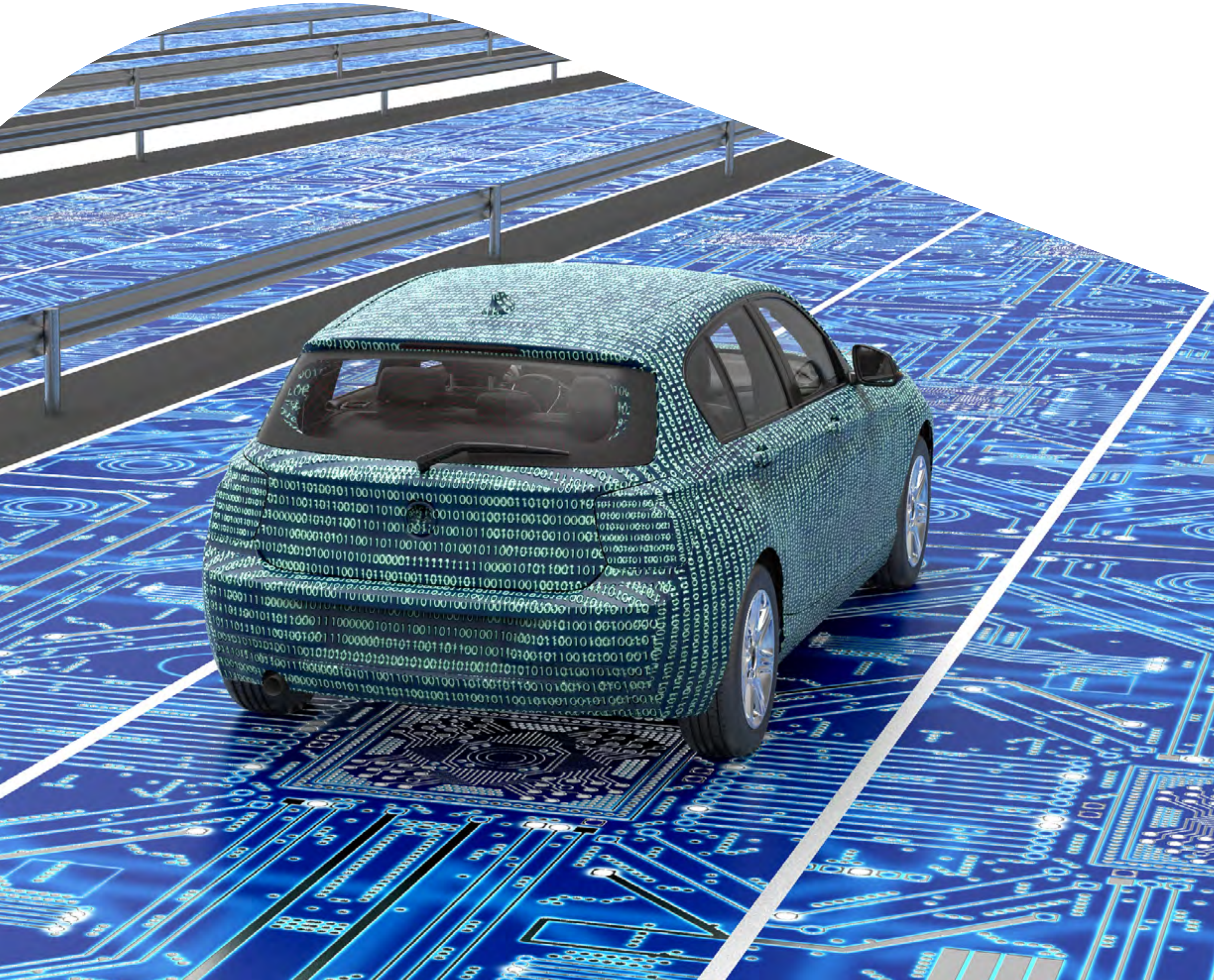
Baker Hughes

X-ray inspection of electronics in automotive manufacturing

How fully inspected, quality electronic components equals safer cars and profit protection



Executive summary

Automobiles today have evolved into technological wonders that filmmakers and science fiction novelists prognosticated over the last century. At our fingertips every day is a sophisticated vehicle with computing power that far exceeds fighter jets, airplanes and even globally pervasive software tools such as Facebook.

Fueling this evolution are electronic components, growing exponentially as an integral part of automobile function and design, thus enabling our cars to become smarter, safer and autonomous. As electronic components in automobiles increase, so does the need for comprehensive, high quality, high-speed inspection, to help ensure automobile safety while protecting manufacturing profitability.

Most vitally, 3D inspection of non-visible areas in micro-electronic components is necessary to achieve comprehensive quality assurance. X-ray technology is the singular solution that enables nondestructive testing at high resolution of both visible and non-visible areas. Automobile OEMs are striving for zero defects and extended component life. Thus, electronics manufacturers are mandated to deliver fully inspected, high quality parts. Automobile safety – and lives – increasingly depends on component quality.

The convergence of extreme sophistication, high volume production and an increasing reliance on electronics for safe and proper automobile operation has spurred the creation of global industry standards and process requirements. Developed by the Association Connecting Electronics Industries (IPC), these guidelines govern the automotive supply chain, with a special focus on electronics standards.

X-ray inspection solutions deliver strong protection, value and competitive differentiation for automotive electronic component manufacturers to help ensure car safety, protect lives and sustain manufacturing profitability. Inspection helps to save lives and improve business, making today's cars more remarkable than any classic work of fantasy or fiction.

Table of contents

Innovations in the automotive industry

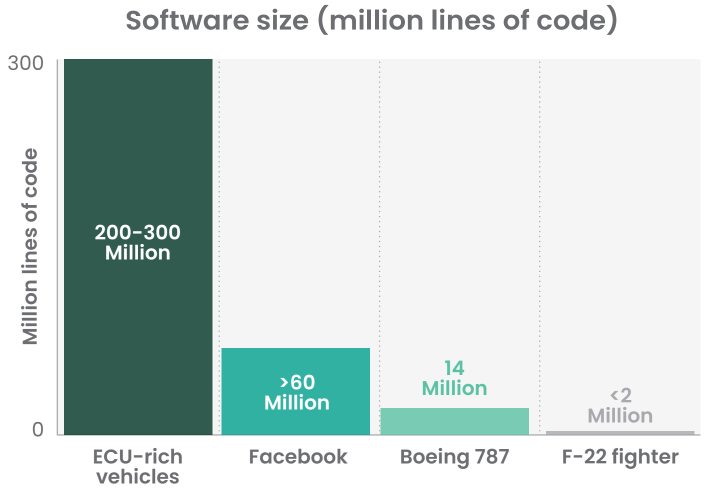
Cars are becoming extremely sophisticated and connected machines, rapidly evolving into smart, autonomous vehicles. It is advanced, technology-based innovations that are significantly increasing car functionality, enabling self-diagnostics, improving driver experiences and offering electric and near autonomous driving capabilities. Today, car performance is ranked as much on characteristics that provide comfort, real-time driver-car interactions and enhanced safety than solely on what is "under the hood". Features such as Wi-Fi, bluetooth, voice control, heated steering wheels, massaging seats, blind spot awareness, anti-collision (car and pedestrian) warnings, 360 degree cameras, self-parking, automatic braking and even semi-autonomous driving are fast becoming more important factors in new automobile rankings.

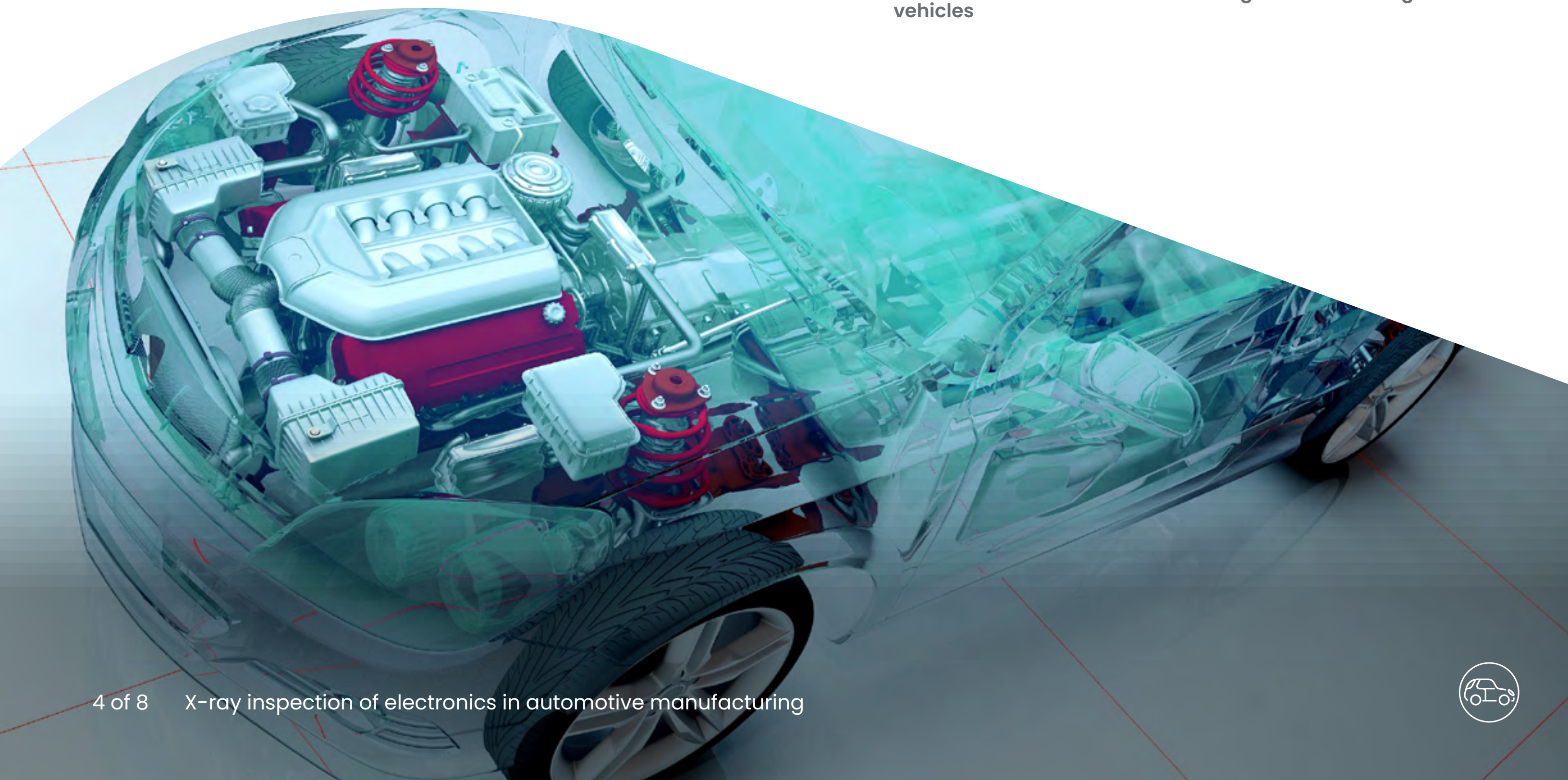
While some of these features may seem frivolous, others help to significantly improve vehicle safety by avoiding breakdowns, preventing accidents and reducing car-related fatalities. Environmental sustainability is also a benefit as electric cars help reduce reliance on fossil fuels. The outcome? Sophisticated automobile technology is meaningfully transforming our lives and our world.

Simultaneously, these positive developments are driving a dramatic increase in the use of electronic components in new vehicles. **Forecasts** predict that electronics will account for over 50% of a car's total cost by 2030.

Electronic devices (known as electronic control units or ECUs) that communicate over controller area networks (CANs) power automobile advancements. The number of ECUs used in cars is continuously expanding across all car types and classes. For example, basic, lower-end cars employ at least **30 ECUs**. For high-end luxury vehicles, the number of ECUs rises to around 100. As the number of ECUs rises, so does the use of semiconductors and printed circuit board assemblies (pcba's) in automobiles. One recent estimate states that a single car employs around **6,000 semiconductors**. In electric vehicles, rechargeable batteries, often lithium-ion, are yet another component in the array of electronic devices integrated into automotive design and operation.

Additionally stunning is the over 100 million lines of software code required to operate these new ECU-rich automotive vehicles. Frost & Sullivan forecasts this number to reach **200-300 million lines** of code in the coming years. These numbers are massive. To put this in perspective, consider that Facebook uses over 60 million lines of code, a Boeing 787 employs 14 million lines of code and an F-22 fighter jet uses less than 2 million lines of code.





Electronic car components create new requirements

As automobile usage of electronics has grown, they have become the leading determinant of proper automobile operation. Thus, an immutable requirement is to produce high integrity components – measured at micro levels of quality on both visible and non-visible areas – to properly ensure automobile safety while protecting manufacturing profitability. Increasingly, overall automobile safety is highly dependent on individual microelectronics quality in components such as semiconductors, pcba's, sensors and lithium-ion batteries.

During the manufacture of semiconductors, for example, non-visible micro cracks, partial solder joints and voids can inhibit semiconductor performance – with failures often emerging during onroad automobile operation. These elusive component imperfections create significant safety and financial vulnerabilities for component and automobile manufacturers *(see scenario at bottom of page)*.

To mitigate these escalating vulnerabilities, three quality inspection characteristics are critical in order to achieve comprehensive quality inspection of electronics:

Characteristic
1. High resolution inspection
2. 3D inspection of non-visible areas
3. Non-destructive testing

Benefit
1. To achieve micro- and nano-levels of accuracy
2. To inspect dimensional and structural integrity
3. To specifically test, then use, each part

Micro- and nano-focus X-ray solutions utilize the singular technology that meets all three requirements, making them the must-have equipment for quality inspection of electronic components. X-ray solutions enable the detection of latent imperfections, such as joint cracks, voids and partially or entirely disconnected elements within electronic automobile components on both visible and non-visible areas. Most importantly, this quality assurance can be accomplished prior to automobile installation and use, thus preventing potential automobile failures and the resulting consequences. It is the "normal" thermal, mechanical and electrical stresses during automobile operation that lead to failures stemming from undetected electronic component defects. To achieve safe vehicle operation, flaws must be detected much earlier in the component manufacturing process.

Other non-destructive inspection techniques, such as optical testing and electrical testing provide partial protection. These alternative techniques cannot offer 3D inspection of non-visible features and can create a false positive. Undetected flaws cannot withstand the vibration and thermal cycling (-20 to 100 degrees Celsius) of automobile operation and can lead to premature and unnecessary automobile failure. Thus, in automobile electronics inspection, less is much, much less as vulnerabilities can escalate quickly and significantly, creating legal, financial and safety consequences.

Impact of semiconductor quality in the automotive industry

In the automotive industry, semiconductor components are a significant and integral part of vehicle function and design. A single car, for example, may require as many as 6,000 semiconductor chips, and that number is increasing as new features, such as advanced driver assist systems, are added. With global production volumes approaching 100 million cars and light trucks produced annually, the quality requirements for automotive semiconductor manufacturers have serious implications.

Semiconductors in automobiles cannot afford to fail. Failure has high company costs such as repairs, recalls and brand image as well as potentially tragic personal consequences such as injuries and fatalities. Large automobile recalls have historically cost automotive manufacturers tens to hundreds of millions of dollars to resolve, and that's without including the impact on brand reputation or personal consequence and loss.

As semiconductors have risen to become the most important components in automobiles, the quality mandates have followed suit. Automotive manufacturers mandate failure rates in parts per billion **(ppb)**, compared to consumer devices that allow up to 10% failure rates in the first two years. The quality "upgrade" from parts per million (ppm) to ppb rate is clearly justifiable as illustrated in this scenario: For an automotive manufacturer producing 25,000 cars per day with 5,000 semiconductors per car, a chip failure rate at a part per million (ppm) will result in 125 problematic vehicles every day.

The good news? For both automotive component and automobile manufacturers, new technology (including X-ray inspection) is available now to help support ppb failure rates. While achieving ppb failure rates demands new process and quality control approaches, it in turn ensures safety, mitigates risks and simultaneously increases manufacturing yield.

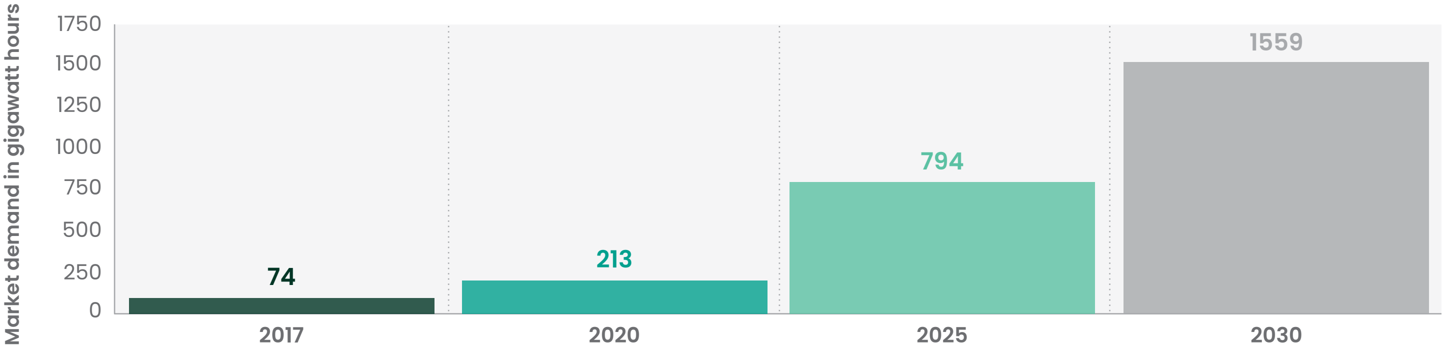
Electric vehicles and lithium-ion batteries

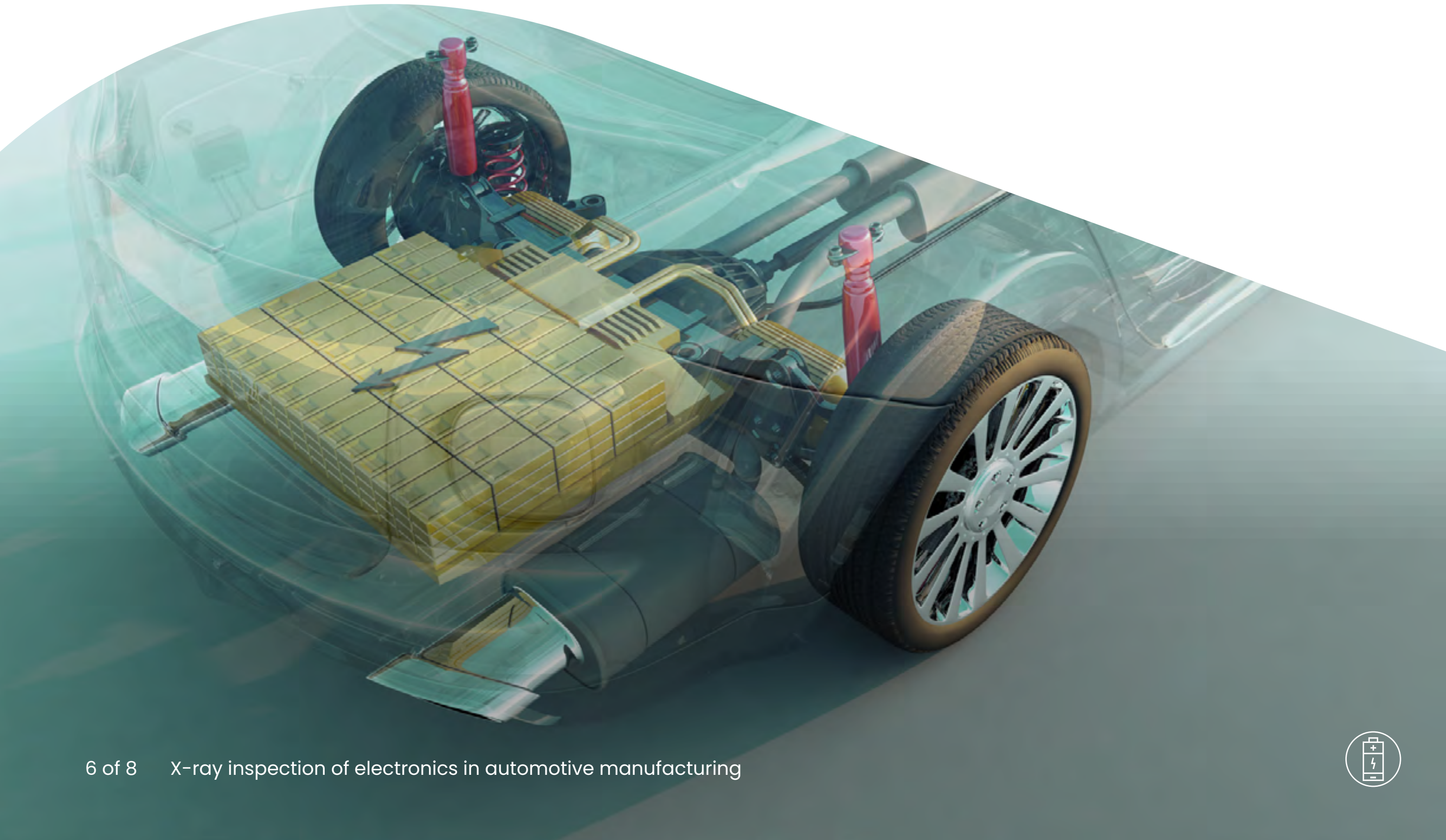
Electric vehicles, yet another amazing innovation, are on the rise and with them the use of lithium-ion batteries *(see graph)*. Distinct challenges exist in the design and manufacture of lithium-ion batteries, as they are, in reality, small chemical reactors that require mechanical containment and tightly controlled electrical systems.

Potential lithium-ion battery failures include poor performance, short life spans, internal short circuits and even thermal runaway that can escalate into explosive fires. Root causes can stem from electrode inconsistency, electrode impurities, voids and welding defects. These elusive, non-visible defects must be detected early in the manufacturing process to properly mitigate and contain risks. High-resolution X-ray and CT (Computed Tomography) inspection stands alone as the technology to check and prevent faulty components from being passed as acceptable and installed into electric vehicles thereby causing greater magnitude failures.

Given the growing use of lithium-ion batteries in electric vehicles over the next decade, adoption of proper inspection technologies is crucial. This means X-ray inspection done early in the component process, before lithium-ion batteries are installed into electric vehicles, to help ensure safe, reliable performance as market adoption of electric vehicles grows.

Projected market demand for lithium-ion batteries used in electric vehicles from 2017 to 2030 (in gigawatt hours)





What matters to automobile manufacturers?

Given the extremely sophisticated nature and high volume production of automobiles today, together with their heavy use and reliance on electronic components for proper and safe operation, the mandate for high-reliability, zero-defect components is crucial. Within the last year, automotive OEMs imposed a requirement that electronic components last **18 years** with zero failures. Additionally, global industry standards and process requirements, specifically designed for the automotive industry, have been developed by the Association Connecting Electronics Industries, known as the IPC*. The automotive supply chain is governed by IPC compliance, with a special focus on electronics standards.

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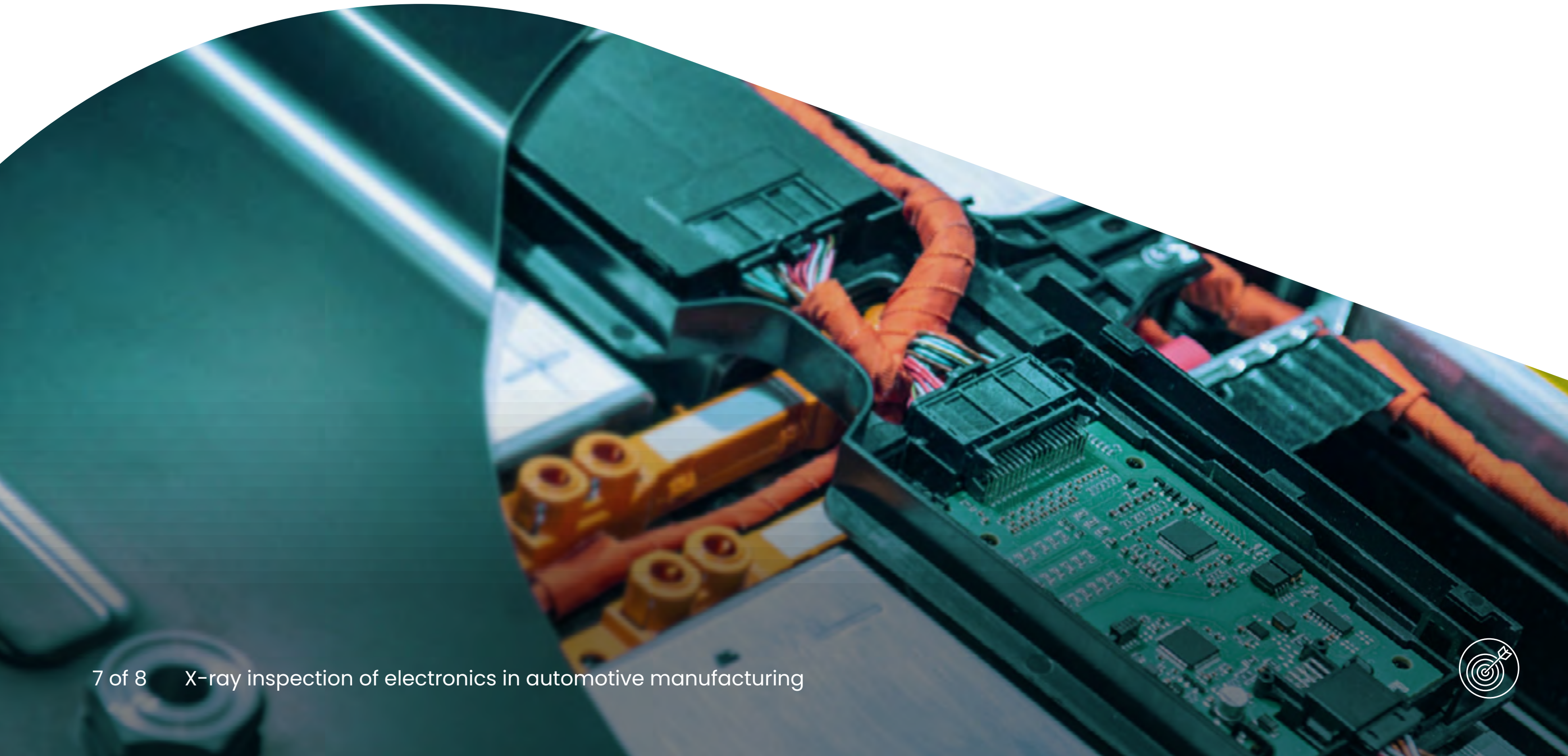
In 2016, **IPC created IPC6012DA**, a special addendum, or "automotive superclass", to articulate rigid printed board quality requirements that ensure they can withstand the harsh vibration and thermal cycles of automobile operation. Key to this new standard is the requirement for comprehensive inspection alongside a recommendation to use automated visual inspection to examine all layers as well as the finished printed board – including non-visible features. X-ray inspection is the sole solution that can provide this necessary capability and help ensure IPC compliance to bolster automobile safety, manufacturing throughput and profit protection.

Additional industry-agnostic IPC standards that direct electronics quality requirements and are now being reviewed for specific automotive updates:

- IPC-7095D for ball grid arrays (BGA)
- IPC-A-610G for electronics assemblies
- IPC J-STD-001 for soldered electrical and electronics assemblies
- IPC/WHMA-A-620 for cable and wire harness assemblies

While IPC compliance is a vital global standard, not all automotive component suppliers pursue this compliance. Why? Because it takes investment of time, education (IPC provides certified instructors), inspection equipment and IPC audits to achieve and sustain compliance. However, automobile manufacturers demand IPC compliant suppliers to ensure levels of quality that mitigate risks, protect profits and create safe and reliable cars. Non-compliance comes with penalties and consequences. More significantly, non-compliance that emerges as failed automobile operation risks much more – and can present "irreversible" damages and potential fatalities. In the automotive supply chain, IPC compliance is a highly valued competitive differentiator, as well as simply being the "right" thing to do.



Summary

In the automotive industry, safety and profit protection are only possible with proper inspection of electronic components. X-ray inspection, providing high-resolution, 3D examination of visible and non-visible areas, stands alone as the solution fit for the stringent quality needs in automotive manufacturing. The hallmark of leading automotive manufacturing companies is IPC compliance and full inspection X-ray solutions to help ensure safety, throughput and profit protection.

For more information, feel free to contact us here: BakerHughesDS.com/Contact

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