

Predictive Quality for Medical Devices

Comprehensive Data to Move Risk-Based
Approaches into Production

Julie Fraser
Vice President, Tech-Clarity

Tech-Clarity

© Tech-Clarity, Inc. 2021

Introduction

How confident is your team that a product will be top quality based on processing conditions? Wouldn't it be great to know and be able to automatically release products when every process stayed within the specified envelope? And to sample or test only as much as a particular process requires, no more or less? Those are the promises of predictive quality.



Table of Contents

| | |
|---|----|
| Predictive Quality | 4 |
| Risk-based Approach | 6 |
| The Next Level of Risk-Based Approaches | 8 |
| Feedback Loops | 9 |
| Data Flows for Good Decisions | 11 |
| Manufacturing Data Platform | 13 |
| Advanced Quality Analytics | 15 |
| Predictive Quality Recommendations | 17 |
| Getting to Action | 18 |
| Software for Predictive Quality | 20 |
| Conclusions | 21 |
| Recommendations | 22 |
| Acknowledgements | 23 |

Predictive Quality

Beyond Traditional Quality Systems

Quality is the cornerstone of medical device manufacturers' success and touches every aspect of the business. Quality is paramount not only for cost and compliance but for patient outcomes. As a result, many companies use sophisticated simulation and analysis to predict outcomes in research and development (R&D). Yet, that is only a part of the quality system. It's time to expand predictive quality into production – and to create feedback loops.

Predictive vs. Traditional Quality

Traditional quality is reactive or preventive at best. Rigid standards and procedures guide all activity, and samples and testing are frequent to be safe. Predictive quality is more proactive and adaptive – within the validated envelope. This new quality approach leverages data from product and process design, inventory, and supplier quality. It combines that data

with real-time production information to foresee whether a product will meet quality specs.

"What predictive quality means to me is the ability to infer quality. If I know materials and components are within specs, and machines are operating within boundary conditions, then I know product quality will be OK."

Abram Ziegelaar
Head of Operations & Engineering Technology,
B Braun

Predictive Quality to Meet Market Pressures

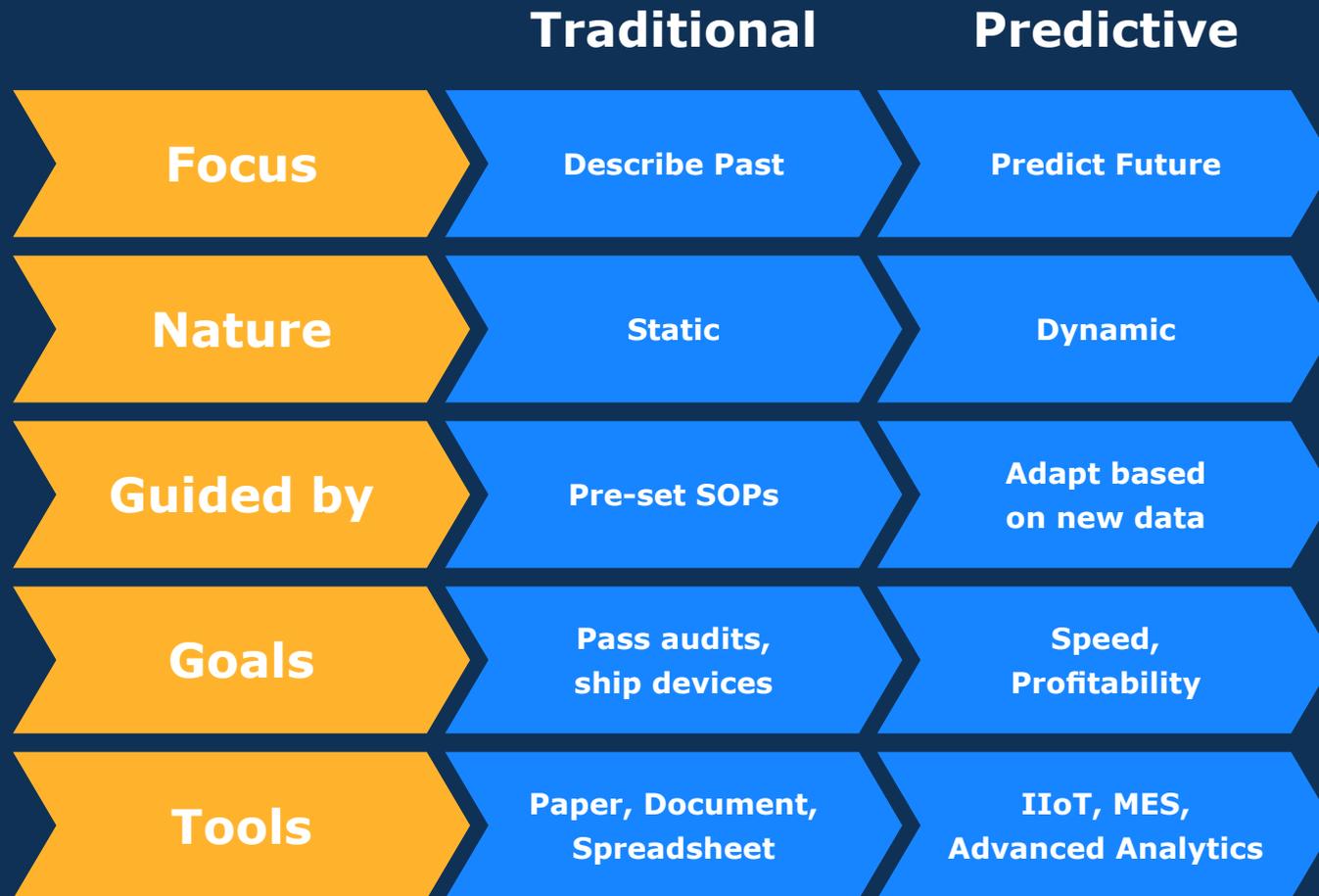
Medical device manufacturers are under new pressures from both the market and regulators. Predictive quality is a foundational approach to meet those pressures:

- Margin: Lower costs through reduced scrap, rework, sampling and testing
- Speed of new products: Improve design for manufacturability and quality (DFM/DFQ)

- Risk: Realize regulators' vision of minimizing both regulatory non-compliance harm and potential health hazards
- Cycle time: Products move in the process envelope with complete documentation at every step
- Quality: Fewer non-conformances during production
- Field outcomes: Reduced customer complaints, adverse events, and in-use products issues, and ability to quickly improve

"Predictive quality is a risk-based approach to quality. Not doing it just because that's how we did it last time."

Megan Menard
Site Quality Manager, Maple Grove,
Jabil Healthcare



Traditional vs. Predictive Quality characteristics

Risk-based Approach

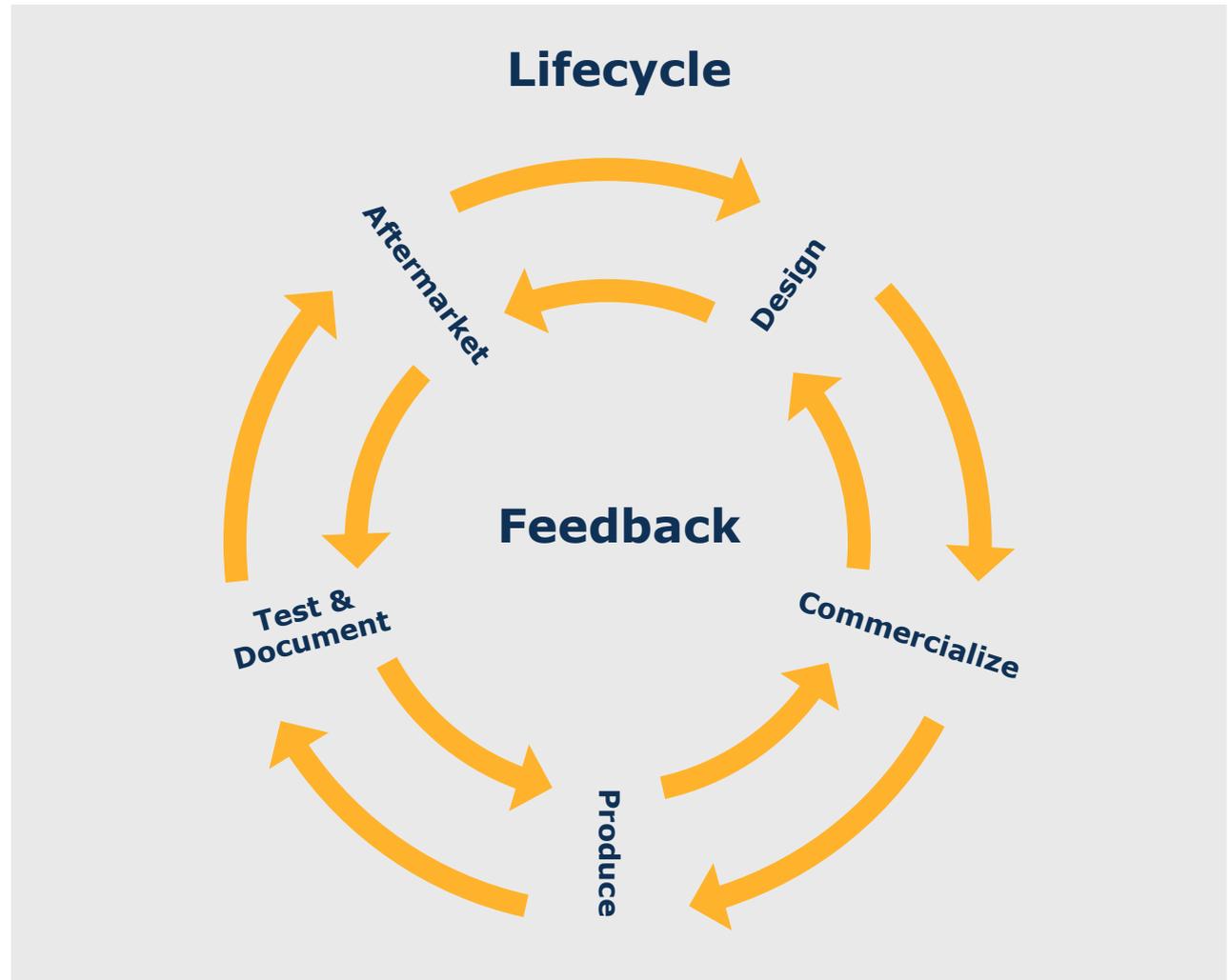
Adjusting Activities to Risks

The goal of risk-based approaches, as outlined in ISO 13485:2016, is to minimize risks as efficiently as possible by adapting activities to the size of each risk. Using this principle starts in product design and development per ISO 14971. Yet, the approach must go well beyond design into personnel, production and process control, and suppliers. The entire Quality System is the target. That means processes, as well as products, need risk specifications.

Risk-based Analysis

Risk analysis is the lifeblood of a risk-based approach, and includes

- identifying possible risks both to patients and employees
- calculating the likelihood and severity of risks
- classifying risks to determine the level of activity needed to minimize the risk.



Risk-based approach areas across the Quality System

While critical to quality (CTQ) areas may be obvious focus points for risk abatement, defining risk for all aspects of the product and process is essential. For most companies, risk analysis becomes challenging with many functions, products, variants, facilities, and suppliers.

"My goal is to create compliant predictable uniformity. Product quality is the outcome of product consistency."

Chuck Anger
Vice President of Manufacturing Operations,
Ultradent Products, Inc.

Defining Risk Measures

Based on the priority of the risk severity, timeframe, and nature of the risk, companies must define process parameters to keep that risk in check. For example, higher-risk issues may need more frequent sampling or testing than low-risk issues. Very severe risks may warrant multiple layers of risk mitigation activity, while lower severity risks may only need one type of action to stay in check.



The Next Level of Risk-Based Approaches

Current Risk-based Quality Systems

While regulators have been pushing risk-based approaches to quality for some years, most medical device manufacturers have only implemented it in pockets. After design, the rest of the enterprise and supply base use what came from R&D. Having only this up-front risk approach leads to relatively static risk analysis and measure definition. As fast as products, production methods, and regulations change, the approach to risk must be more dynamic.

"Lean is an approach that has some history. Some is good. but some is not so good. Lean has always been associated with headcount reduction. Lean is all about work content reduction, not headcount reduction. There may be some reallocations of people, but the focus is on the value stream and the balancing of resources."

Chuck Anger
Vice President of Manufacturing Operations,
Ultradent Products, Inc.

Taking It to the Next Level

Controlling processes during production is vital to minimizing risk. However, paper-based quality management or even document-oriented quality management systems (QMS) are not designed to ensure process control, and would not be timely if they were. Companies cannot afford the delays of employees changing focus from their tasks to sign off on documentation, or the errors inherent in data collected manually.

"You have to look at your process control in general. How you set it up matters: collecting meaningful data is part of control. Standard definitions matter too. For example, what is the definition of an incident? Then it comes to how you classify and group incidents to identify noise vs. a serious trend."

Paul Straeten
Head of Industry 4.0 and Advanced Analytics for
the AIP Network, Medtronic

Accommodating Process Variability

The reality is, most medical device manufacturing has quite a bit of variability in the process. Creating and validating process flows to reduce risks for all possibilities is a starting point for success. Only once that's complete does data gathered from those processes help to indicate anomalies or predict risks.

"Processes, especially manual, paper-driven processes, can have lots of variability in them. Supervisors, line leads, and operators have different skill sets, competencies, and even native languages. There are many ways to stage material incorrectly, mix or assemble a product incorrectly, forget to pull a sample at the prescribed time, transpose numbers, or label product incorrectly."

Craig Pinegar
Senior IT Solution Architect, Digital Manufacturing
Product Owner, Ultradent Products, Inc.

Feedback Loops

Ongoing Updates

From design to manufacturing and back again – quality needs data coherence. For the process envelope to be as large as the risk warrants and no larger, ongoing feedback from the process to the design is essential. Since medical devices change rapidly, keeping up means providing accurate, timely, and complete data about actual conditions and outcomes.

Qualifying Technology

Equipment, automation, and software run processes and are the source of that data. Regulators look for three levels of qualification of these technologies: installation, operational, and performance (IQ, OQ, PQ). These processes are intended to be a feedback loop to ensure everything is installed correctly, operating correctly, and will consistently produce acceptable product. This is the foundation of stable and capable processes.

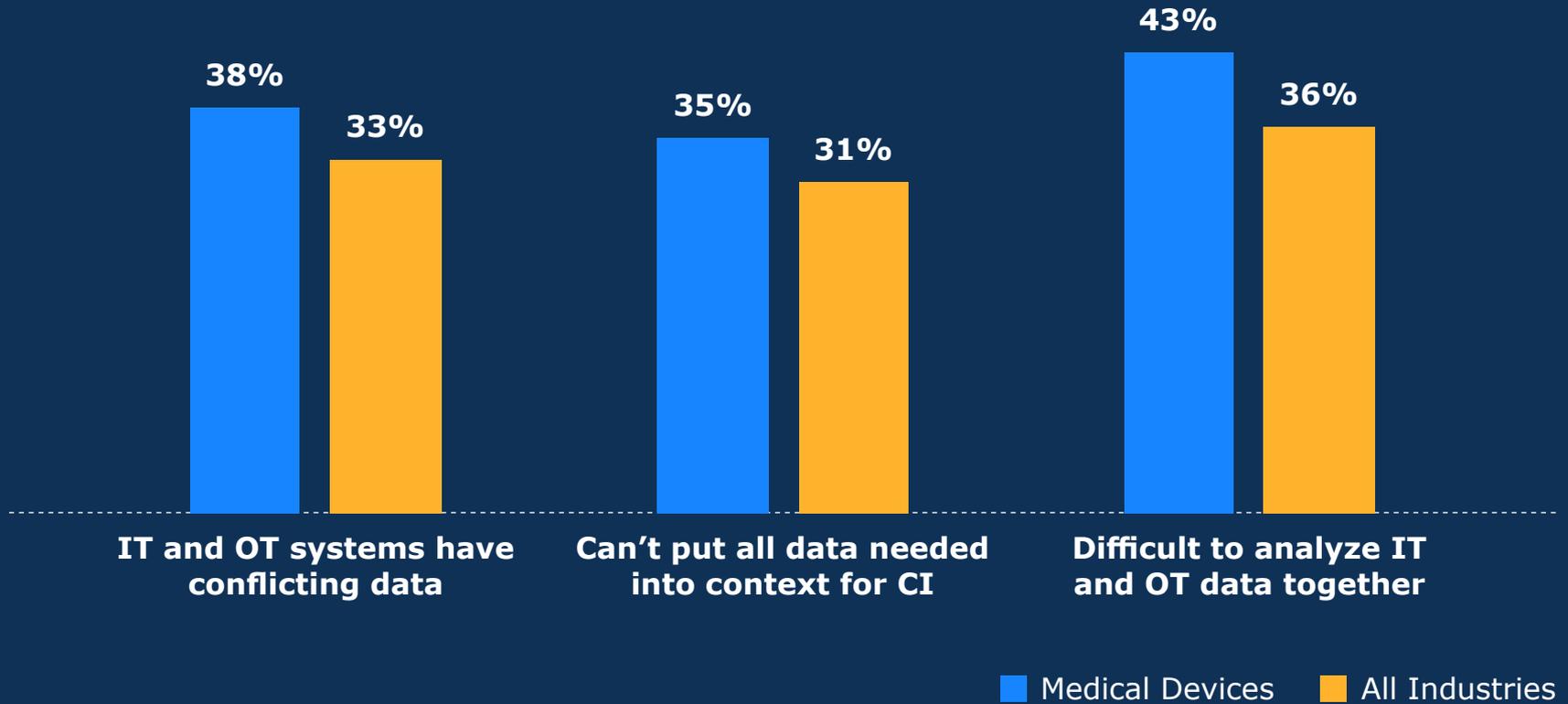
"If test results are consistently good, we can reduce how often we test and how many samples we need. That's part of adaptive and predictive quality: The system must be self-regulating to determine an appropriate and minimized amount of testing."

Abram Ziegelaar, Head of Operations & Engineering Technology, B Braun

Challenges in Manufacturing Data

As companies modernize and add automation and sensors to operations, they get more timely and accurate process data. And yet, putting it into context for specific feedback to design, suppliers, or training is not straightforward. Operational technology (OT) systems including controllers and automated equipment often do not play well with plant information technology (IT). Our research shows that many medical device companies find it challenging to get accurate production data or analysis that combines IT and OT data.¹





Data Flows for Good Decisions

Vertical and Horizontal Integration

In Industry 4.0, feedback loops between offices, plants, and equipment are often called vertical integration. Vertical integration enables predictive risk-based information flows between design and manufacturing and procurement and the plant floor. Horizontal integration points to information flows between plants in a company and between suppliers and buyers of materials, components, assemblies, and contract manufacturing services.

"Integration – getting the data – is a key essential part of predictive quality."

Paul Straeten
Head of Industry 4.0 and Advanced Analytics for
the AIP Network, Medtronic

Cross-source Data Correlation

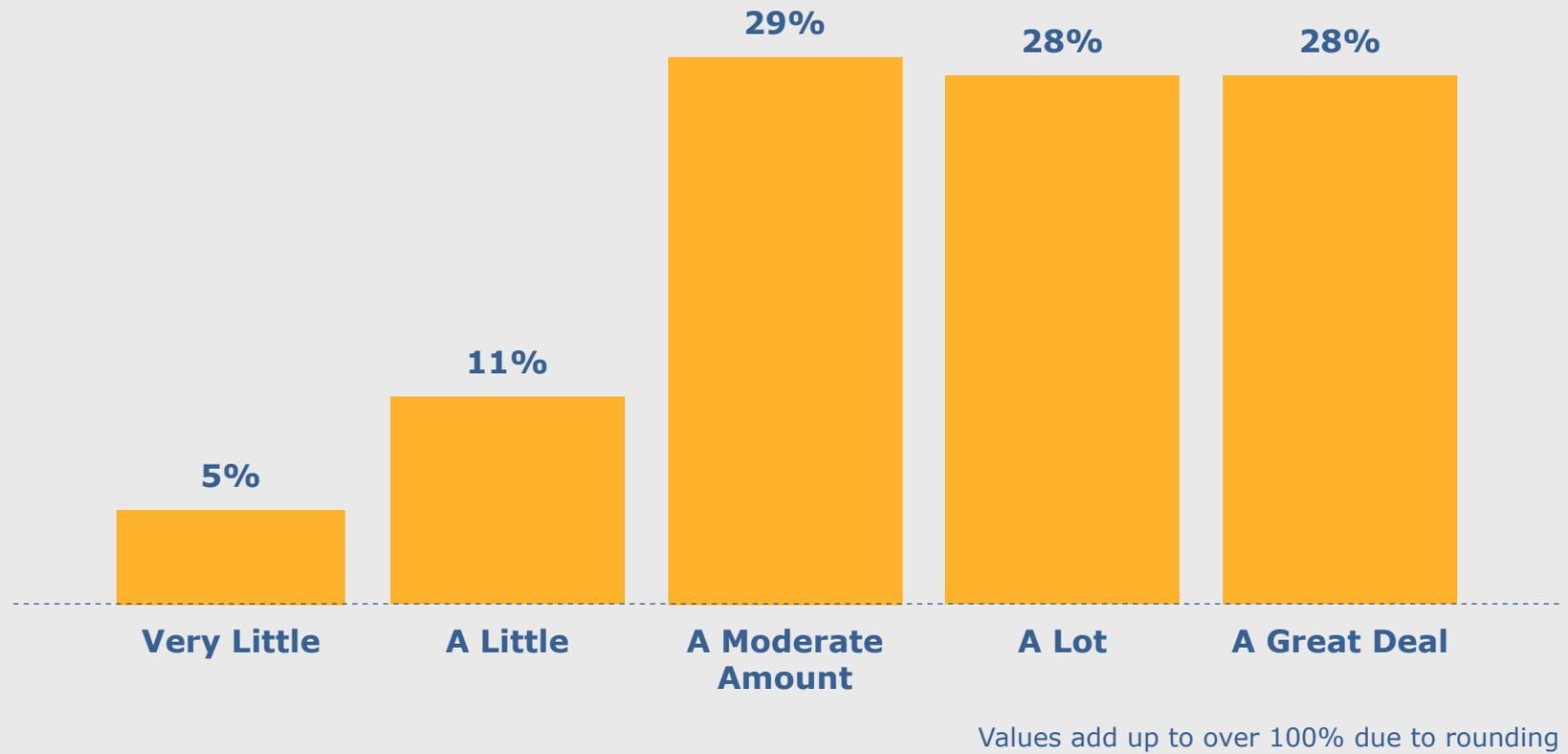
One of the most challenging aspects of quality is that many factors interact to determine it. Thus, data from many sources must come together to create a predictive quality model. The previous figure showed that many companies struggle to bring manufacturing data together and analyze it. The question is: How much time, expertise, and effort are required to integrate and maintain the integration between MES, quality, maintenance, scheduling, IIoT, and other equipment or machine data? The answer is: quite a bit.²

Integration is Essential

Most Manufacturers (54%) have an active program for equipment, plant, and enterprise system integration. 52% have a program for putting OT data into context with plant IT data³. Today, companies can achieve this by selecting and using a system designed to do all of that:

- integrate a wide variety of manufacturing data
- create a context for all of that data
- analyze current situations to predict issues
- drive appropriate activity to prevent quality problems

In short, a manufacturing data platform that includes multiple application types as well as data management is a foundation.



How Much Time, Effort, and Expertise does Plant Data Management Require?

Manufacturing Data Platform

The Manufacturing Disconnect

Since the quality system and risk-based approaches span the entire lifecycle, it may be counterintuitive to focus on a manufacturing-specific data platform. Yet, it addresses a significant data flow gap for predictive quality. For PLM to characterize risks in product and process design accurately, it needs feedback from manufacturing. For procurement to assess a supplier's risk profile, it needs to know how their materials are performing in the plant and in-line testing. Yet, few medical device manufacturers can provide that today.

"Data collected through MES on the shop floor can ensure that automated and manual operations are controlled, and deviations acted on—in real-time. That same data can then be tracked, trended, and mined for insights to improve quality over time."

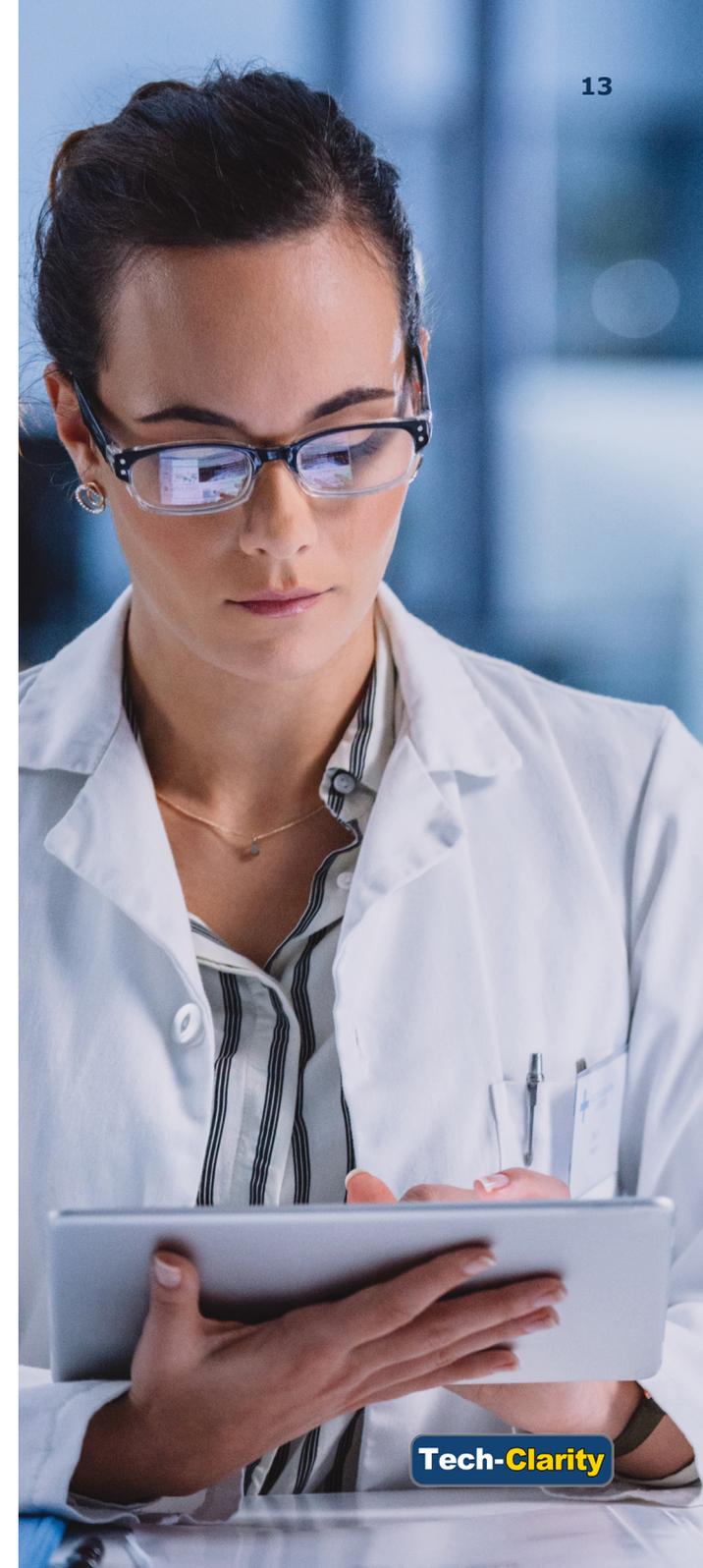
Craig Pinegar
Senior IT Solution Architect, Digital
Manufacturing Product Owner, Ultradent Products,
Inc.

Many Capabilities Needed

Why are plant systems so often the missing link? Because the data in the plant are diverse, coming from both IT and OT and often in paper or spreadsheet format. Applications such as manufacturing execution systems (MES), industrial internet of things (IIoT) platforms, quality management systems (QMS), and manufacturing intelligence (MI) or analytics are useful. No one of these alone can fully support plant aspects of predictive quality because analyzed information is not enough; it must drive employees to take effective action.

"Our integrated MES and data flows error-proof the process while adding efficiency and savings."

Dean Palmer
Director - IT Manufacturing Systems, Jabil
Healthcare



Integrated Manufacturing Data Management

Fortunately, a new generation of manufacturing platform software is emerging. It combines the plantwide guidance and automatic documentation of MES with key quality capabilities, IIoT data capture, multi-stream data contextualization, and analysis.

"It's difficult to be predictive if you don't have the data. For example, we have a program to enhance vision inspection with artificial intelligence (AI) and machine learning (ML). Today, if the operator detects an anomaly, we take a picture. But to train and continuously improve the model, it's important to have digital records of all processes."

Paul Straeten
 Head of Industry 4.0 and Advanced Analytics for the AIP Network, Medtronic



Manufacturing data management platform concept

Advanced Quality Analytics

Quality in MES

While most medical device manufacturers have a quality management system (QMS), some have started using the quality functions of MES to move toward predictive quality. The benefits of incorporating quality analysis into MES are significant.

- Statistical process control (SPC) inside an MES provides greater context about the work instructions, operators, and conditions in which the SPC chart and any out-of-control conditions arose.
- Root cause analysis (RCA) in MES inherently considers the full production record.
- Corrective and preventative action (CAPA) inside MES allows constant monitoring of whether preventive measures are effective.
- Non-conformances (NCs) are all recorded with full context in one place (MES), which starts to show patterns in products, processes, shifts, conditions, and suppliers.

Predictive Analytics

Patterns are the fodder for effective predictive analytics. Many manufacturers have an initiative for advanced analytics to improve process performance. In our research, it was 44% for all manufacturing industries. Yet, we think there is an underlying question: what does that mean? Per the definition in the sidebar, predictive analytics is a form of advanced analytics that uses more data more effectively than past analysis.

Tech-Clarity defines advanced analytics

Advanced analytics includes a range of analytical methods designed to help uncover patterns in data, identify trends, find hidden insights, accurately forecast events, and drive improvement. It goes beyond business intelligence by using sophisticated mathematical algorithms and analytical techniques such as artificial intelligence and machine learning. These enable a more automated approach to easily correlate larger and more complex data sets, explore problems that may not have complete data sets, drive more refined insights, all of which enable more educated decisions.

Analytics Maturity

So how can companies get from where they are to predictive analytics? As with other processes, there is a maturity journey. It gets tricky because you don't always know what data will be valuable before using a predictive analytics model. And quality is notoriously multi-factor dependent.

"Predictive analytics is stage 3 in our quality roadmap. Our ongoing MES journey aspires to collect more granular material and process data in real-time—enhancing our ability to detect deviations as they occur, as well as track and trend failure modes over time. Real-time data collection is the foundation for predictive analytics in more manufacturing scenarios."

Craig Pinegar
Senior IT Solution Architect, Digital Manufacturing Product Owner, Ultradent Products, Inc.



Quality analytics maturity journey

Predictive Quality Recommendations

Gathering the Data

As our research showed, many companies have process and product history data, but it's not always easy to combine and analyze it. Comprehensive data from multiple aspects of the process form a foundation for effective quality analysis. Ideally, it's combined with real-time data from production to keep predictive models fresh and accurate.

The Performance Envelope

Predicting quality relies on fully characterizing the process conditions, parameters, and boundaries when quality is good. Every critical to quality (CTQ) factor included in the product and process design matters. During process design, this becomes the design envelope or ideal parameters against which to measure process control. To predict product quality, the company must monitor real-time data from the production process and compare it to the envelope specifications.

Automated Batch Release

The risk-based approach aims to keep everything about the processes within that performance envelope. Design and development processes aim to consistently deliver a predefined quality at the end of the manufacturing process. Such procedures would be consistent with the basic tenet of quality by design and could reduce risks to quality and regulatory concerns while improving efficiency.⁴ The result would be an ability to automatically release a batch of products based on knowing that the process has been in the envelope throughout.

"From our point of view, the holy grail is automated batch release. You can't always measure quality directly, but you can infer it given enough data and appropriate analytical techniques. You know your product is right because you've collected the necessary data during production to measure and where necessary infer quality as you've gone along. "

Abram Ziegelaar, Head of Operations & Engineering Technology, B Braun

Getting to Action

Guidance

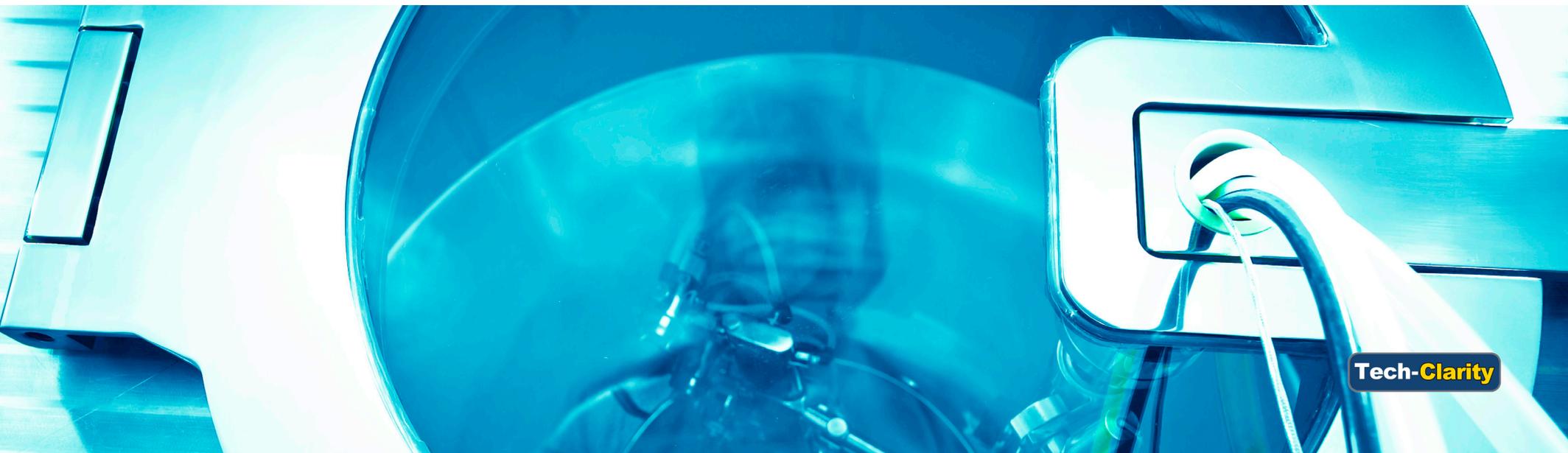
All the analysis and prediction in the world are worthless unless people can take action. Ideally, the systems guiding the production process deliver guidance. To accomplish that, the system that processes predictions and analysis also provides work instructions to employees and prevents errors. MES has always been a system to guide employees in production. It can be considered the “control system for the people.”

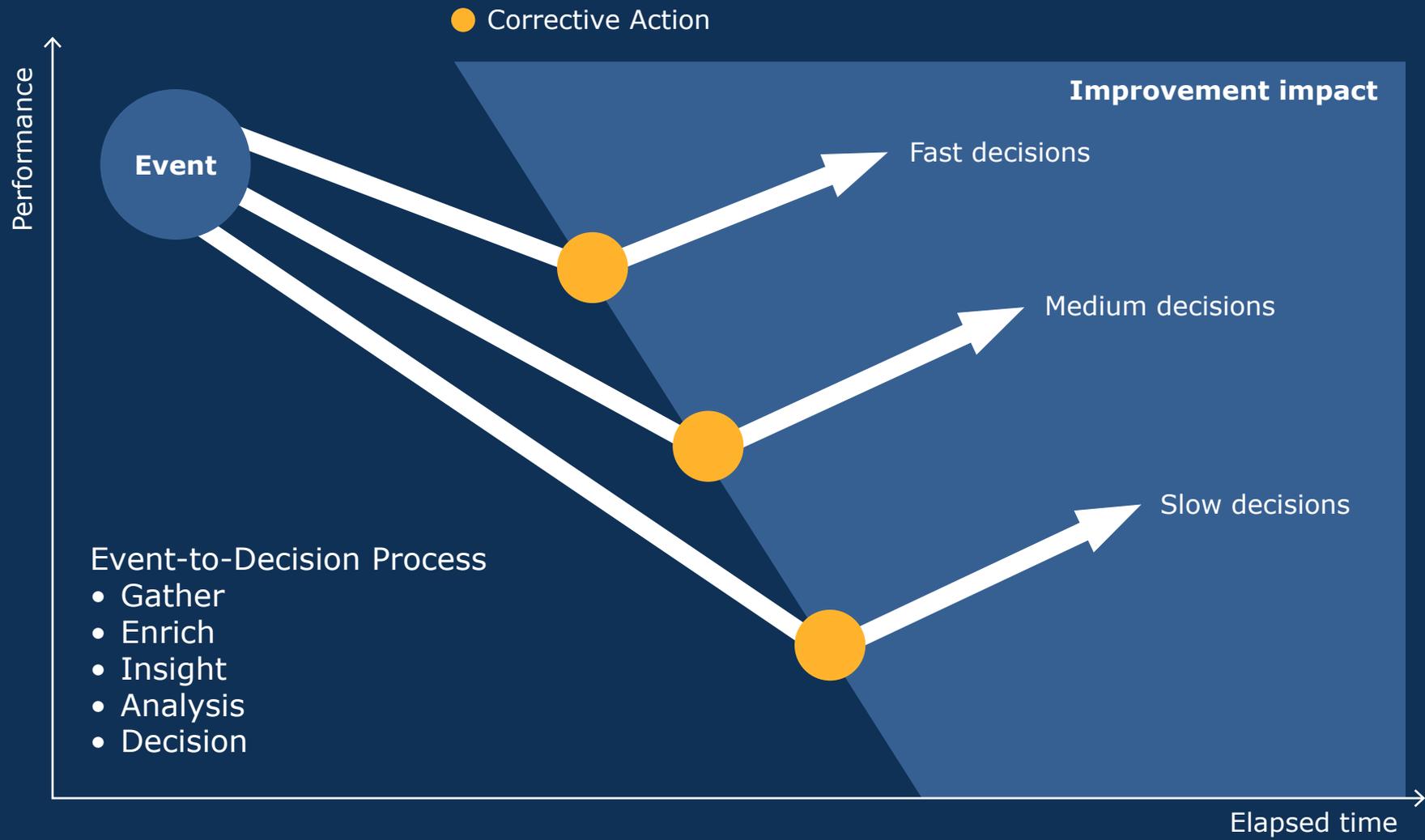
Prioritized Proactive Alerts

When the system predicts a quality exception, engineers, supervisors, and maintenance personnel need to know immediately, as do the operators and technicians. Each person needs to see only the alerts on which they can take corrective or preventive action. Ideally, alerts appear in priority order – based on the level of risk.

Engaging Employees

People are at the heart of any quality system, consistently doing their jobs, watching for non-conformances, and suggesting improvements. Ideally, they can do all of that in a way that allows them to continue to focus on the production tasks at hand. The type of combined MES, IIoT, QMS, analytics, and performance dashboarding system described here is one approach to ensuring that.





Speed makes a difference in performance due to the need for decisions and corrective action

Software for Predictive Quality

Configurability and Enforcement

Every site and product have special needs, so technology must mold to needs, even in a standard quality system. Yet, because the medical device industry requires validated processes, the technology must also be ready for validation and verification. Ideally, it also enforces SOPs and does not allow known non-conformances in process, product, or documentation. Each device maker must find the balance between standardization and unique needs of each site.

Enterprise-grade

While most companies start manufacturing software projects in one site – or even for a few specific use cases – the selection and implementation team must have global roll-out in mind. This enterprise view has not always been the case for MES, which historically was often a site-wide system. Similarly, predictive

analytics projects often start with use cases or solutions to specific problems. Enterprise-grade software configured to support the many aspects of a quality system in a multi-site company and eco-system will be more likely to succeed.

"Our IT colleagues ask for use cases, thinking in individual solutions for particular problems. That's a death sentence in an IIoT world. It means one of our dozens of problems is solved possibly as a POC. That's nice, but it may not scale or be readily transferable to other sites. A solution-based approach will fail. A suitable technology stack is required to address a wide range of known and unknown future use cases, and to scale globally."

Abram Ziegelaar, Head of Operations & Engineering Technology, B Braun

Validation Support

We talked about how software must go through the qualification process of IQ, OQ, PQ. Some solution providers focusing on life sciences are providing pre-packaged support to streamline the software qualification, validation, and verification process. Automating the software side of validation can make a significant difference in the ability to roll out solutions to support predictive quality to sites as needed.

"It's a game-changer when software makers come up with a quick way to perform installation qualifications, operation qualifications, performance qualifications. Help with the risk-based assessment on what those three look like."

Megan Menard
Site Quality Manager, Maple Grove,
Jabil Healthcare

Conclusions

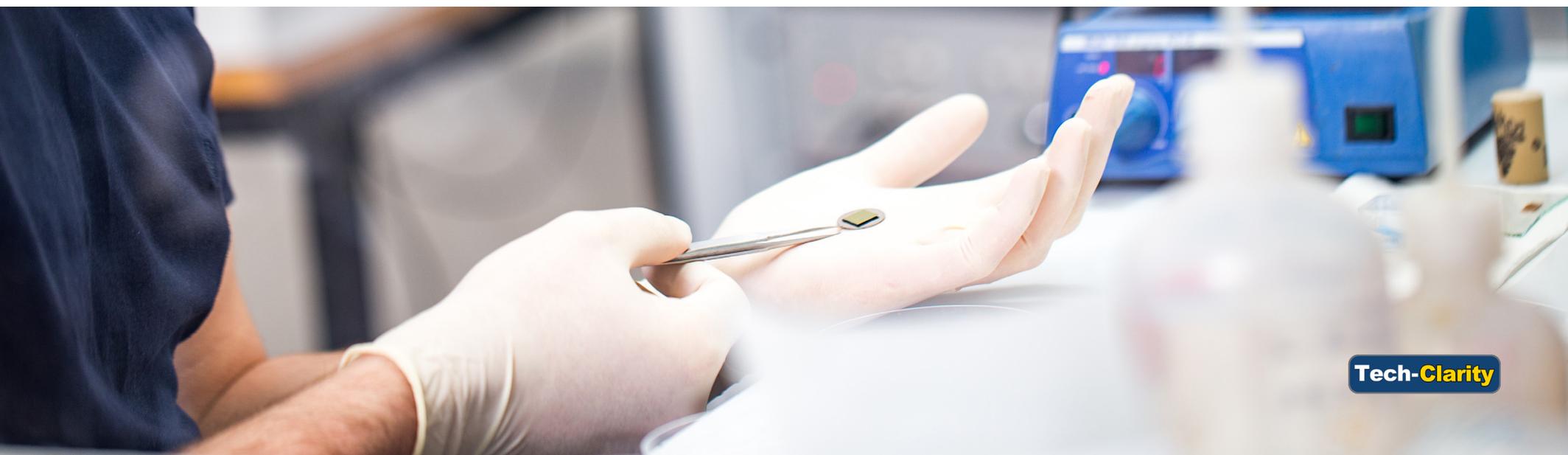
Predictive quality allows a medical device manufacturer not only to comply, but to improve its business results. Building on the risk-based approach to more fully encompass the complete quality system, including production, is a logical next step.

Yet, traditional software approaches leave too many gaps in the information flow. Predictive quality is only possible when medical device manufacturers

have an agile, responsive, and integrated manufacturing data system to support it. The platform must pull in many data streams, put them in context, and conduct effective predictive analysis. It must integrate both to OT and enterprise, creating feedback loops at many levels.

There are companies starting to do that today. Medical device industry leaders are building out the information systems

to enable automated release. So, beyond documentation of the process and product, the system will understand whether all processes stayed within the designed envelope to ensure a high-quality product result. Companies that can step into this next level of predictive quality will have advantages in speed, regulatory compliance, cost, and confidence.



Recommendations

- Expand beyond R&D to create a dynamic risk-based and predictive approach to quality.
- Focus on strong feedback-loops across the entire quality system: design, production, suppliers, regulatory, and in-use customer and field data all playing together.
- Explore whether a unified manufacturing data management system that can integrate horizontally and vertically could improve the company's quality situation.
- Map where data disconnects occur to better understand how to craft the foundation for next-level risk-based and predictive quality.
- Hire data scientists, and train them to work with your process experts to create effective quality analytics.
- Use advanced analytics on complex big data sets to create effective predictive quality models that stay current.
- Aim for process control that keeps within the envelope across all the variations to enable automated release of products.
- Ensure the cycle gets beyond understanding to rapid and effective action.
- Choose manufacturing data management software that will serve the entire enterprise and a multitude of current and future use cases.
- Seek out manufacturing data software suppliers that have expertise in medical devices and can streamline qualification and validation.
- Start the journey toward predictive quality, collecting and analyzing more data as it becomes available to move from reactive to preventive to predictive.
- Engage employees in proactive quality by providing them opportunity to contribute and guidance to stay on track.
- Dare to transform the entire quality system to be data-based and predictive and not tradition-based and reactive.

"What makes predictive quality difficult to scale? Bringing process variability under control with MES. Earning trust in the data and buy-in of stakeholders. Perceived return on investment to deploy predictive quality at scale, compared to other manufacturing investments. In that order."

Craig Pinegar
Senior IT Solution Architect, Digital
Manufacturing Product Owner, Ultradent
Products, Inc.

Acknowledgments



Julie Fraser

Vice President,
Tech-Clarity

Tech-Clarity

About the Author

Julie Fraser joined Tech-Clarity in 2020 and has over 35 years of experience in the manufacturing software industry. She is an enthusiastic researcher, author, and speaker. She has a passion for manufacturing progress and performance gains through Industry 4.0 strategies and supporting software technology.

Julie is actively researching the impact of digital transformation and technology convergence in the manufacturing industries, with a focus on the plant floor and how manufacturing data can be used in conjunction with data from offices, labs, and the ecosystem.

Tech-Clarity is an independent research firm dedicated to making the business value of technology clear. We analyze how companies improve innovation, product development, design, engineering, manufacturing, and service performance through the use of digital transformation, best practices, software technology, industrial automation, and IT services.

References

1, 2, 3 Julie Fraser, The Manufacturing Data Challenge: Lessons from Top Performers © 2020, Tech-Clarity, Inc.

4 US Food and Drug Administration Guidance for Industry: PAT – A Framework for Innovative Pharmaceutical Development, Manufacturing, and Quality Assurance, © 2004

Image Credits

© iStockPhoto / janiecbros (cover) / SolStock (page 2) / Hispanolistic (page 7) / 4X-image (page 9, 18) / Marco VDM (page 13) / CasarsaGuru (page 21)

Copyright Notice Tech-Clarity, 2021

Unauthorized use and/or duplication of this material without express and written permission from Tech-Clarity, Inc. is strictly prohibited.

This eBook is licensed to Critical Manufacturing.
www.criticalmanufacturing.com

