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Six Sigma Enlightenment: Managers Seek Corporate Nirvana Through Quality Control

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Heard the latest management mantra? ***“Six Sigma”.***

In consultant-speak, it denotes the path to a corporate nirvana where everything -- from product design to manufacturing to billing -- proceeds without a hitch. In engineer-speak, it means no more than 3.4 defects per million widgets or procedures.

In practice, Six Sigma is a statistical quality-control method that combines the art of the efficiency expert with the science of the computer geek. And a growing group of big no-nonsense companies like Allied Signal, Motorola and General Electric swear by it.

"Six Sigma has galvanized our company with an intensity the likes of which I have never seen in my 40 years at G.E.," said John F. Welch, the chairman of General Electric.

So fervent a proselytizer is Mr. Welch that G.E. has spent three years and more than $1 billion to convert all of its divisions to the Six Sigma faith. The GE Medical Systems unit recently introduced a $1.25 million diagnostic scanner, the first product that G.E. designed from start to finish using Six Sigma principles. Six Sigma teamwork enabled GE Plastics to produce 1.1 billion pounds more plastics without building one new plant. Over all, Mr. Welch credits Six Sigma with raising the company's operating profit margins to 16.6 percent from 14.4 percent.

So what exactly is this philosophy of flawlessness? First, the name. Sigma is the Greek letter that statisticians use to define a standard deviation from a bell curve. The higher the sigma, the fewer the deviations from the norm -- or, in industry parlance, the fewer the defects. At One Sigma, two-thirds of whatever is being measured falls within the curve. Two Sigma encompasses about 95 percent. At Six Sigma you are about as close to flaw free as mere mortals can get.

No company can really achieve that kind of perfection, of course. But as with any religion, Six Sigma presents an ideal state toward which adherents continually strive.

"Six Sigma gets people away from thinking that 96 percent is good, to thinking that 40,000 failures per million is bad," said James E. Morehouse, a vice president of the consulting firm of A. T. Kearney Inc.

Six Sigma was developed more than a decade ago at Motorola. But since then, it has been embraced by numerous corporations and is even included in courses on quality at the Harvard Business School.

As applied in industry, Six Sigma is a rigorous statistical method of breaking a customer's requirements into tasks or steps, and setting the optimum specification for each part of the process, based on how the parts interact.

"Six Sigma translates fuzzy customer requirements into technically measurable responses," said Maurice L. Berryman, a Six Sigma consultant in Dallas.

Here is an example: Say a customer wants to be billed on the same day each month. With Six Sigma, making that happen means analyzing the interaction of everything involved in processing that customer's order.

When and how does the sales department send through paperwork, and at what point does a difference in days, hours, even minutes, have an impact on when the bill goes out? Does it make a difference when shipping coordinates with billing? How long does mail sit in the mail room, and at what point does it matter?

Once everything is quantified, the what-if scenarios begin: Would a stricter paperwork processing schedule in sales make mail room bottlenecks irrelevant? Would adding a person in accounting give the mail room an extra hour's leeway?

In principle, Six Sigma is little different from the type of analysis that Frederick W. Taylor, the industrial efficiency pioneer, might have performed with stopwatch and notebook a century ago. But in Six Sigma analyses, there are thousands of permutations and combinations -- probably too many for the human mind to fathom, although easy enough for even a moderately speedy computer. Thus, modern information technology has made Six Sigma a practical way to identify the optimum configuration of most products or processes.

"Six Sigma gets people from all over the organization to work together on improving the end product, not just their individual piece of it," said Frank Jones, a Six Sigma specialist at the management consulting firm Booz-Allen & Hamilton.

Scanner Analyses Cost $50 Million

In the case of the new GE Medical Systems product -- a superfast diagnostic scanner called the Lightspeed -- 200 people spent nearly three years and almost $50 million to run 250 separate Six Sigma analyses. While one team was checking out the reliability of measurement devices, another was figuring out which factors affect the scanner's life, while yet another was dissecting image quality into factors that could be massaged to filter out picture-blurring electronic noise.

The Lightspeed, like many diagnostic scanners, employs computed tomography, or CT. CT scanners work by sending electromagnetic waves through the body and recording the amount of energy that comes out. Since various tissues and organs absorb energy differently -- bones absorb more than flesh, for example -- the emerging waves, in the form of light, yield a good picture of the internal landscape they have passed through. The scanners let doctors study wafer-thin cross sections of parts or all of a patient's body without making any incision.

GE Medical Systems, which already controls 39 percent of the $1.6 billion global market for scanners, has high hopes for the Lightspeed. The new scanner captures multiple images simultaneously, requiring only 20 seconds to do full-body scans that once took three minutes -- important because patients must remain perfectly still during the scan. And unlike previous CT scanners, the Lightspeed does not need to cool down for as long as three minutes between uses.

"The speed is breathtaking, and it ran without downtime from the start," said Dr. Carl Ravin, the chairman of the department of radiology at Duke Medical Center.

The Lightspeed is not perfect, of course. But Six Sigma enabled GE Medical to anticipate which compromises doctors would accept. For example, the Lightspeed takes slightly thicker scan slices than doctors normally specify, but no one complained because the thicker slices were virtually free of electronic noise.

"Six Sigma let us predict the amount of variability that customers will tolerate before they perceive it as a defect," said Marc Onetto, who oversees Six Sigma projects at GEMS, as GE Medical Systems is commonly known.

The Problem Of Human Error

Of course Six Sigma itself is not perfect, either, since it cannot compensate for human error. Take what happened when GEMS tinkered with the computer that translates the data the scanner collects into images an operator can read.

CT scanners generate a lot of heat, and the heat often caused the printed circuit boards to overload. A Six Sigma team figured out that by perforating the metal box that holds the boards, they could dissipate the heat. They were right -- except that they forgot to check what other impact that change might have.

GEMS started sending out scanners with perforated computer boxes. The holes compromised the structural integrity of the metal, the metal warped outward and the circuit boards loosened -- causing as many failures as the heat had.

GEMS technicians spotted the problem during field tests, and the company corrected it by reinforcing the metal before any scanner was running at a hospital or a clinic. But the mistake taught GEMS an important lesson about Six Sigma.

"You must take it step by step," said Charles H. Young, a GEMS spokesman who has been steeped in the process. "You get into trouble if you compromise the rigor of the process. You can't skip steps and jump to premature conclusions."

Customer Demand Drives Project

The Lightspeed project started, as so many new products do, with customers clamoring for more, better, faster.

By late 1995, GEMS knew that Siemens, Toshiba and other competitors were working on faster scanners. The company also knew it could probably get its own faster version ready, approved by the Food and Drug Administration and on the market before the 1998 Radiology Society of North America show, the annual December trade exposition at which the medical equipment industry displays its latest wares. But readying a scanner as radically different as the Lightspeed was an iffier proposition.

"Going for that quantum leap in technology in that time frame was one of the toughest decisions of my career," said Vivek Paul, the general manager of the CT business at GEMS. "We shifted development resources from existing products, and that left us very vulnerable if Lightspeed couldn't be built in time."

In January 1996, the race against the clock began.

The most important parts of the scanner are the tubes, which focus the waves, and the detector, which translates them into pictures. So they received the heaviest attention.

The old tubes, which cost $59,000 each to replace, had long been a thorn in GE's side. Hospitals and clinics wanted them to operate for at least 12 hours a day, for 6 months; typically, they lasted only half that long. Moreover, GEMS was scrapping some $20 million in tubes each year because they failed preshipping performance tests. Even so, a disturbing number of faulty tubes were slipping past inspection, only to be pronounced dead-on-arrival -- GEMS really does call them D.O.A.'s -- at the customer's door.

So the GEMS Six Sigma teams deconstructed the tubes. They knew that one problem involved the petroleum-based oil in the tube, which prevents short circuits by isolating the anode, which has a positive charge, from the negatively charged cathode. The oil often deteriorated after a few months, but they did not know why. By using statistical what-if scenarios on all parts of the tube, however, the researchers learned that the lead-based paint on the inside of the tube was adulterating the oil. By November 1996 they had developed a paint that would preserve the oil and protect the tube.

Solving Leaks In Vacuum Tubes

CT scanners generate X-rays by bombarding metals with high-speed electrons. Even a few air molecules can slow the electrons down, so the tube needs a total vacuum. But too many tubes were reaching the end of the production line with "beads" -- tiny openings, usually where glass and metal are sealed, that let air leak in.

So GEMS engineers made a list of things that could cause a vacuum leak. Through Six Sigma analysis, they ruled out type and length of glass. But they did learn that the metal pin through which current flows into the tube tended to tarnish, which would loosen the seal. They also found other significant factors: the type of gas used in processing the tube, and the speed with which the glass cooled down after going through a heat-treating furnace.

Thus informed, the engineers used computer modeling to test numerous combinations of different temperatures, gases and such. They wound up "pre-oxidizing" the metal pin, roughening its surface and helping it adhere to the glass. They replaced the hydrogen gas with nitrogen. And they changed the heating process from one in which tubes move continuously through the furnace to one in which they are processed in fixed batches, making the heating and cooling periods easier to control.

"Six Sigma gave us a methodical way to test how changes in one factor would interact with changes in others," said Beth Hulse, the engineer who led the project.

Trying to eliminate all leaks would have put GEMS way behind deadline and way over budget. And it was now early 1997. So GEMS settled for a process that cut the pre-shipment scrap rate by 40 percent and that has eliminated D.O.A.'s so far. And while the new tubes are priced at $85,000, or 40 percent more, they carry a one-year warranty.

Helping Reduce False Readings

Converting an electron beam to X-ray images is not an efficient process. Only about 1 percent of the energy that hits human tissue emerges as light, with the rest dissipated as heat. And that heat can affect the quality of the image.

Statistical analysis showed that adding a $100,000 resistor would control the temperature. But the same tests also revealed that changing a few inexpensive capacitors elsewhere in the tube, and redesigning how the wires are padded, would yield a similar result.

Another way to cut down on fuzzy images and false readings -- detection of tumors that are not really there, for example -- would have been to tighten the specifications for the focal point, the accuracy with which the electron beam hits the target tissue. But that would have involved a costly tube redesign.

By April 1997, a Six Sigma team had learned that widening the tungsten wires that cover many of the wave-receptor cells in the detector plate would create a bigger target, thereby compensating for any tiny inaccuracies in the beam's trajectory. Although this change requires giving the patient a higher dose of X-rays during the scan, the dose is still within the medically accepted margin of safety. "By making the data collection process less efficient, we made the scanner as a whole more efficient," said Gary Strong, a Lightspeed designer.

But the image quality still needed improvement. The detector surface in each scanner has thousands of "pre-amp chips," semiconductor components that amplify the light signals so that a computer can read them. But each chip emits some energy itself, which in turn gets picked up by other chips, causing extraneous rings or shadows in the image.

Redesigning the chips, GEMS concluded, would take at least eight months, which could mean missing the target date for field tests: April 1998. But Six Sigma analyses showed that GEMS could get the same result by relaxing specifications for the relationship between the amount of energy that comes into and out of the pre-amps, and by writing simple software that would allow the computer to control the variation. The project was completed last March -- just before the deadline for the field tests.

The Lightspeed, which went on the market in September, costs 25 percent more than older scanners but seems to be a hit. GEMS has installed 12 Lightspeeds, and has orders for 50 more.

But the Six Sigma work at GEMS is far from over. The GEMS chief executive, Jeffrey R. Immelt, is working on projects to find a better way to position flexible tabs -- the items that keep electrons in alignment as they travel across the detection panels. And he will soon join a team that will apply Six Sigma methods to reduce variances in customer service.

"Six Sigma lets you approach problems with the assumption that there's a data-oriented, tangible fix at the end," Mr. Immelt said. "And that is a radical culture change."
