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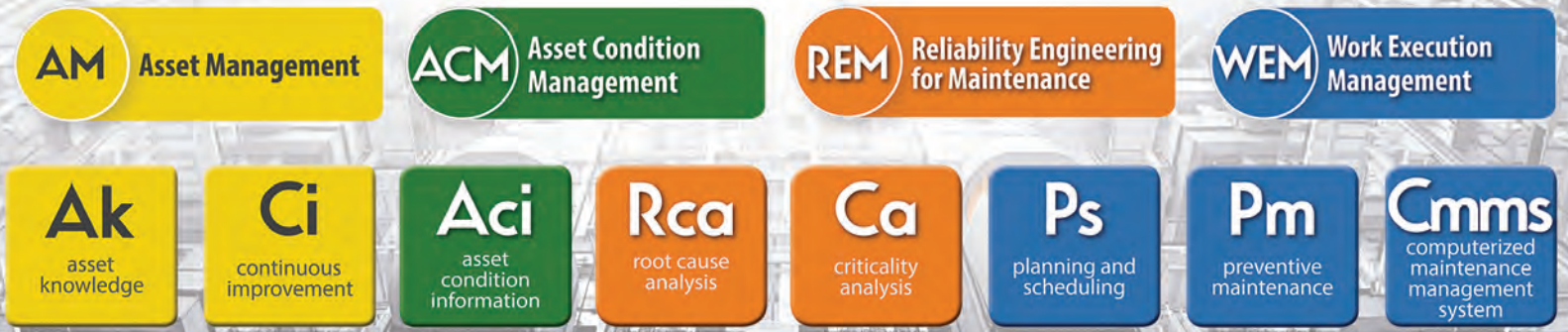
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Creator of Uptime Elements and the  
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— JAMES KIP FINCH

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for reliability leaders and  
asset managers

ON THE COVER  
Can you find the hidden Uptime  
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magazine

**IoT**

A NEW DIGITALIZATION STRATEGY  
**FRAMEWORK**  
TO ADVANCE RELIABILITY AND  
ASSET MANAGEMENT

Rajiv Anand, Michael K. Andrews,  
Mary Bunzel, Sandra DiMatteo, Blair Fraser,  
Rendela Wenzal and Terrence O'Hanlon

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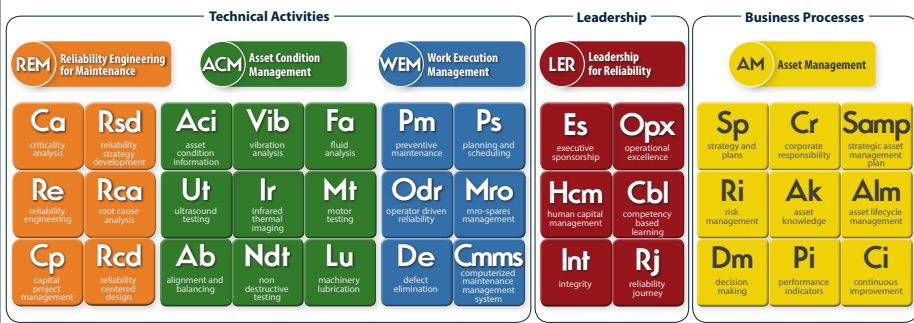


## RELIABILITY PARTNERS

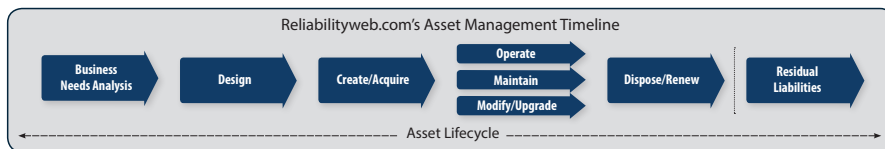
A powerful ecosystem of Reliability Partners who support the Uptime Elements Framework.

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## Uptime® Elements



### A Reliability Framework and Asset Management System™



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Uptime® Elements - A Reliability Framework and Asset Management System™ is in use at over 2,800 organizations around the world to engage and empower reliability culture.

# uptime®

**CEO/PUBLISHER**  
 Terrence O'Hanlon  
 terrence@reliabilityweb.com

**FOUNDER**  
 Kelly Rigg O'Hanlon

**EDITOR**  
 Jenny Brunson

**TECHNICAL EDITOR**  
 Jeff Smith

**CONTRIBUTING EDITOR**  
 Dave Reiber

**CONTRIBUTING WRITERS**  
 Sanket Amberkar, Rajiv Anand, Michael K. Andrews, Mary Bunzel, Sam Deters, Sandra DiMatteo, Grahame Fogel, Blair Fraser, Dean Griffin, Nick Jize, Uwoajega Joseph, Kate Kerrigan, Denis Lisin, Terry McElrath, Victor Melnikov, Terrence O'Hanlon, Anatolii Rybalov, Prakash Shende, Keith Taylor, Rendela Wenzal, Tong Zou

**ASSOCIATE EDITOR**  
 Sean Flack

**DESIGNER**  
 Jocelyn Brown

**PLANNER AND SCHEDULER**  
 Trish Reiter  
 trish.reiter@reliabilityweb.com

**SALES & ADVERTISING**  
 Amy Harlan  
 Client Growth Specialist  
 amy@reliabilityweb.com

**EDITORIAL INFORMATION**  
 Please address submissions of case studies, procedures, practical tips and other correspondence to Terrence O'Hanlon  
 terrence@reliabilityweb.com

**ARTICLE SUBMISSIONS**  
 publishing@reliabilityweb.com

**SUBSCRIPTIONS**  
 To subscribe to *Uptime* magazine, log on to  
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 For subscription updates  
 subscriptions@uptimemagazine.com

**Uptime Magazine**  
 8991 Daniels Center Drive, Fort Myers, FL 33912  
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 www.uptimemagazine.com

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## CHOOSING WITH INTEGRITY

*Have you ever noticed that no one is ever just late?*

*They somehow think that the reason makes some kind of difference to anyone inconvenienced.*

*They place responsibility, or they provide "traffic" as the cause for being late. Is traffic really the cause?*

*They are late because the alarm clock did not go off, and they overslept. Is the alarm clock really to blame?*

*They even may be late because they are not feeling well. Is their health to be held responsible?*

**Being a reliability leader  
is a choice. Being a  
reliability leader is a stand.**

Reliability leaders act as if they are at cause in the matter. They do not assign blame or fault external circumstances. Reliability leaders are late because they are late.

Being a reliability leader is a choice. Being a reliability leader is a stand.

When being a reliability leader and acting on your choice, if what you "chose" is simply an expression of your "reasons" for choosing rather than an expression of yourself (your word as defined in the Uptime® Elements Integrity passport), you may find your commitment to reliability leadership weak and

dependent on those reasons (it could be good for my career, I might get a promotion, it seems like a cool thing to do, my best friend and co-worker did it, etc.). Without a commitment and your word, you will find it very difficult to act on your choice to be a reliability leader with power and integrity.

To be a reliability leader, you have to own your choices; that is, while leaders may reason their way to what they choose, when they finally do choose, they make themselves the chooser, rather than making the reasons the chooser.

To master reliability leadership requires practice. This is another opportunity for you to practice being a reliability leader. It is not easy to be a reliability leader so get used to it. Being able to choose and stick with your choices is critical to reliability leadership. Be tough on yourself if you find yourself creating reasons or excuses for why you did not really give your word, or that it is too hard, or it is not worth it. Those are the marks of non-reliability leaders, and people who fail as reliability leaders.

Choose to be a reliability leader as an expression of yourself with nothing added.

Enjoy the pages of *Uptime*® magazine, an issue filled with examples of reliability leadership. Please consider contributing for a future issue.

Terrence O'Hanlon, CMRP  
About.me/reliability  
CEO and Publisher  
Reliabilityweb.com®  
*Uptime*® Magazine  
<http://reliability.rocks>





# IN THE NEWS

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## Boeing Hosts Reliability Leadership Institute Member Meeting

The reliability team at Boeing South Carolina hosted the first 2019 Reliability Leadership Institute® (RLI) Membership face-to-face meeting, February 7-8, 2019, at the home of the company's second 787 Dreamliner final assembly and delivery facility. Boeing South Carolina was the company's first 100 percent renewable energy site and became the fourth Boeing site to achieve Zero Waste to Landfill status in 2011.

RLI is a community of practice (CoP), where member companies share experiences and lessons related to the implementation of a holistic Reliability Framework and Asset Management System™. The meeting's focus was on the challenges and solutions around reliability leadership, reliability engineering for maintenance, asset condition management, work execution management, asset management and digitalization. The meeting concluded with a behind-the-scenes tour of the Boeing facility.



## Industrial Internet Consortium

The Industrial Internet Consortium (IIC) Meeting, February 11-15

Terrence O'Hanlon, Maura Abad, Terry McElrath and Richard Soley

"Industrial IoT is the core technology supporting digital transformation today," said Richard Soley, Ph.D., Executive Director of the Industrial Internet Consortium. "We are pleased that Reliabilityweb.com has brought its expertise in digitalization to the Consortium's active testbed and architecture activities, an expertise valued by firms undergoing the difficult path to digitalization."

The Industrial Internet Consortium is the world's leading organization transforming business and society by accelerating the Industrial Internet of Things (IIoT).

## Reliability Leaders Earn Black Belt Distinction

The Certified Reliability Leader® (CRL) Black Belt Program is a results-oriented acknowledgment of significant and successful holistic reliability improvement projects delivered on a consistent basis. Projects enable triple bottom line outcomes of improving reliability and asset performance.



A CRL in good standing can earn a belt for each domain in the Uptime® Elements Framework. Once all five domain belts have been earned, the individual is awarded the CRL Black Belt.

### Congratulations to the following recipients!

#### Black Belt

George Williams, B.Braun  
Joseph Anderson, B.Braun  
Eric Newhard, Medtronic  
Jeff Smith, Reliabilityweb.com

#### Work Execution Management (Blue) Belt

Michael Meehan, Worthington Industries  
*Galvanizing Line Entry End TPM Implementation*  
  
Kenneth Hunt, Medtronic  
*Blue Belt Agitator Seal Redesign/Upgrade*

#### Leadership in Reliability (Red) Belt

Tim Allen, Central Arizona Project  
*Enhanced RCM Training*

Bill Hollman, NEFCO  
*Leveraging the CMMS to Improve Reliability via Safety*



CRL belts awarded at IMC-2019: Terrence O'Hanlon, Heather Clark, Eric Newhard, Jeff Smith and Dave Reiber



## ARC Forum

ARC Industry Forum, February 4-7: Terrence O'Hanlon of Reliabilityweb.com and Uptime magazine presented the workshop, *The Digitalization of Asset Performance Management*.

Jim Sullivan, Terrence O'Hanlon, Paula Hollywood, Maura Abad and Brendon Russ



# NONE OF US IS AS SMART AS ALL OF US

## THERE'S A NEW WAY TO GET RELIABILITY

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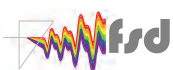
## Reliability Partners Vision:

Advance the industry toward ZERO

• **Accidents** • **Downtime\*** • **Waste**

through a holistic reliability framework.

A Powerful Community of **Reliability Partners** to Advance Reliability and Asset Management with You



For more information: [reliabilityweb.com/directory](http://reliabilityweb.com/directory)



\*Unplanned



# ENABLING EMPOWERING

The Only Things You Get to  
Keep Are What You Give Away

Terrence O'Hanlon



**Give it away, give it away, give it away now  
Give it away, give it away, give it away now  
Give it away, give it away, give it away now**

**~ Red Hot Chili Peppers**

**A**s we launch the Uptime® Elements Digitalization Strategy Framework that is featured in this issue, I would like to share the context for the system of creation that I have cultivated and nurtured over the past 20 years that brings work like this into existence.

In this case, the work grew from the original Uptime Elements Reliability Framework and Asset Management System™. The new Internet of Things (IoT) Knowledge Domain originates from so many ideas, so many people, so many conversations, so much thought, so much work and so much care from so many people. I encourage you to read the article from the incredible team of reliability leaders that were directly involved in this work.

A reliability leader is someone who creates a new future that was not going to happen anyway. The alternative is to simply accept the default future that we all know will show up if we do not do anything different.

Creating is not exclusive to the likes of Einstein, Shakespeare, Lennon, Ford, Van Gogh or Edison. Creating is the gift given to each of us as humans, although the day-to-day whirlwind can often make accessing the capability seem remote. It is easy to forget the times when we have tapped into powerful parts of ourselves to call forward new possibilities in our lives. In the work I do, this is called "the domain of generation."

I have been working and living as a reliability leader for the past 40 years. Much of my work has been split between creating, developing or sharing my new ideas and approaches to advance reliability and asset management, while also enabling and empowering many others to advance their own creations and ideas. Empowering and enabling the possibilities for those around you may seem counterintuitive if you have your own work to do, but like most things in life, the obvious is not always obvious.

The only things you get to keep in life are the things you give away. Be proactive and generous in providing support for other people's projects, and what you will discover is that there will be plentiful support for your own projects. Be scarce with your support, and you will discover scarcity for your own.

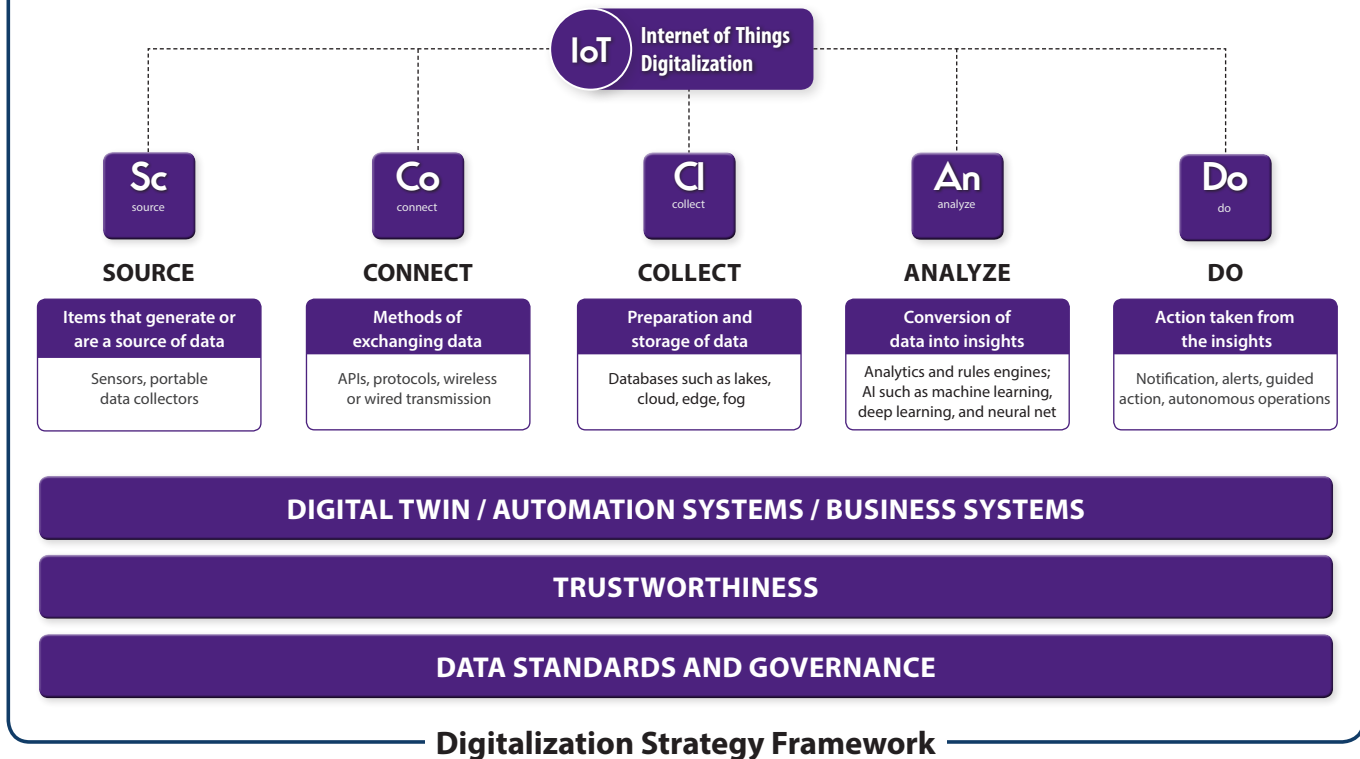
## Clarifying a Created Future

As a reliability leader, we learn to create contexts that leave us empowered and enabled. In the Certified Reliability Leader® workshops, the context we are speaking about that leaves us empowered and enabled is a "created future."

It is the "created future," a high reliability future, that we, and the people we are leading, come to live and work in. This future gives us "being" (as in "being a reliability leader") and "action" (as in "doing reliability

# Uptime® Elements

## Internet of Things Knowledge Domain



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leadership”) in the present that realizes the “created future” (the future that “wasn’t going to happen”).

Where can you find candidates to empower and enable for a “created future?”

I find candidates everywhere I go and in everything I do because I am committed to listen for them. My ears are finely-tuned to distinguish between those committed and the complaining clods who expect the world to care about their ailments, and who expect value to be delivered to them on a silver platter. You know, the ones who are victims of the current set of challenges and circumstances versus those who are willing to create value for themselves, not waiting for it to be created for them. I search for the ones who take a stand for something and live in the future that creates with integrity. I can spot them a mile away! That is who I support relentlessly and unconditionally. You can find them everywhere and anywhere in your work, as well as your life.

Inspiring new projects, giving away my own ideas, providing support, offering pro bono start-up support and stretching my own capability and thinking by working with people who know more and are MUCH smarter than myself are all ways I lead opportunities and possibilities.

Look for opportunities to give things away.

***Give away your leadership. Give away your support. Give away your time. Give away your work. Give away kindness.***

**THE ONLY THING YOU GET TO KEEP IS WHAT YOU GIVE AWAY.**

### SOME CURRENT AND PAST COLLABORATIVE PROJECTS INCLUDE:

- Uptime Elements Reliability Framework and Asset Management System
- IoT Elements/Digitalization Strategy Framework
- Reliability Centered Maintenance Project Managers Guide
- ISO 55001:2014 Asset management -- Management systems -- Requirements
- ISO/IEC TS 17021-5:2014 Conformity assessment -- Requirements for bodies providing audit and certification of management systems -- Part 5: Competence requirements for auditing and certification of asset management systems
- Industrial Internet Consortium Trustworthiness Guidelines
- Industrial Internet Consortium Thought Leadership
- Lubrication Elements
- Vibration Elements
- Uptime Elements Performance Management Framework
- Uptime Elements in Data Centers
- MIRCE Academy Collaboration
- Things to Think About (and Do)



# A NEW DIGITALIZATION STRATEGY FRAMEWORK TO ADVANCE RELIABILITY AND ASSET MANAGEMENT

Rajiv Anand, Michael K. Andrews, Mary Bunzel, Sandra DiMatteo, Blair Fraser, Rendela Wenzel and Terrence O'Hanlon

## An Internet of Things Knowledge Domain Creates Stakeholder Alignment and Common Language

Sensors, cloud computing, artificial intelligence (AI) and machine learning – the Internet of Things (IoT) is coming to your plant or site! The IoT is expected to revolutionize how you work. You likely have high hopes of its potential, but you also may have concerns about the volume, velocity, variety and veracity of data the IoT will bring and how on earth you will manage it. Security, the threat of malware and data integrity also may be weighing on your mind. So, you need a digitalization strategy, a plan and a framework for your success in an IoT enabled organization.

### A COMMON LANGUAGE APPROACH

Today, organizations have a solid reliability and asset management framework in the Uptime® Elements released by Reliabilityweb.com in December 2013. This framework helps achieve a common language and system for organizations who understand that reliability is cross-functional and requires an enterprise approach.

In Internet time, December 2013 seems a lifetime ago and although the IoT and digitalization strategies were born, they were not mainstream. Today, they are advancing like a bullet train and are now ubiquitous in all industries.

A year ago, a small group of Uptime Elements enthusiasts, who also have considerable knowledge and experience, began a project to extend the original Uptime framework into the digitalization realm.

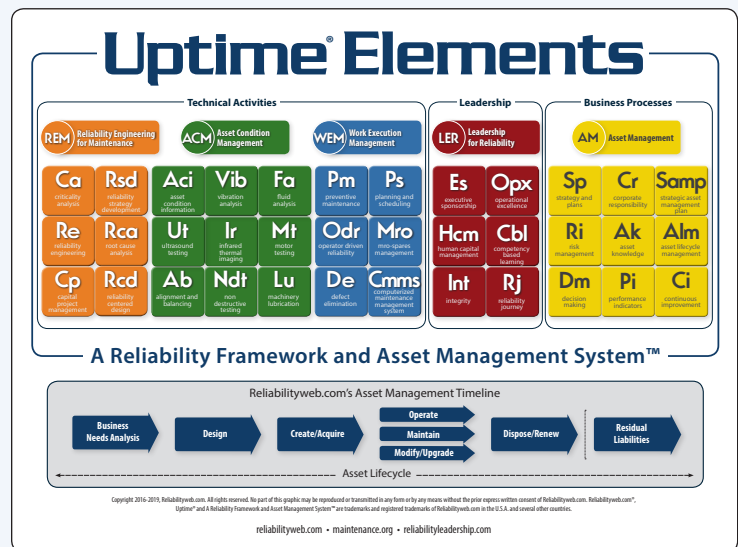


Figure 1: The Uptime Elements framework for reliability and asset management

### A WORD ABOUT DIGITIZATION VERSUS DIGITALIZATION

Words matter, which is why for this article, the word **digitalization**, as opposed to digitization, was carefully chosen because it is evident entirely new business models are emerging from this context.

According to Gartner's IT Glossary, "Digitization is the process of changing from analog to digital form. Digitalization is the use of digital technologies to change a business model and provide new revenue and

# The Uptime Elements Internet of Things Knowledge Domain is a digitalization strategy framework to guide you in your reliability and asset management journey

value-producing opportunities. It is the process of moving to a digital business. *Digital business* is the creation of new business designs by blurring the digital and physical world."

As organizations move to implement the IoT and digitalization, people's jobs will change. Imagine factory workers exchanging traditional handheld vibration analyzers, portable leak detectors and grease guns for machine learning algorithms, informed dashboards and programmed collaborative robots (cobots).

## DIGITALIZATION DRIVERS

Based on a study conducted by Reliabilityweb.com in 2017 and 2018, the top three outcomes reliability and asset managers sought from implementing a digitalization strategy were:

1. Increased Reliability;
2. Make Better Decisions;
3. Decrease Cost.

While these are positive drivers, the research also indicates the pace of digitalization diffusion is increasing significantly within the reliability community. Most organizations lack formal policies, strategies and plans to align these implementations to organizational objectives or aims. Equally, conflicting viewpoints on the interpretation of what defines digitalization and how it applies to organizations make it challenging for companies to plan where and how to start. While some companies have hesitated to tackle digitalization, others have gone all-in without understanding how value will be delivered. These companies may find that the only business victory

they achieve is bragging rights that they have implemented a wide array of science projects.

Thus the need for a unified framework around digitalization, one that gives common terms and an understanding of the challenge areas so they can be communicated across organizations and industries, demystifying the topic. Your enterprise, undoubtedly, will have different operational needs and IT architectures. You will need to assess what areas and guidance of the framework provide value to you. It is not a mandate, but instead a baseline of common terms, good practices and guidance to assist organizations that are looking to make the digitalization journey.

## THE DIGITALIZATION STRATEGY FRAMEWORK

The Uptime Elements Internet of Things Knowledge Domain is a digitalization strategy framework to guide you in your reliability and asset management journey. It includes the Industrial Internet of Things (IIoT), cloud computing and more. Industry 4.0, as it has been named, now must be included in your road map, so this framework contains questions you should ask your organization and provides answers to common questions to clarify what you need to consider in implementing the IoT.

The elements within the IoT knowledge domain are:

- SOURCE – items that generate or are sources of data;
- CONNECT – methods of exchanging data;
- COLLECT – preparation and storage of data;
- ANALYZE – conversion of data into insights;
- DO – actions taken from the insights.

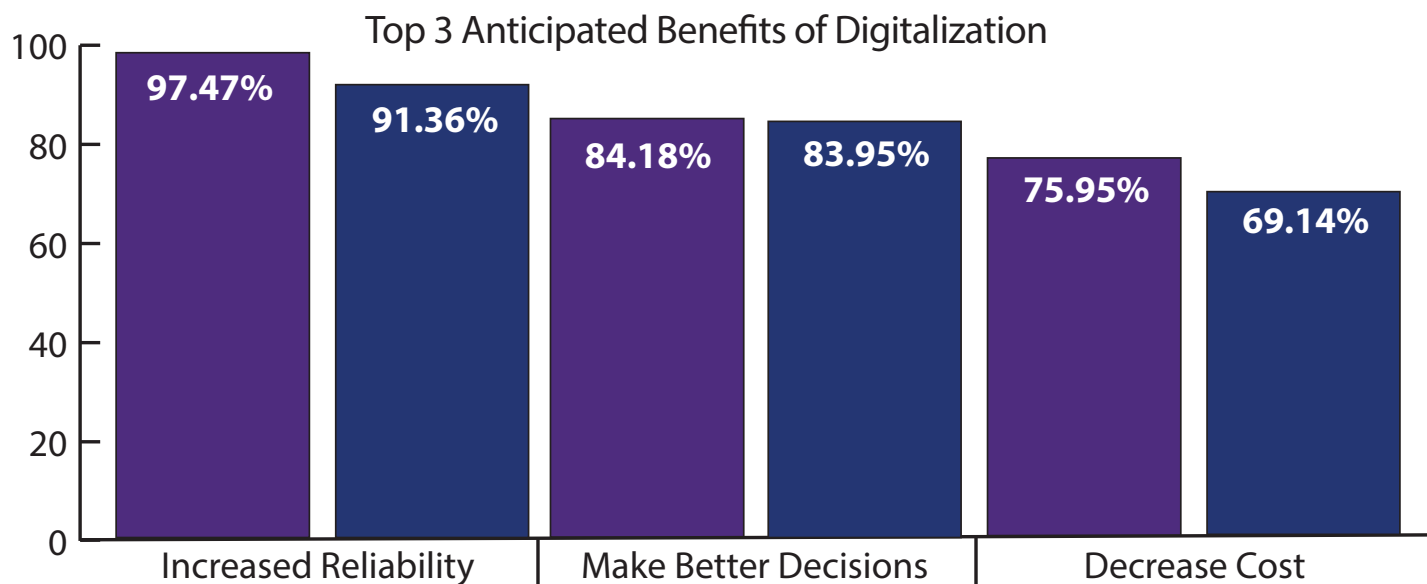
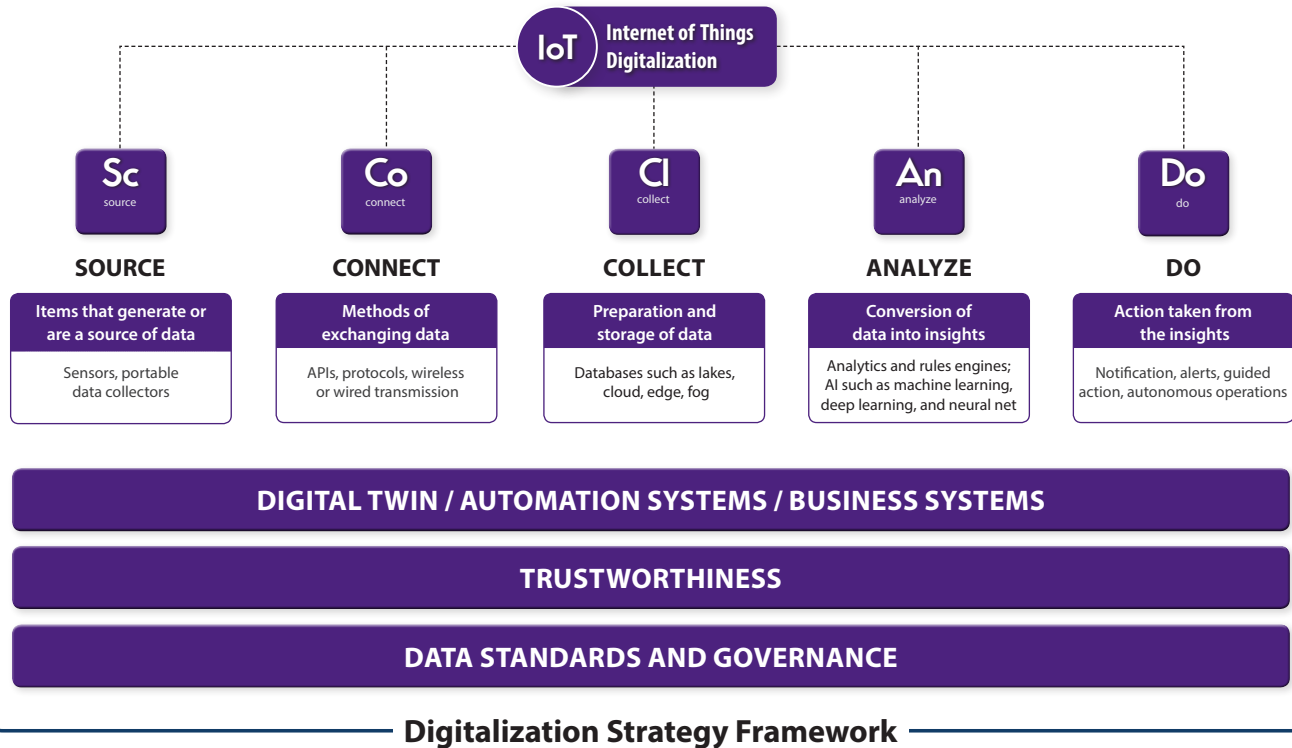


Figure 2: Reliabilityweb.com asset manager survey on IoT, results 2017–2018

# Uptime® Elements

## Internet of Things Knowledge Domain



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Figure 3: The Uptime Elements IoT knowledge domain and digitalization strategy framework

Regardless of which element you are implementing, you need to consider:

- The role of the digital twin, along with your automation and business systems in the context of the IoT: It is conceivable that your future state will be to conduct your work from the digital twin of your asset to better visualize and understand information in context within an accurate detailed digital model.
- Trustworthiness of your data and systems: Identify and mitigate risks from security breaches and malware, and address privacy, reliability, resilience and safety.
- Standards and governance: Learn from IoT data governance guidelines and configuration management principles to ensure data can be trusted.

Let's take a more detailed look into each of the elements within the IoT knowledge domain.

**Sc**  
source

### SOURCE (Sc)

**ITEMS THAT GENERATE OR ARE A SOURCE OF DATA**

Simply said, a source of data is the originating point of information used to inform situational conditions of people, places, or things. Sources can come from physical sensors attached to the things they monitor. Sources also can

come from other external systems, such as social media, internal business systems (e.g., enterprise asset management system, manufacturing execution system, or enterprise resource planning system), as well as archives known under common names, such as data lakes.

Common types of physical sensors include devices that monitor things like temperature, proximity, pressure, water quality, chemical content, gases (present or not), smoke, infrared, fluid level, images (e.g., optical, thermo, infrared), motion detection, accelerometer, gyroscope and humidity.

There are many decisions to make regarding the right kind of sensor to use in which situation. For example, differences in manufacturing processes (e.g., process, discrete, batch process, etc.) have their own characteristics and sensed combinations that are unique to the production type. Other decisions about the type of device to use for sensing are driven by the requirements defined for the solutions. The array of sensing devices is as wide as the applications they serve.

Continuous process monitoring has different requirements than discrete processes. Combining data information feeds from a multitude of sources is often necessary to create a complete picture for performance assessment.

Key questions to ask are:

- How do I configure the sensor to gather the right data?
- How many readings do I take at what dimension?
- What kind of environment will this sensor live in?





## Why Should You Care About Source?

As the world of the IoT expands to address ever wider applications, its darker side becomes more exposed. Any time you connect an asset to an intranet via a sensor, you increase the plane of vulnerability of that asset. Therefore, sensors and devices require management, just as any other IT device. Managing these devices means that installation and configuration follow governance guidelines for provisioning, as defined by your enterprise. As your IoT implementation ramps to full deployment, challenges related to scale, security and connectivity can compound quickly, which, in turn, drive up costs and delay progress. Therefore, IoT deployment plans must include strategies for easy provisioning, configuration, monitoring, updating and de-commissioning – full lifecycle planning applied to devices.

Because of their impact on the assets they are monitoring and their connection to factory control systems, source devices require security management as an active part of your secure operations guidelines. Some of the vulnerabilities to mitigate include unsigned firmware, default credentials, insecure data in transit, insecure key storage and missed firmware/software updates. Remember that pilots and proof of concepts are good learning exercises. Paying attention to key requirements here can save time and money later on.

- Security;
- Durability in the factory setting in which it will be used;
- Cellular plan charges: cellular and 5G requires paying service providers.

In addressing these challenges, several types of wireless applications are available that may make them more applicable to the usage cases you're trying to solve. Zigbee Pro, Bluetooth®, Ethernet, cellular and LoRa® are all choices to consider, each offering unique characteristics to answer a wide variety of applications.

The introduction of wireless technology, whether in the smart grid or as part of the enterprise, control center, or remote site infrastructure, brings with it serious security concerns. Network health and cybersecurity are emerging failure modes that can be significant. Advances in wireless connectivity enhance flexibility and agility, but they also bring increased awareness of security protocols. The wireless network should be isolated from other networks by a firewall and implemented with strong encryption and authentication.

The U.S. Department of Homeland Security has documented the number of attacks mitigated by various security strategies. As a group of practices, they can be effective in preventing most intrusions.

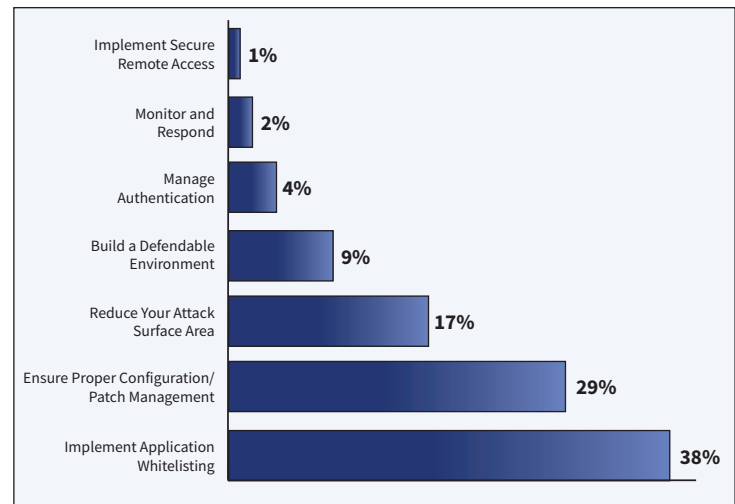


Figure 4: Seven steps to effectively defend industrial control systems (Credit: National Cybersecurity and Communications Integration Center report, 3/24/18)

### CONNECT (Co) METHODS OF EXCHANGING DATA

Of course, once you begin to access devices, it is necessary to set up connections to the enterprise network. A communications link or channel is a single transmission medium used to transport analog or digital information between a source and receiver. The main point of Connect is to build a communications architecture that enables everything from reliable machine operation to real-time analytics. Compare it to the nervous system of a machine, a plant, a company, and link the world. Commonly used transmission paths to support communications include guided media, such as copper wire and fiber optics, and unguided media, such as radio, microwave and lasers. A sound design involves the selection of communications technologies that deliver secure and reliable performance to enable freedom of source device selection and efficient application by machine experts.

Wired networks widely in use in factories today include PROFIBUS, PROFINET, Sercos, HART, CAN and Ethernet. However, running cable for wired networks is expensive and it's difficult to reach some locations. Cable may need to be rerouted if the factory is reconfigured and it is not practical for equipment that is mobile.

Wireless technologies solve the issue of connecting mobile equipment and can be used to accommodate a flexible factory floor. They work well in most applications if the performance and features are aligned to the desired results.

## Why Should You Care About Connectivity?

There are several challenges in wireless communications that need to be considered:

- Reliability: meeting 99.999 percent reliability;
- Robustness: operating in a radio frequency factory environment with extreme temperatures and vibration;
- Determinism: accuracy of milliseconds given the current input and state when there is only one action that can be taken;
- Latency: addressing the millisecond delay between the controller and source device;

### COLLECT (C) PREPARATION AND STORAGE OF DATA

The main reason to collect data is to make it analysis-ready in context. Collecting and storing data is nothing new, but as you start looking at data as the fuel on which digitalized business models will run, collection takes on a whole new meaning. To perform diagnostics and hindsight analytics, mostly performed by human experts, the traditional historians and databases fed by time series data serve a purpose. The ever-increasing amounts and velocity of multivariate, multi-context, analysis ready data for digitalization requires new ways of processing, storing and preparing it in context in real time.

## Why Should You Care About How You Collect Data?

There are more storage options and techniques being developed almost daily to handle the complexity, amount and dynamic nature of manufacturing data. Analysis of data is no longer limited to human analysis. Machine learning

algorithms that may run in the Cloud or at the edge may need access to data collected anywhere else in the organization. Where should you collect and store the data? How do you maintain the original truth in the data as it moves around different usage applications? How will it impact the integrity of the digital twin that defines the lifecycle of the asset? What are the cost implications of retrieving this data, on demand, by different analytic applications? All these implications, and the increasing value of the data as an asset, require a much more careful and consistent approach to data collection.

**An**  
analyze

## ANALYZE (An)

### CONVERSION OF DATA INTO INSIGHTS

You seek insights from data so action can be taken. A natural question is: “I have been analyzing data to gain knowledge and insights before, so what is new about analyzing in an IoT world?” To date, most analyses have been performed by human experts. This limits an asset owner’s ability to analyze all the data, with the efficacy of the insight (i.e., conclusion) dependent on the level of expertise and experience of the expert. Additionally, the conclusion can be subjective. Most analyses have been focused on hindsight and diagnostics. Even when an analysis is performed for the purpose of foresight (i.e., prognostics), it is done as a discrete event.

In the context of digitalization, with more computing power and data analysis techniques, it is possible to analyze more data, create insights not possible before and create actionable prognostics and foresight. Algorithms can be trained to automatically perform analyses and the analyses can be continuous as new data streams arrive. This automation of analysis, performed by machine learning and AI, is a key differentiation to analyzing in the context of digitalization.

### Why Should You Care About Analyzing IoT Data?

The amount of data generated by your assets has increased significantly in the last few decades. This amount of data will only increase further, exponentially, as new assets equipped with more sensors make their way into businesses. This data itself will become a valuable asset for any business. Rapid analysis of the data will make businesses more productive and profitable. How well you take advantage of the data through analysis and resulting action will impact the success of your business. For some businesses, the insights created by applying knowledge to data analysis can be monetized, resulting in new revenue streams.

**Do**  
do

## DO (Do)

### ACTION TAKEN FROM THE INSIGHTS

The main reason to analyze data is to make it actionable. You seek to do something that will return business value. Value derived from these actions can increase key business areas in productivity, revenue and quality. By observing the results of your actions, you learn and gain knowledge of best known methods and allow for continuous feedback improvements for your operations by extracting the most value from your digital and physical assets.

### Why Should You Care About Do?

Industry today spends a vast amount of money on IT infrastructure, like networks, data storage and applications. Companies need to ensure that the expense is delivering value by returning actionable and measurable results. Willing or not, organizations have been thrust into the digital age and, as a by-product, have captured unwieldy amounts of data and information. With this, analytics has become a necessity to glean insights from the mountains of data. However, insights from analytics in and of themselves produce value only when one can **do** something valuable with them.

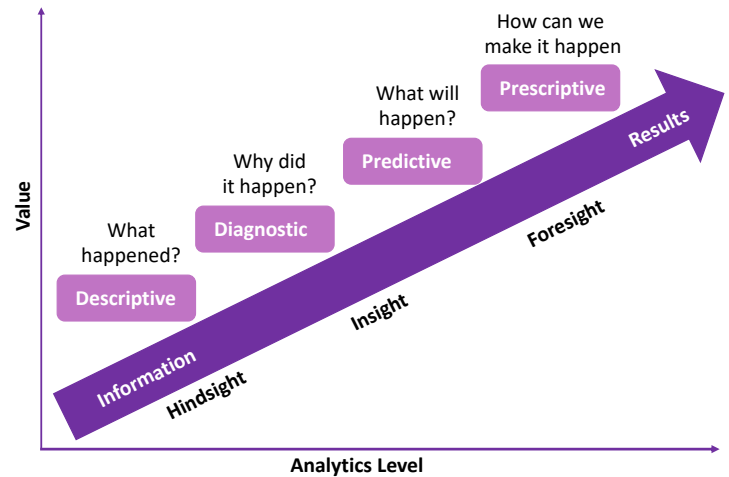


Figure 5: Rapid analysis of data will make businesses more productive and profitable

Turning these insights into action can be achieved with promising advances in technology, like AI, including machine and deep learning; autonomous operations; human augmentation; and electronic workflows. These technologies allow for analytics to be put into action to measure the resulting effect and self-learn. The analytics to action feedback loop is validated when the *do* action produces desired results. You then learn from your data and can then extract the most value from your assets, both physical and digital.

## THE DIGITAL CULTURE OF YOUR ORGANIZATION

For digital transformation, people need to embrace a culture of digitalization, where digital processing is preferred over manual. Leadership is key in driving digital transformation to meet business goals; sharing the vision as a competitive differentiator and seeding cultural changes to shift toward a digital culture.

### ARE YOU READY?

If organizations are to advance from the recognition phase of the potential of AI and the IIoT to taking action, improvement of foundational elements of all five Uptime Elements knowledge domains is required. All domains have an impact, but especially:

- Asset Management;
- Strategy and Plans;
- Decision-Making;
- Asset Lifecycle Management;
- Risk;
- Asset Knowledge;
- Cross-Functional Leadership for IT/OT/ET.

Creating a holistic approach to advancing reliability and asset management built on a foundation of reliability leadership culture across information technology (IT), operational technology (OT) and enterprise technology (ET) is needed to realize the full promise of digitalization. Guiding the vision of the IIoT with the digitalization strategy framework in mind will create credibility at the same time.

Realizing the value of data is priceless. As you create a transparent, decision-making framework and enhanced asset knowledge, you’ll generate new insights cross-functionally and often outside your own organization.

## Realizing the value of data is priceless

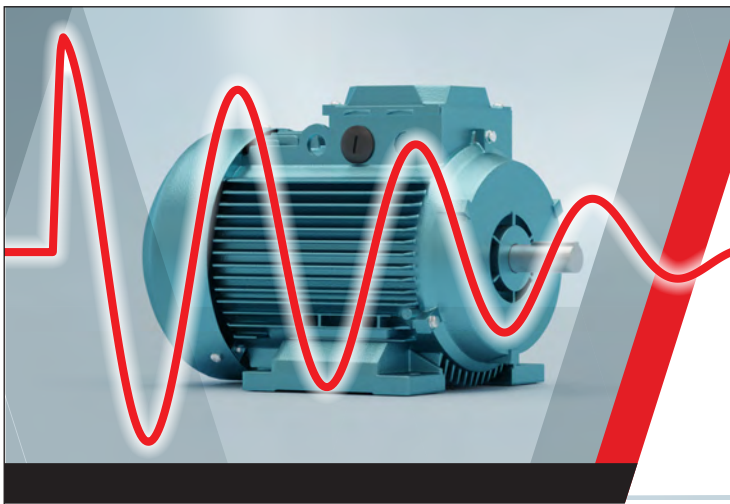
To prepare for the future of work:

- Invest in new competencies and processes as you enhance human capital management, with a focus on enabling and empowering humans to work with digital information for machine-assisted reliability and asset management. Use the Uptime® Elements — A Reliability Framework and Asset Management System™ as a guide.
- Help to shape the workforce of the future. People will always come first before technology. Use your reliability leadership as a foundation and suggest/implement organizational changes that support a cross-functional and collaborative working environment enhanced by AI, machine learning, augmented reality and the IoT.

If you do not have a destination, any road will get you there. Create a policy, a strategy and a plan that includes digitalization and create a line of sight to the aim or objectives of the organization.

### WHAT'S NEXT?

For the full story, attend the Maintenance 4.0 Forum, co-located with The RELIABILITY Conference™, from May 6 to 10, 2019, in Seattle, Washington. The authors of this article will hold a complete workshop on the Uptime Elements IoT Knowledge Domain and Digitalization Strategy Framework. For more information visit [www.reliabilityconference.com](http://www.reliabilityconference.com).



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**Rajiv Anand** is the founder and CEO of Quartic.ai, a company focused on providing machine learning and artificial intelligence solutions for industrial applications, Industrial IoT and smart industry. Prior to starting Quartic.ai, Rajiv spent a year researching Industrial IoT and machine learning and advising technology companies and customers on digital manufacturing strategies. [www.quartic.ai](http://www.quartic.ai)



**Michael K. Andrews** is the Product Line Manager for Applied Materials Pharma Group. Michael has experience in process automation, data analytics, predictive maintenance and equipment design, combined with a background in biologics and managing plant lifecycle and reliability. [www.appliedmaterials.com](http://www.appliedmaterials.com)



**Mary Bunzel** is General Manager, Manufacturing & Industrial Solutions at Intel. Mary leads Intel's Industry Solutions Group focused on Manufacturing, a group focused on driving innovation and best-known practices in the area of Industrial IoT and brings over 30 years of experience in best practices for manufacturing industries. [www.intel.com](http://www.intel.com)



**Sandra DiMatteo** is the Director of Marketing for Asset Performance at Bentley Systems. She has more than 20 years of experience in asset performance management and reliability software solutions, asset lifecycle information management, and enterprise asset management operating in a connected data environment. [www.bentley.com](http://www.bentley.com)



**Blair Fraser**, Manager of Reliability Solutions Business Unit at Lakeside Process Controls, is responsible for the operations and the business development of the Reliability Solutions services and products. With a passion for leveraging emerging technologies to improve asset reliability, Blair is an innovative thought leader focused on implementing sustainable solutions. [www.lakesidecontrols.ca](http://www.lakesidecontrols.ca)



**Rendela Wenzel** is the Global Reliability and Maintenance Leader for Eli Lilly and Company. Rendela has extensive reliability and maintenance experience developing and implementing successful PdM programs, leading RCA activities, and driving maintenance execution initiatives. [www.lilly.com](http://www.lilly.com)



**Terrence O'Hanlon** is CEO and Publisher of Reliabilityweb.com and Uptime Magazine. Terrence is an asset management leader specializing in reliability and operational excellence and is a popular keynote presenter with the ability to deliver awareness about the business advantages of asset management to top management. [www.reliabilityweb.com](http://www.reliabilityweb.com)

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OPENING THE LID OF THE

**ASSET  
MANAGER'S**

TOOLBOX

## Part 2

————— Grahame Fogel and Dean Griffin —————

Asset management (AM) is a recognized value lever for asset intensive organizations. It encompasses a broad vision of possibility and action. Within this new paradigm, AM practitioners need a new toolbox of skills, competencies and tools. This article, written in two parts, opens the lid of this asset manager's toolbox and takes a look inside.

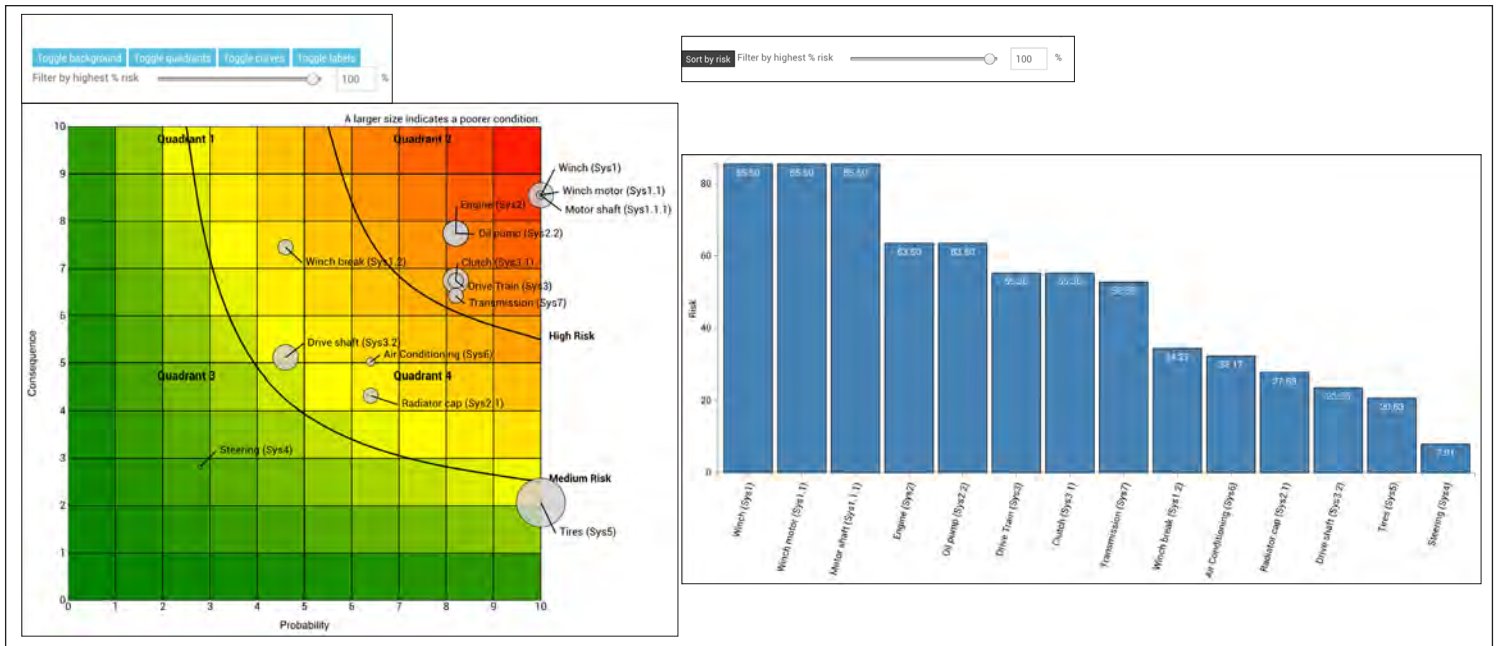


Figure 1: Asset productivity risk

### Modeling Risk and Opportunity: An Effective Risk Model

Most organizations understand risk reasonably well from an enterprise perspective. Usually, there is an enterprise risk department or activity where broad organizational risks are well identified and managed. However, incorporating the asset productivity risk into the risk framework is less mature and most risk matrices do not adequately address this. Often, there is a mismatch of conceptual skills in compiling the enterprise risk register and incorporating the elements of asset productivity risk.

Alternatively, maintenance departments deal at a more static asset risk level. This is referred to as criticality, which directs efforts at allocating maintenance activities and resources to ensure appropriate plant or asset reliability.

There are proven high value opportunities in bridging this divide, creating a scenario where the asset productivity risk is incorporated into the corporate risk framework, thus facilitating the strategic alignment of asset risk. (To read additional information on this, see #4 in the References section at the end of this article.)

### Understanding Complexity: Understanding the Relevance of Complexity Theory Will Increase the Chance of Success and Establish Effective Asset Management Solutions

In industry, there is always a push for standardization and predefined solutions or business processes. They are seen as the solutions to complex situations without truly understanding why situations are complex. These “best practices” are often promoted as the only way forward. However,

experience shows that each situation can be very different within the same organization. Complex systems have many elements, adding to the uncertainty.

When looking at an organization’s specific situation, certain characteristics are evident that, when understood correctly, allow for an appropriate approach or solution. To assist in this evaluation, the Cynefin framework is used. This decision-making methodology, developed in 1999 by Dave Snowden and Cynthia Kurtz, is enormously useful in characterizing problems in order to apply a systematic and aligned approach to evaluating and making appropriate decisions. The argument being that a problem characterized as a simple problem has a very different solution path to that of a complex or chaotic problem.

“...A sure route to failure is trying to apply simple solutions to complex problems”

The framework offers five decision-making contexts or domains: Obvious (known until 2014 as Simple), Complicated, Complex, Chaotic and, at the center, Disorder. These domains help managers identify how they perceive situations and make

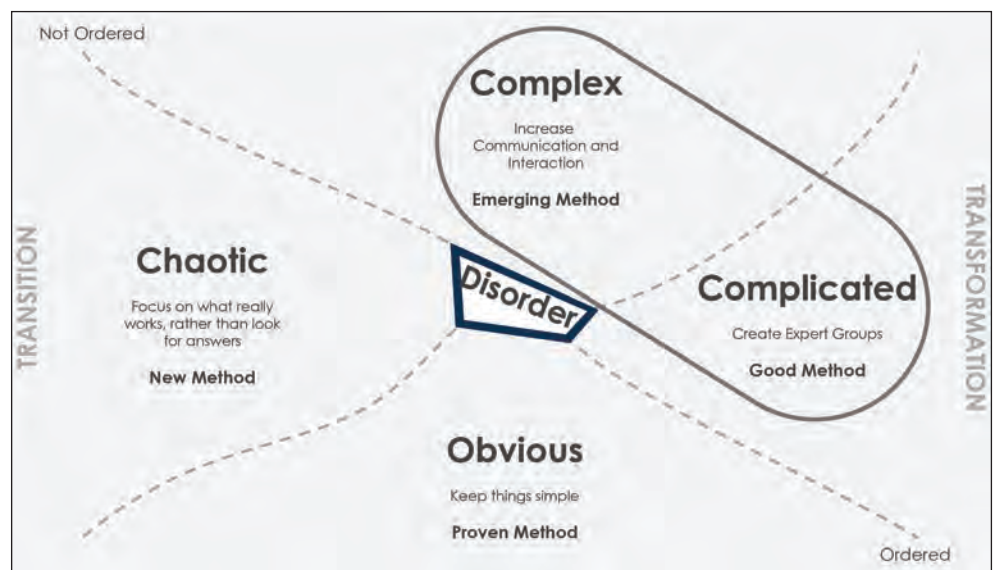


Figure 2: The Cynefin framework

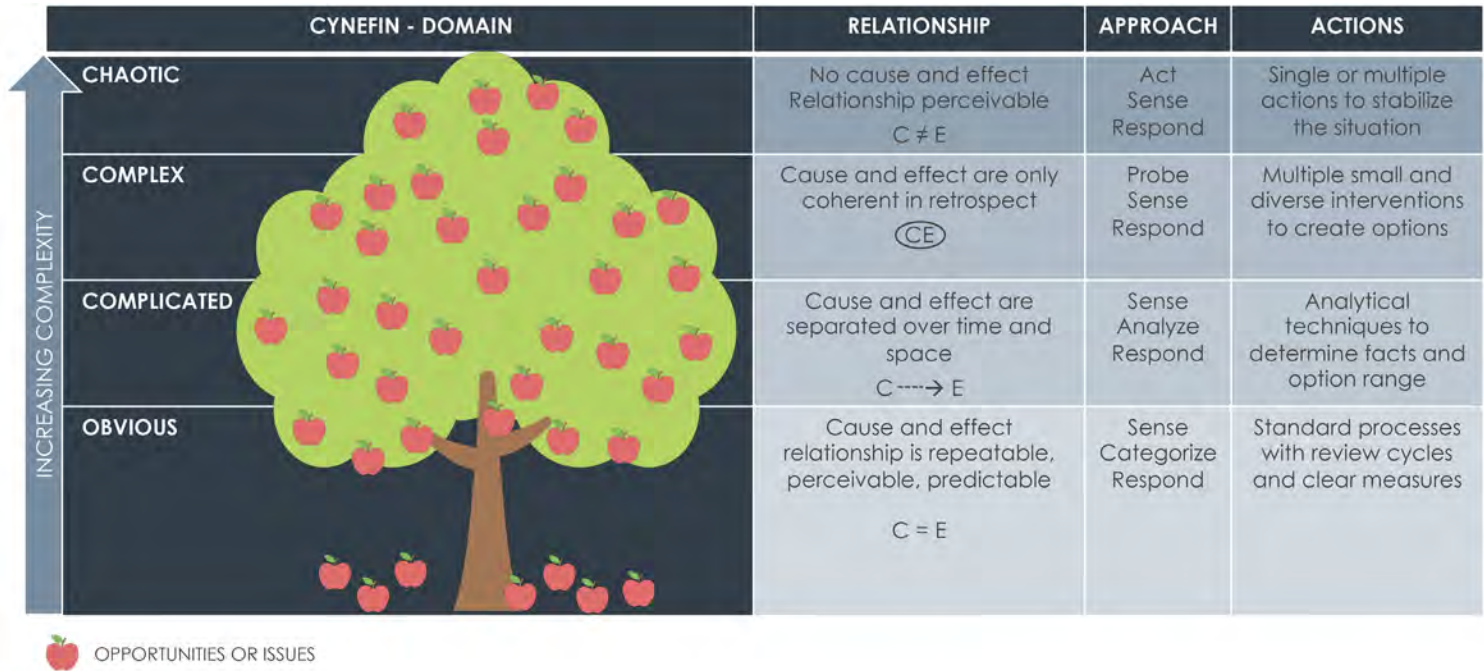


Figure 3: Aligning appropriate solutions to the correct domain

sense of their own and other people's behaviors. The framework draws upon research into systems theory, complexity theory, network theory and learning theories.

Experience shows that characterizing problems provide a clear approach as to how they should be solved. In real-world situations, most problems fit into the complicated and complex domains, and a sure route to failure is trying to apply simple solutions to complex problems.

The idea is that as knowledge and experience increase in organizations (i.e., expertise), there is a clockwise drift from chaotic, through complex

and onto complicated, where it can be captured by procedures.

Most modern-day business problems exist in the complicated or complex domain and, ultimately, have many differing effects. The low-hanging fruit items are usually solved using systems and processes. These items are usually in the obvious domain. As organizations rise higher into the tree, they move through the different domains and the level of complexity increases.

The manner in which an organization addresses an obvious domain issue is to sense, categorize and respond, drawing on previous solu-

tions or best practices. In the same respect, if an organization addresses a chaotic domain issue, the relationship between cause and effect is non-existent. Categorization of the issue and the selection of a solution are not easy. The way to address chaotic issues is to act, sense and respond. The ultimate decision and solution are based on the team's experience in recognizing the issue. Malcolm Gladwell's book, *Outliers*, is a good reference, noting 10,000 hours of experience.

This is why industry standards, like ISO55001 for asset management systems, cannot be at a prescriptive level. One size certainly does not fit

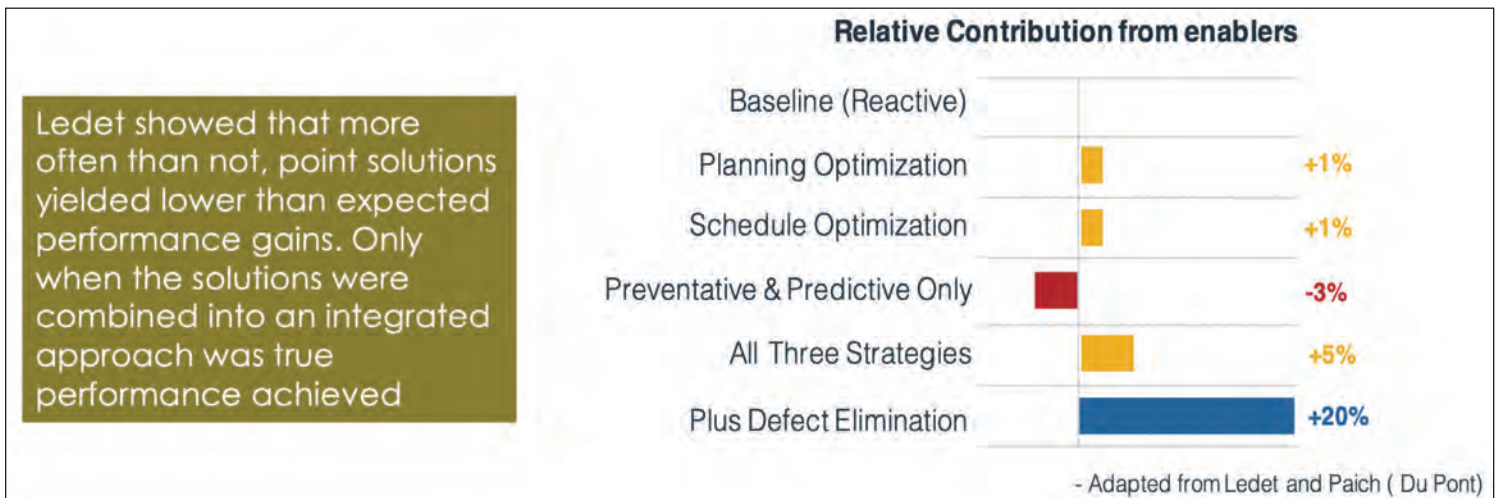


Figure 4: The relative contribution from enablers according to Ledet

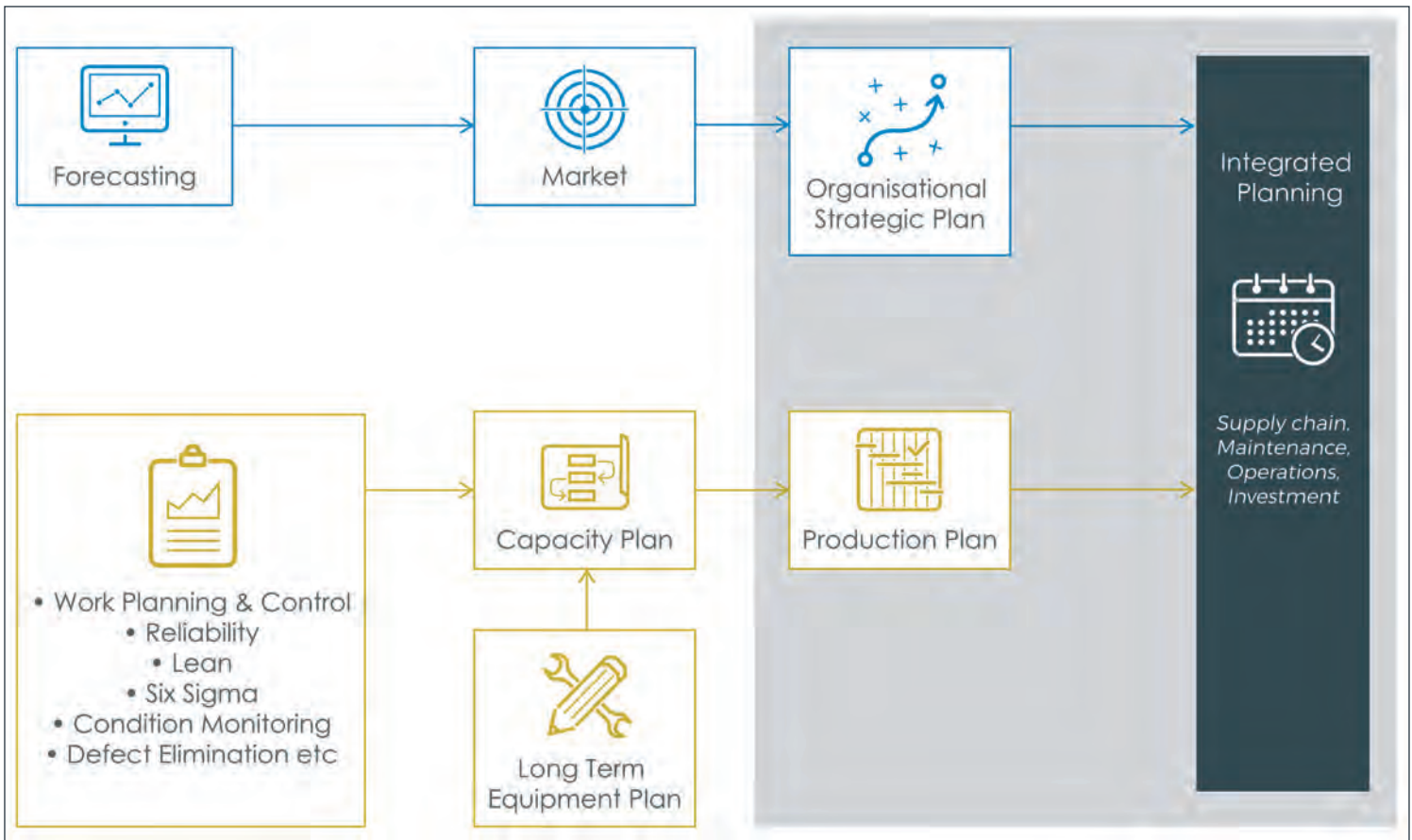


Figure 5: The role of integrated planning in asset management

all. Likewise, when an organization establishes an asset management system, the organizational maturity, situation and ambition must be reflected in the solution implemented. As any of them change, the inherent processes and systems must support complex decision-making and adjustments.

**Maintenance Reliability Tool Kit: Selecting the Right Improvement Tools**

In the book, *What Tool? When? A Management Guide for Selecting the Right Improvement Tools*, author Ron Moore concisely describes the maintenance management/reliability engineering toolbox. Each of the 15 chapters in the book describes a tool that has an effective application in the appropriate circumstance. Some are technical, such as reliability-centered maintenance (RCM), Six Sigma and kaizen. There are also organizational elements, such as lean and total productive maintenance (TPM).

This tool kit would be incomplete without mentioning the condition monitoring/predictive maintenance tools, which are often key to any effective maintenance management strategy.

A core knowledge element in the application of the maintenance reliability tool kit comes from Winston P. Ledet’s work at DuPont, where he modeled the influence of a number of maintenance reliability enablers. He clearly demonstrated that the value was to apply a tightly integrated approach, where single point solutions applied in isolation have limited and, in some cases, a negative contribution.

**Integrated Planning: Realizing the Value from Seeing the Big Picture**

One of the transitions an asset manager has to make is to be able to see the big picture and ensure there is an integrated way of thinking that supports the realization of all the business functions working together. Strategic planning needs

to cross traditional organizational boundaries, which is a formidable challenge. However, the value contribution from such a joined approach can be a strategic differentiator, with dimensions larger than the contribution of a number of independent, individual initiatives.

Looking back at Michael E. Porter’s (see Reference #2) value chain, one can see that a business is only as good as the elements that are aligned and working together. In a company’s haste to create organizational structures to support business delivery, it often creates functional silos. Although these silos are often well managed and, in some cases, optimized, the impact of them on the other functional silos is lost. Effective asset management can only occur when the functional silos are aligned and integrated.

Integrated planning is more than just planning. It ensures that all costs, benefits, risks and opportunities are examined and understood. Often, value only can be created when all functions and departments understand their role in the value chain and are fully aligned. In the effective asset management delivery model, there are no departmental boundaries since it is fully understood how to ensure alignment of the business.

It is very important when aligning business functions and departments to deliver value that the correct level of accountability and responsibility is established.

“...A business is only as good as the elements that are aligned and working together”



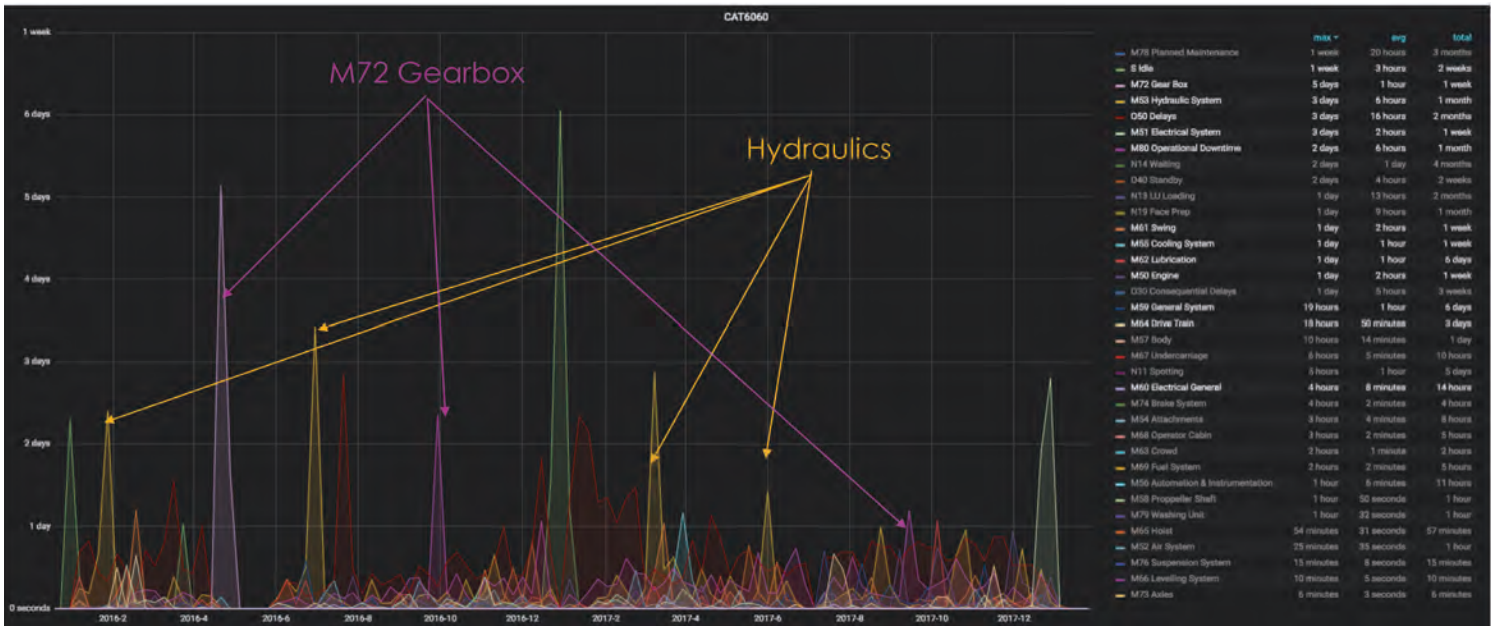


Figure 6: Resolving a large data set into the time domain

### Data: Realizing the Value of Data Analytics

Big data, digitization and the promise of a new future with interconnectivity between machines are hot topics. However, when one digs around, there are few real use cases in the asset management world. It is not because the prem-

ise is not real, but rather the existence of several clear barriers to transform the concept and create tangible value.

These barriers include, but are not limited to:

1. The perception that incomplete data or data with potential errors/inaccuracies has no value;
2. The challenge of integrating and matching different data sets, probably in different data formats; For example, combining technical, performance and financial data, which reside in multiple systems;
3. The lack of skills to work with big data;
4. A poor conceptualization of what to do with the data and where value realization lies;

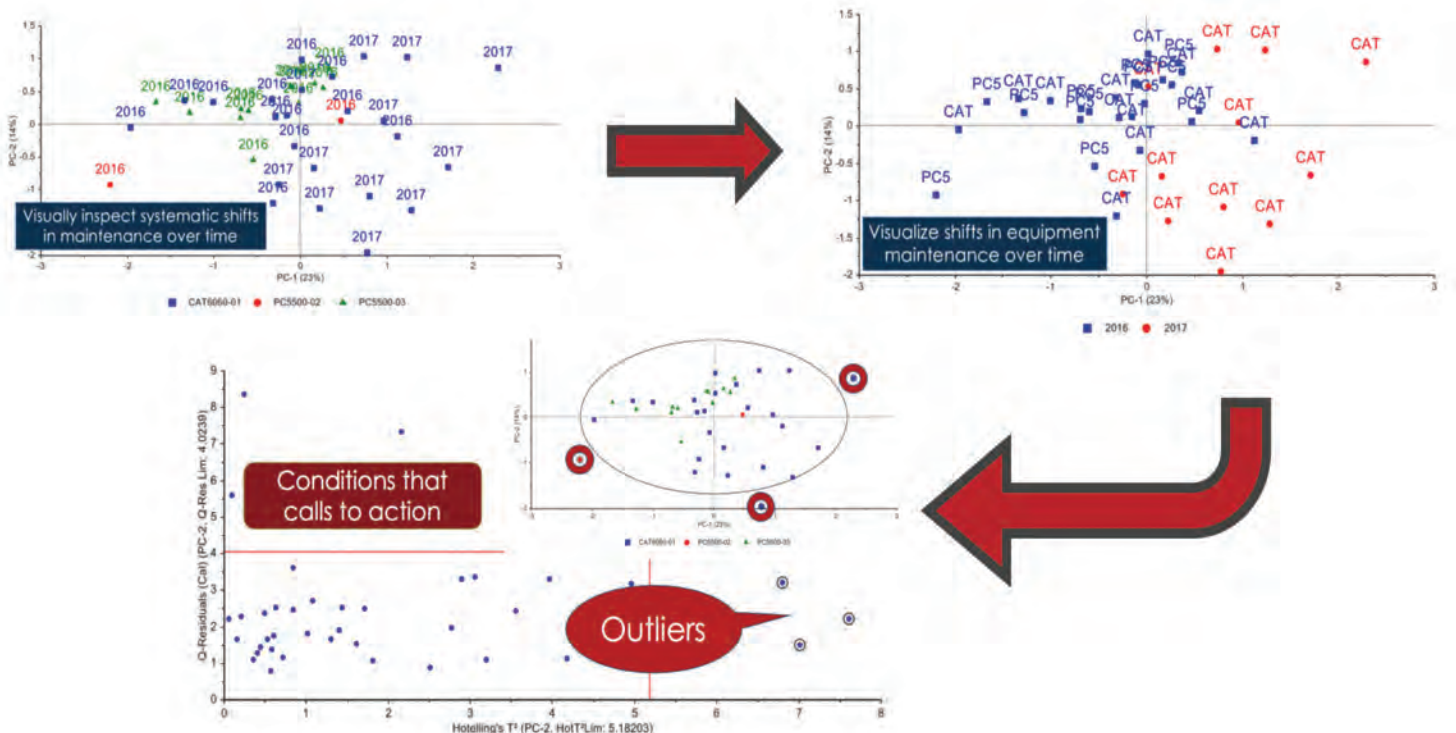


Figure 7: Illustrating supervised machine learning example from asset management big data

5. Poor management of the data to the information, action and knowledge management process.

Foundational to working with big data in asset management is finding the common basis. In most cases, data is time stamped, so consequently, looking for variations, transitions and anomalies is done in the time domain. A typical time domain set of data is illustrated in Figure 6, which is an amalgamation from a series of data sets consolidated to facilitate a time series analysis.

Using big data tools, like principle component analysis or multivariate analysis, one is able to create new elements of knowledge and insight. Ultimately, the development of artificial intelligence and machine learning will enable these advanced analysis techniques to be incorporated into the day-to-day decision-making tools and dashboards available to managers.

Many organizations are feeling their way into the world of big data and have a naive approach, hoping to stumble into new actionable insights.

Effective asset management is a whole business activity that creates strategic alignment and tangible value. One of the most important issues is to be able to make informed decisions on available information and data. This is dealt with in barrier #3, but also falls into the arena of data analytics and has all the attributes that make creating the data value paradigm so important for asset management.

## Going Forward

Asset management professionals must always remember that business and life are linear. As you grow in the field of asset management, your understanding of the operating context changes and develops. The asset management system (ISO55001) that you establish in your organization must be an ever-developing one. One size does not fit all, even within the same organization.

The mission of asset management professionals is to ensure that whatever systems, tools, or processes they establish, they must realize tangible value from them while delivering on business objectives. There isn't a single way of doing it, so doing something is better than doing nothing!

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**Grahame Fogel** is the founder of Gaussian Engineering. He is an experienced International Consultant in the field of asset management. He is a recognized subject matter expert in the fields of strategic asset management, reliability engineering, condition monitoring and change management within the asset intensive industries. [www.gauseng.com](http://www.gauseng.com)



**Dean Griffin** is a thought leader in the area of asset management and contributes significantly in understanding the business effects of asset management. He is Chairman of the South Africa Mirror Committee for TC251 and has contributed significantly to the ISO55000 standard. Dean is a Director of Gaussian Engineering. [www.gauseng.com](http://www.gauseng.com)



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# OPERATIONAL **MACHINE LEARNING** GOES MAINSTREAM

Sanket Amberkar ● 

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# In the next five years, analysts predict the adoption of machine learning and predictive analytics by manufacturers will increase from 15 percent to over 50 percent

The market for machine learning is exploding as companies from every sector begin to recognize the power this new technology offers. One area that continues to see significant traction is in the industrial operations space, where operational machine learning has emerged as a new category of artificial intelligence (AI) that has gained growing adoption across all industries.

This technology enables operations teams to create significant business value by using machine learning and predictive analytics themselves, without the need for data scientists. The infographic in Figure 1 provides an overview of operational machine learning and how it is improving production throughput, uptime, quality and safety across multiple industries and applications.

In the next five years, analysts predict the adoption of machine learning and predictive analytics by manufacturers will increase from 15 percent to over 50 percent. The driving factor behind this is that the technology is no longer limited to data scientists. Companies have developed machine learning systems that are effectively a “data scientist-in-a-box,” which means the systems can be easily used and deployed directly by manufacturing engineers or process engineers, either in the cloud or on premises.

Using operational machine learning, companies can achieve initial results in less than three weeks and deliver five to 10 percent material costs savings, 10 to 20 percent increase in equipment uptime and availability, 20 to 50 percent reduction in maintenance planning time, and five to 10 percent reduction in overall maintenance costs. These gains represent significant savings in the order of millions of dollars annually for an organization.

## Leverages Data Already Available

Another reason machine learning in industrial operations has become so popular is that it leverages time series data already generated by equipment and production systems in most discrete manufacturing and industrial process operations today. This data historically has been unutilized in operations, but machine learning can help industrial manufacturers discover hidden patterns in the data that cannot be observed by humans or traditional analytics. These patterns, in turn, provide insight on the operating state and

identify conditions that precede undesired events to provide an early warning. Depending on the process being monitored, such early warnings may occur hours, days, or even weeks in advance, and can save several millions of dollars annually in operating costs.

## How It Works

Four key capabilities in a machine learning system make it easy for industry practitioners to begin reaping its benefits:

- **Automated Feature Learning** - The system discovers patterns in time series data. Once the patterns have been discovered in the data, machine learning can be applied.
- **Prediction** - You can select a pattern that appears consistently prior to the event and label that as a precursor. Based on the use case, the precursor can provide an early warning or prediction that ranges from several hours to several days ahead of the event occurring.
- **Explanation** - You can determine which of the provided data signals are actually required to make the prediction, as well as how much each signal contributed to that result.
- **Flexible Deployment** - In addition to running models on premises or in the Cloud, you can also deploy them at the edge. This can support low latency applications or disconnected environments that require being close to the data source.

Pattern discovery plays a critical role, particularly for assets, in identifying patterns prior to degradation occurring. This is crucial as it moves asset management from reactionary (i.e., degradation has occurred and you attempt to minimize its impact) to proactive (i.e., you prevent it from occurring).

By identifying patterns that are precursors to undesired events or operating conditions, these predictive systems can provide actionable insights on the current and future health of the production systems and the products they create. With this in place, an operational machine learning system can perform pattern discovery, condition monitoring and predictive analytics in real time on existing operational data.

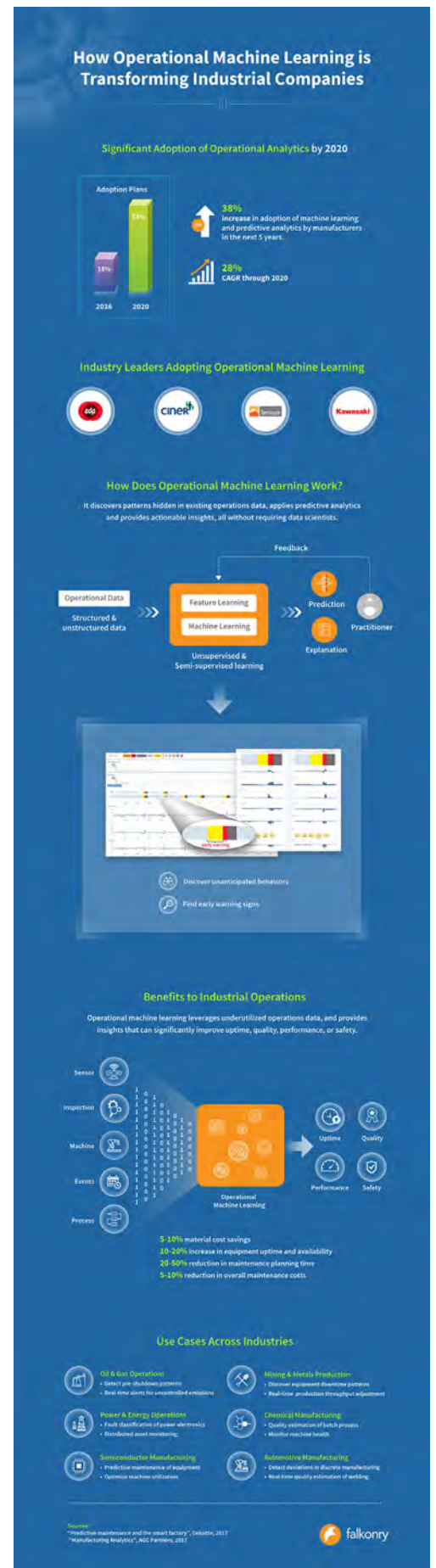


Figure 1: Operational machine learning overview



**Figure 2:** Machine learning enables pattern discovery and early warning

### Spanning Many Industries – Example Use Cases

Since operational machine learning discovers patterns in available time series data, it does not require developing mathematical models of a physical system or organizations having deep domain expertise in a particular industry. As a result, it is highly versatile and can be applied across industries, such as automotive, chemical, electronics and semiconductor, mining and metals, oil and gas, and power and energy. To illustrate the power of this technology, here are some sample use cases in both the semiconductor and automotive manufacturing industries.

- **Semiconductor:** A major semiconductor manufacturer operates complex, expensive equipment that executes many different types of step-based operations daily. Optimizing utilization through predictive maintenance is a high priority. The machines are instrumented to collect operational data every second in the form of sensor readings, control parameters and other settings. Use and benefits of this data proved ineffective in predicting faults to operators. The manufacturer decided to deploy a machine learning system, which was quickly integrated into its operational data store containing trace data, quality measures, and inspector and operator

“With the emergence of operational machine learning, the next industrial revolution is here”

log information. A four-month history of data created a model identifying multiple, abnormal conditions known to create maintenance indicators, thus creating alerts in the system. The availability of advanced warnings provided by the assessment stream enabled early intervention by the maintenance team and resulted in an improvement in uptime and overall equipment effectiveness (OEE).

- **Automotive:** A leading automotive manufacturer needed to assess its welding quality in real time. The quality of its machine welds would vary over time, resulting in expensive manual rework of over \$14,000 per machine, per day. Using a machine learning system, the company was able to discover patterns that precede quality variation in robotics welds and provide advanced alerts. This helped to significantly reduce downstream rework and material losses.

### The Future

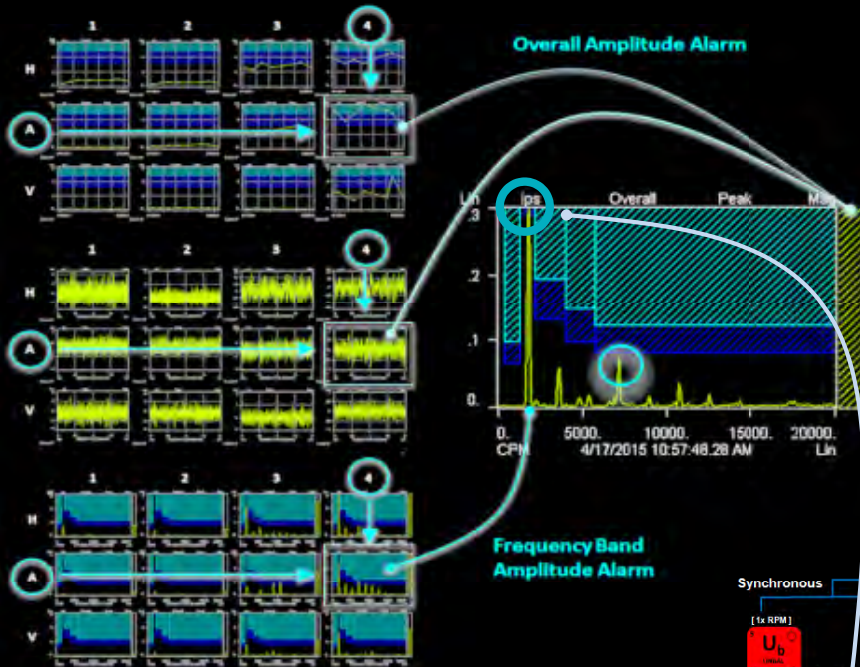
With the emergence of operational machine learning, the next industrial revolution is here. Whether you call it Industry 4.0, industrial Internet of Things (IIoT), or digital transformation, the increased access to machine and operational data, proliferation of two-way communications and speed of data flow, combined with the lower cost of computing, connectivity and storage, has created the perfect environment to transform industrial operations. The time series data generated by these operations, when harnessed effectively, can provide actionable insights to reduce downtime, as well as improve throughput, operator safety and product quality.

There is no better time for industrial operations teams to start harnessing the power of these systems now that specialized resources, such as data scientists, are no longer required to implement them.

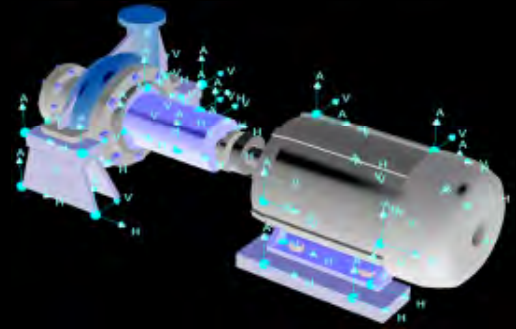


**Sanket Amberkar** is SVP of Marketing & Partnerships at Falconry, Inc. Sanket has over 20 years of experience in the high tech, energy, industrial and automotive markets in areas ranging from product development to market strategy. [www.falconry.com](http://www.falconry.com)

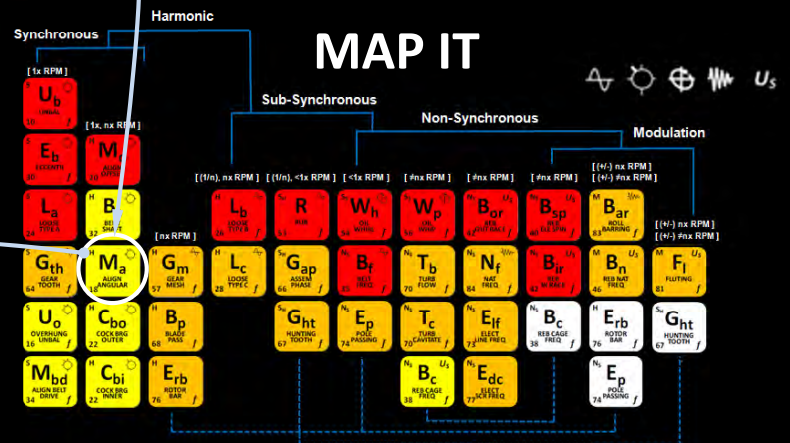
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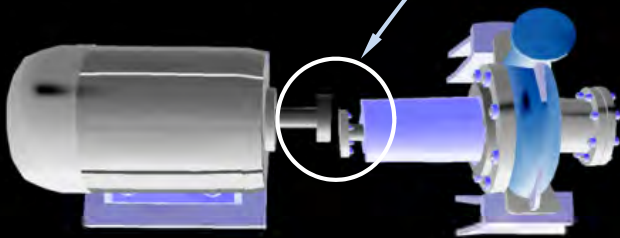
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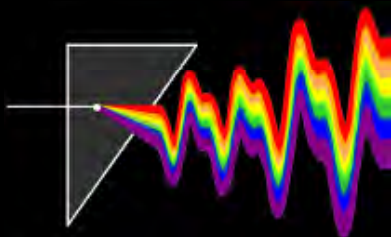
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# GETTING “SMART”

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# PREDICTIVE SOLUTIONS

Anatolii Rybalov, Denis Lisin and Victor Melnikov

**T**he modern transformation of the logistics outlook increasingly changes the world and sets new tasks in the development of information technologies for production management and infrastructure operation. This calls for the development of digital and intellectual technologies for the day-to-day management of capital- and resource-intensive enterprises: railway and automobile transportation, automobile construction and locomotive construction, depot, and maintenance shops.

A huge amount of data, generated by industrial units, has already been accumulated. Thus, it is possible to apply highly effective predictive tools

to rapidly and qualitatively evaluate the condition of operating units, detect the origin and development of abnormalities and identify trends that lead to unscheduled disruptions and failures, by registering the failure probability and remaining service life in real time.

The idea of accurately predicting the technical and qualitative condition originated from the need of resource- and capital-intensive companies to reduce the fast-growing expenses of owning equipment, advertising services and increasing competitiveness.

A big boost has been given to the development of intellectual railway systems by modern tools, such as hybrid models, explainable AI, Indus-

trial Internet of Things, big data, cloud computing and machine learning. These technologies enable optimization of transportation resources, thereby enhancing transportation efficiency.<sup>1,2</sup>

## **Range of Problems – Locomotives, Wheeled and Air Transport**

In the elevated uncertainty conditions, a travel supplier is forced to keep nonproduction reserves of haulage resources against the possibility of unpredictable growth of the transportation load.

For example, for a Russian railway company, excessive off-road time for scheduled repairs, as

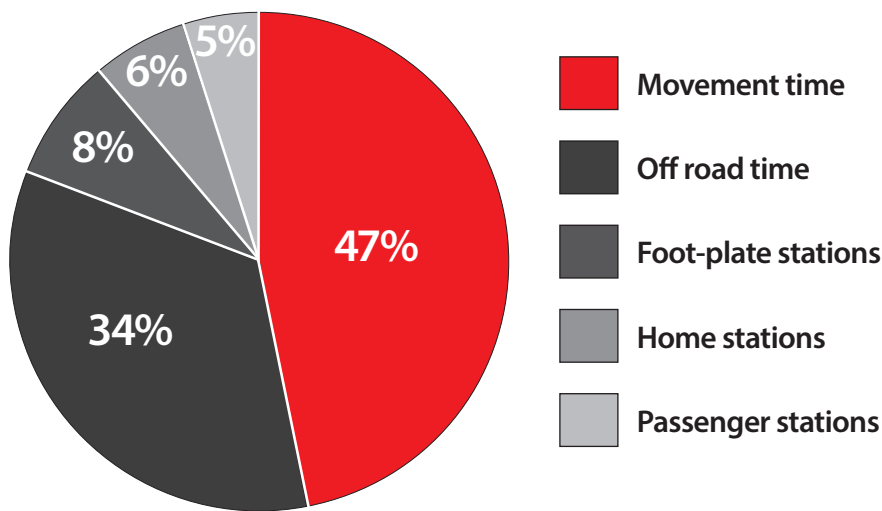


Figure 1: Statistical locomotive time budget, 2016

well as running repairs and waiting for free repair facilities, led to the necessity to take out of service over 1,000 locomotives a day.<sup>3</sup> It has been established empirically that a necessity exists in a locomotive that is ready for service 90 percent of its lifetime during the whole lifecycle.

### Electric Trains

When failures of commuter electric trains occur and upset train time schedules, they dramatically reduce the service level. A breakdown of a single train upsets time schedules of other trains. A seamless movement is dependent on the technical condition of each train.

The basic risk is an episodic falling of railroad cars out of traction. This occurs when a railroad car is disengaged from the traction of the train for some reason (e.g., breakdown, protection systems), but traction is continued by the remaining power railroad cars. This undermines the operation of traction units of all power railroad cars. Predictive analytics make it possible to provide the respective information in advance, before a power railroad car stops to be engaged in the traction.

For example, under normal operating conditions, railway electric motors should equally contribute to the total traction of the electric train. Consequently, considerable variations of energy consumption parameters of individual railroad cars will indicate a malfunction in systems of that railroad car.

In Saudi Arabia, the situation of a train failure amid a desert is of great risk. In such cases, labor inputs and the duration of repair work increase. Subhuman conditions for the passengers are created, who are forced to stay in a frosty railway car for a long time. Prediction and prevention of such breakdowns are critical in such conditions.

### Modeling and Condition-Based Maintenance

Mathematical modeling of complex production facilities is fragmentary in nature because of:

- A lack of high quality, telemetric data from equipment;
- A lack of calculation methods and idealized mathematical models for complex systems;
- Insufficient modeling of individual units;
- A lack of academic privileges in three fields: MRO, mathematics and IT.

Despite more and more scientific articles published over the last few months where scientists are able to combine mathematical modeling methods with machine learning, most of these articles are oriented toward situations that have either a sufficient theoretical development of parts of the modeled system or a sufficient volume of high quality data. The experience shows that such “hothouse” conditions are extremely rare in the world.

### Solution to the Problem

An early detection of emerging defects and failures during operation makes it possible to diagnose problems before they turn into accidents. For example, if a deviation is recorded even before a parameter comes to the pre-alarm level, then a possibility exists of localizing the defect quickly, planning the logistics of spare parts and other resources, and carrying out a scheduled repair.

Predictive analytical solutions collect information from sensors in real time and use it together with the historical data, visual inspection, manual measurement data, video records, equipment functioning data and other useful data.

To solve the aforementioned complexities, one needs to use up-to-date methods for build-

ing prediction systems, knowledge bases and expert systems. As a result, a complex of hybrid systems has appeared that holistically describe the behavior of complex systems, both technical and technological.

### Smart Locomotive – Implementation Example

Since 2017, a locomotive technology company in Russia has been working on a “smart locomotive” project with Russia’s state-owned railway company, which manages infrastructure and operates freight and passenger train services. The rail company maintains and repairs about 70 percent of the entire Russian locomotives and has 92 depots and 10 repair factories.

A system for intellectual diagnostics and technical condition prediction of locomotive equipment has been developed. The failure search module has been implemented on 4,000 locomotive sections. Now, it is possible to identify over 50 types of equipment disturbances and monitor over 20 types of various equipment: traction generator, traction electric motor, fuel and oil pumps, water cooler, turbine compressor, dynamic brake, etc. The system is integrated into the company’s enterprise resource planning (ERP) system. A workshop order is automatically issued to carry out repair work based on detected faulty operation data. This makes it possible to calculate required repair resources and prematurely update the locomotive-to-depot schedule for both planned and unplanned maintenance.

To date, the results show:

- Enhanced reliability and safety of locomotives running on lines: Failures on the line are reduced by 32 percent.
- Improved operational efficiency of the process: Locomotive diagnostic time is reduced from four hours to 10 minutes because the diagnostician gets all the failure incident data before the locomotive enters the depot.
- Increased economic efficiency of the process: The amount of fines imposed on the locomotive technology company by the railway company for failing to provide the technical availability coefficient dropped by more than 20 percent.

The smart locomotive system identifies impending equipment failures weeks or months be-

**An early detection of emerging defects and failures during operation makes it possible to diagnose problems before they turn into accidents**

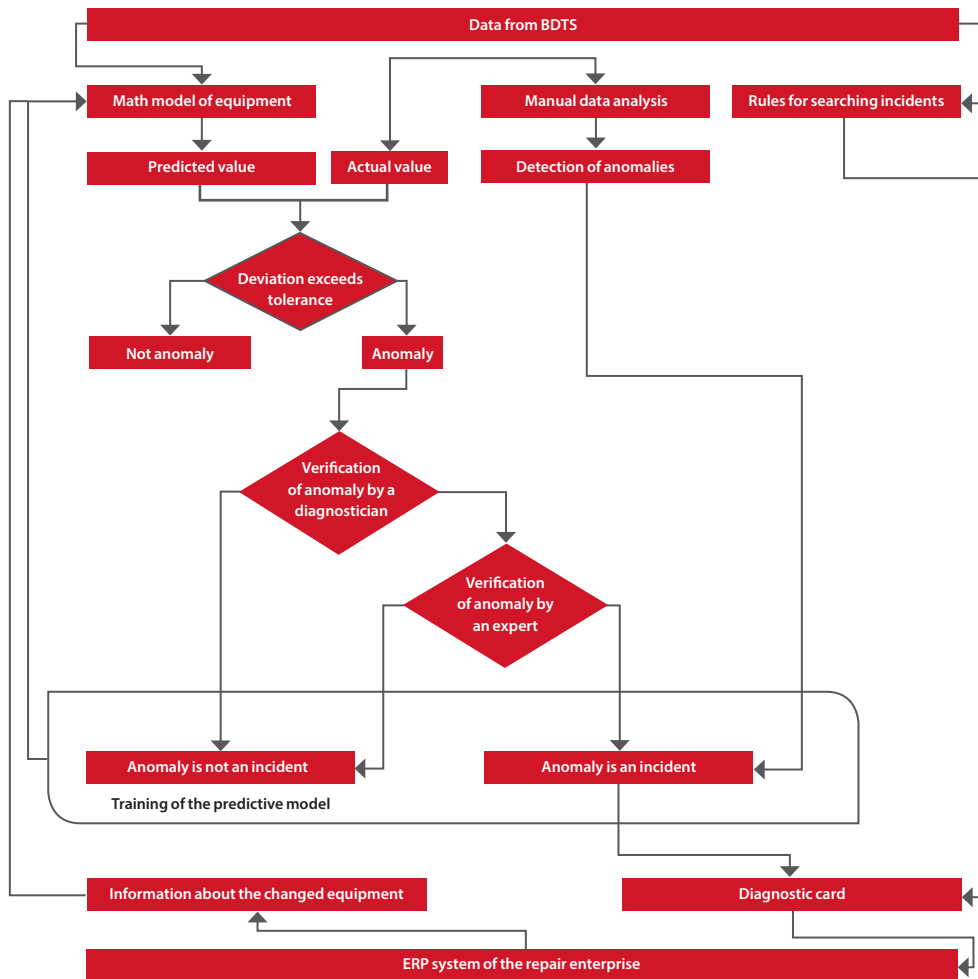


Figure 2: Algorithm of a “Smart Locomotive”

fore they happen. This valuable information gives the railway the opportunity to transform maintenance into a condition-based process.

The solution uses telemetry data from an onboard data transmission system (referred to as BDTS), a diagnostics system and an ERP system. In addition, it uses information about external factors, such as weather, violation of operating modes, etc., to make predictions more precise.

The diagnostics system detects anomalies, as well as operators’ incorrect actions, by means of a mathematical model and then sends them to the ERP system. An anomaly is a situation where any important equipment parameter value differs from the normal one predicted for current operating mode. All the anomalies detected in a server are verified through workstations.

The system also trains the models using feedback data from the ERP system, based on information about performed work and components replaced in the process of repair operations.

Comparing the rate of change in absolute and relative parameter values makes it possible

to determine the equipment degradation rate. Therefore, the diagnostician receives all necessary information about the condition of the railway rolling stock system at least 100 hours before the locomotive enters the depot.

### Conclusion

Predictive solutions help suppliers build more productive mutual relations with the users, thanks to receiving efficient information for making decisions. Such products enable suppliers to predict the lifecycle of their equipment and help the users understand the condition of their equipment and control performance of guarantee obligations. The understanding of the full picture helps the parties conclude correct contracts and find the most efficient interactive ways. For example, a major truck manufacturer in Russia, having placed stake on the predictive analytics development and introduction thrust, totally rebuilt its business models. The company has begun moving from the supply of transportation facilities to the

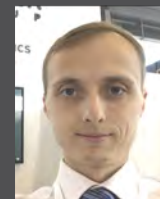
sale of operational kilometers or cargo tonnage haulage up to the conclusion of lifecycle contracts.

The practical use of such hybrid models enables a considerable reduction in fleet maintenance and minimizes the number of unscheduled repairs, thereby improving the operational reliability of the MRO system.

Such a system combines in itself a functionality for integration of data, analytics and supporting tools for decision-making. It all has been developed as a unified, adjusted software product that can be easily used in most of IT structures.

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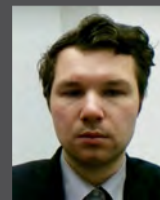
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**Anatolii Rybalov** is Product Analyst at Clover Group. As a leading company in innovative products based on a combination of science and technologies in the areas of machine learning, big data and AI, Anatolii’s role is as the developer of solutions for intelligent analytics and predictive analysis for asset-intensive companies. [www.clover.global](http://www.clover.global)



**Denis Lisin** is the Executive Director and Co-founder of Clover Group. Denis is a STEM manager, asset performance and reliability evangelist, and MRO processes expert with extensive experience in advanced analytics of big data. [www.clover.global](http://www.clover.global)



**Victor Melnikov**, Industrial Expert at Clover Group, is the assistant of the “EMU & Locomotives” department of Russian Transport University (MIIT). Victor is the developer of solutions for locomotive diagnostics according to data from onboard microprocessor systems, solutions for improving locomotive control algorithms and assessing the impact of violations of operation modes on the reliability of locomotives. [www.clover.global](http://www.clover.global)

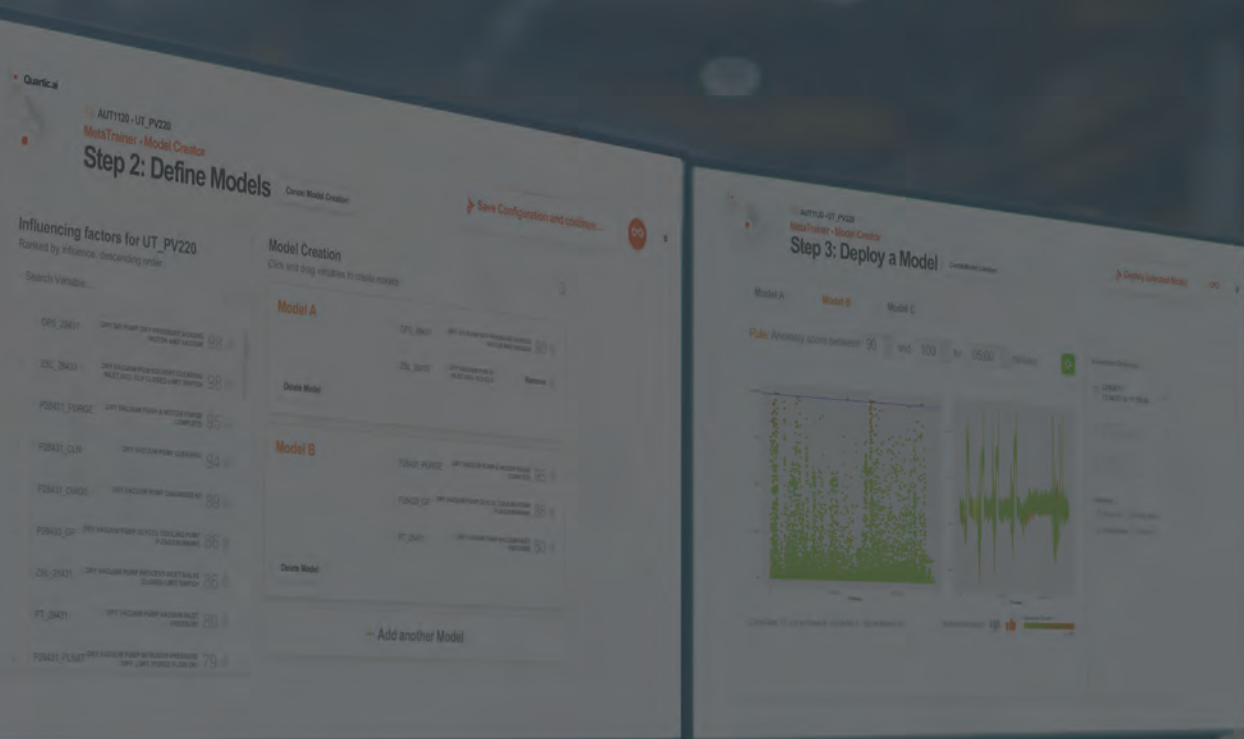


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THE RELIABILITY  
CULTURE:

**SIX**

**COMMON CULPRITS**



A reliability program is only as strong as the reliability culture. There are six common culprits that can rob a reliability program by creating a disengaged and adverse workforce. Employees do not start out this way, but become so as a reaction to these six offenders. Thankfully, once they are identified, corrective actions can be taken to positively reengage the workforce.

“Everyone in the organization should know the mission, vision and goals of their branch and how it relates to the overall enterprise”

## CULPRIT #1:

### Craft Employees' Input Is Unheeded

Maintainers and operators likely know the equipment better than anyone at the plant. Yet, when they have suggestions, they notice when nothing is done with their ideas. For example, one technician stopped annotating his preventive maintenance work orders with any notes or suggestions. His response as to why will change your way of thinking about reliability: “When I first started my career, I used to add notes and reline work orders for any errors. These work orders would come back again and again with none of the changes I suggested. After doing that for a few years, I just stopped doing it.” Another tradesperson recalled his boss telling him his job was to do and not to think! It's no wonder a recent Gallup poll found that less than a third of employees are engaged with their work. When the workforce observes their input is not valued, they begin to disengage. Additionally, ignored feedback begins to feel like unwelcome feedback, thus justifying a culture of disengagement.

If your organization honors and respects craft employees' suggestions, are the employees who make them given any feedback or credit for those suggestions? If not, why not? Many organizations fail to give feedback simply because there is no protocol to ensure meaningful feedback is provided. Leaders must focus on what messages are being sent to craft employees based on their words and actions.

## CULPRIT #2:

### Reactive Work Is Predominant and Rewarded

Many organizations like to celebrate and reward employees who work extra hours and do a great job bringing the plant back into operation after a breakdown. Yes, these folks should be rewarded, however, when do you hear of a celebration because the plant was more reliable and nothing broke down? Imagine a scenario where you do not proactively look at the wear on your automobile tires. Instead, you celebrate because you had a flat and were able to change to a spare in record time. Sounds a little backward, doesn't it? A celebration would be more appropriate if you did not have a flat at all. But, how do you celebrate when nothing happens? Using reliability metrics, such as mean time to repair (MTTR), mean time between failures (MTBF) and ratio of proactive to reactive maintenance are some of the ways you can celebrate when these metrics show improving trends.

## CULPRIT #3:

### Fake Metrics

When using metrics, you have to be honest with yourself. Many organizations tout their preventive maintenance (PM) completion rates as being close to 100 percent. But when you look closer, they either cancel PMs to make the metrics look good or schedule so few PMs that 100 percent completion is meaningless. If you include integrity as part of the reliability culture (and you should), the message you send when you fake your metrics is that fudging or even lying is acceptable as long as the numbers look good.

Another issue with metrics is not setting a challenging goal. When you set the bar too low, the message is that the status quo is fine, when in reality, it is not. Authentic metrics are motivational to the organizational culture and provide a source of pride when they are trending in the right direction. Their meanings and trends should regularly be communicated to your technicians. Metrics are supposed to drive behavior. If no one sees the metrics or understands the meaning of them, how are they going to help drive a change in culture?

## CULPRIT #4:

### Lack of Clear Procedures and Overreliance on Tribal Knowledge

Many PM job plans lack details about the work. For example, a job plan may say, “inspect pump on a monthly basis.” But, what does that mean? To one individual, it may mean closely check for leakage, proper operation, listen for bearing noise, and more. To another, it may mean walk by and make sure it is still there. That may be an exaggeration, but the point here is that unclear job plans lead to inconsistent inspections. Some might argue that the craftspeople are experts and know what they need to do. This is what is known as tribal knowledge. However, if details are not captured in job plans and procedures, what happens when the “tribe” retires? Additionally, if enough details are not provided, PM performance becomes inconsistent. If failures were to occur, how would you know if the inspection was actually performed or if anything was missed?



## CULPRIT #5:

### Mission, Vision and Goals Are Not Disseminated or Understood

Most organizations have high-level mission, vision and goal statements; yet often, these statements are not translated to the branch level. Knowing how each branch can promote and effectively help the enterprise's mission is critical to having a good reliability culture. Maintenance technicians should be able to answer the question on how their work contributes to the corporate mission. This promotes a unifying message that can be used to keep work on track and accomplish steady improvements. Everyone in the organization should know the mission, vision and goals of their branch and how it relates to the overall enterprise.

## CULPRIT #6:

### Bad Housekeeping Is Tolerated

Housekeeping is highly indicative of the success of reliability programs and, for that matter, the safety culture. Within minutes of walking into a plant, a reliability professional can get a sense of whether the culture is engaged or not. Too often, management accepts bad housekeeping because the technicians are too busy to clean up. If management accepts this, it sends a debilitating negative message to their team. Think about the time it takes to find tools or parts when areas are not organized. Organized and clean areas save time and reduce the potential for injury. In fact, if a manager wants to pick one area to improve, housekeeping sends the quickest and best message that a culture change is about to happen.

## AWARENESS IS KEY

To change the reliability culture, you must be aware of how a bad culture is created. One way to do this is to identify whether any of these six culprits, or any others, are going on at your plant. Once becoming more aware of these behaviors, new strategies can be created to turn around the performance and exemplify a new cultural direction.



*Nick Jize is a reliability centered maintenance (RCM) consultant and team motivator. During the past 22 years, Nick has worked directly in the field of maintenance and facilities management while performing numerous RCM analyses and applying the findings to optimize maintenance solutions and innovative software to enhance the RCM process. [www.jmsoft.com](http://www.jmsoft.com)*

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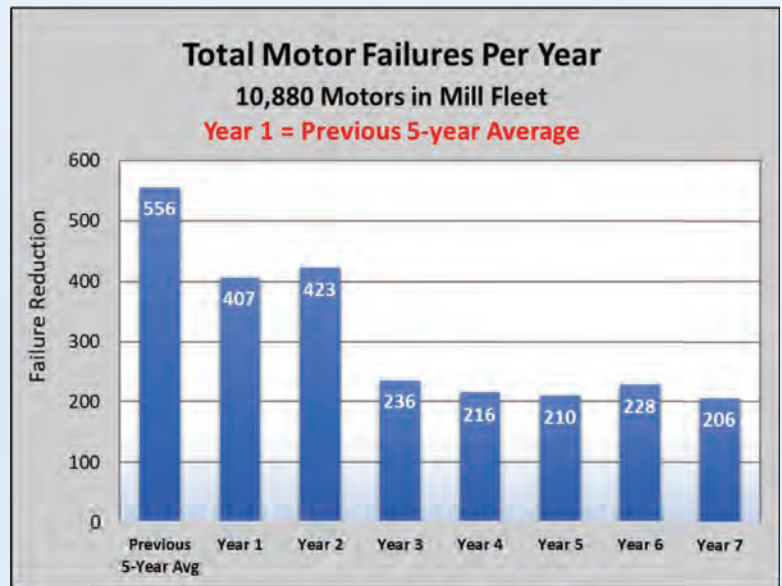
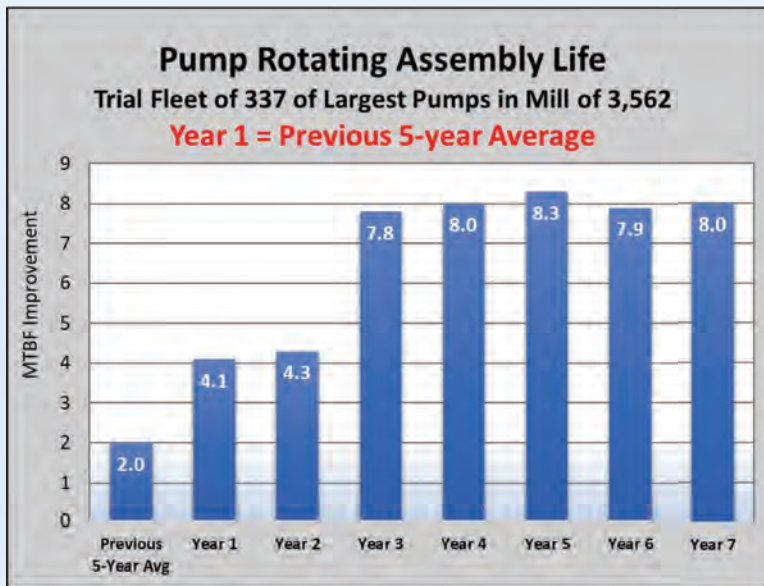
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To ensure that a plant with a 60 year history continues to meet the standards for quality and operational excellence, the company had to change its views on lubrication, as lubrication-related equipment failures were plaguing the mill. The reliability team began implementing multiple lubrication excellence programs, which have resulted in improved uptime, cost savings and safer conditions. To begin the process, the reliability team utilized industry experts to conduct a plant study and identify opportunities for improvement.

### Inventory and Storage

The first course of action was to inventory what was in the plant. For one week, the facility held a rapid improvement event (RIE) and performed a lube scavenger hunt. Some of the findings, shown in Figure 1, included oils and greases stored everywhere and in all kinds of containers! As Figure 2 shows, the mill was using milk cartons as dispensing containers. The plant discarded 1,200 gallons of waste oil, 1,200 pounds of grease and 45 empty barrels, totes and kegs, and freed up 10,000 square feet of storage space. The effort also included compiling a list of lubricants needed, discarding what wasn't needed and organizing lubricants into a central storage area.

The reliability team and industry experts saw a significant opportunity to improve storage and handling practices. The major challenge was the large assortment of suppliers and lubricants in totes, which resulted in excessive inventory levels. In the end, the plant moved from 50 different oils and greases and 10 vendors down to 19 lubricants and two suppliers.



Figure 1: Initial state of area with several various containers holding oils



Figure 2: Milk cartons and other containers



Figure 3: New lube room



Figure 4: New lube room

### Climate Control

In addition to organizing lubricants and improving inventory management, the development of a new lube room allows the facility to control its storage climate. Before, it stored some bulk lubricants outdoors in a covered area, which exposes these lubricants to moisture, debris and a broad range of temperatures throughout a central Indiana year. Small amounts of moisture and debris travel with the lubricant to machinery and is destructive in a lubrication system. To combat this, the plant implemented sealable refillable containers, bulk storage with filtration and filter carts to top-up lubricant reservoirs. In addition, to ensure the integrity of lubricants moving forward, a standard for filtration was set and aligned with ISO cleanliness codes on bulk storage.

### Fork Truck Shop

Incorporated into the lube room is the fork truck shop. Filtered lubricants for engine oil changes, transmission oil changes, differentials and hydraulic system top-ups are piped to the truck shop through hose reels. This new routing eliminates the need for a mechanic to push barrels around or handle sealable refillable containers around the shop, which reduces the risk of injury.

“As part of the lubrication excellence program, efforts to reduce leaks resulted in a 75 percent decrease in one year”

### Reducing Leaks

Hydraulic oils that leak into rolling oils in a cold rolling aluminum facility can cause significant problems. They can slow down running speed, impact metal quality and result in a costly coolant cleaning process. excellence program, efforts to reduce leaks resulted in a 75 percent decrease in one year. The primary action? A culture change – the reliability team helped all employees understand that leaks were no longer acceptable. Employees were encouraged to speak up when they saw a leak and a plan to address the leak was identified as soon as possible, either through unplanned work or through a planned outage.

### Hydraulic Oil Management

In addition to reducing hydraulic oil leaks, the reliability team also developed a plan to maximize overall service life. Hydraulic oil service life increased by keeping it clean, cool and dry.

Housing the oils in the lube room was the first step. From there, the plant implemented operational checks of the hydraulic systems to alert the team when a filter required changing. Operational checks also alert the team when temperatures rise too high, which cause higher rates of oxidation and break down the oil.


New air cooled heat exchangers were installed to eliminate the possibility of water entering hydraulic systems. These air cooled systems are more efficient at maintaining proper oil temperatures because the facility's water would foul the heat exchangers quickly. Desiccant breathers installed on the reservoirs also help to keep moisture out on days when the weather is hot and muggy.

The improvements in hydraulic oil service life resulted in significant cost reductions for hydraulic parts, like pumps, cylinders, valves, seal kits, etc. From 2015 to 2017, Novelis Terre Haute reduced these costs 65 percent.

### Lubrication Task Management

Along with these changes to equipment and the storage process, the team conducted a lube point audit to build a lube point list. From the lube point list, it implemented a lubrication task routing tool to ensure that the plant's lube technician had accountability for all lube points on a regular basis.

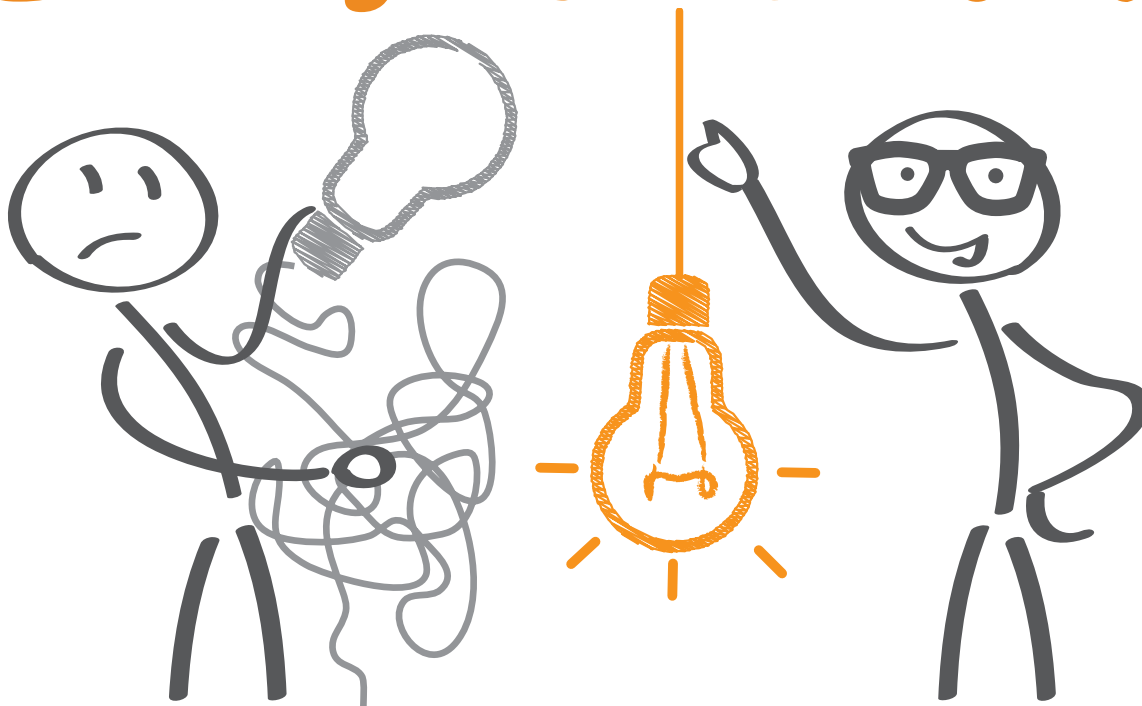
The program catalogs each lubrication point with a schedule, specific lubrication and the practices necessary for the task. This program allows the team to fine-tune the schedule using calculations that identify the proper amount and timing for grease applications. This ensures effective and efficient equipment lubrication. In fact, the plant saved significant costs in oil and grease expenses after implementing the program. The plant team continues to focus on lubrication excellence, driving towards reduced unplanned downtime and long-term operational excellence.



**Sam Deters** is the EMRA Leader at Novelis Terre Haute, where he has worked since 2007. He is a Certified Maintenance and Reliability Professional responsible for the optimization of equipment utilization and efficiency. Sam holds bachelor's and master's degrees from Rose-Hulman Institute of Technology. [www.novelis.com](http://www.novelis.com)

Prakash Shende

# MECHANICAL INTEGRITY SIMPLIFIED



It's horrific to read about fires in refineries. Granted, process safety management (PSM) principles, with a greater emphasis on mechanical integrity (MI), have been embraced across the globe, greatly reducing the number of incidents. However, citations remain high, with the U.S. having the highest number of them. What's the problem? A consistent implementation and application of MI. This article attempts to simplify the MI program, with the hope that organizations can achieve 100 percent mastery in avoiding incidents.

It's puzzling how refineries work for years without incident and then suddenly, a news report of an explosion or fire. Whether it's in the U.S., China, Russia, Europe, or other South Pacific countries, the scenario appears to be the same. The latest one occurred on April 26, 2018, when a series of fires and explosions rocked the Husky Superior Refinery in Wisconsin. According to reports, at least 15 people were injured.

## A Troubling Situation

Under the expertise gained from decades of PSM and expert guidance from thousands of experts using so many techniques, like risk-based inspection (RBI); reliability-centered maintenance (RCM); reliability, availability and maintainability analysis (RAM); and root cause analysis (RCA), many organizations have reached the pinnacle of success. Yet, they fail in mastering 100 percent incident avoidance.

Is it the knowledge that is lacking? Has a risk-taking habit increased disproportionately? Is it the grandeur of success that also must show the inevitable doom?

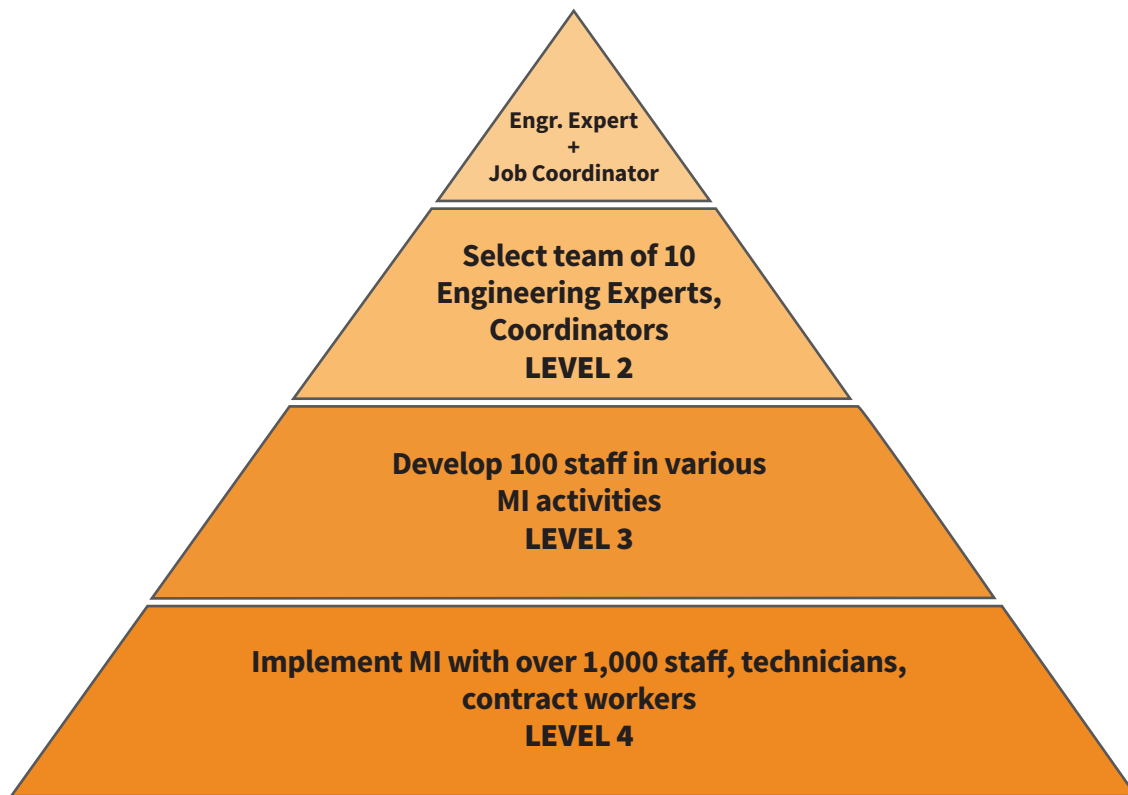
Finding the answer is difficult and perhaps not worthwhile for organizations to pursue in finding one. So, they continue along a path of modesty, consistency and adhering to basic principles. "COME WHAT MAY!!!"

## The Regulatory Take on MI

The U.S. Occupational Safety and Health Administration (OSHA) regulates mechanical integrity this way:

"OSHA believes it is important to maintain the mechanical integrity of critical process equipment to ensure it is designed and installed correctly and operates properly. PSM mechanical integrity requirements apply to the following equipment:

- Pressure vessels and storage tanks;
- Piping systems (including piping components such as valves);
- Relief and vent systems and devices;
- Emergency shutdown systems;
- Controls (including monitoring devices and sensors, alarms and interlocks); and
- Pumps/Compressors.



**Figure 1:** Developing the workforce for MI implementation

“The employer must establish and implement written procedures to maintain the ongoing integrity of process equipment. Employees involved in maintaining the ongoing integrity of process equipment must be trained in an overview of that process and its hazards and trained in the procedures applicable to the employee’s job tasks.

“Inspection and testing must be performed on process equipment, using procedures that follow recognized and generally accepted good engineering practices. The frequency of inspections and tests of process equipment must conform with manufacturers’ recommendations and good engineering practices, or more frequently if determined to be necessary by prior operating experience. Each inspection and test on process equipment must be documented, identifying the date of the inspection or test, the name of the person who performed the inspection or test, the serial number or other identifier of the equipment on which the inspection or test was performed, a description of the inspection or test performed, and the results of the inspection or test.

“Equipment deficiencies outside the acceptable limits defined by the process safety information must be corrected before further use. In some cases, it may not be necessary that deficiencies be corrected before further use, as long as deficiencies are corrected in a safe and timely manner, when other necessary steps are taken to ensure safe operation.

“In constructing new plants and equipment, the employer must ensure that equipment as it is fabricated is suitable for the process application for which it will be used. Appropriate checks and inspections must be performed to ensure that equipment is installed properly and is consistent with design specifications and the manufacturer’s instructions.

“The employer also must ensure that maintenance materials, spare parts and equipment are suitable for the process application for which they will be used.”

### Simplifying MI

So, based on OSHA’s requirements, the MI program can be simplified so that its implementation and application with consistency would be undertaken with unwavering interest year after year without falling into the trap of, “Oh, I Missed It.”

The simple solution is to assign the jobs and develop the workforce for MI implementation, as indicated in the pyramid in Figure 1.

It is a top-down approach. Two fairly senior people are selected, one who is good in coordination and the other excellent in engineering. Both of them work together to develop the managerial and technical path for implementation.

Although MI requires both inputs, the fact of the matter is that only two people implementing the approach in today’s complex refineries is practically impossible. So, next comes one more crucial list of 10 people, possibly one from each plant. Now, these 12 MI stewards take the implementation to realization within a period of six to nine months.

To start any MI program, the first and foremost requirement is the critical equipment/item list, which will be covered under

this program. It simply may be the list as proposed under OSHA’s mandate.

The 12 MI stewards are tasked with ensuring that within a two-week time frame, the list of equipment/items covered under MI is ready.

Having overcome the base hurdle, the strategy for MI implementation is now a two-prong attack: Decide what is required preinstallation and what is required post-installation from the plant.

For preinstallation checks, refer to OSHA’s directive for new equipment/installation, as well as as-built drawings, manufacturing record books (MRBs) for pressure equipment/machinery, various test packs/construction records, etc. Make sure these materials have been fully reviewed and certified to contain all the information that assures quality of the equipment/item. This step



**To start any MI program, the first and foremost requirement is the critical equipment/item list**



will require experts from mechanical – inspection/rotary, electrical, instrumentation, civil, etc. All it needs is a concerted effort by one or two experienced experts to review all available documents and specifically look for any remarks giving some concessions or repairs, if any were carried out!

It may be slightly difficult to dig out this information for older plants built, say, prior to the 1990s, but the effort will have rewards of its own as the team would lay hands on deficiencies noted and develop the liquidation plan for the same.

People in levels 2 and 3 of the MI pyramid help develop the deficiency list, but for liquidation, the full organization should be available.

The treatment for post-installation of the plant (i.e., the operating plant) requires level 3 and 4 teams to be in place. It is here where a time period of six to nine months may be required so that all concerned are trained in the basics of mechanical integrity and everyone is engrossed in implementing the MI program in letter and spirit.

So now, the larger team takes this forward by developing plans to assure the continued integrity of process equipment. Elements of this phase of the mechanical integrity program have been covered in the previously noted OSHA requirement.

Here, inspection, the rotary group, maintenance, instrumentation, electrical and the civil group need to develop their own plans based on applicable codes and standards. Staff in levels 2 and 3 of the MI implementation pyramid will be able to develop the first draft document on inspections, tests and frequencies within three months.

The plan's execution requires that tests and inspections are conducted properly and that consistency is maintained even where different employees may be involved. The appropriate training should be provided to various inspection staff and engineering discipline maintenance personnel that covers

The key to success of an MI program is written procedures and its implementation

procedures, safe practices, and the proper use and application of special equipment or unique tools that may be required. This training is part of the overall training program called for in the standards.

Employees performing maintenance activities must be trained in the activity, as well as the hazards associated with that activity or maintenance procedure.

The phase of training can be completed in six months if there is focused attention and conscious efforts. Most organizations are adept in developing training modules and providing 40 to 60 hours of planned training. This training should be made available to all those participating in the MI program – the list of level 3 and 4 staff should be made available by the end of the first month of launching the MI program.

The key to success of an MI program is written procedures and its implementation. This task should be performed by level 3 and 4 people in a time span of six months. Start with 500 procedures to be written and then decide the team and time per procedure. The expert planner in the company would know how much time to allocate.

The start of an MI program is important, but if it is backed by planning and encouragement provided by management, the controls will automatically be in place and success will be achieved.



*Prakash D. Shende has over 47 years of experience in the hydrocarbon industry and has worked in renowned and reputed organizations in India and Venezuela. He is currently a private consultant.*



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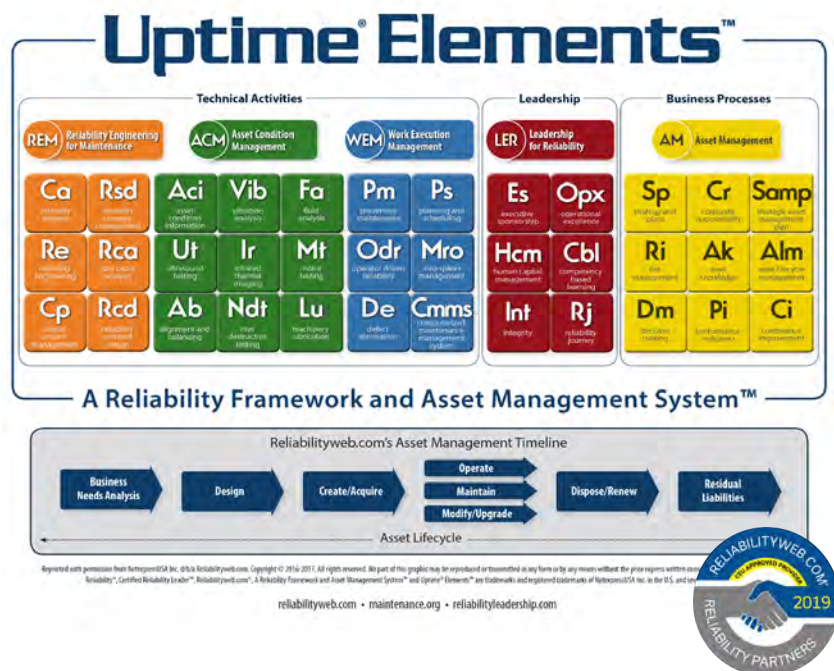
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Ab

alignment and  
balancing

# SUSTAINING LIFE SPAN OF ROTATING EQUIPMENT IN PLANTS

“ Uwoajega Joseph

...reduced equipment downtime, reduced equipment failures, improved safety, reduced financial risks, increased equipment uptime, lower operating costs and **increased profits for stakeholders**

**Y**ou are 17 times more likely to introduce defects during equipment start-up than during normal equipment operation. Additionally, over 90 percent of rotating equipment has defects at start-up that result in premature equipment failures. What's causing these start-up defects?

Misalignment and unbalance are two of the most commonly overlooked conditions that lead to these unwanted statistical results, according to a study by a leading industrial equipment supplier. Misalignment in equipment leads to increased vibration levels, bearing failures, coupling wear, seal failures, shaft fatigue, increased power consumption and other negative effects. Unbalance in equipment can introduce structural-related issues, bearing defects and other problems. Both conditions can create unwelcome safety concerns. Additionally, both conditions can be present on the same equipment and, working in concert, can unfortunately amplify the referenced failure conditions.

So, how do you prevent misalignment and unbalance conditions from making your equipment part of these negative statistics and placing your company at financial risk?

**The answer is to apply condition monitoring technology and procedures, such as laser alignment, equipment balancing and vibration analysis, to your equipment.**

These condition monitoring activities will lead to reduced equipment downtime, reduced equipment failures, improved safety, reduced financial risks, increased equipment uptime, lower operating costs and increased profits for stakeholders.

What reliability improvements can you make in your facility that do not require expensive or complicated actions? Start with the basics, such as:

- Align: shaft, coupling, etc.;
- Balance: rotating components, such as fan blades, impellers, rotors;
- Tighten: eliminate looseness and excessive vibration;
- Lubricate: correctly, meaning not too much or too little;
- Inspect;
- Apply condition monitoring;
- Understand where your efforts should be focused.

Don't wait until the equipment has been installed and is operating. These basic functions must be included in the specification, design, purchase and routine operation of your equipment. Failure to address these vital aspects from the beginning through operation of your equipment will result in higher maintenance costs and reduced equipment reliability.

### Sustaining Bearing Life

Like any mechanical device, bearings wear out over time. This is an unavoidable fact of life. Yet, there are ways of getting the maximum life out of the bearings in your rotating equipment.

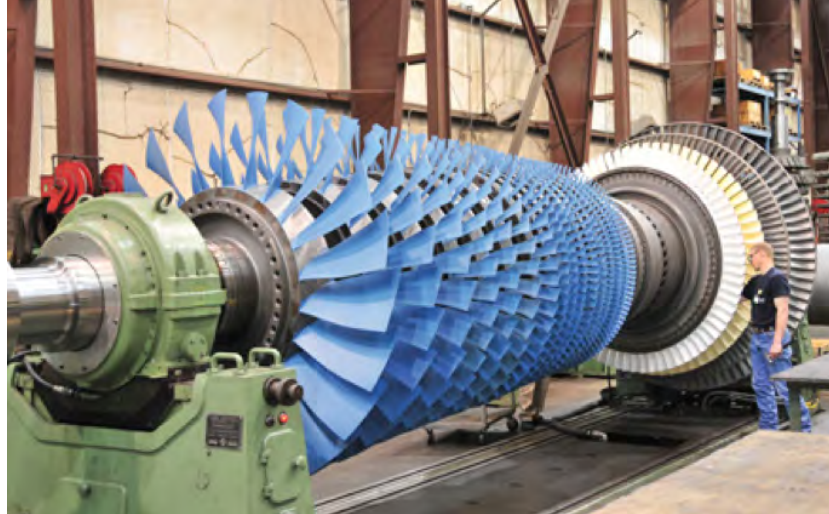
To start with, there are five simple things you can do to maximize bearing life. These five steps are: keep your bearings clean, dry and cool, and keep your equipment balanced and aligned.

- Clean, dry and cool means addressing the lubrication issues of the equipment. For instance, circulating oil systems are used when the heat build-up at the bearing is more than a static oil system can radiate away. In this case, the system provides external cooling. However, just like in a car, circulating oil must be changed periodically. Oil deteriorates over time from heat, oxidation, catalytic reactions, and dirt or water contamination. It is a good idea to change the oil whenever it becomes dirty or cloudy.
- Grit and dirt contamination act as abrasives and over time will remove the hard facing of the bearing. Once the hard facing is removed, the bearing will quickly deteriorate to failure. Therefore, it is important to keep the dirt contamination out.
- In wet environments, keeping bearings dry can sometimes be difficult. It is also important since water will separate the lubricant. If you notice a milky look to the grease being purged from the bearings, it is an indication of contamination by water.
- Balanced and aligned refers to minimizing the destructive energies present when imbalance and misalignment are allowed to continue. Keeping these forces to a minimum greatly adds to extending bearing life. Many companies use vibration monitoring equipment to determine the severity of these forces or shut down the equipment if these energies get too large. As an example of vibration levels seen in the field, it is not uncommon to see vibration velocities of 0.10 in./sec or lower for initial operation, 0.30 in./sec for an alarm setting and 0.45 in./sec as the shutdown setting for a heavy duty fan. However, as there are many applications, it is always best to check with your fan supplier on these matters.

### Achieving Long-Term Reliability

Long-term reliability is a common goal for all plant operators. Achieving it requires a considered approach that takes into account a range of contributory factors and makes use of the most appropriate technology and manpower available to them.

Rotating equipment that is in direct contact with the process media and under constant attack presents a major challenge. It is possible, however, to reduce degradation to a minimum by selecting the correct coating system.



**Figure 1:** Protective coatings can help increase the efficiency and extend the service life of a gas turbine

Generally, turbines, compressors and pumps are all subject to a variety of environmental conditions that contribute to corrosion, erosion, fouling and various temperature-related issues.

The first step is to understand the operating environment of the machinery. From there, the sources of degradation can be classified and specific coating systems can be used to increase efficiencies, lengthen the interval between scheduled maintenance and reduce the occurrence of unscheduled maintenance events.

In the case of a gas turbine, the flow path of air and fuel presents a number of different conditions that can have an adverse effect on the performance of the turbine. The combination of heat, microscopic abrasives and a gradually increasing concentration of corrosive elements can cause significant damage to a once smooth airfoil surface. As the surface finish slowly degrades, the efficiency of both the compressor and turbine is reduced.

“  
**Long-term reliability is a common goal for all plant operators**  
”

### Compressor Section

This process can be arrested in the compressor section of the gas turbine and the surface finish restored by the application of suitable metallic coatings. There is a range of options open to suit the specific duty of a gas turbine, but all include a type of metal deposition where a tough corrosion-resistant surface is created.

An aluminium base layer is typically used in gas turbine compressors for corrosion protection of ferritic/martensitic steel components in moist conditions. It provides galvanic protection, which means that small scratches to the surface layer are less likely to cause corrosion. It is produced by spraying a slurry of aluminum and an inorganic binder, rendered insoluble by a medium-temperature baking process. This layer can be then covered by a harder layer that might include metals, such as chromium.

The harder layer is usually applied using a spray coating method, such as chemical vapor deposition (CVD), atmospheric plasma spraying (APS), low pressure plasma spraying (LPPS), or high velocity oxygen fuel (HVOF). Which one is applied will depend on the coating thickness required and the sensitivity of the part to heat, as some processes are hotter than others.

By applying corrosion inhibiting and surface finish enhancing coatings to the compressor section, it is possible to increase the efficiency and extend the service life of the gas turbine.

## Hot Section

Modern gas turbine hot section components are made using nickel or cobalt based super alloys, which are designed to operate in high temperatures.

However, these alloy compositions are not as well suited to providing corrosion and oxidation protection and need to be supplemented with custom coatings that can deliver the hot corrosion and oxidation protection required for extended service lives.

The process of oxidation causes a layer of metal-oxide to form on the surface, which, in general, protects the underlying material. Therefore, the oxidation process slows down as the thickness of the oxide layer increases. This process can be replicated with the intentional formation of oxides that provide a protective layer, preventing further atmospheric attack.

Corrosion of a gas turbine component usually occurs in one of two ways. Hot corrosion may take place between 788°C and 899°C and it attacks the entire surface of the component. Alternatively, corrosion at cooler temperatures is more localized and, therefore, tends to create distinct layers of oxide and exposed metal. Further damage can be caused by erosion, which involves repetitive mechanical abrasion by particles in the air stream.

Stand-alone high velocity oxygen fuel applied MCrAlY coatings are sufficient to combat corrosion/oxidation at lower firing temperature gas turbines. For newer technology, higher firing temperature gas turbines, the combination of a MCrAlY bond coat coupled with a ceramic thermal barrier coating, reduce the surface temperature of the substrate, thus reducing the degenerative effects of oxidation and corrosion.

## Compressors

Pumps and compressors account for more than 20 percent of the world's electricity demand and the energy costs to run them represent 95 percent of the running costs. Therefore, it is essential to minimize these costs by improving performance and efficiency. These efforts also will have the beneficial effect of improving reliability and service life.

While turbines extract energy from a gas expansion process, turbofans and compressors are used to increase the energy of gases. As such, the main issues with these components are corrosion, erosion and fouling.

## Conclusion

Proper equipment function and sustainability requires a properly aligned and balanced machine. Allowing a machine to operate with an unbalance situation can result in coupling damage, bearing damage, cracks, loose components and many other costly maintenance issues.

Bearings should be clean, dry and cool. Loose debris can dislodge and impact the balance quality of a machine/equipment. Debris buildup on the impellers/blades and other rotating parts can create unbalance conditions.

Before balancing the machine, it is very important that the rotating surfaces (e.g., blades, etc.) are cleaned of any debris. Removing buildup will help ensure that the machine can be properly balanced and remains in a balanced condition.

**Special Thanks to** Travis Cockrell, Component Superintendent of the Coating Department at Sulzer, Houston Service Center, Texas, for contributing information to this article.



*Uwoajega Joseph is the Field Service Engineer/Team Lead for Nigerian Agip Oil Company. Nigerian Agip Oil Company has the production capacity of 75,000 bbl of crude oil and 475 mmscf of gas production per day. Uwoajega is a seasoned professional with twelve years of experience in the oil and gas industry.*

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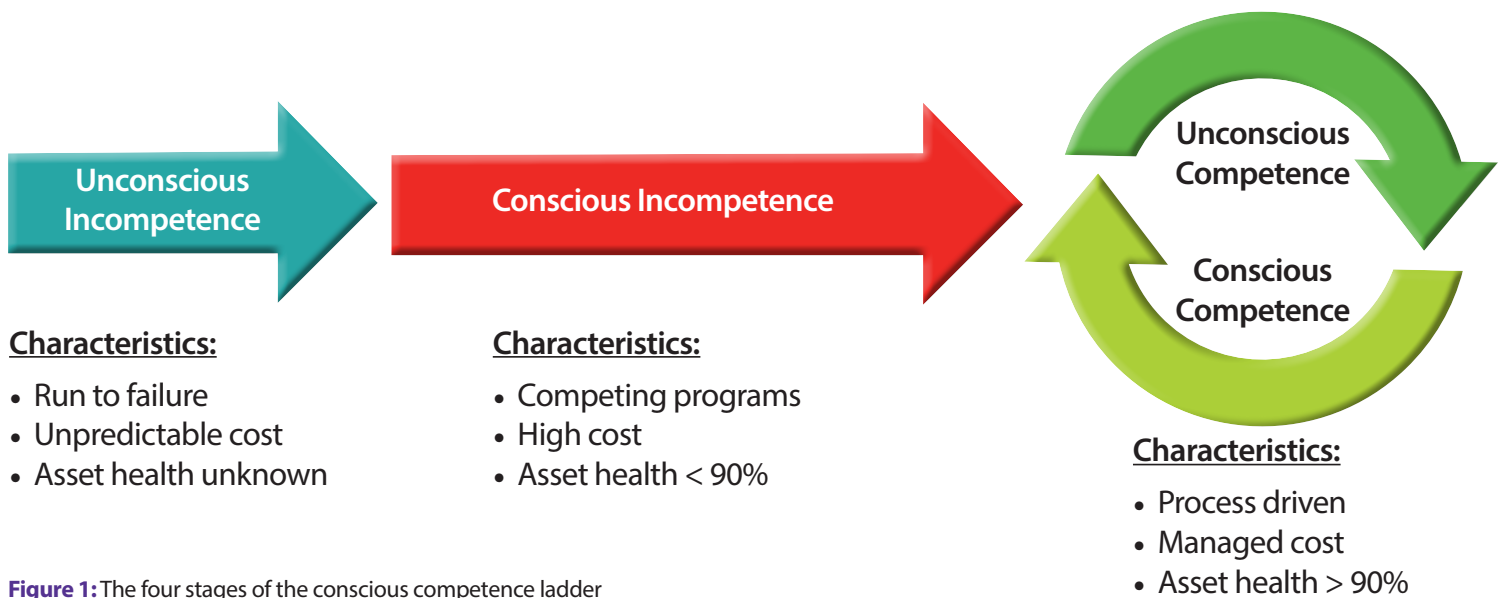


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**Figure 1:** The four stages of the conscious competence ladder

## STAGE 1

The first stage is unconscious incompetence. In this stage, you don't even know there is anything wrong. The organization does not realize it is unreliable or it does not value reliability as a competitive advantage.

The unconscious incompetent organization seeks to save money today without considering long-term implications. Examples might include not changing oil or other wear items until there is evidence of machine complications. These organizations do not make the connection between symptoms, warning signs and the eventual failure until after the failure occurs.

## STAGE 2

An organization that has incurred significant failure may enter into the conscious incompetence stage. This organization realizes its past actions have negatively affected reliability. However, it is not sure what actions to take to ensure reliability nor how reliability impacts the total cost of ownership. These organizations are actually the ones at the biggest risk of failure when it comes to reliability. That's because they are aware of a problem, they just don't know how to fix it.

These organizations often institute reliability programs or offices without the full realization that the entire organization needs to change. There needs to be a fundamental mind-set change at all levels of organizational leadership. The process and metrics must be put in place to drive asset reliability into all decision-making.

This is where reliability leaders must take a stand, declare the new future, and implement action to make that new future. The Uptime® Elements and the ISO55000 series are enablers to helping organizations understand the breadth of the change that needs to take place. Indicators of conscious incompetence include:

- Having a preventive maintenance program, but not evaluating its effectiveness;
- Starting an operator maintenance program, but not providing management support to review findings of operators;
- Identifying engineering changes, but not implementing them because they would cause project delay or cost overrun;
- Instituting condition monitoring programs, but not using them to drive repairs until the repair is obvious.

Organizations that are in conscious incompetence may use the phrase, "we tried that and it didn't work." It is hard to change. Think of changing a golf swing or learning a new language. You should not expect results as soon as you start any program. Discipline in following the program (e.g., sticking with the new swing or practicing the language) needs to stay in place until the conscious competence emerges. Accept that failures in your reliability program will occur and that they do not negate the value of the program overall.

Taking equipment from an unhealthy state to base condition costs money and takes time. The conscious incompetence phase is the most expensive stage of reliability. When you go looking for defects, you will find them. Consciously instituting reliability initiatives is expensive and can be more disheartening than the unconscious incompetence phase. New techniques and involvement of the whole organization create a large list of maintenance repairs that need to be prioritized and funded.

The conscious incompetence phase, unfortunately, is where most organizations sit. It is difficult to recognize incompetence. An inward focus and a tendency to excuse or explain away unreliability characterizes these organizations.

When in doubt, assume your organization is incompetent. Work toward developing processes that drive long-term reliability decisions. Use key metrics that drive reliability into the decision-making of all organizational levels and asset lifecycle stages. Empower the workforce to question why failures occur and develop solutions to prevent or mitigate defects.

The move from incompetent to competent is evident when asset health is routinely greater than 90 percent and costs are predictable. Asset health is defined as the percent of assets that are evaluated by any preventive maintenance program that do not have an identified defect.

## STAGE 3

If an organization can make the leap from conscious incompetent to conscious competent, then it has made it over the valley of despair and is effective at reliability. These organizations are successful at reliability, but they must continually and consciously work at it. They regularly consult their processes and make sure they are following them.

These organizations may revert back to conscious incompetence, but their awareness of what good looks like should drive them back onto the





path of reliability competence. Good metrics will help to drive them back to competency. Indicators of these organizations include:

- Project phase gates with all departments represented and having an equal voice (total cost of ownership and reliability targets are embedded in project deliverables);
- Rigorous failure analysis programs, with systemic and latent root causes identified and funding justified to make sustainable improvements;
- Operating systems that are understood by all departments;
- Costs are predictable;
- The price of both reliability and unreliability are evaluated to determine lowest total cost.

The conscious competent organization has a culture without fear. Colleagues are not afraid to question why or make suggestions for reliability. This questioning and suggesting process is good for business, but requires that team members understand their boundaries and how decisions are made.

Not every suggestion is a good one and sometimes the answers to questions are not available for confidentiality or other reasons. As long as team members feel they are being treated fairly and given information they need to know, these boundaries can be managed. Conscious competence takes strong leaders who are willing to delegate properly, but also take responsibility appropriately. This strong leadership is what is needed to keep the organization from slipping back into conscious incompetence. Reliability competence requires understanding long-term implications.

## STAGE 4

Those rare organizations that make the transition to unconscious competence have practiced the conscious so long that they innately become unconscious. New employees and visitors may make them realize what they have accomplished. Indicators of these organizations expand those of the conscious competence to include:

- Asset health metric >90 percent and understood at all organizational levels;
- Cost decisions driven to the lowest level;
- Standard work practiced and driving continuous improvement;
- Line of sight from decisions and actions to results.

## THE CYCLE

Because reliability is a journey, not an end state, organizations must continue to practice and learn. This means that while unconscious competence may be the major state of these rarefied organizations, they must continually work in the conscious zone to adapt and keep pace with the latest technologies and innovations. Just as athletes continue to train and be challenged by others in their field, organizations must seek, learn and adapt new techniques to remain reliable and continue to satisfy their stakeholders.



***Kate Kerrigan** is a Reliability and Operations Excellence Engineer, Certified Reliability Leader and coach. Kate specializes in maintenance and reliability management and has in-depth experience implementing total productive maintenance (TPM) and lean manufacturing. Mitigating risks and maximizing company assets is her mission.*



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# HOW TO USE MECHANICAL INTEGRITY INSPECTIONS

Keith Taylor

**Are you getting all the  
benefits you can from mechanical  
integrity inspections?**



**F**or many organizations, these inspections are something they have to do to meet regulations. And, that's important – those regulations are there to help provide a workplace that is safe for workers, the environment and the surrounding community.

But, some companies are able to leverage those inspections to gain new insights into their operations and build additional efficiencies.

This article shows how manufacturing professionals can work smoothly with a third-party mechanical inspection provider and use inspection results to build greater efficiency in their operations.

## **Meeting Your Company's Regulatory Obligations**

The most frequent reason why companies call inspectors is for regular professional inspections to meet environment, health and safety (EH&S) regulations. These inspections cover a wide area of issues, depending on what's being inspected – a pressure vessel, a tank, a pipeline, a boiler, or other pieces of equipment. Each inspection is different in terms of what the inspector is looking for, the type of equipment and the requirements of the regulatory standard.

Inspectors can do their work most effectively, allowing a company's operations to return to normal as soon as possible, if:

- Any equipment that needs to be taken out of service for inspection has been shut down, locked out and isolated for safety, particularly if it is a piece of equipment that the inspector will need to enter in order to perform the inspection.
- Equipment that is excessively hot or cold has been given time to reach a workable temperature.
- Obstructive coatings of oil, product residue, ice buildup, or other material have been cleaned to permit an unobstructed evaluation of the equipment.

- Specifications for the equipment are available, including the manufacturer's data report, construction drawings and details about previous inspections and repair history.

Here's why that last point matters. Consider, for example, a pressure vessel rated for 200 psi of internal pressure. An inspector calculates the minimum thickness of the shell and the heads, and determines if there is still adequate thickness and whether or not it has corroded away below the standard required. In order to perform those calculations, the inspector needs to know the strength of the material used to build the pressure vessel. Without the original drawings to indicate it was built out of a given type of steel, the inspector has to make conservative assumptions. As a result, the inspector may need to report that, based on available information, the pressure vessel isn't fit for service. On the other hand, if the inspector knew the material was a higher strength steel and could confirm it through company-provided specifications, then the pressure vessel could be reported fit for service, provided all other conditions are met.

## Most regulations in place today requiring mechanical integrity inspections stem from the need to **IMPROVE WORKPLACE SAFETY**

### Going Beyond the Regulations to Gain Operational Insights

Some companies are using regulatory inspections to find ways to gain additional value from them. In many cases, these efforts help improve operational reliability. Here are some examples:

**Prevention is better than cure:** Sometimes, managers concerned about the viability of a piece of equipment will have it inspected. Inspectors encounter a wide range of equipment in the course of their work, so they have a good idea of what can go wrong. They're often able to help discover potential problems or reassure managers when there doesn't appear to be any cause for concern. In some cases, the equipment appears to the owner to be in poor condition, when, in fact, an inspection determines the issues are only superficial and with some minor cleanup, the equipment will be good as new.

**Determining operational life expectancy:** Everything wears out eventually. Inspections help determine operational life expectancy, or when that "eventually" might be. Sometimes, inspectors will point out changes that can be made, such as the installation of a new protective coating or some weld overlay, to increase that life span.

**Boosting productivity:** An inspection can determine whether the throughput of a process can be increased because the equipment is actually rated at a higher pressure or capacity than it is being used for.

**Planning capital expenditures:** Finance departments need to know well ahead of time if they need to budget for a major capital expenditure. To this end, mechanical integrity reports can help them determine the likely timing

of those expenditures by understanding the life span of the equipment they have.

**Putting a price on it:** If a plant is changing hands, the prospective owners need to know if they are getting their money's worth and that the assets won't pose an imminent safety or environmental liability. This includes the value, expected life span and maximum throughput of the equipment they're acquiring. Having a good database of credible third-party mechanical integrity reports allows them to put a true value on the company's assets.

**Being seen as an employer that cares about safety:** Frequent mechanical integrity inspections help flag potential safety issues, such as a leaking tank or pressure vessel, before they become serious. This creates a safer workplace. It also demonstrates to employees that their company cares about their safety. This, in turn, helps with worker recruitment and retention.

**Helping to extend equipment life:** Inspectors can determine when a piece of equipment is nearing the end of its service life. They also can recommend changes the company can make to lengthen service life. This might involve replacing a worn flange, applying a weld overlay on some pitting, or replacing a corroded area of a shell to keep the equipment in compliance. Inspectors can put together a repair plan for making the equipment both compliant with applicable codes and workable for the company and repair contractor.

### Helping Reliability Professionals Get the Resources to Do Their Work

Besides helping to improve operational reliability, inspections can help reliability professionals build allies within other departments.

For example, on the safety aspect, employers need to protect their Total Recordable Incident Rate (TRIR), the resultant measurable that stems from a U.S. Occupational Safety and Health Administration (OSHA) requirement to report workplace injuries. An unfavorable TRIR can result in difficult OSHA inspections, higher insurance costs and the possibility of sanctions, fines and orders to redesign workplaces and procedures. As such, the EH&S department may be supportive of the mechanical integrity testing program because a safer workplace helps it meet its goals.

Most regulations in place today requiring mechanical integrity inspections stem from the need to improve workplace safety. In fact, since the Occupational Safety and Health Act was signed into law in 1970, OSHA reports that workplace injuries and fatalities have decreased by more than 60 percent.

As previously mentioned, mechanical integrity inspections can also support the work of the finance department in planning capital expenditures and in demonstrating the financial value of the company's physical assets.

Being seen as a good place to work helps the human resources department meet its goals, as well as enable it to attract and retain the best employees.

Clearly, mechanical integrity reports are essential for meeting regulatory obligations, but reliability professionals can go beyond that to help meet other goals of the organization, too.



**Keith Taylor** is the Director of Mechanical Integrity at the Buffalo, NY-area multidisciplinary firm Encorus Group, a Service-Disabled Veteran-Owned Small Business (SDVOSB). Keith's specialties include nondestructive testing, fixed equipment mechanical integrity evaluations, failure analysis, API inspections, and repair procedures. [www.encorus.com](http://www.encorus.com)

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Tong Zou

# EQUIPMENT STRATEGY DEVELOPMENT USING A MODULAR APPROACH

One of the most cost-effective approaches for system-level reliability improvement is to develop strategies for critical equipment. Equipment strategies may include preventive maintenance (PM), predictive maintenance (PdM), continuous monitoring, commissioning, and redesign. Each of these strategies can be used individually or combined with one or more of the other strategies, with the ultimate goal to optimize the lifecycle cost (LCC).



The key idea is to divide each complex system into smaller blocks and develop a generic equipment strategy template for each of the unique types of blocks



The development of these strategies for a chemical plant can be very laborious, as well as time and resource intensive. One way to minimize the effort and time required to develop plant-wide critical equipment strategies is to utilize a modular approach. This article will outline how to do that. However, before diving into the modular approach, let's make sure the basic concepts are covered.

## THE BASICS

For repairable equipment that has been and will be operating for many years, the most commonly used equipment strategies are PM and PdM. For the rest of this article, equipment strategies refer to PM and PdM only. Depending on the failure mode, the cost of failure and the cost of performing maintenance tasks, the benefit ratio of implementing PM/PdM could be as low as 0.1 to 0.3 (lower is better). Here, the benefit ratio is defined as the ratio between the lifecycle cost with the implementation of an equipment strategy and that of running equipment to failure.

Preventive maintenance aims to preserve and maintain equipment reliability by repairing or replacing the worn parts before they actually fail. If not associated with any predictive maintenance, PM is usually performed at a fixed interval, such as every three years of operating time. Predictive maintenance uses techniques to determine the condition of in-service equipment and predicts when a PM is necessary. PdM enables condition-based maintenance, as the PM interval is not only based on the equipment age, but also the equipment-specific configuration and operating conditions. The effectiveness of PdM depends on the timeliness and accuracy of being able to detect problems that will eventually lead to equipment failure.

When developing the equipment strategy for critical equipment, it is important to include both the critical equipment itself and the supporting equipment necessary for the critical equipment to function properly. For example, when considering a centrifugal compressor whose function is to compress a certain type of fluid before it reaches the next chemical processing step, it is important to realize that:

- In order for the compressor rotor to rotate, it must be driven by a motor through a coupling that connects the shafts of both equipment;
- For the compressor bearing to be continuously lubricated, it needs one or two oil pumps;
- To achieve the desired compression ratio, the fluid needs to be cooled by an interstage cooler (e.g., heat exchanger);
- Control panel, instrumentation and control valves are essential for normal and safe operations.

The equipment strategy for the compressor system is not complete unless an equipment strategy for all the previously mentioned supporting equipment (e.g., motor, coupling, pump, cooler, control valves, etc.) is also developed. As the failure of all supporting equipment is tied to the functional failure of the compressor, their reliability cannot be neglected.

Before performing a cost optimization and/or risk mitigation, the following framework for the equipment strategy should be established:

1. **Location** – this can be a single asset or a multiple level of assets following a system hierarchy;
2. **Function** – expectations of the asset by its users; for each location defined at the level above, there needs to be one or more functions defined;
3. **Functional Failure** – ways in which the asset can fail to fulfil the expected function(s); for each function defined at the level above, there needs to be at least one functional failure defined. A functional failure refers to the failure mode (e.g., overheat, high vibration, insufficient lubrication, etc.);
4. **Cause** – each functional failure defined at the level above should have at least one cause associated with it; a cause refers to the failure mechanism (e.g., fatigue, corrosion, wear, etc.) that induces the corresponding functional failure (i.e., failure mode). For each cause, the following details need to be defined:
  - a. **Failure distribution** – the commonly used Weibull distribution with two (shape and scale) distribution parameters can be fitted using the available equipment failure data;
  - b. **Corrective maintenance (CM)** – when equipment fails unplanned, the CM task specifies the action, duration and cost to bring it back to running; labor, spares and tools associated with the CM task also should be defined;
  - c. **PM and PdM** – to ensure equipment capability is maintained or restored when it deteriorates, PM and PdM tasks are the vital lifeline; for each cause, multiple PMs and PdMs can be created. In addition to

cost and duration, a detailed PM/PdM procedure helps the planner and technicians perform their tasks more effectively. Labor, spares and tools associated with each PM and/or PdM should be defined.

- d. **Effect** – each cause also should be assigned one or more failure effects; the effects may include production loss in dollars, safety and environmental severity.

Once the equipment strategy framework is completed, simulations can be performed to determine the optimized frequency for performing an individual PM/PdM task or a group of tasks. It also determines statistically what the optimal component(s) of the equipment strategy will be: PM only, PdM only, or PM and PdM.

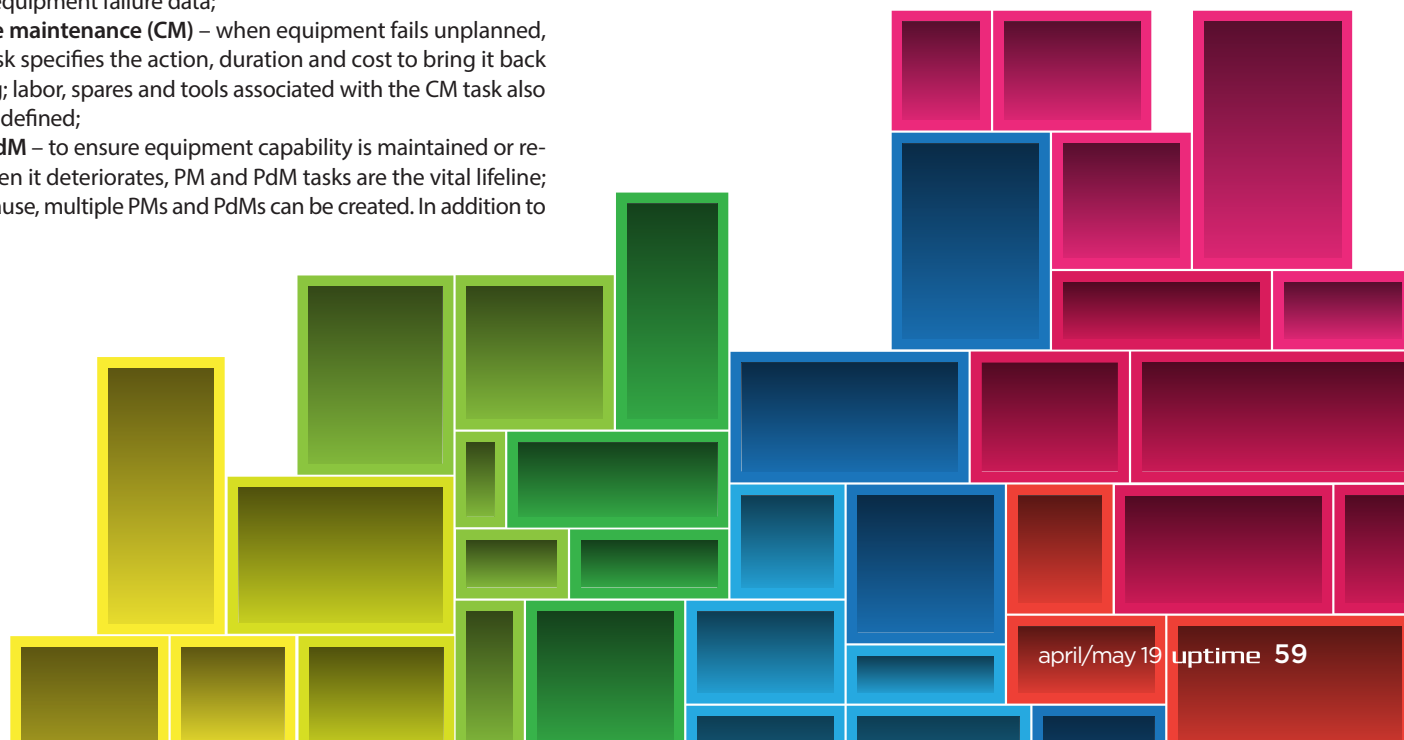
Now that the basic concepts have been reviewed, let's explore the modular approach.

## GOING MODULAR

It is evident that developing equipment strategies for a complex system like a centrifugal compressor is time-consuming. Given that it is not uncommon for a chemical plant to have hundreds of critical equipment with similar complexity as the centrifugal compressor, the efficiency of equipment strategy development becomes vital to the success of the plant's reliability improvement program.

A modular approach is proposed to improve the efficiency of equipment strategy development. The key idea is to divide each complex system (e.g., centrifugal compressor) into smaller blocks and develop a generic equipment strategy template for each of the unique types of blocks. Since the majority of block types are common for multiple systems, significant amounts of time spent on developing the same block for all systems can be avoided. The procedure for the proposed approach is as follows:

- Establish a list of plant equipment by class. For a chemical plant, this list may include compressor, pump, motor, drive system, heat exchanger, etc.
- For each equipment class, one or more levels of equipment types can be generated. As an example, for a pump, two types can be added: centrifugal and positive displacement. You can further divide the centrifugal pump into three subtypes: conventional pump, canned motor pump and magnetic drive pump.
- Once equipment class and types (or subtypes) are determined, the generic equipment strategy can be developed for each lowest level equipment type. For a generic equipment strategy, all information in the equipment strategy framework is required, except for failure distribution and effect. At this step, it is important to include as many possible functional failures





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# Q&A

## TERRY McELRATH

Senior Executive, Consultant and Entrepreneur



Terry McElrath is Vice President Operations & Business Development at the Object Management Group (OMG) and is responsible for the development of the IoT Solutions World Congress conference program.

Leveraging extensive experience with start-ups and rapid growth scenarios, Terry is a valuable asset for companies seeking guidance on change management, developing new revenue lines, and organizational structure. Her broad areas of expertise include business development, content development, strategic partnerships, marketing strategy, communication, and event strategy and execution.



### Q. What is the mission and vision of the Industrial Internet Consortium (IIC)?

The vision of the IIC is to be the world's leading organization transforming business and society by accelerating the Industrial Internet of Things (IIoT). Our mission is to deliver a trustworthy IIoT in which the world's systems and devices are securely connected and controlled to deliver transformational outcomes. Bottom line: we want to make the world a better place by providing an ecosystem that develops and builds life changing IIoT solutions.

### Q. To date, what has been the biggest accomplishment of the IIC?

The growth of our organization in the past five years has been amazing. Companies join for many reasons, some getting heavily involved and dedicating the people resources needed to truly engage with the ecosystem, others for the awareness and access to the IIoT knowledge base among our membership. I'm most proud of the fact that we've produced seven foundational documents that have become implementation guidelines for the industry; our working groups have published 15 whitepapers with as many in the pipeline; and our nearly 30 test beds have delivered results and even generated requirements for new standards that the IIoT market needs.



**Q. What is your role within the IIC? What has been your most important contribution?**

I've worked with OMG since 1992 and have always been impressed with the organization's ability to see where the technology industry is going. This is due to Dr. Richard Soley and Bill Hoffman, true visionaries who helmed OMG for nearly 30 years. Throughout my career, I remained in touch with them and in 2015, I received a call from Bill to work with IIC to launch the inaugural IoT Solutions World Congress (IoTSWC) with Fira Barcelona. We've grown that event to be the largest IIoT global event, with over 16,000 attendees in 2018. This led me to a larger role with OMG as the vice president of operations. My focus is now on developing and growing all the programs under the OMG umbrella.

**Q. What advice do you have for young women who are interested in becoming involved with the IIoT?**

I encourage women young and old to get involved in the IIoT by looking at all the ways it touches our lives. The word, industrial, can evoke visions of grease and dark warehouses, but the IIoT is shaping so much of our lives, from agriculture crop management to intelligent urban water supplies to smart manufacturing and autonomous vehicles. There are so many opportunities for women to find an area of the IIoT that excites them. At most of

the IIoT events and member associations, more and more women are getting involved, which is great to see. In fact, we held our first "Women in IIoT" event at the IoTSWC in 2018 and it was a sellout. My advice for young women is not to be intimidated by technology and know that many women bring a different skill set that, when shared in collaboration with others, can result in new solutions, applications and business outcomes.

**Q. Which university programs would you recommend for IIoT?**

There is a huge skills gap in industry today. I would encourage students to find programs that can educate and intrigue them to find a career in technology and, more importantly, in industry. Industrial environments are not what they used to be and with technology disrupting these environments, they're actually really cool. More and more colleges and universities are offering programs in data analytics, data science and computer science. My recommendation is to find the program and school that fits the student. If someone is out of school, they shouldn't feel limited by the words on their degree. There are many great retraining programs to learn more about a new field and experience in other areas brings different points of view to an IIoT team.

**Q. Which companies are leading the way in this technology?**

It's an ecosystem and a movement that is compiled of many companies. One of the great things about the IIoT is that no single company can win the IIoT. End to end solutions require companies to work together. This is where IIC comes in. We provide the ecosystem where ideas become test beds, test beds deliver results, and those results turn into solutions. Our members have the opportunity to work together, sometimes sitting directly next to their competitor, to build new solutions and applications with the latest technologies in a noncompetitive environment.

**Q. Why is diversity important in technology-focused companies?**

Diversity helps avoid groupthink and IIC as an organization helps avoid groupthink. We have more than 3,000 individual members from hundreds of companies in countries around the world. Each person brings their own perspective to the table and their own learned experiences. Access to IIC will help anyone interested in broadening their own perspective.

**Q. Where do you see this technology in five years? How do you think this will affect your role?**

Looking at the maturity of the IIoT marketplace, I think we've come a long way, but there's a lot of opportunity to come. What I see next is the incorporation of artificial intelligence (AI), machine learning and blockchain into IIoT projects. As far as my role, I look forward to what the future brings IIC and will ride this technology wave while ensuring our ecosystem continues to be at the forefront of IIoT development and leadership around the world.




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