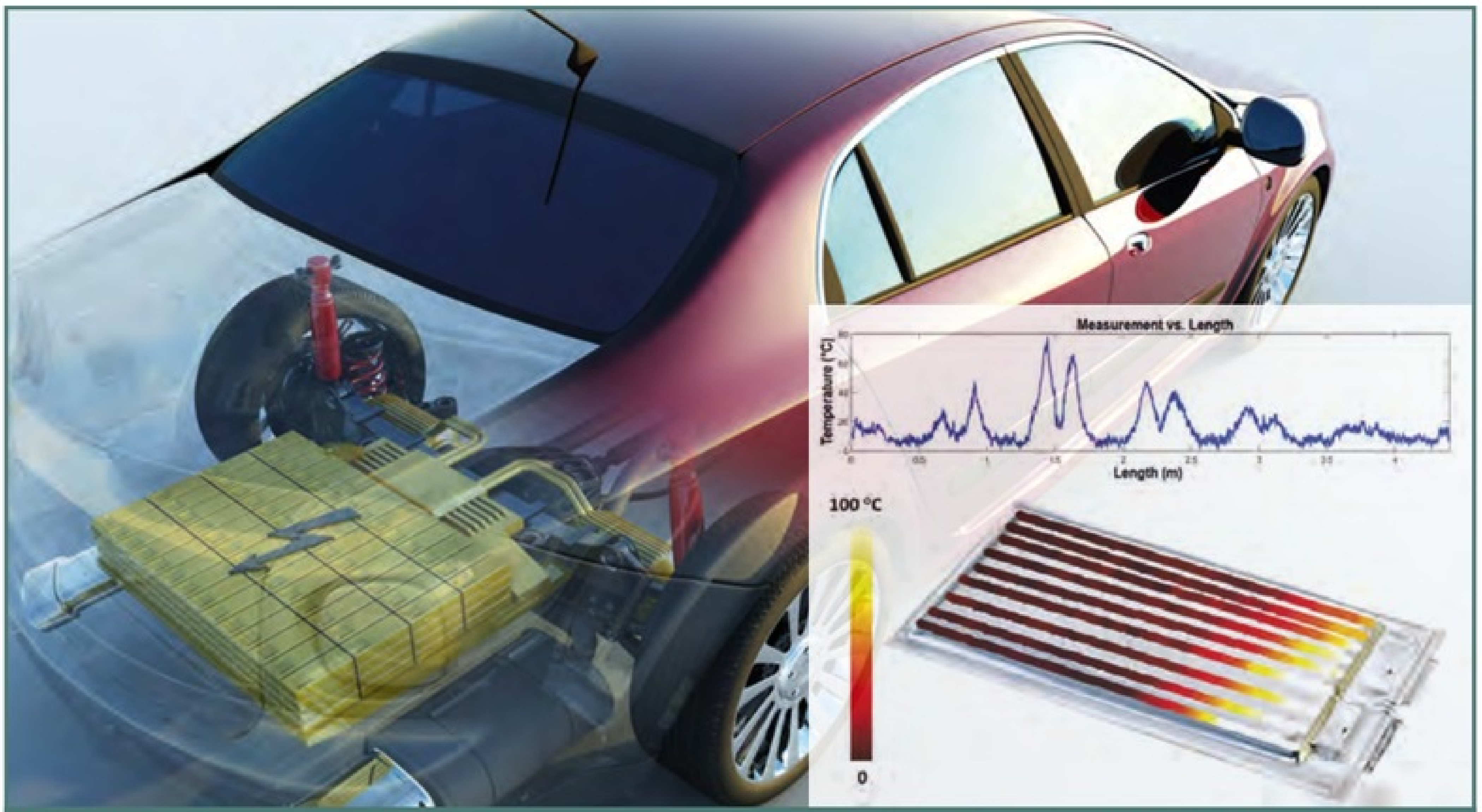
Fiber-optic sensing

Substantial advances being made in battery technology will ultimately lead nowhere if outdated current test methods are not developed to keep pace with changing times



Main: Luna's system helps overcome thermal management system design challenges for electric and hybrid automotive applications; Inset: Temperature measurement taken from a 5m length of fiber sensor, using Luna's advanced system

Continued advancement in battery technology will be a critical enabler in transforming transportation and power generation infrastructures to a greener global footprint. Although these technology advances will likely involve substantial improvements in battery chemistry and materials, it is important to consider that advances in thermal modeling and test methods will also be needed.

The thermocouple is the primary method used to measure temperature during thermal testing of batteries. The thermocouple is a copper wire and is both electrically and thermally conductive. A single thermocouple can measure just one point and, given the wire's thickness and conductivity, can be inserted inside the battery only with great difficulty. Thermocouples are susceptible to electrical noise; if multiple wires are installed inside the battery they draw away heat, thus impacting the measurement of temperature. Indeed, it will be difficult to develop battery technology for the 21st century using 19th century test and measurement technology.

Temperature defines a battery's performance limit, and thermal management is critically important for any application. The temperature range for lithium-ion batteries in standard commercial applications is typically -20°C to +40°C. Operation above this range can result in reduced life, and operation below in loss of performance. Furthermore, the operating temperature from cell to cell in a battery pack needs to be within 3-4°C or the cells will not age equally. In electric vehicle applications, the number of permutations in operating cycle and environmental conditions is wide, making the design and application of batteries even more challenging. In military applications, the operating conditions can be more extreme. Care needs to be taken to understand the actual rating of batteries operating in these severe conditions outside their normal rating. In order to compensate for the lack of sufficient temperature data from inside the battery, packs are frequently over-designed in order to account for unknowns and contingencies. This over-design results in extra battery cost, and in electric vehicle applications, battery packs are already the single biggest cost driver.

Luna Innovations of Roanoke, Virginia, USA, has developed an advanced system that uses unaltered single-mode fiber-optic cable as a distributed sensor to measure both temperature and strain along a continuous length of fiber. Fiber-optic cables, when illuminated, have the equivalent of an optical fingerprint; this fingerprint will change, in a predictable and repeatable way, in response to changes in strain and temperature. This fiber, when installed inside a battery, can replicate a virtually continuous line of temperature sensors with just millimeter spacing between sensing points. Unlike traditional temperature sensors, distributed fiber-optic sensing is corrosion resistant, immune to electromagnetic interference (EMI) and inherently a dielectric. The fiber can be embedded within the battery and placed directly in contact with the battery's cells without causing short circuits. A single cable can provide an accurate and complete picture of the distribution of temperature within the battery under all operating modes. Temperature data can be displayed versus length, or individual points can be selected anywhere along the fiber and displayed versus time. The Luna system uses standard unaltered cable, which means that sensor location, measurement density and gauge length can all be changed dynamically through software. This reconfiguration of the distributed fiber-optic sensor can be done in minutes versus the hours it would take to re-instrument a battery with traditional sensors.

The Luna ODiSI (Optical Distributed Sensor Interrogator), with HD-FOS (high definition fiber-optic sensing), will help battery engineers optimize the internal design of new battery technology. Outside of the battery cell, the Luna system will help automotive engineers characterize the thermal management system of the complete battery pack under actual operating conditions. Luna's ODiSI, with HD-FOS, is truly 21st century test technology for engineers working on 21st century designs.