What is Design for Six Sigma?

The best Six Sigma projects begin not inside the business but outside it, focused on answering the question, how can we make the customer more competitive?

—Jack Welch

Six Sigma: The Basics

Since you're reading this book, you're probably familiar with at least the basics of Six Sigma. So, we can review briefly before getting into Design for Six Sigma.

Six Sigma is a revolutionary business process geared toward dramatically reducing organizational inefficiencies that translates into bottom-line profitability. It started in the 1980s at Motorola; then, organizations such as GE, Allied Signal, and Seagate worked with the initiative during the 1990s and made it the most successful business initiative of the era.

Key to the Six Sigma methodology of the 1990s is a five-step process—Define, Measure, Analyze, Improve, and Control

(DMAIC). By systematically applying these steps (with the appropriate tools), practitioners of this approach have been able to save substantial dollars.

Six Sigma Defined and Explained

The basis of Six Sigma is measuring a process in terms of defects. The statistical concept of six sigma means your processes are working nearly perfectly, delivering only 3.4 defects per million opportunities (DPMO). As you know from your experience with Six Sigma, Sigma (the Greek letter σ) is a statistical term that measures *standard deviation*. In the context of management, it's used to measure defects in the outputs of a process and show how far the process deviates from perfection. (We'll get into the statistics in later chapters.)

A one-sigma process produces 691462.5 defects per million opportunities, which translates to a percentage of satisfactory outputs of only 30.854%. That's obviously really poor performance. If we have processes functioning at a three sigma level, this means we're producing 66807.2 errors per million opportu-

Sigma (σ) A term used in statistics to represent standard deviation, an indicator of the degree of variation in a set of measurements or a process. A one-sigma process produces 691462.5 defects per million opportunities—a percentage of satisfactory outputs of only 30.854%.

Standard deviation A measure of the spread of data points in relation to the mean. It's the most common measure of variation in a set of data.

Six Sigma A philosophy of managing that focuses on eliminating defects through practices that emphasize understanding, measuring, and improving processes. It's based on the statistical concept of six sigma, measuring a process at only 3.4 defects per million opportunities (DPMO).

Defect A measurable characteristic of the process or its output that is not within the acceptable customer limits, i.e., not conforming to specifications. The sigma level of a process is calculated in terms of defects per million opportunities (DPMO).

Capability Index	Defects per million opportunities	Percent of output defect free
6 sigma	3.4	99.99966%
5.5 sigma	32	99.9968%
5 sigma	230	99.97%
4.5 sigma	1,350	99.865%
4 sigma	6,210	99.4%
3.5 sigma	22,800	97.72%
3 sigma	66,800	93.3%
2.5 sigma	159,000	84.1%
2 sigma	308,000	69.2%
1.5 sigma	500,000	50%
1 sigma	690,000	31%
0.5 sigma	841,000	16%

Figure 1-1. DPMO at sigma levels

nities, delivering 93.319% satisfactory outputs. That's much better, but we're still wasting money and disappointing our customers.

Most organizations in the U.S. are operating at three to four sigma quality levels. That means they could be losing up to 25% of their total revenue due to processes that deliver too many defects—defects that take up time and effort to repair as well as make customers unhappy.

It's Only Words ....

Smart managers realize the impact of words. Be sensitive to the possibility that the word "defects" may bother employees. You may prefer instead to use the word "nonconformance." As D.H. Stamatis writes in the preface to *Six Sigma and Beyond: Foundations of Excellent Performance* (CRC Press, 2002):

"(We prefer the term nonconformance for legal reasons. The traditional verbiage has been defective.) A nonconformance is a deviation from the requirement."

Whether you use "defect" or "nonconformance" or any other word, what matters is that you're measuring things that are not right with your products or services—without blaming people or making them feel defensive.

A Goal—and a Process

The concept of Six Sigma is to eliminate defects. Six sigma is the goal, but it's less important than the objective of pursuing continuing process improvement.

Sometimes the Six Sigma implementation team needs to set more realistic goals, depending on customer requirements and expectations and the complexity of the product or service. Smart managers know that the six sigma quality level is an idea; what's real is the focus on identifying defects and eliminating their root causes.

The central idea of Six Sigma management is that if you can measure the defects in a process, you can systematically figure out ways to eliminate them, to approach a quality level of zero defects.

The goal is to get the maximum return on your Six Sigma investment by spreading it throughout your company, continuing to train employees in the Six Sigma methodology and tools to lead process improvement teams, and sustaining the exponential gains you achieve by keeping it going.

But in addition to the expanding practice of the methodology and dollars redirected to the bottom line, there's another dimension to consider. Six Sigma doesn't exist in a vacuum; while its principles remain constant, there's an evolution of its message that can take companies in exciting new directions.

Design for Six Sigma

We're referring to the discipline known as *Design for Six Sigma* (DFSS)—an approach to designing or redesigning product and/or services to meet or exceed customer requirements and expectations.

Robert G. Cooper states in *Winning at New Products: Accelerating the Process from Idea to Launch* (Cambridge, MA: Perseus Books, 2001, 3rd edition) that only about 60% of new products launched are actually a success and that for every seven new product ideas, only four make it to development—and then only one succeeds. What's wrong with this picture?

Design for Six Sigma (DFSS) A systematic methodology using tools, training, and measurements to enable the design of products, services, and processes that meet customer expectations at Six Sigma quality levels. DFSS optimizes your design process to achieve six sigma performance and integrates characteristics of Six Sigma at the outset of new product development with a disciplined set of tools.

The new product cycle is definitely not operating at a six sigma level. In fact, it's closer to the average four sigma quality level at which many companies operate today. Plus, even as manufacturing problems are corrected by deploying Six Sigma methods, newly developed products often are the source of new problems. So, an organization practicing the methodology in various functional areas and attaining Six Sigma status may well be far below that level in developing new products or services.

Once you've mastered the essentials of Six Sigma, you may well be ready for the essentials of DFSS, to carry that improvement into the development and design of your new products. DFSS is based on the notion that when you design Six Sigma

Prepare for the Elevator

It's smart to have a 30-second explanation of DFSS, an "elevator" speech, to answer a question that people are likely to ask. Here's one proposed by Jim Parnella, Staff Statistician for Alcoa, Point Comfort, TX:

> Six Sigma is a disciplined, data-driven approach to process improvement aimed at the near-elimination of defects from every product, process, and transaction. The purpose of Six Sigma is to gain breakthrough knowledge on how to improve processes to do things *better, faster,* and at *lower cost*. It can be used to improve every facet of business, from production, to human resources, to order entry, to technical support. Six Sigma can be used for any activity that is concerned with cost, timeliness, and quality of results. Unlike previous quality improvement efforts, Six Sigma is designed to provide tangible business results, cost savings that are directly traceable to the bottom line.

quality right at the outset of new product development, it's probable that you'll sustain that gain as customers accept that product. By incorporating DFSS, you're virtually assured that the product or service you're launching will perform dependably in the marketplace, thus setting it up for very positive acceptance.

Like its parent Six Sigma initiative, DFSS uses a disciplined set of tools to bring high quality to launches.

It begins by conducting a gap analysis of your entire product development system. A gap analysis, as explained in Chapter 3, finds the gaps in your processes that are negatively affecting new product performance. It also addresses a highly significant factor, the voice of the customer (VOC). Every new product decision must be driven by the VOC; otherwise, what basis do you have for introducing it? By learning how to identify that voice and respond to it, you're in a far better position to deliver a new product or service that customers actually want!

Once the gap analysis is done and the VOC is identified, DFSS goes to work with its own version of the DMAIC (define, measure, analyze, improve, and control) of Six Sigma, a five-step process, known by the acronym PIDOV:

- Plan—enable the team to succeed with the project by mapping all vital steps
- Identify—hear the voice of the customer to select the best product concept
- Design—build a thorough knowledge base about the product and its processes
- Optimize—achieve a balance of quality, cost, and time to market
- Validate—demonstrate with data that the voice of the customer has been heard and that customer expectations have been satisfied

Some Six Sigma people equate DFSS with another five-step process—DMADV:

- Define—determine the project goals and the requirements of customers (external and internal)

- Measure—assess customer needs and specifications
- Analyze—examine process options to meet customer requirements
- Design—develop the process to meet the customer requirements
- Verify—check the design to ensure that it's meeting customer requirements

Others use only the IDOV steps listed above. Design for Six Sigma is relatively new, so we can naturally expect some inconsistencies and evolution of the models as companies and consultants apply them.

The success of this Six Sigma offshoot requires the active participation of management. You and upper management must monitor its progress regularly to keep it on course. DFSS can be a very useful tool to companies as they get comfortable with Six Sigma and look to grow its benefits in other areas.

Ultimately, DFSS is not that different from the Six Sigma work you're undertaking. In fact, it's a natural progression to continually—and relentlessly—root out defects and route hidden dollars to the bottom line.

Because of the similarities between Six Sigma and DFSS, people frequently talk about DFSS as the logical extension of Six Sigma at the manufacturing and service level, DMAIC. This may be true, but it's important to realize the initiatives are tremendously different. Here are the basic differences between the Six Sigma DMAIC and DFSS:

- DMAIC is more focused on reacting, on detecting and resolving problems, while DFSS tends to be more proactive, a means of preventing problems.
- DMAIC is for products or services that the organization offers currently; DFSS is for the design of new products or services and processes.
- DMAIC is based on manufacturing or transactional processes and DFSS is focused on marketing, R&D, and design.

- Dollar benefits obtained from DMAIC can be quantified rather quickly, while the benefits from DFSS are more difficult to quantify and tend to be much more long-term. It can take six to 12 months after the launch of the new product before you will obtain proper accounting on the impact of a DFSS initiative.
- DFSS involves greater cultural change than DMAIC, because for many organizations DFSS represents a huge change in roles. The DFSS team is cross-functional: it's key for the entire team to be involved in all aspects of the design process, from market research to product launch.

Design for Six Sigma Defined and Explained

DFSS is a business process focused on improving profitability. Properly applied, it generates the right product or service at the right time at the right cost. Through its use of product and team scorecards, it's a powerful program management technique.

DFSS is an enhancement to your new product development process, not a replacement for it. A documented, well-understood, and useful new product development process is fundamental to a successful DFSS program.

Your new product development process provides the roadmap to success. DFSS provides tools and teamwork to get the job done efficiently and effectively. By rigorously applying the tools of DFSS, you can be assured of predictable product quality.

Roots of DFSS

DFSS has its roots in systems engineering. In turn, much of the learning that underpins systems engineering evolved under the guidance of the Department of Defense and NASA. To control the lifecycle process, they developed a management approach that uses performance specifications, as opposed to volumes of product, subsystem, assembly, part, and process specifications.

In the systems engineering world, management of require-

ments (such as those aspects of the end product that must meet customer expectations) guides and drives the entire process.

Requirements at the senior or point-of-use level can then evolve through use of a variety of techniques generally described under the heading of *requirements flowdown*.

Requirements flowdown The process by which all high-level requirements are allocated to the various elements of a system, to make sure that some part of the process is meeting every requirement and no requirement is neglected.

When statistical or quantitative methods are used to establish requirements between system performance and underlying inputs, the design process methodology transitions from a reactive, build-and-test mode to a predictive, balanced, and optimized progression.

DFSS provides a systematic integration of tools, methods, processes, and team members throughout product and process design. Initiatives vary dramatically from company to company, but typically start with a charter (linked to the organization's strategic plan), an assessment of customer needs, a functional analysis, an identification of critical-to-quality characteristics (CTQs), concept selection, a detailed design of products and processes, and control plans.

The beginning of the process centers on discovering customer wants and needs using tools such as Concept Engineering™ (Center for Quality of Management) and quality function deployment (QFD). From this "fuzzy" front end, requirements take shape. Customer issues, competitive advances, technology roadmaps, and disruptive influences commingle in a stew of initial uncertainty.

CTQ Critical-to-quality characteristics, the select few, measurable characteristics that are key to a specific part of the product, service, or process that must be in statistical control in order to guarantee customer satisfaction.

The Marketing Basics Around DFSS

Understanding the needs of the customer for a particular market segment is critical to success. We must get it right in this important first stage. All too often, however, this does not happen. Far too often, organizations do little more than review complaints and simply ask the customers what new features they would like to have added to the product. That's valuable, of course, but it's not going far enough.

Focus groups and interviews can also provide valuable information about the customer, but many times respondents offer feedback couched in terms of technical solutions. Customers offer technical solutions because they believe this is the best solution they're aware of. For example, they may want a laptop computer with a 40 GB disk drive, but what is their underlying need? Do they want faster boot-up time, storage space for pictures, audio, video? It's far better for the design team to understand the latent underlying need and then allow the technical arm of the design team to determine the best technical solution. In Chapter 3 we'll touch upon a technique called *contextual inquiry* that's valuable in helping us understand true, underlying customer needs.

Myths and Misconceptions About DFSS

One common misconception about DFSS is that it's a replacement for your current new product development process. If no formal process exists within your company, it could be used to guide the development process, but typically DFSS provides the tools, teamwork, and data to supplement the new product development process already in place in an organization.

Another misconception is that DFSS is just Six Sigma in design. The truth, simply put, is that DFSS is a complex methodology of systems engineering analysis that uses statistical methods.

Related beliefs are that DFSS is just Design for Manufacturability and Assembly (DFMA) and/or Design of

Experiments (DOE) and Robust Design concepts in engineering. (We'll get to those and other concepts and tools in Chapters 7 and 8.) Those beliefs are based on an overly simplified understanding of DFSS. It's actually a comprehensive process that involves DFMA issues and applies DOE and Robust Design among many methods.

Because of its use of statistical methods, people may believe that DFSS demands extensive statistical analysis and modeling of all requirements. This is untrue. DFSS calls for dealing with each engineering requirement optimally. Consequently, some requirements are analyzed statistically but some requirements are handled with traditional engineering methods.

Another misconception is that DFSS allows too much design margin, so that costs are higher, and/or increases development cycle times, so that market opportunities are missed. In fact, however, DFSS balances cost, cycle times and schedule, and quality.

Some people think of DFSS as being simply a collection of tools. This is a misunderstanding. Although DFSS uses some powerful tools, those tools alone will not ensure success, not unless those using them know how to apply them to specific engineering design opportunities.

Another misconception is that DFSS involves just the core product design team and has no impact on marketing, research, and manufacturing. Because of tools recently added to DFSS, this is no longer true. The most effective product development teams are cross-functional, with strong project management leadership and management support. Marketing, research, design, and advanced manufacturing engineering are typical representatives in a DFSS wave. The team works together to scope customer requirements, select design concepts, detail the product and process design, select suppliers, and ensure that supplier capability meets or exceeds customer-driven engineering needs.

One comment that we hear is that DFSS may apply to

many engineering disciplines, but not to all. However, since DFSS is not specific to any discipline, it applies to all. The analysis will differ according to the discipline, but most of the DFSS principles will apply.

Another misconception is that all management needs to do is "sign the check" and DFSS will happen overnight. Management must play an important role in leading the change effort. Activities such as linking the DFSS process with the company vision, establishing an executive change council to drive implementation, making successes visible, guiding implementation throughout the organization, and making DFSS integral to the company culture are all vital.

Start with a Firm Foundation

Before beginning DFSS in your organization, it may be wise to address any misconceptions about it, to make sure that everybody has a solid understanding and appropriate expectations.

Another misconception involves classroom training. Training in tools with no implementation plan does not result in cultural change. Far too many organizations develop or purchase extensive training initiatives, train employees in a classroom environment, and expect implementation to just happen. Classroom training that is not integral to implementation does not work. Another approach is just-in-time training. Team members learn about a tool as they need it; initial facilitation support is provided as they learn how to apply the tool and simultaneously work on the new product.

Manager's Checklist for Chapter 1

- ❑ Six Sigma is a philosophy of managing that focuses on eliminating defects by understanding, measuring, and improving processes. The methodology is based on measuring processes in terms of defects—most specifically the statistical concept of six sigma, which means only 3.4 defects per million opportunities. Six Sigma uses a five-

step process—Define, Measure, Analyze, Improve, and Control (DMAIC).

- ❑ Design for Six Sigma (DFSS) is a systematic methodology using tools, training, and measurements to enable the design of products, services, and processes that meet customer expectations at Six Sigma quality levels. DFSS optimizes the design process to achieve six sigma performance and integrates characteristics of Six Sigma methodology in product development.
- ❑ Design for Six Sigma is relatively new, so there are differences in the models as companies and consultants apply them. Some use the following five-step process:
  - Plan
  - Identify
  - Design
  - Optimize
  - Validate

  Others use another five-step process:
  - Define
  - Measure
  - Analyze
  - Design
  - Verify
- ❑ DFSS is surrounded by myths and misconceptions. It may be wise to address any of these in your organization before beginning DFSS, to make sure that everybody has a solid understanding and appropriate expectations.