IN PURSUIT OF THE PERFECT PLANT

A Business and Technical Guide

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The creation of *In Pursuit of the Perfect Plant* took place through an unprecedented process of collaboration that involved a group of more than 100 experts. The authors and sponsors used their personal networks and the resources of their companies to reach out to invite people to participate in the book and the response was overwhelming. Dan Woods and the team from Evolved Media orchestrated the interviewing and writing process, but the true stars of the book are all of the generous people who helped provide ideas for the book and also carefully reviewed the content. Their names are included below.

The authors would like to convey special thanks to Ian Ryan and David Katona for coming up with the “Perfect Plant” concept in the first place and their continued efforts to push this forward.

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This book was truly a community effort, experts coming together to share their knowledge, experience, and passion for the topic of this book. We hope that this community experience continues on after you read the book at www.pursuitoftheperfectplant.com.
Flat world dynamics have rapidly given way to a new world order in business. The days of a single company competing against another company, or a single region competing against another region are over. The evolving rules of business mandate that business networks that cut across multiple organizations and geographies must now compete against other business networks. This new dimension of competition is changing the pressures on manufacturers, dispelling the traditional notions of quality, delivery, and costs metrics. Virtualization of manufacturing increasingly means that the individual plant may have to become part of one or more business networks, groups of separate companies that assemble and reassemble to meet market demands. Specialization means that the core competency of each plant must be precisely defined and meet ever-increasing regulatory and customer standards.

The disaggregation and localization of supply and demand, combined with the virtualization of manufacturing, means that manufacturers must do several things at the same time. They must run responsive supply networks in perfect synchronization with their customers, suppliers, and partners; ensure operational excellence throughout the value chain; and extract the optimal value across distributed assets and energy bases. Furthermore, manufacturers must do all this while maintaining product and service leadership to provide differentiated value to the customer.

The need for rapid change arrives at a time most plant managers are beginning to understand that the extreme heterogeneity of plant systems architecture is a significant barrier to progress. Yet rip and replace is not a workable strategy. Rather, multiple players inside an organization must work together in concert with the appropriate vendors and partners to move incrementally toward a flexible architecture. The gaps between enterprise processes, operations, execution, asset management, quality management, and energy management must be closed rapidly. Granular information must be
made available in the right context and at the right time to support proactive
decision-making across plants and operations.

Against this backdrop, the book that you are holding in your hands has
been in the making for decades. The goal of the book is quite simple: to
examine the most important aspects of the journey towards the perfect
plant and to show how companies can use the vision of the perfect plant to
help them make hundreds of incremental improvements that are unique
to their own environment and corporate strategy. For the first time, authors
have successfully put together a roadmap for designing and operating
manufacturing operations for the new era, offering both a methodology as
well as best practices to help you design your own perfect plant. This book
shows how to combine new elements of information technology with time-
tested production technologies and best practices. Instead of presenting this
information in a dense textbook, the authors bring these ideas to life in a
conversation. The result is a book that is easy to read and accessible to senior
management, plant managers, staff, and IT personnel at all levels.

The world is full of books that provide hundreds of pages on micro topics
in manufacturing. Lean manufacturing, Six Sigma, and other improvement
initiatives have ornate methodologies that work wonders in the right hands.
Instead of taking a deep dive on individual topics, the authors, Pat Kennedy,
Vivek Bapat, and Paul Kurchina, have focused on a wider view, concentrating
more on the essence of improving each area discussed. The business novel
The Goal provided a general sense of how to go about change. In Pursuit of the
Perfect Plant provides a general view like The Goal but with specifics in key
areas relevant to improving manufacturing operations in today’s business
environment.

I am doubly excited to support this book because of the very collaborative
nature of the project. It exemplifies how a business network of participants
can come together to provide unique value. This book is the work of
a network of participants from leading vendors such as SAP, OSIsoft,
Cisco, and TCS combined with individual contributions from hundreds
of industry experts. This diverse group came together as partners, each
bringing their unique competencies to produce a guide that focuses on
helping manufacturers anticipate and solve the next-generation challenges
in manufacturing operations.
The networked partnership that this book represents brings to the table all of the people who will help create a perfect plant: plant executives, domain experts who work on plants, consultants, vendors, and analysts. I am proud that SAP has joined in this effort and I hope that you will be as pleased with the result as I am. Most of all, I hope that this book will inspire companies and help them accelerate their journey toward the ever-elusive goal of the perfect plant.

Richard Campione
Senior Vice President
Suite Solution Management
SAP
Introduction – The Transformation Challenge: Reaping the Rewards for Managing Change

If you spend your days in the Byzantine world of manufacturing—making products, fixing equipment, supervising quality, implementing software, analyzing planning data, or managing the big picture—this book is for you. Our goal is simple and direct: provide information and suggestions that will help you improve the quality of your plant.

Making any one part of a plant work better is difficult, but hardly impossible. The real challenge facing most companies today is how to create a blueprint for an entire plant, or portfolio of plants, that integrates all strategies and processes to function under a single, consolidated plan. In the face of continual change, you need a vision to guide you on the path to achieving this plan. You must know where you want to go, and, just as importantly, how you would like to get there. What do you want your plant to accomplish? How can you coordinate all of its operations to work in concert toward that goal?

Local optimization—focusing on improving just one area—is a losing proposition. To succeed, your plant must improve as a whole, not just in one aspect. For example, if you reduce unplanned outages through more frequent maintenance, the plant’s output may be diminished. If, on the other hand, you run a plant to avoid shutdowns for maintenance, the lifetime of your equipment may be shortened. Trade-offs like these abound in any plant and cascade into problems of mounting complexity.

What keeps you in the game is the knowledge that, although there are no easy solutions to such difficulties, solutions do exist. The first thing to recognize is
that the modern manufacturing plant is a complex, interrelated system. For better or for worse, changing one part always affects those around it. When all the parts are working to benefit the others, you have achieved a vision of what we call the perfect plant.

To really make a difference in improving the operations of a plant to meet its owner’s goals, you have to have a comprehensive vision of what the plant should accomplish and how every aspect of the plant’s operations can help in the face of continual change. While each perfect plant meets the needs of its owner in a unique way, at the end of the day, each is still like all the others: every perfect plant is an extension of the financial and business strategy of the company that owns it, and every perfect plant produces certifiable business benefits and does not seek to meet KPIs for their own sake.

In Part I: Pressures on the Plant, we look at the big picture. We examine the payoff for improvement, the cast of characters and systems that run a plant, the pressures required to generate positive change, and the shape and requirements of a comprehensive vision.

In Part II: Making Progress Toward Perfection, we examine each of the plant’s primary concerns, from traditional challenges like planning and asset management, to newer issues such as energy management and sustainability. We study the history of each, investigating who is involved, how to keep score, and what information is needed to succeed. We take a detailed look at how every perfect plant advances from one level of maturity to the next, undergoes transformation through patterns of success, and evolves a culture of reciprocity and tribal awareness. Further, we examine how each of a plant’s various functions interacts with its counterparts, and then suggest methods that will help you improve all those functions in concert, while keeping the plant running smoothly.

Part III: Making It Happen addresses the problems of change management. Having envisioned the perfect plant, how do you move toward it quickly and efficiently? What are the best methods and techniques to communicate your vision to the vast mix of people who run your plant? What motivates these people, and what are the most effective incentives to change their behavior? These are just a few of the quandaries to which this book provides a series of well-considered, holistic solutions.
The Perfect Plant Is Not a Methodology
The past 20 years have seen a blossoming of new theories about how to run a manufacturing plant that meets the highest levels of efficiency and productivity. From Lean Manufacturing, to Six Sigma, to the Theory of Constraints that is set forth in the novel, The Goal, the suggested methods of improvement are as rich as they are abundant. While each has been proven in practice, it is important to note that they are sometimes applied ineptly.

It is not our intention to supplement the already exhaustive literature on plant methodology. Every company must deploy its own process of analysis. Until you see your plant as a single unit of finely tuned, complexly interrelated parts, your efforts to marshal all those parts will likely be frustrating. As we have suggested, a vision of the perfect plant infers a vision of the big picture. Once you hold this picture firmly in mind, your task lies in sharing it with as many people as possible.

This book will be of assistance in spreading an understanding of the big picture throughout the plant. For instance, it can be a fantastic vehicle through which to educate the people with whom you want to share your vision and to raise the consciousness about your plant across the enterprise. Consequently, you increase the chances that everyone has a clear idea not only of their role and its effects, but also of the role of those around them. Whether you are employing new methodologies or revamping established ones, they will all work better as a result of expending the effort to deepen your collective awareness.

How Perfect Is the Perfect Plant?
The perfect plant is one that knows how to achieve business goals with minimal resources. Sometimes this means prudently pushing everything to the limits to achieve objectives, with full knowledge of what those limits are.

If the perfect plant were a high-performance racing car, everyone in that car and on the pit crew would be focused on how to make sure that the car was moving as fast as possible without taking unreasonable risk. To do this, you must know a lot about how the car is operating and the track conditions. You must know
how fast the engine can run, how much wear is on the tires, and what the tire pressure and oil temperature are. In short, you need instrumentation and the means to analyze what the instruments are telling you.

Many plants are struggling today because they lack a clear and precise vision for their future state. Without it, they cannot explain where they want to go and how to get there.

Another related concern pertains to employee motivation. If a business has not taken care to conceive a vision for what it wants to achieve, and then convey this vision to its employees, why would the employees care about improving their performance? The experts we consulted repeatedly explained that the most important contribution this book could make would be to show people how to create a workplace culture that is founded upon a clear vision of the perfect plant.

The drive to improve manufacturing processes and optimize return from resources is nothing new. However, the industry has seen astonishing change and growth, much of it driven by technology that makes it easier to execute processes that were once incredibly difficult, if not impossible. Today, for example, cheap, reliable online spectrometers can provide analysts with readings of chemical processes that only a short time ago were unattainable without engaging manual lab procedures that were time-consuming, costly, and error-prone. Many organizations balk at techniques that are now either proven or promising simply because they remember how difficult they were in the past.

Many plants, too, are not attempting to understand their limits and push toward them. This leaves money on the table and reduces the probability that the plant will survive. Let’s look at various industries for a few examples of the challenges facing different types of plants:

- Paper mills must be pushing the limits of cost and efficiency given their market context.
- Refineries must increase asset utilization because demand and prices for their products are high.
Power plants must meet financial, regulatory, and reliability requirements to maximize return.

Discrete manufacturers must deal with balancing the needs of a large workforce, competition from abroad, and consumer demands for more products, higher quality, lower prices, and customization.

All manufacturers must make the right products at the right time with minimal rework and resources.

This book attempts to survey the range of difficulties every plant will encounter on the path to meeting these challenges, from choosing the right objectives to understanding the performance of the plant, from sales and operations planning to quality, asset, and energy management, among a host of others.

Where We Found the Wisdom

We set out to examine every important facet of manufacturing across the process, discrete, and utility industries. As such, this book’s scope is broad, and yet we have strived to ensure that it is also deep.

Imagine that you had time to do a research project whereby you personally interviewed the experts and specialists of every aspect of the manufacturing industries, learning the secrets to achieving superior performance in all that you do. Well, we had time, and we used it to interview over 100 people renowned by their industry peers for their proven expertise. Of course, we added our own insights to this collective wisdom, then boiled it all down to 13 chapters of approximately 25 to 30 pages each. (Some of the people we consulted are noted as contributing authors to one or more chapters, while others contributed to parts of one or more chapters, or provided comments as reviewers. Please see the acknowledgements for a comprehensive list of who contributed.)

The following list provides a few examples of how to best use this book:

Senior management at the corporate level can read it to refresh their knowledge about the details of each important area in a plant.
Plant managers can read it and help educate others in the plant about the bigger picture.

VPs, managers, and operators in the plant can read it to learn better ways to communicate with other departments in the plant.

Operators, engineers, and technologists in the plant can read it to understand the implications of their actions on the plant and on the business as a whole.

New employees at any level can read it to gain an understanding of any plant’s general and specific operations.

A number of the people involved with this project are affiliated with companies that sell technology or other services. Regardless, we have worked hard to guarantee that the book remains free of marketing messages or specific product promotion.

This book, like the perfect plant itself, is but a journey. Each of its chapters was improved through the input of people who read the content at www.EvolvedTechnologist.com/perfectplant. The same site will also be used to discuss issues that arise after publication. We invite you to drop us a line to let us know if our book has made a difference at your plant.

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John Bonhoffer sat at the head of the conference table, going over her notes and handouts for her upcoming presentation, while Peter Moulton and Krishna Bala drank coffee and quietly compared their progress on the project so far. After a moment, John Mulcahy emerged from his adjoining office, carrying a box of markers and a note pad.

“Last session,” Mulcahy said, “Peter gave us an important look at execution. Today Joan will talk us through the ins and outs of asset management.” He ceremoniously handed Bonhoffer the box of whiteboard markers, which she accepted with a playfully regal nod of her head.

“My goal, as John defined it,” she said, “was to figure out what the experts say about successful asset management in plants and to hear what our own plants have to tell us. After meeting with a multitude of experts and visiting each of the plants, my conclusion is that if we did nothing but focus on asset management this year, we will have done quite well for ourselves. Getting asset management right means that many other things must also be going well.”
“So what type of people did you talk to?” asked Mulcahy.

“I started with some top IT analysts, because I felt they could give me a good view of the processes and the big picture. Terry Wireman from Vesta Partners has written several books on asset management and related topics. He provided the big picture. Kristian Steenstrup from Gartner created a hierarchy of maintenance strategies that provides a clear way of seeing and implementing with them. The people I spoke with have talked to hundreds, if not thousands, of companies, so meeting with them was like attending a graduate seminar. At first I couldn’t keep up, but I picked up the lingo pretty quickly and then, like any true nerd, I found all of this stuff intriguing.”

“I’ve discovered,” Bala said, “that not everyone fully appreciates the IT universe. Wouldn’t starting with IT make some people in the plant suspicious?”

“I’m sure we can assume she balanced out that perspective,” Moulton said. “Who else was on the list?”

“The asset management vendors were also illuminating,” Bonhoffer said. “They’ve talked to as many or more companies as the analysts, and have had to struggle to make their solutions actually work. I got a fantastic overview of all of the different kinds of data involved in asset management, as well as the way companies are starting to standardize their approaches. This is important. Not only do we need to acquire the right data, but also we must learn how to make sense of it such that it works for us. And once we have used the data to make decisions about what we want to do, we need to consider how we intend to implement it. One of the managers took the idea of asset management in the plant and connected it to this larger concept of enterprise asset management, which changed my perspective slightly.

“After I had spent so much time focusing on software,” Bonhoffer said, “it occurred to me that IT can only help us once we understand our processes. To do this, we needed to get inside the heads of people in the plants. We were able to come up with a list of mistakes to avoid that we can circulate to our plants. My trip through our plants added even more items to this list. For example, implementing centrally mandated systems without enough local input is a common way to overspend. I also found that implementing systems in isolation can be just as much of a problem.”
“That doesn’t surprise me,” Mulcahy said. “Taking a top-down or bottom-up approach is no guarantee of success in an environment as complex as a plant.”

What is Asset Management?
“The first thing that confused me about this topic,” Bonhoffer said, “is that the term ‘asset management’ doesn’t seem to emphasize one of the main activities of the area, which is maintenance. In the most abstract sense of the word, asset management in a plant is about increasing the return on the money invested in all assets. The definition of assets is basically everything you can physically see when you walk through a plant. Three types of money are involved with this: money used to buy the assets, money spent fixing and maintaining the assets, and money spent running the assets to make products. Tracking all of this in a transaction-based system is corporate’s responsibility.”

“That’s the kind of system,” Bala said, “that John would use as EVP of Manufacturing. What about inside the plants?”

“People there,” Bonhoffer said, “are more interested in a system that helps them keep everything going and communicates the needs to all five shifts. It’s not about ROI, but about scheduling, efficiencies, capturing maintenance histories, and reporting period results. People in the plant need a way to implement advanced strategies that reduce unscheduled downtime. Engineering at corporate needs a way to help ensure that long-term problems are solved. Originally software to support maintenance of equipment was called Computerized Maintenance Management Systems, or CMMS. Later, that name got dropped, and, along with every other asset-related matter, was placed beneath the umbrella of the vague term we use now, ‘asset management.’”

“I’m sure there must be an analyst firm to blame,” Bala said.

“It’s just like the terms ‘enterprise’ and ‘open source,’” Moulton said. “They’re used so often, in so many ways, it’s hard to know what they mean.”

“They reduce language to a level of generality,” Bala said, “that borders on meaninglessness.”

“True as that may be,” Mulcahy said, “we just have to live with the term. Fortunately, everyone knows what it means.”
“So if you talk about increasing return on assets as being the goal of asset management,” Bonhoffer said, “then the original purchase price is sunk cost. You can increase return, however, by decreasing the money spent to maintain the assets and increasing the money made from using them.” Bonhoffer wrote an equation on the whiteboard. “You can draw a map of almost everything to do with asset management starting from this ratio.”

![Diagram]

**RETURN ON ASSETS**

Money earned from using the assets - money spent maintaining the assets

Money invested to buy the assets

“There is a huge amount of play in all these numbers. By making different assumptions, you can distort your ROA. Most companies would have a tough time making this calculation in a defensible way, especially in the plant where some of the data is missing. Another real challenge in this area lies is benchmarking. Take a like-for-like pump exchange, for instance. Whereas one plant may capitalize the entire project, another might capitalize the equipment, but expense the labor. Accurately benchmarking your ROA at different sites requires that a standard be selected. We’ll delve into the details of this later.”

**Cast of Characters**

“Everyone at the plant reports to the plant manager,” Bonhoffer said, “so ultimately, when something big happens, the plant manager gets involved. But the day-to-day action in asset management centers around the maintenance supervisor. It can also involve the production supervisor, the quality manager, the head of engineering, and whoever is in charge of planning, usually the planning coordinator. One way to look at asset management is as a constant stream of deal making between these five roles.”

“If asset management is really about maintenance,” Bala said, “what’s the conflict?”
“It’s primarily about scheduling, and lies between the maintenance supervisor and the production supervisor,” Bonhoffer said. “The maintenance supervisor focuses on the equipment. His goals are to perform scheduled maintenance and to avoid unplanned outages due to equipment breakdowns. From time to time he wants to shut down the equipment to maintain or repair it. The maintenance supervisor, as we will learn, uses any number of strategies to figure out when equipment needs maintenance. And, like everyone else, he’s also interested in keeping costs as low as possible.”

“So the maintenance manager is Mr. Fix It,” Moulton said.

“Which would make the production supervisor,” Bala said, “Mr. Pedal to the Metal.”

“Exactly,” Bonhoffer said. “The production supervisor is rewarded for keeping the plant running and getting as much production done as needed to meet the orders. Downtime for maintenance gets in the way of this, and unplanned downtime can be a disaster. That’s why it’s so important that Mr. Fix It be given information that is timely and accurate enough for him to drive actionable results.”

“How do the quality, planning, and engineering roles fit into this?” Bala asked.

“The quality manager,” Bonhoffer said, “attempts to make sure the products are created to specifications, since product that is off spec decreases production. Planning is all about figuring out how to create the products needed to fill the orders from corporate. Plans at the plant level have to accommodate windows for maintenance and respond to unplanned downtime. Engineering strives to improve the long-term performance of the plant. This means helping maintenance decide between like-for-like replacements and upgrades. Also, there may be significant engineering required to set up production of new products, especially while working around current production. Engineering is also often tasked with improvement of financial return or quality. I have a good diagram to illustrate the roles, responsibilities, and different values.”
“How do these roles end up meshing together?” Bala said.

“This example came up a couple times,” Bonhoffer said. “Let’s say the planner is told by corporate about a new time-sensitive order. The planner and the production supervisor work out a deal to get the order done, but there’s a catch. They have to run the equipment at higher than normal speeds, plus skip a maintenance window. The maintenance manager, of course, could get quite upset by this. Can the equipment make it to the next maintenance window? To
find out, he needs to ask the engineering manager about the effect of running
the equipment at higher than normal speeds.”

“That doesn’t sound so bad,” Bala said.

“This is absurdly oversimplified,” Bonhoffer said. “In the typical plant there
are 5,000 to 10,000 assets. Some are in the critical path, like the equipment on
the line or cooling pumps. Others, like a light bulb or the air conditioner in
the break room, are not as critical. Just being aware of all of this is the first
challenge. Then you need to understand how to take care of it all and make
sure that your plan allows you to produce what you need. It makes no sense
to have beautifully maintained equipment if you aren’t making money. You
can have perfect equipment, and still get the plant shut down. Depending on
the strategy from corporate, and the expected life of the plant, it might make
sense to delay maintenance and reduce the working life of some kinds of
equipment.”

History

“Twenty years ago,” Mulcahy said, “we never engaged in the sort of
conversation you just described. Either production would skip the
maintenance window without checking, or the maintenance manager
would shut down the line without asking.”

“That still happens sometimes,” Bonhoffer said. “But in the best run places,
there is good collaboration. Decisions are made transparently, with complete
information. In the worst run plants, the maintenance people are prima
donnas. They have nothing to lose by taking all the time they want to fix
things. After all, they have a great excuse—imminent danger to personnel.
The more common problem lies in a misunderstanding of the critical path. A
machine breaks. It turns out to be more critical than realized, but parts to fix it
aren’t available. Before you know it, the downtime lasts much longer than you
had estimated.”

“We once handled such matters using a system of work orders,” Mulcahy
said. “The operators would fill out forms requesting work—either inspections
or scheduled maintenance. Clipboards would be passed to maintenance
supervisors, and then to the maintenance technicians, who would look at the
orders, grab any parts, and do the work. This system was first automated with
the implementation of the CMMS you just mentioned, Joan. It started out as software on mainframes that processed work orders based on a simple model of the equipment in a plant. It was more of a job scheduling system than a real model of the assets."

“T’m told that the real model of the assets,” Bonhoffer said, “was in the mind of the maintenance supervisor.”

“In every plant there were one or two guys who knew the equipment like their families,” Mulcahy said. “They were like the Barney character on Mission Impossible, who could fix anything.”

“Or Scotty on Star Trek,” Moulton said.

“Or Geordi La Forge,” Bala said. “Remember, we’re moving into the next generation of plant management.”

“These were the guys who knew when the dilithium crystals were going to blow,” said Mulcahy. “And they knew how to prevent it. When any of them retired, the plant suffered massive shock.”

“Capturing tribal knowledge is a big focus of the modern asset management systems,” said Bonhoffer. “Since most of the modern generation of asset management software aims to create a complete model of the assets along with bills of materials for parts, maintenance histories, inspection reports, performance data, and so forth, the management of assets becomes more systematic and less a matter of relying on a key person’s special skills and knowledge. However, before we talk about systems, we need to examine how people keep score of, and balance, the conflicting values.”

**KPIs**

“As I explained,” Mulcahy said, “in my day, it was the plant manager who did the balancing. After hearing everyone out, Thomas Mattern, the plant manager who trained me, would make the call about whether to do the work the maintenance supervisor had requested, or to keep production going.”

“Plants,” Bonhoffer said, “have become too big and complex for the key-person approach to work very well most of the time. Plant managers do call the shots
at the morning meeting. Throughout the day, however, they are busy meeting with local groups, performing safety reviews, analyzing financials, and dealing with the nice people from corporate. It’s a much more outward facing job than it used to be. Now the work is often left to the people who report to the plant manager, so it’s crucial that they have the right incentives to work together.”

“Otherwise,” Mulcahy said, “whoever is the most politically powerful pushes to make their KPIs work for them. In plants, operations are the top dog because they’re responsible for putting people and equipment in jeopardy. A worst-case scenario would involve a production manager who runs things full tilt until the machinery breaks, and then blames maintenance for not keeping it running. Even in best-case scenarios, it’s rare that the maintenance manager shuts the line down whenever he wants. The trick is to get people to work together for the good of the plant. KPIs should be designed to keep things in balance. Everyone across the organization needs a shared set of KPIs and a singular vision for how to achieve established goals. Remember, too, the difference between metrics and measures. Most KPIs are just measures—they are easy to compute. Metrics, on the other hand, are a measure of what is important from the viewpoint of the customer. Production rates are a measure. How close you meet your promised date is a metric. In the end, metrics are the only things that should influence behavior. As for asset management programs, they can be as diverse as those that simply track inventory to those that build a multi-dimensional history of multiple assets. The goals and the vision for achieving them must be closely aligned and understood.”

“My research has shown there is no easy way to do this,” Bonhoffer said. “Each of the five roles involved has its own KPIs to measure functional processes. These are measurements of how well you’re meeting your planned maintenance, availability, mean-time between failure, and, my favorite, wrench time—the amount of time maintenance technicians actually spend fixing equipment. These measurements are at the lowest level of the KPI pyramid. At the top of the pyramid are the highest level financial and business related KPIs. Return on assets is the king for this area, but return on capital employed, and just plain old operating profits are all crucial. The key to this balancing act is the aggregated KPIs that combine the measures for each of the roles. The goal is to motivate each of the roles to achieve the optimal
performance overall, as opposed to a narrow measure that might punish other areas if optimized in isolation.”

“So what KPIs are at this level?” Bala asked.

“The KPI that gets the most attention is OEE, or overall equipment effectiveness,” Bonhoffer said, and wrote the OEE formula on the whiteboard.

\[
\text{OEE} = \text{Equipment Availability} \times \text{Performance Efficiency} \times \text{Quality Rate}
\]

“The goal is to see whether your use of equipment is balanced. OEE is the product of three numbers: equipment availability, performance efficiency, and quality rate. You want to see a number that encompasses all these factors. Equipment availability indicates that you can run when you need to. Performance efficiency shows whether you’re getting the most out of your resources. Quality rate lets you see that you aren’t making defective products.”

“In the long run,” Moulton said, “these KPIs also prevent people from thinking they can rob Peter to pay Paul.”

“I was impressed at first, as well,” Bonhoffer said. “Then it was explained to me how easily it is to game this number. Equipment availability is straightforward. All the metrics that flow into it tell you how well you’re keeping the equipment ready to work. You’ve got wrench time, mean time to failure and repair, and planned to unplanned maintenance. Together, they reflect the health of your planned maintenance program.”

“Are these more granular metrics direct input in the equipment availability?” Bala asked.

“They’re simply the metrics for activities that are related to availability,” Bonhoffer said. “The other two metrics are where most of the distortion or, in the worst case, manipulation of this metric happens. Efficiency, for example—against what does it measure your performance? Many places compare current performance to historical averages. This is fine, though it won’t reflect
the equipment’s actual capabilities any more than John’s dream Ferrari will provide an accurate benchmark for its true capabilities if he only drives it 40 miles per hour. You can do the same thing with quality rate by selectively including or excluding various kinds of defects.”

“All you’re saying,” Moulton said, “is that this number, like any other, has to be used properly and sincerely.”

“Some of the distortions are unconscious, though,” Bonhoffer said. “It’s not enough to use OEE. You’ve got to dig into it to make sure it means something. In some plants, I’m told, this metric is seen as more of a solution than it actually is. One of the reasons is that doing a better job requires people to perform work that they may not have the time or skills to perform. At bottom, we need to use the right diagnostics to drive maintenance activities, and then measure PM and CM, or preventive maintenance and condition maintenance, ratios to determine if we’re doing the right amount of each.”

**Process and Architecture**

“This really catches my interest,” Mulcahy said, “because it seems that the whole floor for asset management has been raised. It’s no longer about people putting out fires. Before I get too excited, though, I want to see whether you got all of this from the maintenance people, since they could have inflated the importance of the maintenance role in the plant.”

“Fortunately,” Bonhoffer said, “there’s a growing body of literature to help us keep this all in perspective. Wireman has written numerous books on this topic, for instance. The one he wrote on KPIs is especially instructive. John Moubray has written some excellent stuff on Reliability Centered Maintenance, which provides the most comprehensive theoretical framework. Although it won’t apply directly to specific equipment in a plant, it’s vastly improved my thinking about the plant as a whole. The Smart Signal guys, too, have a fascinating system that uses real-time statistics to get an operating signature for an individual piece of equipment. If used correctly, it can provide an early warning about when equipment will fail, or even a model to predict failure. Remote monitoring is becoming more popular because it can drive down costs and increase standardization of the way assets are managed. But the key for plants, as I learned, is to understand their asset management problem and apply the parts of all of this that make sense. You don’t need a heart surgeon to cut
your steak, and you don’t need reliability-centered maintenance to change a light bulb.

“One thing I discovered is that attention to asset management is now starting much earlier in the process. There’s a whole class of companies called EPCs, which stands for Engineering, Procurement, and Construction. These are the Bechtels and Fluors of the world, who build power plants, nuclear reactors, refineries, and other large manufacturing facilities. The asset management process starts with them. They use products for asset management during the design and construction phases so that part of the deliverable is a fully populated database of assets. The best explanation for what people want from EPCs came from an owner-operator who said, ‘I want you to deliver two plants—one made of steel, the other made of information—and I want them to be the same.’”

“So the challenge of asset management in an existing plant,” Bala said, “is to build the plant made of information to the level you need to maintain the plant made of steel.”

“It’s now practical to capture and maintain all of the information about all of the equipment,” Bonhoffer said. “But you want to maintain the context, as well. It doesn’t make sense to have thousands of data points about every piece of equipment without the tools to search and analyze the mined data. You want to leverage your efforts, and to do that, you must be able to analyze and react. For many plants, the inability to do this is a major barrier. The people in charge of maintenance don’t have the wherewithal to execute the analysis they need to better understand their data. Not only is it imperative to establish a data architecture, but also, once you’ve done that, everyone working with it must abide by a set of rules and definitions that describe how to use that data.”

“Are you saying they know how to maintain the equipment on a tactical level,” Moulton said, “without giving equal consideration to their strategy?”

“It’s different at each plant,” Bonhoffer said. “Even so, the range of analysis required to do the right work is vast. Naively implemented asset management systems are often reactive, as opposed to proactive. People track work without having planned it beforehand. I read a recent book called Lost in Translation
that describes how to implement effective IT by thinking of each part of a company as an information system with five dimensions—values, policies, events, content, and trust. The authors call it the ‘VPEC-T framework.’ The concept provides a powerful lens through which to more clearly see asset management from a high level, especially as it relates to value.

“Now, we’ve already discussed value in term of KPIs,” Bonhoffer said, and began to create a new list on the whiteboard, “but I’d like look at it another way, too. Both the operations department and the plant manager, for instance, are rewarded based on throughput, quality, and responsiveness. When the plant operates smoothly, they’re happy. The maintenance manager wants the same thing, in the form of smoothly running equipment and no unscheduled outages. So do the engineers. They want their equipment to perform at peak efficiency while meeting their long-term goals. Corporate, on the other hand, may value different things. If the plant is near the end of life, it may make sense to cut back on capital but to improve maintenance and let engineering worry about the equipment. If the plant is key for the long term, it may make better sense to spend more capital.”

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**VALUES**

**PLANT MANAGER, OPERATIONS**
- More throughput

**ENGINEERING**
- Increased performance

**MAINTENANCE**
- Avoid unplanned outages, protect equipment

**QUALITY**
- Maximize product quality

**CORPORATE**
- Establish goals and set expectations for useful life of the equipment
“Here’s a way this might all play out in practice,” Bonhoffer said. “Imagine a plant in a sold-out market, whose energy costs are hurting productivity. To remedy these concerns, corporate might expand the plant and replace, rather than repair, any equipment that is on the blink.”

“They could also inventory all of their old equipment,” Bala said, “and separate those they’ll repair from those they’ll run until failure. As for those that waste energy, they could be preemptively replaced.”

“All good ideas,” said Mulcahy. “But remember—the point here is to ensure that your asset management program never runs on automatic. It must undergo constant assessment with an eye toward serving the larger corporate goals.”

**Maintenance strategies**

“Once you get into it,” Bonhoffer said, and began to create yet another diagram on the whiteboard, “you find that there are many choices to make, none of which are obvious. To cite just one example, for each piece of equipment in the plant there are at least half a dozen maintenance strategies that may be appropriate, of which one is the best. The goal is to find out which one that is.

“Kristian Steenstrup from Gartner was extremely helpful in explaining all this. He provided some simple graphics, to help you get the idea.
He has much prettier graphics, but you get the idea. ‘Run to Fail’ is the oldest strategy in the book—don’t fix anything until it breaks. It’s a fine way of working with equipment that isn’t critical or that costs the same to let it fail. Light bulbs, laptops, paper towel dispensers in the bathroom, and the like fall into this category.”

“The plant manager would not say his burnt out light bulbs weren’t critical,” Moulton said.

“It’s always complicated, of course,” Bonhoffer said, “but you get the idea. Some things can run to failure and be fixed when you can get to it. When the cost of failure rises, you can execute planned maintenance based on time or usage, the way, for instance, that some people maintain their cars. Changing your oil every 3,000 miles would fall under the usage model. Getting a safety inspection once a year falls under the time, or calendar, model. These
strategies are basic and can be applied at any plant. To pick the one that matches the usage, you can simply ask, ‘Is this something that deteriorates over time, or does it depend on how much you use it?’

“The next group of strategies requires you to invest in some sort of technology. Condition-based maintenance involves checking for circumstances that merit attention. The gist is the idea is to collect and analyze data whose results you use to drive actionable results. One example that Streenstrup found at a company in Asia was the ‘grey cards’ that technicians used to dip in the grease lubricating railroad cars. When the grease was darker than the card, you changed the grease.”

“I love things so simple that you can’t mess them up,” Mulcahy said.

“Of course that’s a very low-tech form of condition monitoring,” Bonhoffer said. “Nowadays, real-time spectrometers test oil for impurities, and sensors detect vibrations. Companies like Smart Signal offer technology that monitors the behavior of devices based on the historical norms. Patterns emerge. When a piece of equipment’s behavior deviates from the pattern, you inspect the equipment. The more data you want to collect and monitor, the more technology you’ll require.”

“What distinguishes condition-based maintenance from predictive?” Bala asked. “The condition is just a way to predict that a failure is near.”

“That’s true,” Bonhoffer said. “But the best predictive maintenance specifies the exact time of failure. It relies on an accurate model of some aspect of the machine to show when it will fail. Such models don’t grow on trees, either. They take time and money to develop.”

“The more complex the maintenance strategy,” Moulton said, “the more expensive it is, right?”

“And as you just noted, Joan,” Bala said, “there are so many to choose from. How do you figure out when and where to apply one or the other?”
The critical path

“In theory,” Bonhoffer said, “it’s possible to develop a model that predicts when your light bulbs will fail. In practice, however, we simply maintain an enormous stock of light bulbs. This reduces the impact of failure and widens the window for maintenance. The downside is how it increases inventory cost.”

“But say I have just one light bulb,” Moulton said. “Why should I still care if it fails?”

“This is not a question about light bulbs per se,” Bonhoffer said, and pointed to the whiteboard. “We have a variety of maintenance programs, each of whose goal is to narrow your focus to the most important equipment in the plant so that you can determine the critical path. The real question is, ‘Where is the impact of failure most costly?’”

“Are there formal approaches to determining the critical path?” Bala said.

“Reliability Centered Maintenance is one of the most advanced,” Bonhoffer said. “RCM comes from the aerospace and aviation industries, where the cost of failure is extremely serious. People die. At first, airplanes were maintained with maintenance based on time or usage. But the parts didn’t fail as often as the predictions said they would. And replacing parts can lead to errors. This created the unpleasant situation where maintenance led to decreased reliability and inaccurate schedules. With jet engines, the time between overhauls is dictated by the quality of the monitoring and historical information maintained. The shortest time between overhauls is reserved for engines that have manual readings on a routine basis, and the longest time for engines with real-time data monitoring, analysis, and recording.”

“Not super efficient,” Mulcahy said. “Even so, since these are airplanes we’re talking about, I think the conservative approach is best.”

“The RCM framework starts with what is called a failure modes and effects analysis,” Bonhoffer said. “Instead of taking the manufacturer’s recommendation about the life of parts, you look at the machine as a system. If it’s an airplane, you look at all the ways it could fail and what
the effects would be. Then you construct your maintenance strategy to prevent catastrophic failure. Feeding this analysis back also leads to improvements in design.”

“After you perform this failure mode analysis and find a vulnerability,” Bala said, “you figure out a way to introduce redundancy, which lowers your maintenance requirements, right?”

“But in a plant that has critical equipment such as turbines or feed conveyor systems,” Bonhoffer said, “RCM works best without redundancy. If you model a plant as a system, and then perform your failure mode analysis, the relationship between critical pieces of equipment becomes clear. This can lead to the introduction of redundancy or advanced strategies to reduce downtime.”

“Just like the failing equipment we discussed earlier,” Moulton said. “You could calculate the expected value of increased uptime less the expected cost of downtime, and then compare the cost of implementing the advanced strategy with the benefit.”

“But the biggest benefit from doing an RCM analysis on the plant as a system,” Bonhoffer said, “is that it identifies which equipment is critical. Of the 5,000 to 10,000 assets in a plant, you want to spend your time on the ones that matter most. RCM is just one way to find the dependencies. While you could have learned most of this by using common sense and paying attention, a more systematic approach enables you to capture and disperse big chunks of tribal knowledge about key equipment.”

**Asset management software**

“It sounds like the real task,” Mulcahy said, “is to understand the critical equipment, assign the right maintenance strategy to it, and do what it takes to keep everything running. Can existing asset management software help you do all this?”

“There’s no short answer to that question,” Bonhoffer said, and began to draw another diagram. “Asset management software has evolved in the following stages.”
“Everything started with CMMS on mainframes or personal computers,” said Bonhoffer. “These systems turned paper work orders into an electronic record and provided communication between maintenance personnel. This made it much easier to enter maintenance schedules and manage the work orders as a team. The work order is the key document. It’s used for planning, and all parts and labor are charged to it. It can be used to create an asset or maintenance history, too. Having the work orders in a database turned the lights on in a big way.

“Then came best of breed asset management software, which offered more data and more automation. These systems have a rich data model, bills of materials for each piece of equipment, asset and maintenance histories, inspection reports, photographs, links to manufacturer specifications,
notes captured by technicians, and lots of reporting. Some functions, however, such as communication, have been replaced by other solutions, including Exchange, portals, and blogs. Asset management systems allow you to assign various maintenance strategies to a piece of equipment so that work orders are automatically generated based on the calendar or inspection data. These systems can also accept measurement values. If a condition indicates the need for maintenance, a work order for an inspection or repair is automatically generated. The more advanced functionality includes extending the system to mobile devices. With these, you can take pictures and draw. You can also capture the dependencies between parts to determine the impact of a failure.”

“How is best of breed different from the asset management software sold by the ERP vendors?” Bala said.

“Here’s where the vendors argue quite a bit,” Bonhoffer said. “They usually call their software enterprise asset management, or EAM, software. Asset management is an extension of the core model of a business that is kept on ERP. While the best of breed software has an intense focus on the equipment, the EAM software connects the descriptions of the equipment to the financial, budgetary, and process models in the ERP software. In other words, asset management becomes an integrated extension of ERP. People don’t need a separate identity to log in to the system, the costs are tracked and rolled up, and established workflow processes, email notifications, and user interfaces are used.”

“So which is better?” Moulton said.

“There’s no general purpose answer,” Bonhoffer said. “EAM vendors say their comprehensive standardized solutions are integrated with other important applications, such as warehouse, and do everything important. Non-ERP vendors would say that the integration with other applications, while important, is not as valuable as the concentration on the job of the mechanic. From the partnerships that have formed, it’s clear that both categories of companies
have respect for each other. The companies that sell business suites also sell plant level maintenance applications. The non-ERP vendors are improving integration. In some instances, the EAM solution may be enough. In others, the point solution or both are needed. Either way, these are advanced condition assessment systems that represent an evolution from plain tribal knowledge. Before you can choose the right one, you must first understand the assets you want to manage. Remember, you don’t need to know everything about everything, just everything about choice concerns. It costs money to gather information, and more to store it. Anything extra is waste.”

“What have our plants done?” Mulcahy said.

“We seem to have one of each sort of mistake,” Bonhoffer said. “At one plant they bought a best of breed system they didn’t really need. Your predecessor as EVP of Manufacturing Operations then forced the ERP asset module on one of the plants that actually needed the best of breed EAM solution. At some point, we have to decide how to balance the need for a standard approach, which we could get if we picked an EAM solution, with the fact that some of our plants require specialized asset management and would prefer to use the best of breed.”

“That’s why we get paid the big bucks,” Mulcahy said.

**Enduring Challenges**

“There are a range of other issues we need to address at the corporate level if we’re going to do a good job,” Bonhoffer said as she wrote on the whiteboard, “and none of them are easy.”
“There is no way to solve any of these problems from our cubes in corporate,” said Bonhoffer. “But the plants don’t have the budget to support the research you’re asking for, either, so we can only help show the way. All of these problems are interrelated. For example, with many workers retiring in the next 5 to 10 years, loss of tribal knowledge is a worry across almost every aspect of the plant. It’s especially acute in asset management. But if you systematically capture tribal knowledge, where do you put it, and how do you find it when you need it? Unless you’re going to use a wiki or something like that, you need asset management software set up with the right data model. You also need to provide incentives to capture knowledge.

“Another area of concern is organizational alignment. You want operations cranking out the product, and you want the equipment maintained, and
yet often the two departments don’t use a common scheduler. At one of our plants, they put the operations and maintenance people right next to each other in the same set of offices. This informally encouraged knowledge transfer and awareness of each other’s problems. Another approach was to have the operators perform simple maintenance tasks that they could handle. One plant put maintenance and operations in the same department with a set of common KPIs. None of this stops the tension, but it increases the incentive to communicate.

“To capture tribal knowledge, or to align maintenance and operations requires a change in culture, and that’s never easy. Steenstrup also told me a great story about how a mining company achieved a culture change that better aligned operations and maintenance by making a simple policy change. They had lots of heavy equipment run by operators who were rewarded for more volume. They used massive bulldozers and trucks to move mountains of dirt and ore. Maintenance was an afterthought. The operators simply ran the equipment until it broke.

“They changed the culture by reprioritizing how maintenance was done. Unscheduled repairs were put to the back of the line and planned maintenance had top priority. This meant that operators who ran their equipment until it broke now paid a stiff penalty in terms of downtime. It didn’t take long for operators to make showing up for planned maintenance a priority.”

“But we can’t make specific cultural change recommendations,” Mulcahy said. “Those have to come from the plants.”

“That’s right,” Bonhoffer said. “But the people in a facility want to succeed, so we can provide the tools and information needed to drive collaboration. We can also help shine the light on the sort of change that’s needed by improving communication. The reason the mining company knew it needed to change their culture was that the maintenance issue was clearly communicated in business terms to a high enough level. Whoever ran maintenance was able to articulate that emergency repairs were more harmful to the equipment and had potential to lengthen downtime, so better maintenance planning could increase output.”
“Teaching the nerds who run maintenance to speak in terms that will grab the attention of the policy makers won’t be easy,” Moulton said.

“But by providing examples and educating both sides,” Bonhoffer said, “we can make an impact. If we get this right, then we should be able to better synchronize the asset management practices with corporate goals. For example, when a plant that has been in a sold-out market finds that this is no longer the case, then the asset management strategy should change from one focused on uptime to one focused on reducing costs. Or if a plant is going to be sold, then perhaps an investment in asset management can increase the price by giving potential buyers more confidence in the quality of the plant.”

“In my experience,” Mulcahy said, “I’ve never heard someone at corporate, or even a plant manager, say, ‘Well, part of this strategy change means we’ll have to change our maintenance practices.’”

“Any recommendations we make or training we do in this area has to address how the software will support it,” Bonhoffer said. “This was the biggest complaint I got when I visited the plants and asked about asset management. They often felt that since technology had been inflicted on them without proper consultation or analysis, it never worked.”

**Asset Management from the Plant’s Perspective**

“Here’s a problem,” Bonhoffer said. “Apparently, the former EVP of Manufacturing, along with many other top-level people, mandated an EAM solution without first having learned to make the system work. IT, not the maintenance managers in the plants, was in charge of the project. Most IT departments don’t fully understand the business process unless you work closely with them. When you do this, they can see that since the system is evolutionary, it’s never complete or done. New equipment is constantly added or changed. Algorithms are constantly being improved through more data or better use of existing data. In our case, sometimes IT set the system up to collect too little data, sometimes too much. Sometimes the data was irrelevant. Collecting it didn’t help run maintenance any better, and yet it required a lot of data entry. Too often, they said, the system just tracked work orders without doing the needed work of learning how to improve maintenance.”

“That sounds typical of corporate executives who aren’t listening,” Mulcahy said.
“Nevertheless,” Bonhoffer said, “in the end, even if you create a network of systems that makes good use of the work order to build asset and maintenance histories, you’ll need to spend time analyzing whether the work you have planned is the right work. This requires a nuanced relationship between data-collection systems, diagnostic data-collection systems, manual-inspection data systems, lab analysis, and so forth, followed up by decision support and then, in turn, by work management.”

Best Questions about Asset Management
“We’re now ready to see the results of my analysis,” Bonhoffer said, and began to write on the whiteboard, “in the form of best questions. Let’s start with those you could use to assess the level of maturity a plant has for asset management if you only had an hour or so to do it.”

Top Questions for a Quick Evaluation of Asset Management Maturity:

1. What is your CRITICAL EQUIPMENT that if it failed could halt production?
2. What is your MAINTENANCE STRATEGY for each category of equipment?
3. How are INCENTIVES and KPIs balanced to encourage COOPERATION between maintenance and operations?
4. How is COLLABORATION between maintenance and operations around planning and problem resolution supported?
5. How did you determine the AMOUNT of data to capture in your asset management system?
6. How is the WORK ORDER used to capture data for asset and maintenance histories?

“The first question about critical equipment establishes the level of analysis that has been done,” Bonhoffer said. “Many plants have an informal sense of what’s critical but have never thought everything out, written it down, and scrutinized it. The best answer here is that the company has a document used for training that shows all of the equipment related to the critical path.”

“So if a company can’t answer that quickly,” Moulton said, “then they probably haven’t done the analysis.”
“You can tell when someone is making something up on the fly,” Bonhoffer said. “If they don’t have any documentation, that’s another clue to how seriously they have considered something. When asking these questions, it’s important to make sure you’re addressing the person who should know the answer. This first question would be best asked to the director or VP of maintenance. It would, of course, be ideal if all the maintenance techs had the answer, as well.”

“So you get additional information from how widely propagated the key knowledge is,” Bala said.

“Another key point,” Bonhoffer said, “is that not everyone has to have all this knowledge. The best answer to the question about the maintenance strategy for each category of equipment might come from a search through the asset management system or training documentation. The questions about KPIs and support for collaboration tell us whether they have their eyes on the business results and are aware that there are tensions to balance. It is the operators and maintenance techs that will start the conversations about how to make trade-offs. They need to be aware that it’s their job to raise issues for everyone to discuss. Support for collaboration means that there must be a way to get the attention of the right people and record the results of any decisions.”

“Otherwise,” Mulcahy said, “they just do what’s on the schedule without considering the consequences.”

“The last two questions,” Bonhoffer said, “get at the quality of the data being captured and how well the standard maintenance processes are used to keep up the database that describes the assets. If the IT department decided what fields would be used, that tells you a lot. If the work order captures useful data that is not harvested, that could be a problem.”

“One way we could quickly get a handle on our plants,” Moulton said, “would be to send them these questions and have them respond with answers in a day. They won’t be able to paper over anything in that little time, and it will get across what we think is important.”

“That could be construed as a bit hostile,” Bonhoffer said. “It would be better to ask these in a more friendly way, as part of the process of building a stronger asset management program. Here is a longer list of questions that can be used
if we have more time to spend, or if the people in the plant feel that answering these would be useful.” Bonhoffer wrote several more questions on the board.

1. **How is that information correlated, analyzed, and put into a business context?**
   - What KPIs are collected to measure maintenance activities?
   - How visible are asset management KPIs at all levels?
   - Who is involved in changing maintenance and production schedules on the fly?

2. **What are the most effective patterns of execution?**
   - Are mobile devices appropriate for use by maintenance technicians?
   - Can condition monitoring be automated and performed in real time with spectrometers or other sensors?

3. **How is the activity in this area monitored, analyzed, and corrected?**
   - Do planners from production and maintenance meet and review how well the plans they made were executed?
   - Are planning methods improved based on an analysis of how well the plans were executed?

4. **What are the opportunities to apply automation?**
   - Does the asset management system automatically generate work orders based on schedules, inspection reports, or other input?
   - Is any equipment so critical and so productive that an investment in advanced condition monitoring and predictive maintenance would be justified?
   - Would RFID tagging of devices help improve maintenance processes enough to justify the investment?

5. **How can you encourage a successful culture in this area?**
   - Have any organizational strategies to encourage cooperation been considered such as putting maintenance and operations staff in adjacent offices?
Asset Management Opportunities

After looking at the list, Mulcahy had a question. “Joan,” he said, “what’s your general advice as to how we should start to improve asset management?”

“Like everything else we’re dealing with,” Bonhoffer said, “we can’t just do it in one fell swoop. There are levels of maturity and sophistication in asset management. It’s important to understand our processes so that we can determine what data we need to support them. We’ve got to understand the data, too. We’ve also got to have a firm grasp on our existing tribal knowledge. Once we have all these in hand, we need to consider how best to leverage them to establish a condition score for all of our critical equipment. It’s at this point that we’ll pinpoint the exact locations of our data, and then centralize it for management and decision-support activities. In short, we want to know where we’re starting, where we want to go, how the ideal asset management processes support corporate strategy, and how that strategy may change.”

“Some of the biggest mistakes I’ve seen,” Mulcahy said, “have been around misapplying technology, hoping it would solve the problem instead of having it provide a deeper understanding of exactly what you want to do and how to change the business processes to do it. So I’m on board with an incremental approach. But what would you have our departments do?”

“Answering the questions in the handout is a great first step,” Bonhoffer said. “Next, we need to collect more data or make better use of data to help identify opportunities. After that, we need to identify the critical equipment and increase the sophistication with which we manage it, especially if doing so will bring big gains.”

“Much easier to think about than to do,” Mulcahy said. “Thanks for getting us off to a great start.”