all stages as well. At factory acceptance it documents that reels left in known good condition. After stranding and stringing it confirms that tensioning, clipping, and termination methodologies respected the core's structural integrity. After storms, faults, or contact events it triages spans so crews spend time and use equipment where it matters. The data reduces disputes, shortens punch lists, and gives wildfire or other insurers and regulators objective evidence rather than inference.



Together, resin tiering and **CORECHECK** convert composite performance into bankable project value and operational certainty. Owners can specify exactly the temperature capability they need at a price point that clears CAPEX gates, and they can instrument the asset so its condition is known rather than assumed. That is why the current decade is different: composites are no longer a single, risky, expensive option; they are a field proven configurable platform with built-in verification that meets today's affordability, reliability, and safety requirements.

Today's market is crowded with "advanced" bare conductor designs, but the term itself has no agreed technical meaning. What matters for utilities is understanding the underlying architecture and materials, not the label. The design path is increasingly clear: match conductor architecture to corridor constraints; tune resin and fiber systems to the required thermal window and capital plan; and interrogate the asset so condition is measured, not assumed. Epsilon's **LITE** conductor brings standard-temperature, low-sag performance within typical CAPEX constraints, while **CORECHECK** delivers overhead asset assurance in an underground-style, field-ready format, with further capability in development. A grid serving data centers, electrified transport, and sustained load growth cannot rely on materials optimized for the last century; qualified composite engineering, proven over 20 years and expanding today, is the platform for what comes next.



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Joseph is Epsilon Cable's Director of Business Development in the US. He is passionate about delivering innovative solutions that improve the efficiency and sustainability of the power industry.