Chapter Five

The Vision of the Perfect Plant: Coordination, Planning, Execution, Integration, and Intelligence

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Bonhoffer, Bala, and Moulton were knocking back their coffee, trying to jump-start the early morning lesson they were about to get with John Mulcahy. "I see you're all ready to drink from the overflowing cup of my wisdom," he said. "Today, I'll try to communicate my vision for a perfect plant. If you can absorb it, you'll be well prepared to perform the research for the second part of this project."

"Consider us ready for absorption, oh wise one," Moulton said, spreading his hands out from his forehead.

"Given the size and scope of what falls under 'Manufacturing,'" Bonhoffer said, "I'm not sure how it can be captured by one vision. So far, you've mentioned three major categories of manufacturing. Process industries include everything from refineries to paper mills. Companies in the discrete manufacturing industry, on the other hand, make laptops, washing machines, and other

devices. In utilities, both process industries and discrete manufacturing industries generate power. So far as I can tell, the distinctions between these categories are blurry and overlapping, especially when you get into the details."

"For example," Bala said, "pharmaceutical companies produce lots of little bottles of pills. The creation of the medicine inside the pills is a process on the line, and all of the ingredients and batches that yield the medicine must be tracked. At the same time, each little bottle is a discrete unit that has to be tracked and correlated to the ingredients and batches inside the bottle."

"It's true," Mulcahy said. "Manufacturing is a huge world, loaded with incredible variation. But in our discussion of processes and systems, we heard that some basic processes are in play at all plants, and that the pressures on the plants are getting more intense. So let's start with why running plants is so difficult."

Balancing a Complex Act

"So far," Mulcahy said, and began to bullet some points on the whiteboard, "we've described a flow through the plant that involves the following steps, each of which is supplemented by two key activities."

- COORDINATION
- PLANNING
- EXECUTION
- INTEGRATION
- INTELLIGENCE

"Coordination," Mulcahy said, "is the flow of information from the corporation to and from all of the plants it owns or controls. Basically, my job as EVP of Manufacturing Operations is to direct the plants to do what the corporation needs. The planning process takes corporate goals and turns them into specific plans at various levels. Execution makes it happen."

"And integration and intelligence are supporting activities," Bala said.

"Integration," Mulcahy said, "is the way all the activities are synchronized at the levels of process, information, and automation. Intelligence is about making all this visible, and constructing models of what's going on to help run the business. All the areas you're researching in the next phase of this project fit into these dimensions in some way."

"But we're going to research areas that are much more specific than these broad categories," Bonhoffer said.

"That's partly true," Mulcahy said, "but as you delve into each area, you'll find that the complexity never stops growing. It's like a fractal. That's what makes improving plants so difficult. Let's go through some examples, starting with my job.

"A plant exists to carry out the corporate strategy. Another way of looking at it is that the plant fits into some sort of corporate-wide process that provides value to the customer. Nowadays, though, there are so many more choices for how we can make things. We can either improve our existing plants or build a new plant, or we can use an outsourced manufacturer for part or all of the process. When we look at the portfolio of plants, we have to decide who gets what. I only have so much capital to spread around. Everybody wants more. The amount is decided by figuring out what corporate needs each year from the plants. What is needed from the plants gets determined by corporate's long-term strategy."

"So you have to figure out which plants need to be more productive to meet growing demand," Bonhoffer said, "and which are nearing the ends of their useful lives."

"Exactly," Mulcahy said. "This influences how we allocate capital investment and our maintenance strategy. Planning goes deeper into detail. Once the corporate plan is set for the year, it's broken down into quarterly and monthly plans. There's quite a bit of back and forth between the plant managers and me in this process. After that, it's up to the plant managers to make it happen."

"That doesn't seem so complex," Moulton said.

"If you aren't worried about whether your plan is right," Mulcahy said, "and if you don't listen to your plant managers, you can whip something off pretty quickly. However, if you don't want the CEO tap-dancing in front of financial analysts, trying to explain revenue shortfalls, spikes in production costs, or the reasons behind massive accidents, it's much more difficult. Still, in a way you're right. The planning process is simpler than the operations inside the plant, where the number of moving parts dramatically increases.

"Say you're a plant manager and your maintenance manager reports that a pump looks like it's going to fail, a pump that's critical to keeping the line going. Do you keep the line running and hope for the best? Or do you stop the line and do the maintenance and blow that shift's schedule? When you do the maintenance, do you fix the pump or do you replace it with a more energy efficient model? Everyone has a dog in this fight. Sales will go crazy if a crucial order is delayed. Production wants to keep the line going. Maintenance wants to fix it. Those in charge of decreasing energy usage want a new pump, but what does that mean for the capital budget? If you're in a sold-out market, one set of decisions will seem right. If you aren't, then you'll lead in a different direction. All of this will be influenced by the plant's long-term plan. If you're building capacity and want this plant to run efficiently for years, then buy the pump. If you're at the end of life, fix it. Of course, the relative cost difference must be taken into account, which not only includes the cost of a new pump but parts and labor to fix the old one."

"Okay," Moulton said, "so you do have to make difficult decisions."

"It goes way beyond that," Mulcahy said. "The whole team is involved, everyone in the plant. When you run a plant, you're optimizing a massive multivariate, non-linear equation. You want to create products to a high degree of quality, for the lowest cost, meeting the plan, maximizing use of equipment, using energy efficiently, staying in compliance with environmental, health, and safety regulations, and adhering to labor union agreements. You have to keep a close eye on the stream of orders and supplies arriving at the plant even as you ensure that products are shipped and delivered on time. Oh, and, by the way, the costs of bad decisions or lapses in judgment are incredibly serious. Because of Sarbanes-Oxley, for instance, a CFO might go to jail for a bad financial statement. In a plant, a series of bad decisions means equipment can blow up and kill people, a thought that's never far from a plant manager's mind."

"Now it sounds intense," Moulton said.

"When you get it right," Mulcahy said, "it can be a thrill. But you have to get used to living in fear and taking action to prevent things from getting out of control. When you start trying to improve one area, like energy usage, your solution might affect quality or reliability or costs."

"When you push one knob in," Bonhoffer said, "another pops out."

"So how does this multivariate equation get optimized?" Bala said. "Anything easy would be done quickly, leaving you stuck with problems that are embedded with contradictory goals."

"Yes," Bonhoffer said, "like how to execute planned maintenance without interrupting production. Or how to save money without affecting quality."

"The short answer," Mulcahy said, "is that the plant gets better in a set of incremental steps carried out by a large team. So far, I've been somewhat romantic about the role of the plant manager, the heroic figure of the plant. Few plant managers would disagree with me that theirs is the key role, but if the plant manager doesn't create a team to run the plant, then he or she can quickly become a barrier to progress."

"But if each team is in charge of optimizing a different set of variables in this equation," Bonhoffer said, "and is motivated by different key performance indicators, or KPIs, then how do you resolve all that tension?"

"This is perhaps the most challenging part," Mulcahy said. "You have to somehow create a culture that is able to see the big picture and take into account what's best for the plant. And each area has its own culture. In your upcoming research, pay careful attention to the culture of success. Joan, you'll be looking at energy management and quality management. Moulton, from you I need to know how teams involved in coordination, planning, and execution work successfully. And Bala, I want you to explain the culture that helps plants successfully transform themselves."

"Solving these problems sounds like a tall order," Bala said.

"I'm not asking you to figure this out yourselves," Mulcahy said. "You'll talk to the experts in each area to extract information and ideas and distill them into a form we can use to educate all the people working in Wolverine's plants. I chose you three for this task because this ability to synthesize is your strength.

"Before you can do any of that, however," Mulcahy said, and began to write on the board, "you'll need the vision."

WHAT IS A PERFECT PLANT?

A perfect plant is 100 percent on stream at full capacity producing consistently high quality product with no health, safety, or environmental incidents with optimal use of resources.

A perfect plant is a plant where everyone can handle change, where everyone is aware of the processes of the plant, aware of their role in them, and aware how their actions affect other people.

In a perfect plant, the lights are turned on, the right information is in the right place at the right time to increase the velocity and impact of decisions. Information flows so people can make the best decisions based on information not instinct.

"This description is pretty good but there are many ways to put it," said Mulcahy. "A perfect plant is one that offers a 360° view into all operations. It allows you to increase visibility and improve integration with business processes. It enables you to progress from reactive management of operations and maintenance to proactive management of operations and predictive maintenance. Your 360° visibility into all plant operations provides the ability

to positively impact the business' bottom line. With it, you can plan and schedule in real time, and you can respond faster to operational issues and customer delivery targets."

"So you can see what's happening and react quickly," said Bonhoffer.

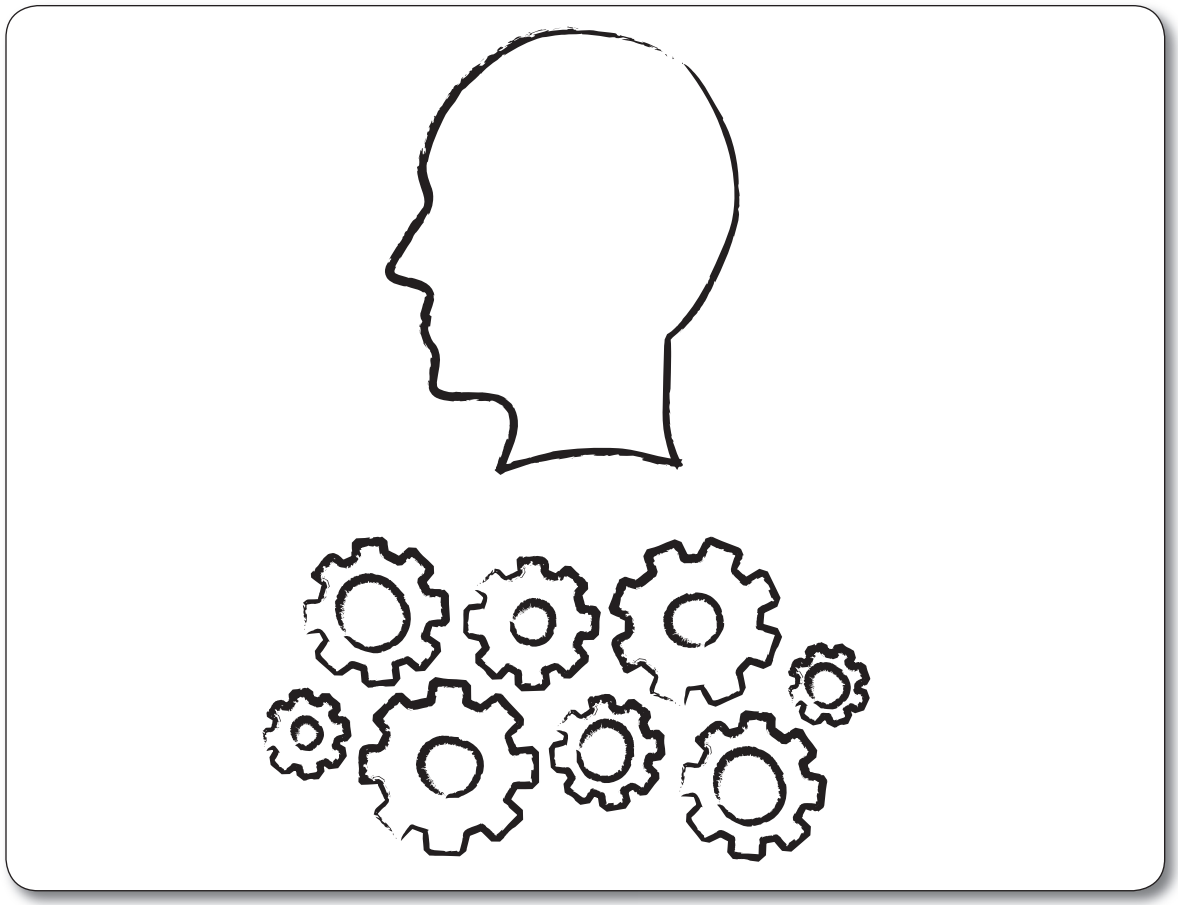
"But we need a *prescription* to help make our plants better," said Mulcahy. "The perfect plant is an ideal meant to serve as a blueprint for your own manufacturing transformation, helping you to prioritize when and where to devote resources to produce steady, incremental improvements to your manufacturing processes. In the perfect plant, you can optimize your use of manufacturing assets and drive increased production performance—all in concert with enterprise-wide plans and objectives. In a perfect plant, personnel no longer waste effort constantly reacting to line failures, supply network disruptions, and operations emergencies. As Bonhoffer pointed out, the vision can't be too specific, because the plants in our portfolio are so different from each other. But it can't be too general, either. While they're not all the same, there are finite numbers of business processes that most organizations run at the enterprise level that we can talk about. When you get into manufacturing, there are business processes at the operational, supply chain, and manufacturing levels that can be dramatically different, depending on the specific industry. As a result, one of the challenges you'll face in making a recommendation is whether to provide a lowest-common-denominator set of best practices, or to suggest implementing an industry-specific, next practice."

Assessing Flawed Approaches to the Perfect Plant

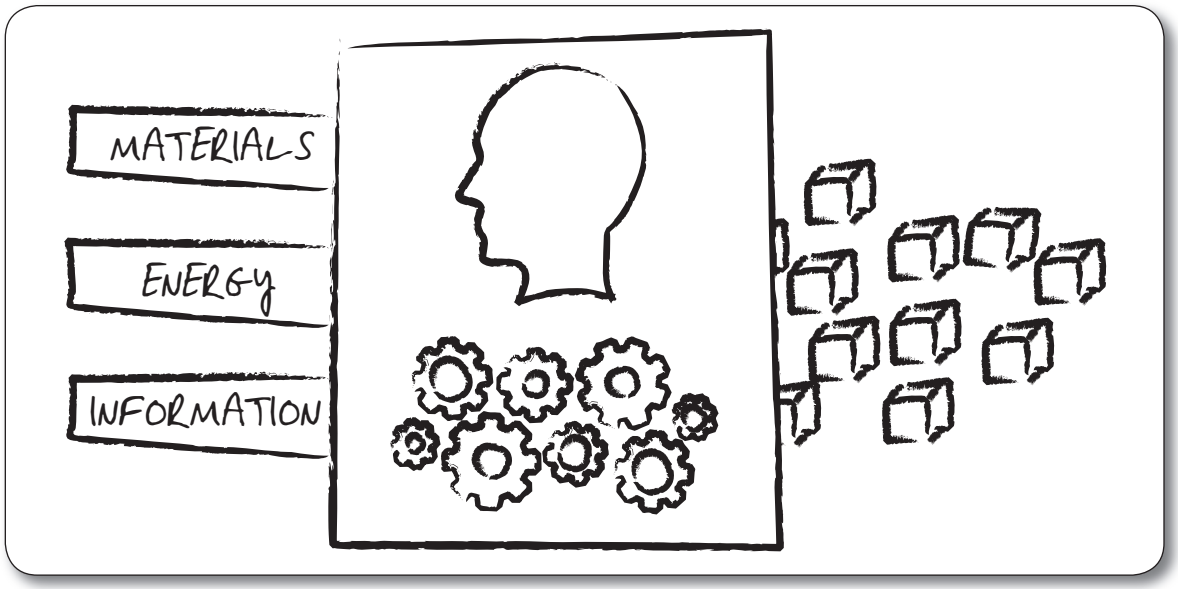
"I'm going to explain some things, now," Mulcahy said, "that do not work. I'm not pointing out these problems from some high place of scorn—over the years, I've made all of these mistakes myself at some point. I simply want to educate you about negative patterns so that you can recognize them in our plants and help to fix them."

"So we'll be sort of like medical interns," Moulton said. "We won't really know what we're doing yet, but we can propose a diagnosis now and then."

"Maybe by the end of this process, you'll be more like residents," Mulcahy said, and began to draw on the board. "Remember, the first rule of medicine is to do no harm, which is why it's important that you know what *not* to do."



"Everything that happens in a plant is controlled by brains or machines," Mulcahy said, expanding on his drawing. "And when I say machines, I'm including software. To make things work well, the brains have to know what's going on in the plant, and the machines have to have instructions to do what's needed. In our first meeting, we said that a plant can be thought of as a flow of materials, a flow of energy, and a flow of information. These flows run through the machines and brains in the plant. From the other side, products emerge."



"The challenge of running a plant is to have all the materials, energy, and information directed and transformed by the brains and the machines. The most common negative pattern, one that I fell into as a beginning plant manager, is the one-brain command and control model. I used to call this the military model, but I ran into someone from West Point who said the military doesn't work this way anymore.

"In the United States, when the modern world of manufacturing was created after World War II, many of the people who ran plants came out of the military. They brought that era's ideas of command and control with them. In other countries it was much the same way because hierarchical management ruled the day. The idea was that everyone would get general direction in the form of standing orders, which in the plant translated roughly into directives to optimize certain KPIs and specifically to how to do things. This seems like a good model in the same sort of way that a planned economy does, but it leaves little room for individual contributions and initiative. No set of rules can handle every situation in a plant, so either people act on their own, in violation of policy, or they send all decisions upstairs."

"Which is when the managers become the bottleneck," said Bala.

"That," Mulcahy said, "is because you have a much smaller number of brains working on your problems than you would using other models. But you do have clear lines of authority and a sense of control. This model is probably more common than most people acknowledge. The personality type that tends to become a plant manager can lead in this direction."

"It must be a tricky balance," Moulton said. "The plant manager has to understand everything, but not be involved in a way that takes responsibility away from the teams."

"Like most plant managers," Mulcahy said, "I'm interested in everything. So it was hard for me to step back and let the processes I'd set up resolve situations. But there are no panaceas—even when responsibilities are delegated, things can go wrong in different ways.

"Once you create a separate group to handle each major area—all of which are necessary to run a plant—sometimes they don't communicate. The teams devolve into what people usually call silos. The overly involved plant manager provides an important and often unacknowledged benefit—he or she acts as a conduit for communication. The cost of over-involvement is that it creates a bottleneck."

"What happens when teams are in their own silos?" Bonhoffer asked.

"All of the things you would expect that come out of a lack of coordination and poor communication," Mulcahy said. "Key maintenance is put off to keep the line running, or the line is interrupted for maintenance that could have been put off. Nothing, including planning, is optimized to maximize throughput. At its worst, lack of communication can lead to safety or environmental problems. Most large disasters are attributable to some sort of communication breakdown."

"But, you have to have focused departments and teams to run a large plant," Moulton said.

"Yes, but even then, they need to communicate," Mulcahy said. "A shared vision for how the plant is supposed to run can help resolve communication

issues. Plants work better when people know what everyone is doing and how it all fits together. Without a widely shared vision, your plant may need more communication than is practically possible."

"So with the vision," Bonhoffer said, "teams communicate when needed, not just to check on Standard Operating Procedure."

"Even then, you can still have problems," Mulcahy said. "Some plants optimize in a pathologically focused manner. A friend of mine visited a plant that was dedicated to having the lowest possible labor costs. The plant manager had done everything to keep wages down and staffing levels low. Benchmarking showed that the plant was at the top of the first quartile in terms of labor costs."

"That would be considered a victory in most companies," said Moulton.

"Perhaps," Mulcahy said. "The benchmarking, however, failed to reflect another, critically important factor. Further analysis demonstrated that the plant was wasting huge amounts of energy across it entire operations. All of the savings from lower labor costs were being blown out the smokestack."

"It wasn't wrong to keep labor costs low," Bonhoffer said, "but that was far from the whole story."

"The moral here," Mulcahy said, "is that you must always balance your efforts."

"I see your point," Bala said. "But how do you do that when the balance is always changing?"

"When I talk about the vision of the perfect plant," Mulcahy said, "some people suggest that the best plant might be one that runs in lights-out mode, with no people in it. That's theoretically possible for a plant that makes the same thing over and over again for decades, but no plant is really like that. New products, new equipment, new ways of working, new regulations, and new market conditions all mean that balancing and rebalancing is in continual flux. The total automation vision is impossible, so we need smart people to run plants."

"But increased automation is a reality," Bala said. "In every area of the plant, more technology and software is being applied."

"Depending on the approach," Mulcahy said, "technology and software can help or hurt the plant. You can make the same mistake about automation in each department, too. At their best, technology and software provide people with what they need to make the right decisions and take the right actions. It opens up possibilities for enhanced information sharing and hence for innovation. At its worst, technology generates useless data, or a reliance on technology without an understanding of the process the technology supports or drives. Since there's no feedback about how things are working, or empowerment to do a better job, the technology gets in the way.

"The perfect plant is not a machine that operates in isolation, like a lawn mower or a tractor. It's a key part of delivering the value proposition of a company to a customer. The more often the plant, its operations, and its products provide high value to its customers, the more frequently you'll have a sustained and defensible profit margin."

Understanding the Duties of the Perfect Plant

"The whole notion of a plant as an isolated unit," Mulcahy said, "gets in the way of the idea model of the Perfect Plant. As we pointed out before, plants exist to serve the corporations that own them. There is a large-scale process of creating value for the end customer of the business that begins in the corporation, flows through the plant and all the suppliers, and then continues downstream as the product is distributed to the customer. Many of the important processes flow through the plant. Some processes are inside the plant, but increasingly even those involve communication outside the plant. Let's zoom in on some of those.

"If you look at the big picture, it's clear that the plant is part of larger processes that begin outside it and then continue after it has done its work. The sales and operations planning process, for example, starts at the board level, cascades down to specific goals for a plant, and then continues through delivery to the customer. A famous general once said, 'No battle plan ever survives contact with the enemy.' As sales proceed and production continues, the plan will have to be monitored and adjusted. Information about how well

the production plan was fulfilled will flow from the plant to corporate, and adjustments to the plant will flow back. The same sort of communication has to take place between the plant and the customer receiving the orders. Can we deliver late? Can we deliver early? We have some extra capacity, do you want more product at a lower price?"

"But isn't this sort of communication routine?" Bonhoffer asked.

"The conversation with the customer may be routine or may not happen at all," Mulcahy said, "but constant communication about the plan is far more unusual than you might think. This is just the tip of the iceberg. If a plant makes standardized products that are also made elsewhere, the two plants could help each other by filling in gaps in each other's production plan. But to make this work, they must keep in close touch. They must maintain the standards that are the foundation of standardized products. If there are any problems with supply, they must be detected as soon as possible, hopefully before they can affect the process."

"It sounds like information must flow in and out of the plant all the time," Bala said.

"Communication is perhaps the most important aspect of a perfect plant," said Mulcahy. "As you do your research and visit plants, you'll notice that plants see themselves as self-contained islands. Inside the plant, we already talked about how silos can form that retard communication. The best plants have lots of communication: Everyone in the plant knows how the plant is performing, what is coming down the road, and what the effects of their actions are. The second part of being a perfect plant is pretty obvious—performance. The best plants optimize the multivariate equation at all levels."

"All business is about optimizing performance," Moulton said. "What you're saying is, if you want good performance, you have to find a way to measure it. There are all sorts of numbers to keep track of in a plant. To get good performance in a plant, it seems to me you need to follow your KPIs."

"But what if the KPIs are in conflict?" Mulcahy asked. "How do you sort that out?"

"I thought management was supposed to decide these things," Bala said.

"That's the point," Mulcahy said. "How do they decide?"

"ROI?" Bonhoffer asked.

"ROI is a fine thing," Mulcahy said, "but I'm looking for something more fundamental. If you consider all the numbers used in a plant, we can think of them in different ways. I call most of the numbers 'measures.' That is, they're numbers that indicate the performance of some activity—like the stats for baseball or soccer. On-base percentages or number of shots, or saves, or red cards are important indicators, but they don't win games. Scores wins games. I call the scores in the plant 'metrics,' and I define them in a special way."

"Most people would call your 'measures' 'metrics,'" Bonhoffer said.

"For our purposes," Mulcahy said, "'metrics' will be defined in a special way that I think is best for gauging the performance of a plant. A metric is the way the end customer recognizes the value created by the product, as we covered in our first session. On-time delivery, for example, of a complete order."

"How is this different from measuring ROI?" Moulton asked. "In my book, ROI is a fantastic way to keep score."

"Not for your customer," said Mulcahy. "If you focus on measures like ROI and profit in the absence of a focus on customer value, you may end up extracting more profit in the short term but abuse or anger your customers. If you focus on value and optimize everything else to meet that target, you'll keep your customers happy and create a strong position in the long term. Of course, the plant isn't completely in control of adopting this philosophy. Some plants will be run to maximize profit regardless of the effect on the customers."

"What about change?" asked Bonhoffer. "Hasn't that got to be a vital aspect of the perfect plant, too?"

"Yes," Bala said. "Nothing stays optimized for long. Products will have new requirements, customers will have new demands, supply conditions will change, and strategy will shift. Regulations will also come and go, and market conditions will ebb and flow."

"You're both right on," Mulcahy said. "The perfect plant reacts and keeps meeting the demands of customers, corporations, regulators, suppliers, and competitors. However, you can't expect change to happen by waving a magic wand. You have to have a culture to promote change in the right direction. That's what continuous improvement programs are about. But you also have to build the systems in the plant and design the processes in the plant with flexibility in mind. You can invest in technology in a plant and end up with a rigid, frozen structure, or you can end up with the ability to support rapid change and improvement. It's all a matter of your approach."

"These goals are fine," Bala said, "but frankly, they're sort of like Mom and apple pie—hard to disagree with. If we are going to help make Wolverine's plants run better, we have to give more specific advice than this."

Creating the Perfect Plant

"You're exactly right, Bala," Mulcahy said. "We can't just run around saying, 'Do better guys. Communicate. Perform. Prepare for change.' We need to dig in and come up with specific recommendations. That's what you'll do in your research." Mulcahy stepped up to the whiteboard and wrote the steps toward the perfect plant.

- ☐ DEFINE THE VISION
- ☐ BREAK DOWN THE WALLS
- ☐ FEED THE BRAINS
- ☐ CLOSE THE LOOP
- ☐ INVEST IN INFRASTRUCTURE
- ☐ ADAPT THE ARCHITECTURE
- ☐ CONTINUOUS INCREMENTAL IMPROVEMENT
- ☐ CREATE A CULTURE: CELEBRATE WINS

"By taking a closer look at each of these steps," Mulcahy said, "you'll understand more thoroughly my idea of a perfect plant. When you do your research, you'll have a way to organize the information you're hearing. If someone suggests a way to improve asset management, you'll be able to associate that idea with one of these steps. When you're done with your research, you'll be able to clearly describe what you found."

Defining the Vision

"To improve a plant," Mulcahy continued, "its leaders must develop a vision that is common and simple, one that is easily understood and seen as a picture that each employee can put into his or her own words. Until this happens, what you have isn't so much a vision as a dream. Leaders who succeed in transforming their companies understand their mandate. Not only can they translate their plan into an understandable vision, but also they can break it down into components that their teams can digest and own. In short, effective vision amounts to the perfect plant leader's translation from the corporate strategy into an ambitious mandate with deliverables that can be described, delegated, and digested by the plant leadership and employees.

"Once you have this vision firmly in hand, you will be able to understand where you are, how well you're doing, where you want to end up, and why. Manufacturing as an industry is better off than many other kinds of businesses because benchmarking statistics are well developed.

"These are like the stats in sports. There are companies that conduct annual surveys of what's going on in plants at a very detailed level. Some firms specialize in the refining and automotive industries. The participants who provide their data get a complete set of industry averages in return. You can then use this data to determine how well you are doing in key measures."

"Sort of like seeing how well you're hitting or pitching as a team compared with the rest of the league," Moulton said.

"But it's more complex," Mulcahy said. "In a way, each plant plays a different game because it serves the needs of a different owner. One plant may want to have the best pitching but not care too much about hitting. In a plant, the measures would be energy usage per unit of product or inventory level. The numbers don't tell the whole story, though they do help keep track of progress—you can see the trends. Are you getting better or worse?

"Perhaps the most important kind of vision is one that expresses the personality of the plant. Southwest Airlines is 'The Low Cost Airline,' and everybody who works there knows it. Most plants can't have a slogan that simple, but it helps to try. The more the personality of the plant can help guide decision making, the better. 'We are the safest, most profitable, most responsive refinery in the industry,' would be an initial attempt at such a vision. But a really excellent plant will then take that vision and translate it into a clearly defined way of working that everybody knows about. This is where the vision gets transformed into culture."

"A great vision will be industry-specific," Bala said.

"I can't tell you guys," Mulcahy said, "what vision to look for when you visit the plants. But when you are in a plant, you can ask: 'What is this plant all about? What are you guys trying to be? How do you do things around here?' At a great plant, you'll get clear answers to these questions, and there will be

a sense that the vision is up-to-date. People do things a certain way because they learned from experience, not because a plant manager 20 years ago liked it that way."

Breaking Down the Walls

"The vision, then," Mulcahy said, "is just a target, as specific as possible, of where you want to go. The rest of these steps have to do with how well you get there. The next step, 'breaking down the walls,' is one of the toughest. When you start visiting plants, you'll find yourself really getting into the culture. You'll start to learn this huge amount of interesting stuff about each area of the plant. This creates a nerdish sort of isolation. The plant and each silo becomes a cult. There are those who know and those who don't. What naturally follows this is a communication barrier."

"But everybody can't know everything," Bonhoffer said.

"No," Mulcahy said, "but everybody can know more about each other, and how they're interdependent. They can also know that they can make better decisions if they cooperate. The best plants systematically work against isolation by setting up rewards for achieving common goals, locating departments that need to communicate in the same offices, and things like that. A common technique that helps break down barriers is visualization. When people see the effects of their actions on other departments and the big picture, they tend to communicate more and make better decisions."

"Won't this change as younger workers start taking responsibilities at the plant?" Moulton asked. "The digital natives, like us, are used to working in groups."

"The forces that create silos will work on younger people, as well," Mulcahy said. "Even with a bunch of people running around texting each other about mass balances and maintenance schedules, the cult of nerdism will create silos. You have silos of data, silos of workflows, silos of networks, silos of responsibility. Silos are embedded in the infrastructure, architecture, and networks in a plant. It seems strange to think of a network in a silo, but that's exactly how many plant-level networks work. Networking within a manufacturing cell is all about exchanging data between equipment and

controllers at high speed, not about transmitting information to other parts of the plant or the rest of the company outside of the plant. Remember, much of the equipment and the systems in plants weren't built to be transparent. The architecture of many plants was created to allow each area to be separate. The need to communicate and perform in a more collaborative and transparent manner is an idea that came on the scene much later. None of these silos will go way by themselves or very easily. The best plants plan ahead and make a lot of effort to break down the walls."

"How can they do that," Bonhoffer asked, "if plants see themselves as isolated units cut off from the company and the rest of the world?"

"What happens at the silo level happens for the plant as a whole," Mulcahy said, "and can have an extremely negative effect, now that the need for transparency is growing faster than ever. For example, virtualized, outsourced manufacturing requires that the plant communicate lots of details to the people outside who are ordering the manufacturing. Nike doesn't own manufacturing plants, but it has an extremely detailed model of what goes on inside all of its contract manufacturers, so it can make adjustments as market conditions change. Companies like Cisco and Li & Fung operate the same way."

"So the factories," Bonhoffer said, "report the state of their production lines, materials inventory, their work in progress inventory, and so forth?"

"Inside Nike," Mulcahy said, "there is a massive model of all of the manufacturing that it's ordered. Nike monitors supply shipments to the factories and movements of products from factory to factory and to distribution centers. In order to be a Nike supplier you have to be transparent."

"Transparency, then, could be a competitive advantage," Moulton said. "It can make you easier to work with."

"Not just for contract manufacturing," Mulcahy said. "Most companies are working together more and more, in collaborative business networks, which requires more transparency so each company knows what's going on. The winners will be plants that can recognize problems early and react to market

conditions. As EVP of Manufacturing Operations, I'll never argue against having a better window into what's going on in a plant. If I can see how well the plan is being fulfilled on a daily basis, I get a great sense of security."

"If transparency requires reporting information to those who need it," Bala said, "consuming information from others, and modeling activities outside the plant that you are relying on, like Nike does, must translate into a certain style of Information Technology."

"We'll explore the information sharing and IT requirements in a minute," Mulcahy said. "You'd be surprised how many plants are paranoid about sharing this information. I still run into plant managers who think it's none of my business what they're doing as long as they meet their objectives."

"Don't plants have to do a lot of reporting about safety and health and sustainability?" Bonhoffer asked.

"That's a domain of enforced transparency," Mulcahy said. "The other area of excellent cooperation industry-wide is safety. Plants generally share information about how to make things safer, or help each other, or police and fire departments, deal with chemical spills extremely quickly, with no questions asked."

Feeding the Brains

"The next step toward a perfect plant," Mulcahy said, "entails making sure people have the information they need to do their jobs. Since plants are run by brains and machines, you must feed the brains so they can make better decisions. Visualization is especially important. Simplified visual models that boil down lots of information into the essential trends and components make information more valuable. In addition to information, brains need tools to analyze that information and to communicate with other brains."

"So you're talking about defining a set of information," Bala said, "analysis tools, and ways to communicate and collaborate for each role in the plant."

"But doing this," Mulcahy said, "implies that the people filling those roles are empowered to actually do something with the information. In different

industries, especially refining, the equipment operators play a hugely important role. They make decisions that have a significant economic impact on the bottom line. Ideally, you want that information and visualization to not just be about the physical processes, but also how that physical process is part of a business process with an economic impact.

"Visualization should not be about some abstract measure of efficiency, but about how much money the department or plant made in the past hour—focus on business impact. Make decisions with the lights on. In other roles in the plant, however, sometimes less is expected of the people. You want to make sure that if you have a person doing a job, they have a chance to make the best decisions."

"But this needs to be more than just about empowerment," Moulton said. "It's got to be about ownership, too. Nobody in the history of the world ever washed a rented car."

"That's true," Mulcahy said. "You want the reward structures to encourage the right behaviors, but you also want an element of flexibility. In some plants, working according to plans and procedures is so emphasized that people don't make suggestions for improvements, even when they are obvious and make sense. Sometimes people focus on instrumenting a problem to get more data but never ask the operators what they think should be done.

"The collaborative aspect is all about making it easy to get more eyeballs on the problem. Once you're looking at some data, how can you get others involved? Young people do this naturally with texting, email, wikis, all that sort of stuff. Those people in plants who aren't young need to be encouraged to collaborate. They need to be shown how to use the tools that get other people involved."

Closing the Loop

"There is another aspect related to feeding the brains that is crucial," Mulcahy said, "but hard to accomplish a lot of the time. Have any of you guys read that book called *Flow*, by Mihaly Csikszentmihalyi? He's a psychologist who explains this state he calls 'flow,' in which you become so engaged in an activity you lose your sense of time passing. To achieve a flow state, a balance must be struck

between the challenge of the task and the skill of the performer. If the task is too easy or too difficult, flow cannot occur. Csikszentmihalyi makes a case that being in flow a lot makes you a much happier person."

"What does this have to do with a plant?" Moulton said.

"Flow happens," Mulcahy said, "when your skills are adequate to cope with the task at hand in a goal-directed, rule-bound system that provides clear clues as to how well you are performing. What's most important in this notion is seeing these clues. In plants, frequently people take actions when the effects of those actions are not clear. If you can see the results of your action through visualization, you'll change behavior."

"In other words," Bala said, "you want to turn the plant into one massive video game. Each person should be able to see the effects of their moves as soon as possible."

"The video game analogy applies to some processes in a plant," Mulcahy said, "but most of the time the effect of an action can't be visualized in real time. This is what I mean by closing the loop. This is where you must introduce discipline, to actually take the time to follow up and see what happened.

"Closing the loop on a planning process involves taking a look after the plan was executed to see how well things went. In refineries, they have models for chemical processes that predict how much gasoline will be produced from certain types of crude oil. To improve these models, you must see if your predictions were accurate and then either explain the differences or improve the model. Closing the loop applies to almost every process in the plant. It's not easy, but it's the essence of continuous improvement."

"You are playing the game to maximize some sort of score," Moulton said. "And if you can give that score actual business value, meaning money, then you can really get things humming along."

"In the best plants," Mulcahy said, "everyone's compensation is tied to the financial results the plant produces. In some plants, 30 to 40% of everyone's pay may be determined that way. People with this sort of incentive structure are highly motivated."

Investing in Infrastructure

"This next step is perhaps the most crucial," Mulcahy said. "Everything we'll talk about today implies a set of requirements for the systems in a plant.

"Consider what we've said so far. The vision step requires that you understand where you want to go. Breaking down the walls implies that communication and transparency must be supported. Feeding the brains means that information must be available, as must be tools for analysis and collaboration. Closing the loop means that these tools must be used in a certain way, to encourage better decisions and continuous improvement.

"Let's also include the steps that are to come—adapting the architecture, continuous improvement, and creating a culture. The first two are about flexibility and change. The last is about creating positive habits, a sense of the way we do things around here."

"So the systems in a plant," Moulton said, "have to provide information, networks to move it around, tools for analyzing that information, ways to visualize that information, and ways to collaborate. Oh, and it all has to be flexible."

"I think he's got it," said Mulcahy. He turned to the whiteboard and wrote the implied requirements.

INFRASTRUCTURE REQUIREMENTS

PROVIDE

- INFORMATION
- NETWORKING CAPABILITY
- ANALYSIS TOOLS
- VISUALIZATION TOOLS
- SUPPORT FOR COLLABORATION
- SUPPORT FOR FLEXIBILITY AND CHANGE

"Given all we've said about empowerment," Bonhoffer said, "it will be important to avoid installing systems that are too well-defined, too locked down. Otherwise the systems will restrict people. But if you put information in the hands of people in the plant along with tools for analysis, visualization, and collaboration, then they'll do things you never expected."

"And if those tools are easy to use and flexible," Bala said, "they will keep innovating. Plus they'll be likely to stay empowered and engaged, too."

"Here's a question," said Mulcahy. "How much can you predict in advance about the good things that will happen if you provide these tools?"

"To predict anything like that," Bonhoffer said, "you'd need a model of the value of the innovation you'd expect from each person who got the tools. Some of the people would innovate a lot, while others would use the innovations but not create them. I can't see how you would figure this out in advance."

"You would have to invest in this infrastructure on faith that there would be an ROI," Mulcahy said.

"That makes me uncomfortable," Moulton said. "My MBA training didn't include a course on faith. We had lots of courses on measuring financial value."

"Investing in infrastructure, as we have defined it," said Mulcahy, "does require some level of faith. But you can prove the value incrementally in small steps—you don't have to put infrastructure all over a plant in one fell swoop. You can put it in for one department. See how that works. Determine how people in your plant adapt to it. Find out what help they need to use the infrastructure. As you become comfortable that an investment in infrastructure makes sense, you can do more, where you need it. You may not need it everywhere."

"The infrastructure as you describe it doesn't seem focused on automation," said Bala.

"Right," Mulcahy said. "At first it's intended to break down the walls, feed the brains, close the loop, adapt the architecture, and support continuous improvement. Only after all that does automation really make sense because you then understand the problems you're dealing with and can crystallize the solution in an automated way."

"So that's when you use the big software applications for ERP, asset management, and so on," Bonhoffer said.

"No, no, no," Mulcahy said. "Every time I give this talk people think I'm bashing enterprise applications, but I'm not. The definition of infrastructure is systems that provide access to information, analysis and collaboration tools, and so on. Every enterprise application is a collaboration tool. Every enterprise application is a powerful source of infrastructure, if you use it that way. Nowadays, they almost all come with web services that allow you to get at the information quite easily. The automation of the enterprise applications must be approached more carefully based on the needs of your plant. A lot of what is in enterprise applications is automation of proven best practices. Other stuff is more cutting edge. You have to know your problems to know what applies.

"At first you want to have systems, networks, infrastructure, and enterprise applications that are a mile wide and an inch deep. The value of investment in infrastructure increases with the scope of information provided and the number of people who are involved. All sorts of good things happen then. The closest thing I have seen to what I really want in our plants is something like Facebook."

"Social networking software for college kids?" Moulton said.

"Think of it as an open, collaborative environment," said Mulcahy. "That's what I want in my plants, where it makes sense. In Facebook, you can create widgets, let other people know about them, get notified of what other people are doing, create communities of interest, share information."

"Google just created this standard called Open Social that has the same sort of layer defined across many sites," Bala said.

"Platforms like this," Mulcahy said, "with the right information and tools, are the essence of infrastructure."

Adapting the Architecture

"The next step is a willingness to adapt the architecture," said Mulcahy. "It's important to break the mindset that everything about the plant was set in stone when it was built."

"But plants are engineered with a purpose in mind," said Bonhoffer. "You can't just change things that cost tens or hundreds of millions to put in place."

"That doesn't mean you can't change anything," said Mulcahy. "This step is more of a reminder to have an open mind. You should be open to the possibility that the physical architecture of the plant, meaning the steel, can be changed. Sometimes just thinking in that way opens up people's minds so affordable changes occur to them. It is really hard to talk about how in general you might change the structure of a line or the cells in a plant. But there are other parts of the architecture of a plant that are easier to change. Adding infrastructure to extract and manage information from plant equipment or RFID tags and readers and sensors can have a dramatic effect on what becomes possible in a plant. Improved visibility allows for more optimization."

"So the architectural change is to add infrastructure for data collection, for turning the lights on," said Bonhoffer. "But that doesn't seem like an architectural change, perhaps an addition."

"Well, it depends on how you categorize things," continued Mulcahy. "The way networks are now converging in plants provides a great example of how architectures that were set up for different purposes can be incrementally adjusted into a new form. As I mentioned earlier, most plants have a siloed approach to networking. Each cell or workstation had equipment talking, frequently over non-standard network protocols, with PLCs that were controlling the equipment. This all was put in place before Ethernet and IP became the standard. And frankly, it is only recently that Industrial Ethernet and IP could handle the high speeds that some manufacturing applications needed.

"But now that that's true, you have Ethernet and IP at the company level, running the business operations of the plant, and you have the possibility of converging the network architecture of the plant onto that same standard. There are security issues to solve because the network in the cells or the workstations usually weren't built to be secure. You don't want your PLC controlling a high speed machine hacked into or taken offline by a virus. But if you get this convergence a lot of the things that we are seeking can happen."

"Why would convergence be of any benefit?" asked Bonhoffer. "What's the advantage of having everything on the same network standard?"

"Well, think of how it works without a network that connects the workstations to each other or to the business operations. You yell from one cell to another or go over there to see what's up. The plant manager doesn't see what's happening in the plant from his desk. But if you put the right kind of network in place, an architectural change, at a work station you can see out to the rest of the plant and into other workstations. From the rest of the plant you can see into the workstation. You can do a lot more optimization with this information because of convergence on a common standard."

"Can you give me an example of something you could do with a converged network?" asked Bonhoffer.

"Okay, imagine that you have one spot on the network where you can see all the traffic. Now imagine that at that spot you have a device that can look into the traffic and understand what is inside the packets being sent around. For example, if a PLC starts reporting that a device is slowing down or stopped or has indicated that it needs maintenance, you can identify that message and raise an alert. Or imagine that you can see larger patterns of what's going on that are revealed by network traffic sent by dozens of sources. Perhaps you notice that yield is unusually low in one of the early processes and that the effect of that will be that some important orders will be at risk. All of this is called network mining, where you look for certain patterns or special events and react to them."

"This sounds pretty advanced," said Bonhoffer.

"Well, it is not quite as hard as it sounds once you have the converged network in place," said Mulcahy. "And it is likely that this sort of capability will come as a product, and not be developed by the plant. But this is just one form of convergence. Imagine now that you overlay a communication system on the same network. You can do all sorts of tricks with sensors and RFID, keeping track of who is where, what equipment is where, where pallets are, with a generalized infrastructure. All of these changes can be made incrementally, but they are all enabled by changing the architecture by adopting a standard form of networking."

Continuous Incremental Improvement

"The last two steps," Mulcahy said, "continuous incremental improvement and creating a culture, are part of a stream of thought that begins with closing the loop. When you start to give people the ability to see the effects of their actions, it doesn't take long for them to start to make suggestions. If sensible suggestions are ignored, then people will stop making them.

"So, on one level, continuous improvement means listening to suggestions. But at the highest level, continuous improvement is about creating processes in the organization so that data is constantly being gathered and analyzed to determine the places in the organization that need to be changed. Some companies become drunk with continuous improvement and have lots of conflicting initiatives. It doesn't need to be that complicated. The novel *The Goal* puts forth a method invented by the author, Eliyahu Goldratt, called the

'Theory of Constraints.' The idea is to find the constraint in a system that limits productivity, then subordinate everything else to making that constraint as productive as possible. Eventually, you may find that the constraint has moved to a new part of the system, and you then start all over again. Six Sigma, a method we'll discuss in detail later, is a way to identify the causes of unwanted variation in a system and eliminate them. Total Quality Management is another method with different goals, and so is Lean. Before we move on, however, I want to give you an example of this last one, since many of its principles will be the basis for much of the work ahead of us.

"Throughout the '50s and '60s," Mulcahy said, "Toyota worked hard to develop their Toyota Production System, which was based on notions that had been in play ever since Eli Whitney invented the cotton gin. In particular, they elaborated on the work of W. Edwards Deming and Henry Ford. By the mid-'70s these guys had honed their system down to some basic principles that were aimed at ridding their processes of waste. Fifteen or so years went by before James Womack wrote a book in 1990 called, *The Machine That Changed The World*. He is the man who actually coined the term 'lean manufacturing.' The book made some real waves here in the States, enough to convince people in the plants that it was time to implement significant changes. The long and the short of Lean is this: until a plant can say with proven confidence that its processes aren't inconsistent, overburdened, or wasteful, its 'lean factor' has not yet reached critical mass."

"In theory, that sounds easy," Bala said. "Making it happen on the floor, every day, 365 days a year is an entirely different story, though."

"The first thing you've got to do when implementing Lean," Mulcahy said, "is identify your objectives. Any of you care to take a stab at what they might be?"

"The first one is a no-brainer," Bonhoffer said. "Value. What is the plant doing everyday? What is the enterprise trying to serve? It's trying to make a product that customers *value*."

"You hit on both of the plant's primary objectives in a single breath," Mulcahy said. "We want to focus on value, but we particularly want to focus on value from the perspectives of products and services. These, in turn, bring

us to the customer, who, after all, is our ultimate target, whether it's a plant downstream or the people in the stores."

"It makes perfect sense," Moulton said. "Once you've zeroed in on your key values, you can design and create your activities around them."

"Value as a concept is an interesting, complicated affair," Mulcahy said. "Consider the way value is perceived by different customers, for instance. If you're selling a widget, your customer's first value criterion may be on-time delivery. When that's the case, you need to understand their demand patterns and plan your production to meet the delivery requirements that are a function of them. For another customer, value could be the price or quality of your product. Or it could be any of the above. On the other hand, your customer could be a part of your own organization, which would be true if you were producing subcomponents or subassemblies for your finished goods assembly plant. Whatever the case, it's imperative that you have crystal clarity into the value that you'd like to produce.

"Once you've determined your value, you can embark on an exercise called 'value stream mapping.' Basically, this entails mapping all of the different activities in a value stream process, identifying the source of your inventory, and determining the cycle and lead times for each of your process steps, both up- and downstream. Understanding these matters enables you to enhance the flow of product through your facilities. Theoretically, this is called 'consumption-based material pull.' In practice, this means that your product doesn't move unless your customer demand is pulling it."

"Isn't that," Bala said, "in direct contradiction to a push-based production, where you maximize the lot size or batch size of production to get the most out of your assets?"

"It is," Mulcahy said. "The reason 'pull-based' is better than 'push-based' is simple. When you run a push-based approach, sooner or later you're bound to lose track of the customer's needs—their demand pattern, their product mix requirements, and so forth."

"So how does Lean work on the floor itself?" Bonhoffer asked.

"The same way it does in the market," Mulcahy said. "Just as the market sends signals as to what is needed, and when, so too are signals sent up and down the production line, either to initiate a process or to stop one. This way of doing things can sometime force plants to reengineer the shop floor, often from scratch. The goal is to create 'cellular manufacturing units,' whereby you maximize the efficiency of your workers so that they can balance everything they do across the key steps in your processes. All of this gets happens by way of up- and downstream signals."

"All right," Bonhoffer said. "We've got the principles down. What about the waste you mentioned?"

"I'm glad to see you're all still with me," Mulcahy said, and began to write on the whiteboard. "In Lean, there are seven kinds of waste to be eliminated."

SEVEN TYPES OF WASTE IN A PLANT

- OVERPRODUCTION
- TRANSPORTATION
- WAITING
- INVENTORY
- MOTION
- OVER PROCESSING
- DEFECTS

"The first point here," Mulcahy said, "overproduction, is about honing the process so that you're not producing ahead of demand. In short, produce only what is needed, when it's needed. The second, transportation, concerns eliminating unnecessary product movement. If the process doesn't inherently require something to move, it ought not to move. And waiting. The last thing you want is workers sitting around on the line, waiting for product to show up. All processes must be engineered to ensure that when one step is complete the other is ready to go.

"As for inventory, having too little of it can generate obvious pain. But having too much of it can do the same, too. So you must pace your production such that inventories are kept on target. To do this requires that they be constantly monitored. You've got to anticipate any potential variability in your demand, as well as in the mix of products requested by your customer. All of your components, your work-in-progress, and your finished product are considered to be part of your inventory.

"Next on the list is motion. Whereas wasted transportation relates to moving *things* unnecessarily, wasted motion pertains to your people themselves. This means that each department must take precautions to improve local ergonomics, and to make sure that everyone has what they need on hand to do their job. You don't want people stopping what they're doing to run off to a tool shed.

"Now, over-processing. When you don't have the right tool, or the product design generates useless activity, you're working too hard. It's pretty darn simple—all processes must be winnowed down to their essential components. Last on the list are defects. This should be clear to anyone, though frequently it's not. When you create defective products, you've got to inspect and fix them, and that is lost time and money. One of the attractive features in the Japanese system is the way it empowers workers on the floor. Any time they see a bad batch or a quality defect, they can stop production of the entire production line. This is a core element of Lean. Waste no time addressing problems once they've been noted. When you analyze what's wrong and then fix it fast, it doesn't have the chance to become a systemic issue.

"That," Mulcahy said, "is Lean in a nutshell. Of course, there are entire books written on the subject, and we could spend weeks talking about it. I merely wanted to give you guys a good sense of where we're headed."

"All of these techniques can be effective," Bonhoffer said, "and all can be used ineptly. What I hear you saying is that everything starts by turning the lights on and understanding how well you are doing."

"Implementing a program of continuous improvement is healthy," said Mulcahy, "because it explicitly recognizes that the definition of perfection is always evolving. Organizations with continuous improvement programs

aren't seduced by the idea of a big bang, some major change that will fix all their problems. Instead, they constantly categorize problems and challenges according to a Pareto analysis, asking themselves how to identify the 20% of the factors that cause 80% of their problems. Then they attack those factors, keep monitoring, and then do it again and again. In my experience this sort of rifle shot approach has a huge impact. Rather than implementing one project for $250,000 that returns $1 million, why not do five smaller improvement projects for $50,000 each that each returns $500,000?"

"So you do think about ROI sometimes," said Moulton.

"I do," Mulcahy said, "but I usually calculate it after the fact. I find the numbers are much bigger, and I know they're right."

Creating a Culture: Celebrate Wins

"At a higher level than continuous improvement is culture, which allows you to adapt your organization and move to new types of business models," Mulcahy said. "This is the soft and fuzzy part of running a plant. Culture is cultivated by communicating the values and expectations the company has for its employees, and is nurtured through shared rewards. In a company with a strong positive culture, everyone knows what they are supposed to do and, more importantly, why. People know this because when someone does something right it is pointed out and celebrated.

"The most vital aspect is a sense of trust. In a positive culture, the management wants to know what the staff is thinking, and the staff knows they want to know. In a positive culture, the efforts to improve things start by asking the operators or the technicians or whoever is close to the problem what they think is happening, and, just as importantly, what would help. Lots of analysis can follow, but in a positive culture the staff is valued and respected. It becomes their responsibility to make suggestions, point out problems, communicate, and raise their hands when they need help. In many ways, younger workers, the so-called digital natives, are more attuned to a positive culture. They expect it. They demand it. They were raised to work collaboratively and expect to be listened to."

"In a negative culture," Bonhoffer said, "people are afraid to speak up, ask questions, or make suggestions."

"Say you have a boiler that you never run above a certain temperature," Mulcahy said. "In a negative culture, nobody asks why. It may be because three plant managers ago there was a dangerous condition, or perhaps the plant manager who wrote that rule blew up a boiler at his previous plant. In a negative culture people know they're not valued. They simply follow orders and go through the motions. It's boring to work in such a culture. Everyone is just waiting for retirement."

"I'd much rather work at a perfect plant," Moulton said.

"Me, too," Mulcahy said. "But there are tremendous implications in a positive culture, especially when you have been steadily moving on all the dimensions that we have just described. Once information is available, walls are broken down, and people have the tools to see what's happening, it changes the way people work. It's like with Wikipedia. That project started with a traditional highly structured content management system and went nowhere. This sort of system was highly controlled and allowed very little freedom. When the wiki was introduced—a way of creating content that was flexible and easily adaptable, and especially easy to use—people used it to create a new set of rules about how to work together, rules that people at the time said would never work—for example, letting anyone change any page."

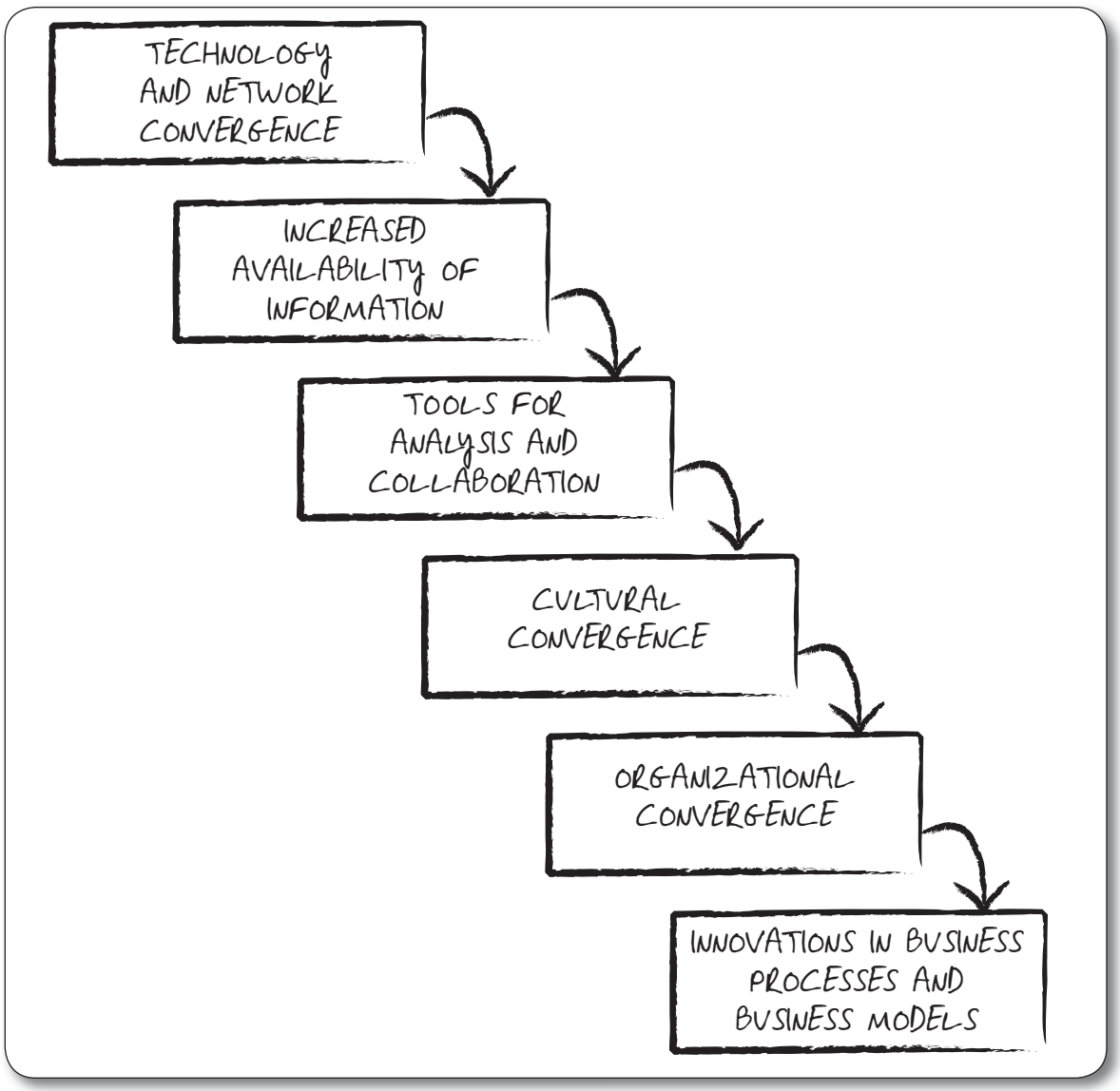
"It is amazing that Wikipedia really works that way," said Moulton.

"In a plant, the same sort of transformation can happen. Everybody isn't going to able to change anything, but if everybody can *know* everything or at least as much as possible, the culture will change. New forms of collaboration will emerge as needed. Putting in a new layer of technology and networks that make information more accessible is like putting a wiki in a plant. When you can see what's happening everywhere, when information is available and flows back and forth, then a new set of rules takes hold. This new culture can lead to organizational changes where new sorts of groups form. This can lead to new business models. For example, we have the same complex plant equipment in several of our plants at Wolverine. With the right infrastructure in place, we could have our best, most experienced people monitoring that equipment from a remote location to make sure it is running properly and being maintained as it should. If operators in cells can see the inventory levels in real time, farther upstream they can raise alarms earlier. The key to all of this is for the business

significance of the information to be recognized as early as possible, possibly in real-time. Finding out that inventory is low is one thing. Understanding that it is low and going to stop a crucial order from going out is quite another."

"So technology and information lead to a culture of collaboration," said Moulton. "As opposed to one of top-down, hierarchical control."

"Exactly, and the more that the technology and information provide information in a business context the better this happens," said Mulcahy. "Let me draw for you what I see as the pattern."



"The pattern I hope we can be a catalyst for at our plants is as follows: Technology and network improvements improve the flow and availability of information," said Mulcahy. "Then we add tools for analysis and collaboration so that people can understand what they are seeing. This should lead, Wikipedia style, to a new culture in which it is okay to ask others for help in solving problems. In some cases I have seen this lead to organizational changes like tighter alignment of maintenance and production. If all goes well, the whole company creates an understanding of the business and you can find new and better ways of working."

"I would love to be a part of that," said Bala.

"Now that you understand this vision at a high level," said Mulcahy, "I want you to go and research each of the areas assigned to you. Come back with specific ideas for how our plants can make progress using the steps I've just outlined to better meet Wolverine's goals."

"Well, guys," Bala said, turning to Moulton and Bonhoffer, "it sounds like we're off to boldly go where no MBA has gone before…"