Research Spotlight

Leveraging the Internet of Things to Improve Product Quality: What You Need to Know

Some believe that the hype for the Internet of Things (IoT) has peaked. This is likely true, and it is a good thing: because after the zenith of hype comes the rational and important task of execution. IoT is a term describing ubiquitous connectivity where things, (i.e. people, processes, sensors, and devices) ranging from "dumb" devices such as kettles to "smart" devices like self-driving cars are able to communicate in real or near-real time via standard Internet technologies.

The world already has smart connected products. The "Smart" in this designation comes from the use of algorithms and logic with embedded computing power to improve performance to meet specific functional goals based on collected data from local sensors. Think about the original iRobot, manufactured by Roomba, with the ability to navigate certain obstacles in the home, detect dirt, and return to a base to charge. "Connected" comes from the ability to communicate with other things—think: people, processes, systems—to enhance coordination and overall system performance across a distributed network. Think about a pump station in a Liquefied Natural Gas (LNG) terminal where multiple sensors and flow meters are nodes that are monitored centrally for safety and performance.

> "…how smart connected products can transform the value chain and improve manufacturer's ability to design, deliver, and service market leading products."

When products are smart and connected, the new use cases are endless. The world is just now beginning to see where these can go with new products like Nest, the revolutionary thermostat with advanced, connected control, self-programming and learning capabilities that are not only simple and convenient, but deliver a simple to understand and measurable return on investment. However, to date much of the research and innovation has been focused on how smart connected products can transform the user experience. An untapped area of research is how smart connected products can transform the value chain and improve manufacturers' ability to design, deliver, and service market-leading products. Paramedics and hospitals, for example, are armed with intelligent defibrillators that use biphasics, impedance compensation, and synchronized cardioversion to guide and calculate shock delivery in life-threatening situations. It is not difficult to picture the smart connected defibrillator feeding back this data, along with usage statistics, readiness state, battery life and other valuable performance metrics both outside of and potentially during actual operation. Failure of these devices in the field could have dire consequences, which is why reliability and quality performance are paramount issues for manufacturers and users alike.

A proactive approach to quality that arms engineering and product design teams with this field-borne information makes sense. Using data from hundreds of thousands of these devices to derive reliability insight and quality performance information is an example of how applying IoT can improve Design for Quality (DFQ) initiatives. Usage statistics could even impact healthcare operational and deployment decisions, demonstrating the cross-industry opportunities that IoT-driven data can yield.

Using data from hundreds of thousands of these (smart connected) devices to derive reliability insight and quality performance information is an example of how applying IoT can improve Design for Quality (DFQ) initiatives.

For the quality management professional, the IoT is the gateway to decision-driving intelligence in performance, reliability, and all manners of in-field product data that was once unique to organizations like space agencies communicating with their assets. This latest technology wave is the engineered product equivalent: making field performance feedback available to quality and engineering professionals on a scale never seen before, enabling engineering and development to adjust and design-in quality and reliability based on current field data.

To be successful, organizations will need to accelerate their quality management maturity efforts and support quality-related IoT initiatives, including closed-loop enterprise quality management and the harmonization of quality processes.

In this Research Spotlight, specifically LNS Research will cover:

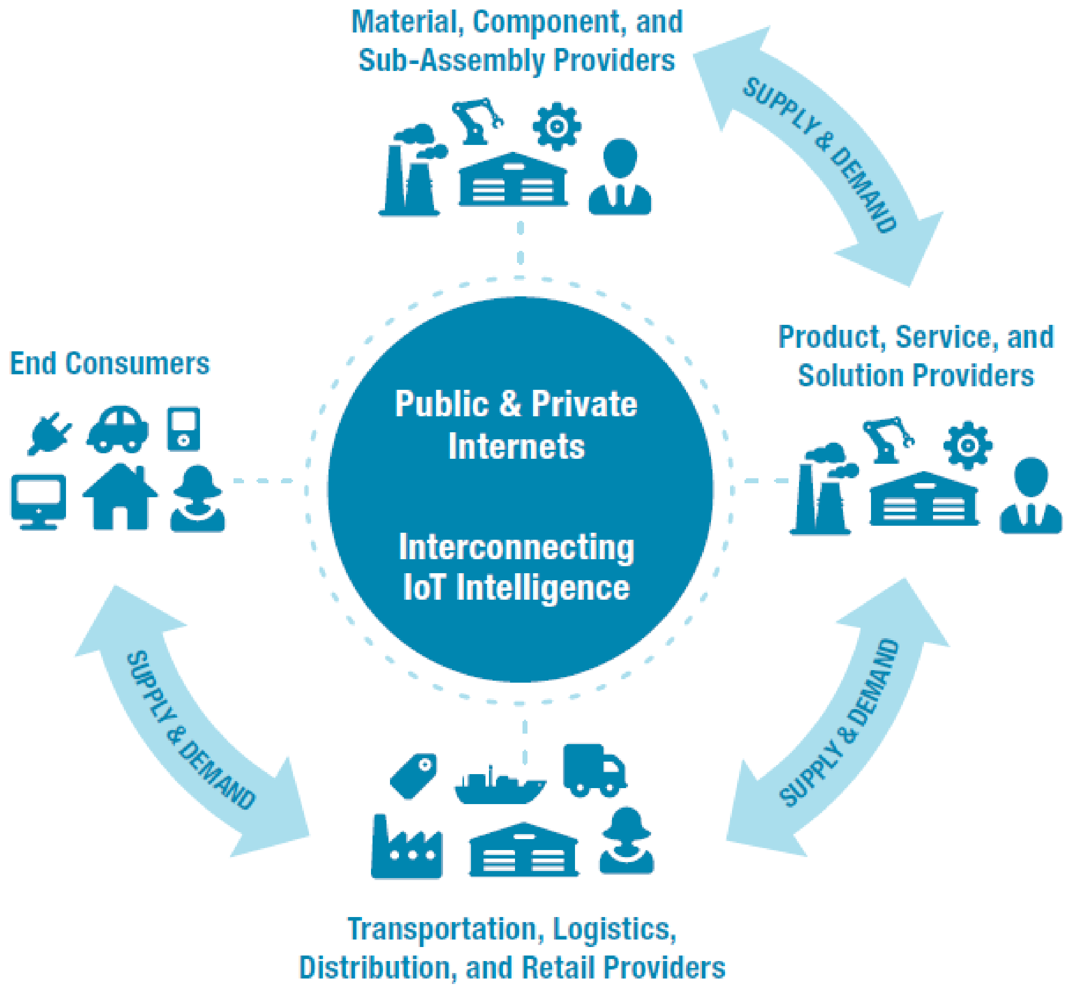
- Awareness of IoT and the relevance of closed-loop quality processes
- Harmonization of quality data and processes across the enterprise in order to shift from reactive to predictive, agile quality management
- Challenges and the cost of inaction
- Actionable recommendations to position your organization for future success

IoT in the Context of the Industrial Value Chain and Closed-Loop Quality Processes

Constituents of the industrial value chain are becoming increasingly excited about the future possibilities of smart connected products being simply and inexpensively interconnected and collaborating together via Internet technologies to achieve innovative and amazing results.

IoT technologies create the potential for billions of everyday devices to become more self-aware and intelligent, and to be able to negotiate communications with each other via public and private Internets in order to create new ways of collaborating, working, and living together.

The IoT Scope of Opportunity



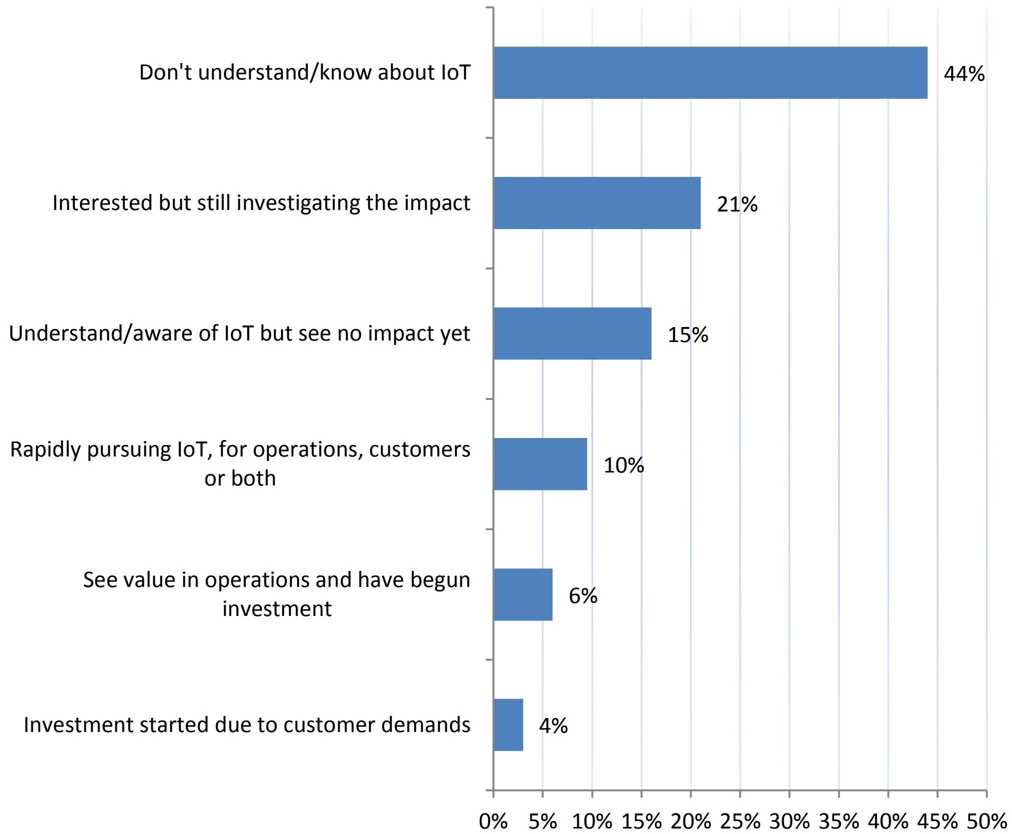
Smart connected devices yield data that previously lagged in finding its way back to product engineers or was probably never gathered from the field before.

Each of the physical, human, and computing elements involved will have the ability to directly negotiate communication—streamlining supply and demand chains along with operations within the four consumer and supply chain areas depicted above.

What will define the next wave of leading product engineering companies and their access to changing or newly defined markets is the ability to prepare a quality-driven foundation for the deluge of actionable intelligence and structured feedback from engineered products. Smart connected devices yield data that previously lagged in finding its way back to product engineers or was probably never gathered from the field before. As a result, the infrastructure to harness, analyze, and act on the intelligence returning has likely been underestimated. This gap exposes manufacturers to the risk of being usurped by those who adapted in a timely manner, or even worse, entirely new and disruptive entrants to the market.

Therefore, the imperative is for a combination of IoT awareness and education for quality managers in conjunction with addressing quality management infrastructure to facilitate the transformation of how a reliable, quality product is delivered. The first element, awareness, is illustrated in the chart below.

How IoT Is Currently Impacting Business, N=367



Clearly, most companies are still just at the nascent stages and the ability to quickly ramp up internal capabilities and momentum will go a long way to determining future success. Many have already expended significant capital and intellectual resources to harmonize core processes and connect across functions, both of which are key differentiators for leading engineered product OEMs. But a significant number of companies still struggle with disconnected quality management processes and disparate systems across engineering, quality, manufacturing, and customer service, a state that will undoubtedly hamper their ability to dramatically improve quality as a result of data streaming from smart connected products.

Whether they are aware of it or not, those organizations that have already made progress towards or have implemented harmonized, closed-loop quality processes, already occupy an advantageous position. This is because IoT has many facets, from the software (embedded) and hardware (sensors, actuators, etc.) components in the product through connectivity, transfer protocols, data storage, security, and analysis. The fundamental outcome is control (if applicable), and data-driven product intelligence. Whether the information flows only back to the manufacturer—or whether it is bi-directional—from a quality management perspective the net yield is potentially the most significant boost enterprise quality could have hoped for—objective, reliable, continuously streaming feedback, performance and reliability data. This is why, in addition to awareness and education regarding IoT, the case for a mature approach to EQMS that provides the system and infrastructure to tap into this data is so important. Preparing for the inbound quantitative (reliability engineering) and the primarily qualitative product quality data is crucial to success.

While this data does belong to the family of big data, unlike most of the unstructured and nebulous majority of big data, the data flowing back from engineered smart connected products to organizations has the potential to be highly structured—by design—so that the type, scope, and volume of data being returned is expected, understood, and measurable against anticipated parameters.

…unlike most of the unstructured and nebulous majority of big data, the data flowing back from engineered smart connected products to organizations has the potential to be highly structured…

Prior to a product being launched to the field, the dependability or reliability has been tested with certain conditions for a set amount of time. The outcome is expected behavior within the condition parameters; how often and in what ways is the product expected to fail? What maintenance schedule is required to prevent failure and therefore assure reliability with some confidence? Where IoT and smart connected products have the potential to transform reliability is in the provision of timely actual reliability data. This direct feed of objective reliability information pertaining to how a product actually performed (or is currently performing) yields unprecedented access to answer questions like failure frequency, cause of failure, and failure effects. It allows for validating and improving the accuracy of predictive methods with a complete and accurate record delivering real world versus expected comparisons for failure rates, cause identification and where appropriate safety risk mitigation. The widespread availability of real-time direct feed data is unprecedented in the history of reliability engineering. Today's professionals can even tell, with unprecedented access and accuracy, why the issue happened and identify what the effects were—based on real-time readouts from the product itself telling what data the sensors recorded at the time of failure. This is potentially far better than a subjective, human derived failure report.

Analytical strategies can be formulated and built around this structured returning data specifically. These will evolve and adapt over time, but what is key is the fact that reliability and performance data has a shape. The evident problem, and therefore the challenge, is how the returning data, once analyzed and processed into intelligence, is put to action, routed, shared, and tracked across the value chain both effectively and efficiently. One solution befitting this challenge is to exploit core processes automated and built on the infrastructure of an EQMS.

Bringing Traditionally Disparate Information Together

A closed-loop approach to quality is the fundamental mechanism by which to connect stakeholders throughout the value chain from design, engineering, and supplier to the field and back. Today, field data is typically returned via the services and customer account management function, and often this is bundled under the label of complaints, already a somewhat narrow and challenged approach. The issue of subjectivity and inaccurate feedback requires significant vigilance; for example, a failure report with inaccuracies due to potential operator error.

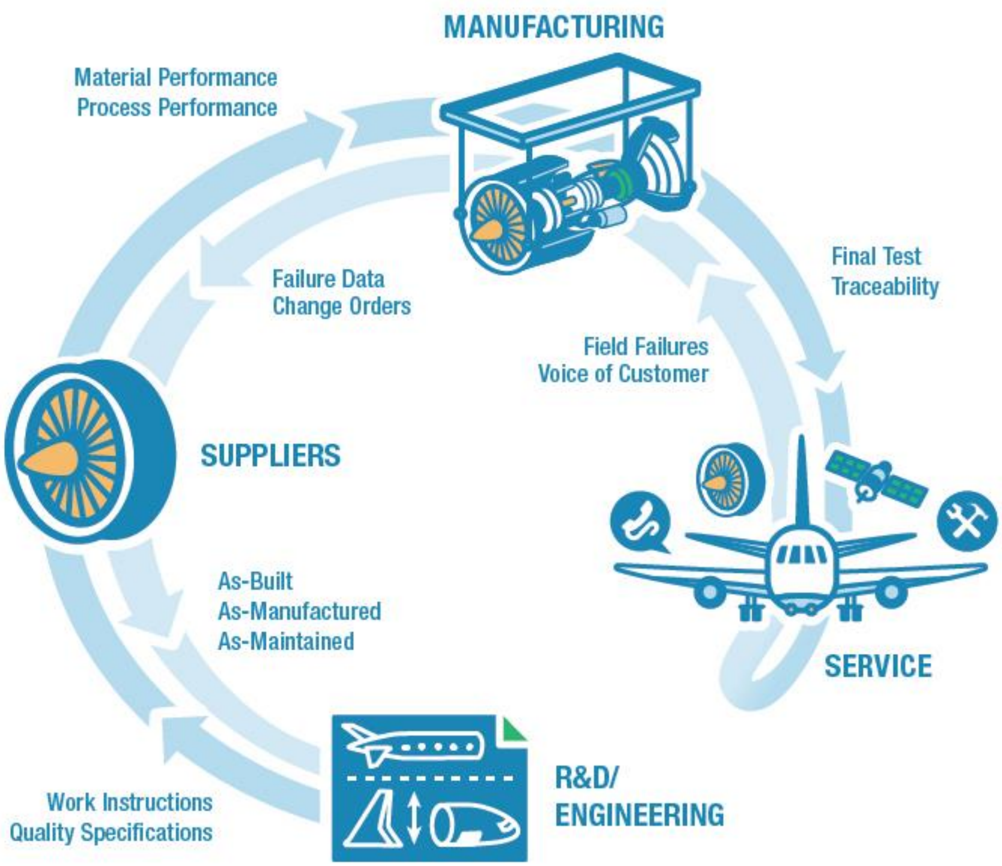
We must give consideration to the fact that data from smart connected devices requires a splash-down location. This is essentially the analysis phase. The subsequent activity upon return to base is where derived intelligence is now actionable in the context of product design; this is where the "closed-loop" in closed-loop quality comes into play. By using the information about how the product is actually behaving, comparing it against how the product was supposed to behave (known from reliability prediction and early reliability analyses) this information can be used to drive actionable intelligence. Where the actual varies significantly from the expected, there is a targeted area for improvement and therefore the party in need of the information must be identified. Examples include a design improvement in engineering, a service improvement that can quickly rectify the problem, or a manufacturing improvement that will tighten tolerances and eliminate the issue.

A closed-loop approach to quality is the fundamental mechanism by which to connect stakeholders throughout the value chain from design, engineering & supplier to the field and back.

A closed-loop approach to quality processes is typically best achieved through EQMS technology either as a standalone software application integrated with PLM and ERP or part of the existing PLM or ERP platform, extended by quality process capabilities spanning the value chain. To best leverage IoT data via prediction of expected values and analysis of actual values, this closed loop should include the analytical engine.

Understanding Closed-Loop Quality Processes

Without closed-loop capability and harmonization of related processes, particularly in the quality non-conformance (NC) and corrective and preventive action (CAPA) processes and the appropriate procedures, categorization and escalations to manage them, resources are wasted and effort duplicated. Fragmented quality processes distributed across many organizational silos can become sinkholes for valuable quality data. For example, siloed processes can result in the recurrence of quality issues – requiring the repeat of costly investigation and fixes. Additionally, valuable quality intelligence, when it is spread out across various data siloes, is difficult to interrogate and track for all of the functions that need it, a fragmentation that threatens to block both organizational agility and predictive quality efforts.



A seamless conduit for quality data to and from engineering is required to effectively harness IoT derived [product] intelligence.

The most desirable approach is for the closed-loop to direct and connect to those stakeholders who can use the data to improve product development and design. A seamless conduit for quality data to and from engineering is required to effectively harness IoT derived intelligence. For instance, engineers can use reliability information to drive more reliable product and service design. The information they have can be a boon to reliability engineering because, as these changes are made in engineering, they need to be reflected in the reliability analysis to keep it up-to-date and accurate.

Aiming for Predictive and Harmonized Processes

By tethering the analysis of returned data from smart connected engineered products to the EQMS, availability to engineering and design functions is ensured—aiding not only responsiveness but also the predictive approach to product quality. Take this and couple it with an actionable outcome that is then given vital cross-functional visibility and accountability, for example from the CAPA side, engineers are often a valuable part of a corrective/preventive action plan, driving invaluable quality improvements as part of a seamless enterprise-wide quality process

Connecting engineering seamlessly with EQMS processes like CAPA prevents a segmented approach to the prioritization, collaboration, and execution of quality processes, and ultimately builds a corporate quality and reliability repository for long-term product quality memory.

One way such a mechanism is vital for organizations is to retain actions that are rejected in the quality system. It is an often overlooked detail, but tracing an issue that was rejected or placed in a holding pattern in the past can be as important retrospectively as current issues. There is potentially valuable context in a previous issue that may have been deemed low priority and held back originally.

The ability for any organizational stakeholder to access and leverage this deep, archived quality knowledge precisely at their point of need to improve product design and development is one example of a successful EQMS: deep, systematic organizational learning that is product-focused. Supplying the data captured and analyzed from smart connected products—in context with quality and engineering data—to enhance decision-making and improve product and process quality throughout the enterprise would unlock the potential that the IoT holds for product development companies.

As the reliability, performance and product quality data stream increases with IoT technology, an increase in queued issues will be experienced. A formal process to address these issues for escalation already in place in the quality management system can be leveraged and tuned to meet the demand. The challenge is that without a formal approach to CAPA some of the valuable actions associated may become "lost-luggage." Priorities will shift and some will be put on hold, which is more than acceptable, provided they are prioritized, ranked and assigned appropriately beforehand. The criteria and holding pattern, like all other appropriate workflow and notification triggers, should be harmonized across the value-chain. A common vernacular here is as important as the effort to maintain smooth integration in the closed loop.

If every department were to drive its own approaches to managing issues, so that the volume of actions required results in a series of segmented CAPA solutions, this may over time become a record of inaction where priorities constantly slip and issues are not managed with consistency and effectiveness. It is imperative that the capture and analysis of data from smart connected products back to the organization, a potential deluge, has a consistent and traceable output mechanism to accommodate agility and manage velocity.

The first and most important step is to provide clear visibility and an efficient mechanism to prioritize, investigate and process incoming quality issues. The first-in first-out approach to CAPA does not allow the organization to effectively allocate resource and ensure that engineering stakeholders have what they need to address product quality in design. A harmonized process with clear notification, escalations and time-sensitivity will provide consistent "flow" in the high throughput world of IoT quality management systems.

Some key capabilities of the IoT infused EQMS will include the cross referencing of product with previous or in-flight CAPAs or reliability data, investigations or previous engineering adjustments. The right technology platform will link traceability from supplier specifications updates (upstream), new materials (design & procurement), procedure updates through to maintenance frequencies or firmware updates over time.

The shift towards an improved predictive quality management should ultimately plateau over time for established products based on maturity of the IoT feedback of performance and real-time reliability data availability. As the approach matures it is anticipated that more emphasis will be placed on new product introduction (NPI) as these are particularly benefited by data that came before, but IoT derived field data will yield rapid improvement cycles in the form of larger closed-loops that benefit upstream product design and engineering processes.

Supplying the data captured and analyzed from smart connected products […] to enhance decision-making and improve product and process quality throughout the enterprise would unlock the potential that the IoT holds for product development companies.

The Cost of Inaction

Although many companies today have not yet implemented the full technology approach described above, there are some that have begun putting closed-loop quality management processes in place. By cross-analyzing over 1,000 survey respondents reporting the establishment of closed-loop quality processes with different performance metrics, the true impact of closed-loop quality management can be quantified.

	CLOSED-LOOP QUALITY PROCESSES IN PLACE	ALL OTHERS
Median Overall Equipment Effectiveness	87%	80%
Median On-Time and Complete Shipments	95%	92%
Median Successful New Product Introductions	85%	76%

Across three key performance indicators—OEE, On-Time and Complete Shipments, and Successful New Product Introductions—companies with closed-loop quality processes established displayed impressive performance in comparison to those without closed-loop quality processes established.

These metrics are important, since they each encompass many different variables around quality and operations. For a large organization, improvements are particularly notable, as a percentage point difference could have considerable impacts (up to millions of dollars) on costs. It could also mean the difference between being the first to market with a new product, maintaining reputation as a supplier, winning additional contracts, or passing an audit. Closed-loop quality introduces new ways to strategically and sustainably improve these KPIs over time.

Engineered products will only become more and more smart and connected over time, providing new opportunities both for unique customer experiences and new modes of operation throughout the value chain. Ubiquitous connectivity provides us with the means to leverage the advantage the IoT delivers.

Some key capabilities of the IoT infused EQMS will include the cross referencing of product with previous or in-flight CAPAs or reliability data, investigations or previous engineering adjustments.

The anticipated bottleneck—managing the deluge of IoT data that will be returned—is where the challenge lies, and those who do not act now to address it will be left behind. Their market will be usurped and others who adapted early will consume their opportunities.

EQMS strategies, if in place, can be adapted within sensible time-frames to prepare for the deluge of data. Some vendors have already embarked upon the provision of such functionality.

Vendors have already adapted their offerings and will continue to provide the tools to manage the new era of smart connected products. These vendors will also contribute to the standardization of communication protocols and enhanced security. Organizations that understand the importance of these factors and align with leaders will gain advantage.

Those that adapt early will be well placed to adjust and realize new opportunities, some of which are unknown to us to date. The IoT is potentially the new industrial market for this kind of breakthrough sea change for smart connected products and their applications.

Actionable Recommendations

Plan how the incoming data will be analyzed and answer the “what then” questions. Allocate time for planning and strategy sessions to walk through and assess risks of data deluge from smart connected products. Effort also needs to be spent on understanding current software and process capabilities that span engineering, manufacturing, and service with an eye towards establishing the best architectural approach to EQMS for meeting the value chain opportunities that come with smart connected products. To ensure success, organizations should focus on:

- Leveraging harmonized processes such as CAPA management with new eyes on repeat or recurring issues, as well as quick interrogation to prevent duplication while allowing for tagging updated feedback to previously resolved CAPAs. Special attention should be paid to the role of the quality engineer and how the organization as a whole can gain value from enterprise-wide access to harmonized systems for managing product and process quality.

- Plan for data-driven preventive or improvement actions for products in the field. Design in quality, thresholds, and tolerances that can be monitored by smart connected products to trigger risk, reliability, and performance flags.
- An organization must know its products and use reliability engineering intelligence (how a product fails) upstream to measure against actual in-field performance. This enables a shift to a state of readiness for the return of structured data from smart connected products, knowledge that allows a remedy to be determined and implemented effectively.
- Prepare the engineering and quality function for the triage of vast amounts of performance and reliability intelligence. Reliability and product management will see the benefits of analysis direct from deployed products and in turn will result in significant actionable outcome. Ensure the end-to-end management of this data using PLM-EQMS functionality and drive designed-in quality.
- One of the key emerging technologies for enabling Smart Connected Products and the subsequent value that can be unlocked from improved reliability and closed loop quality is the Internet of Things Platform. The IoT platform helps companies rapidly connect to IoT devices and build software applications that will leverage and communicate data to other business systems and enterprise stakeholders across the organization. LNS Research defines four key capabilities that should be part of an IoT platform: Connectivity, Cloud, Big Data Analytics, and Application Development. This is still a very new technology area and LNS Research will be doing more work in this area to help define this space and functional requirements in the coming years.

Allocate time for planning and strategy sessions to walk through and assess risks of data deluge from smart connected products.

LNS Research provides advisory and benchmarking services to help Line-of-Business, IT, and Industrial Automation executives make critical business and operational decisions. LNS research focuses on providing insights into the key business processes, metrics, and technologies adopted in industrial operations.

Authors:

Matthew Littlefield, President & Principal Analyst, matthew.littlefield@lnsresearch.com

Rob Harrison, Research Analyst, rob.harrison@lnsresearch.com