

Business Process Initiative:

Design for Six Sigma



Design for Six Sigma

Focuses on planned quality

Summary

For the majority of organizations, long-term success is tied directly to the new product development process. Tomorrow's revenue and growth are tightly bound to how successful organizations are at launching new products. Understanding what aspects of a product are key to customer's perceptions of a product is critical in ensuring a successful product. Value attracts customers. Quality earns respect and innovation differentiates one product from another. Actively building in these items into a product development process, to drive it, provides a key way to ensure product success. This is the key to Design For Six Sigma (DFSS).

DFSS provides a proactive, systematic method to build important customer requirements into all related aspects of the product development process that can be measured, verified and optimized.

DFSS provides a way for customers to incorporate performance characteristics into their product manufacturing and development processes. Manufacturing and development processes can then be optimized to meet those customer requirements using specific and quantifiable metrics. Customers can then manage quality levels against a specific budget.

DFSS is therefore able to provide a rigorous methodology to further ensure planned product excellence.

Business Challenges

- Customers demand product excellence
 - Excellence is defined as the ideal balance of product attributes, such as Cost, Quality, Performance, Aesthetics, Packaging, etc.
 - Manage variability of customer-facing product attributes
 - Improve the predictability and capability of the product development process
- Market demands reduced costs and increased profitability
 - Increase product development process effectiveness
 - Directly meet customer requirements
 - More effectively manage product development costs

Process Objectives

- Effectively identify and manage key customer-facing product attributes
- Design products to specific performance metrics against those attributes
- Identify contributing product design elements and processes that affect those attributes
- "Design in" customer-facing product attribute quality levels directly into contributing product development processes
- Manage, verify, balance & optimize customer-facing product attributes throughout the product development process

Company Examples

General Electric's Medical Systems Division (GEMS) led the way for DFSS application in the late 1990s with the introduction of the Lightspeed Computed Tomography (CT) System. It was the first GE product to be completely designed and developed using DFSS and it revolutionized the capabilities of CT. Doctors were able to scan more patients per shift and saw productivity double. The increased speed and image quality enabled doctors to more accurately treat patients while making decisions with greater confidence.

Consequently in 1999 Jack Welch announced that all GE products would be designed using the DFSS approach. As a result further gains were made.

GE Capital saved \$2 billion in 1999 using Six Sigma. GE's competitors also started to notice. Iomega and Seagate and other organizations also have corporate level initiatives focused on DFSS.

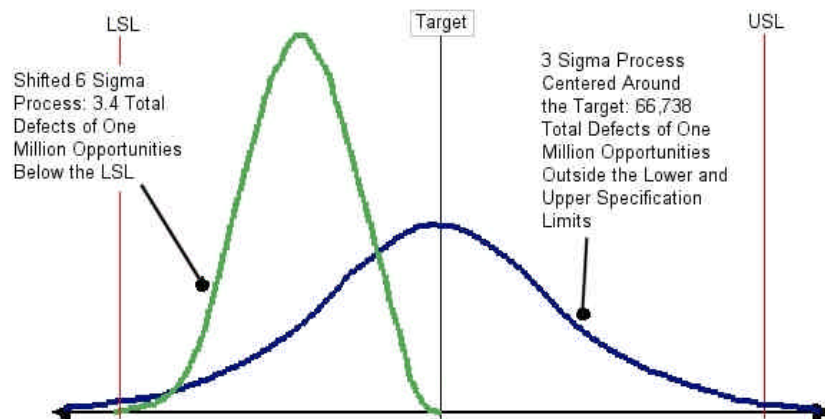
GE Aircraft Engines has managed to hone their jet engine product development process down to a fine art with their adoption of DFSS. By incorporating customer requirements directly into design, simulation and manufacturing models, GE is able to ensure that the important aspects of its product development are geared to meeting customer requirements. A WAVE control structure combined with Knowledge Fusion, all managed by NX and Teamcenter, provide a core linchpin of their success.

Process Details

Six Sigma finds its roots in the fact that all product development processes are inherently unpredictable. The outcome of any product development process produces products that fall within a band, or range, of performance. Six Sigma provides a way to measure this variability.

When most people refer to Six Sigma, they are in fact referring to a methodology known as DMAIC (Define, Measure, Analyze, Improve, Control). This methodology aims to reactively improve an existing product or process when it is not meeting customer specification or is not performing adequately.

DFSS is more of an approach than a defined methodology. However the common theme is that DFSS is used to design or re-design a product or service from the ground up in an effort to more predictably manage product development and manufacturing variability.



Differences between Six Sigma and Design For Six Sigma	
Six Sigma	Design for Six Sigma
<ul style="list-style-type: none"> DMAIC : Define, Measure, Analyze, Improve, Control 	<ul style="list-style-type: none"> DMADV : Define, Measure, Analyze, Design and Verify DMADOV : Define, Measure, Analyze, Design, Optimize, and Verify
Looks at existing processes and fixes problems	Focuses on the up-front design of the product and process.
More reactive	More proactive
Dollar benefits obtained from Six Sigma can be quantified rather quickly.	Benefits are more difficult to quantify and tend to be 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.

Unlike the DMAIC methodology for Six Sigma, the phases or steps of DFSS are not universally recognized or defined -- almost every company or training organization will define DFSS differently. Most times a company will implement DFSS to suit their business, industry and culture.

Roots of DFSS

DFSS has its roots in systems engineering. Much of the learning that underpins systems engineering evolved under the guidance of the Department of Defense and NASA.

In the systems engineering world, management of requirements (for example, those aspects of the end product that must meet customer expectations) guides and drives the entire process. Requirements at the user level can then evolve through a variety of techniques generally described under the heading of requirements flow-down.

Using statistical or quantitative methods to establish links between system performance and underlying inputs, the design process transitions from a reactive, build and test mode to a predictive, balanced and optimized progression mode.

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, functional analysis, identification of critical quality characteristics, concept selection, detailed design of products and processes, and control plans.

To achieve this DFSS utilizes many possible methodologies. The fact is that all of these DFSS methodologies use the same advanced design tools (Quality Function Deployment, Failure Modes and Effects Analysis, benchmarking, Design of Experiments, simulation, statistical optimization, error proofing, Robust Design, etc.). Each methodology primarily differs in the name of each phase and the number of phases (and, of course, the acronym).

The beginning of the process centers on discovery of customer wants and needs using tools such as concept engineering and quality function deployment (QFD). From this “fuzzy” front end, requirements take shape. Customer issues, competitive advances, technology roadmaps and disruptive influences co-mingle in a stew of uncertainty. Giving focus to the translation of customer wants and needs into language that can drive the design process is essential.

When personal computer users indicate speed is important, how is this simple idea translated into actual performance measures? Is speed the RPM of the drive spindle? Or does speed mean reduced time to accept new data into a file? Or time to find a desired segment of data? Or, does speed mean the rate at which an amateur photographer can compose, edit, store and send the kid's photos off to Grandma?

The answer is 'yes,' but 'not always.' DFSS methods highlight and resolve such dilemmas before design teams start detailed development. It eliminates ambiguity at the front end that can lead to chaos at the back.

Predicting Design Behavior

DFSS now looks to predict how the designs under consideration will behave. Numerous engineering and statistical methods provide the basis for prediction.

However, many aspects of product performance are difficult to predict during the early stages of product development. In addition numerous factors can affect the eventual outcome, some of which are independent, some of which are not. In this phase of DFSS, engineers need to define relationships between desired response and critical dependent factors via transfer functions.

Transfer functions, models, simulations and fundamental physics can all play a role. Transfer functions can then enable engineers to inject variation into the models to understand how the distribution of variation can alter the desired performance. This allows you to predict what will happen in actual operation.

Predictions bring another critical element into the DFSS methodology: process, part and measurement variation. Pay dirt from deploying DFSS stems from analysis of the effect of variation before manufacturing begins. Such analysis leads to trade-offs between factors, balancing outputs to optimize overall performance while allowing you to rate risks associated with decisions about program status from a schedule, cost or profitability perspective. Analysis of variability leads to rational decisions regarding whether to insist on design improvement, investment in new capital equipment or the launch of a massive process capability improvement.

As with the fuzzy front end, rational decisions based on available data are always better than educated guesses or dependence on luck. Which would you choose?

So, what if the predictions are wrong? What if something unexpected happens? Technology companies know full well there are always unknown unknowns. As Mikel Harry, co-founder of the Six Sigma Academy, says "You don't know what you don't know."

DFSS provides a structured way to constructively use the information learned from such events in the next program.

To reap the benefits of DFSS, an organization must make fundamental changes in the way it develops new products and processes. Ironically, while tremendous changes have taken place in common methodologies applied to improving manufacturing efficiencies (such as just in time, lean, statistical process control, design for manufacturing and assembly), many organizations still use 20-year-old fundamentals when scoping market requirements and designing a product and its processes.

Self Assessment Symptoms

If your company has the following issues, you might benefit from improving the tools and processes discussed in this document:

- Products that do not meet the needs of customers:
 - Products that have quality issues
 - Products that are late to market
 - Lack of product performance metrics
- Processes not directly geared to meeting end user product requirements:
 - Particularly overtly expensive and inefficient product development processes
 - Obvious product platform requirements
 - Falling short of effectively balance product manufacturing requirements to best meet customer requirements

UGS solutions applied to Design for Six Sigma

A complete product development environment

DFSS is based on having a suite of measurable, customer-oriented attributes, which can be defined, measured, analyzed, optimized and verified (DMADOV). The outcome of these product or process attributes needs to be directly built into a product development process so that the product development processes is specifically geared to producing pre-defined quality limits. This means embedding specific design intent within a product's design to meet specific and understood, customer-facing performance metrics, automatically where possible.

The range of product attributes that any engineering company may wish to incorporate into their design is very much dependent on the industry in which that company operates, and the processes used to produce a particular design. In addition successful products are rarely the result of any specific focus on a single customer-facing attribute alone.

Therefore in order to be able to most effectively meet those needs any reasonable product development process is going to need to support as broader range of engineering, physics, and manufacturing processes as possible. This is also true of any effective product development tool that may support these processes. Today the most complete solution that can currently offer most support for these product and process attributes are embodied within NX and Teamcenter, from UGS. No other suite of product development solutions is able to offer such a broad and powerful range of product and process coverage, completely integrated together. NX includes the widest and most flexible array of product modeling abilities coupled with some of the most advanced CAE and CAM capabilities integrated into any single product development environment.

This allows customers to easily define, measure, analyze, optimize and verify the disparate range of engineering disciplines required to be able to most effectively meet their product development goals. Here both Teamcenter and NX are able to offer a wide variety of solutions to define product requirements; incorporate those requirements into design intent; and then outline and optimize design performance and product manufacturing, against those requirements.

A unified product development environment

With the definition, measurement, analysis and verification of specific customer-facing product attributes comes the need to be able to effectively visualize, filter and verify these attributes. By unifying this into a single environment it becomes possible to compare and optimize disparate attributes and objectives more easily and simply.

NX brings together a multitude of flexible product definition, performance and manufacturing capabilities together into a single environment. This single environment provides a basis for directly tying performance and manufacturing considerations into design intent. Only with a single development environment does it become truly possible to start to compare, balance and optimize disparate product requirements.

With numerous other systems, customers are forced to cobble together ad hoc connections between disparate product development tools. This is time consuming and expensive. NX is able to provide these links as a matter of course.

Once done then it becomes possible to provide tools that are able to identify critical design areas that affect whatever customer oriented attributes are required. This is where numerous quality tools (Quality Function Deployment, Failure Modes and Effects Analysis, benchmarking, Design of Experiments, simulation, statistical optimization, error proofing, Robust Design, etc.) tools can play a part. Once identified it becomes possible to meet specific product or performance goals by optimizing and balancing various design objectives, bearing in mind manufacturing variability.

Digital Management

The complexity of today's product development challenges invariably means that the amount of data created to meet the needs of the customer is huge. Different applications, different file types, different data within the different file types all complicate this issue. Therefore keeping track of all the data associated to any particular product development program and effectively managing the processes through which a product is manufactured becomes a paramount importance. The tight integration of Teamcenter technology with NX keeps track of all product development data.

The benefits of an integrated system become most obviously seen when a design change is proposed or implemented. With NX it becomes possible to push changes downstream to all aspects of the product development environment much faster than with non-integrated systems. As an example once a change is outlined in the geometric model, updates can immediately be pushed to the simulation and manufacturing models. It then becomes possible to more quickly understand the effects of that change. The difference in time can be measured in months and weeks versus days and minutes. In addition Teamcenter provides a number of process, workflow and affectivity management capabilities that ensure these changes can effectively be controlled in an appropriate manner, amongst disparate product development groups as necessary.

One of the core aspects of DFSS is the need to be able to effectively capture customer oriented product requirements and embed these requirements into all pertinent aspects of product development.

One of the cornerstones of the UGS solution's value to customers is the ability to digitally connect customer, marketing, and regulatory requirements to designs, documents, specifications, models, test results, and other types of product information that comprise product definitions.

At a base level Teamcenter is able to provide an attractive method for customers to formally and flexibly capture, manage and distribute a variety of requirements and associated performance metrics. Since it is embedded within the Teamcenter environment it is able to provide pivotal information that can be used to directly influence product direction.

Product Performance, Quality Metrics & Verification

As mentioned above DFSS finds its roots in ensuring products are able to meet customer requirements. Predicting product and process performance requires experience and a broad suite of advanced toolsets in a variety of disciplines.

NX provides the most advanced simulation tools available within any product development environment. In addition NX is also able to leverage the strongest suite of manufacturing and product development process management applications available today. This powerful range of product and process performance prediction provides a bedrock for ensuring that products meet specific customer requirements, without the need for costly prototypes and tryouts.

By integrating these capabilities into a single associative system, together with an advanced product modeling environment, NX ensures that the links between product design elements, product performance and manufacturing variability can be understood and optimized.

As a simple example NX provides methods for the complete definition of shape through the use of GD&T (Geometric Dimensioning & Tolerancing) schemes. In order to meet a particular customer specification, for fit, it's necessary to understand how the variation of the numerous GD&T features most directly contributes to that customer specification. Since the variation of those GD&T are based on manufacturing capabilities it's necessary to introduce probabilistic simulation methods to simulate that variance. It's then possible to understand which GD&T functions most directly affect the customer specification. They can then be managed appropriately to a specific cost.

This case outlines variances in shape. The same concepts can be applied to variances in a variety of product and process performance areas and is the primary reason why NX has some of the most advanced CAE tools available today coupled together with a range of optimization capabilities. In fact in the example above within the NX system it is even possible to incorporate the variance of GD&T on performance by directly linking FEA simulation to GD&T variability.

Geometric, Performance and Process Modeling Flexibility

Once the key customer-facing requirements of any product have been identified, defined, simulated and approximated, a design intent based on meeting those requirements can be outlined.

This provides a way for designs to be re-used and product platforms outlined to ensure that future product derivatives are more able to meet customer requirements, with a minimum of re-engineering.

At a base level embedding this requirement knowledge directly into product definition requires a broad and flexible ability to model product definition so that is able to incorporate product and process performance.

NX includes an extremely broad range of product modeling capabilities that encompass a wide array of geometric, performance, process and knowledge modeling abilities.

The geometric modeling capabilities of NX provide a case in point. NX incorporates an advanced array of knowledge-based system, assembly, parametric, polygonal, direct and explicit modeling toolsets to ensure that customers are able to embed an extremely wide array of design intent into model definition. In addition this can be achieved appropriately to meet customer needs, rather than the needs of the system. As such NX is not restricted by the overly constrained approach of a parametric only system. Nor is it limited by not being able to effectively capture an extremely broad array of requirements. From simple and quick parametric free modeling, to extremely advanced, knowledge-based capabilities to directly relate simulation and manufacturing requirements directly into product design NX is uniquely positioned to provide the most flexible modeling system available today.

In addition, NX provides a broad range of platform-oriented product modeling toolsets. Advanced product configurations and variances can be controlled directly through a range of toolsets. From the advanced parametric control of large systems and assemblies, through products like WAVE, to more discrete management of part family variations NX is able to boast a range of tools aimed at managing and controlling product configuration and variation. In addition additional levels of configuration and variant control is provided by the high level tools within Teamcenter. This ensures that product derivatives can be easily modeled and, very importantly, effectively managed.

This type of flexibility outlines one of the underlying themes behind NX and Teamcenter. DFSS is all about highlighting those aspects of a product and its accompanying product development process that most directly affect customer requirements. NX and Teamcenter provide ways to allow product development organizations to focus on the things that matter, in the manner that best meets their needs, rather than the needs of the tools at hand.

Industry References

1. Robert G. Cooper, *Winning at New Products* (Boston: Addison-Wesley Publishing Co., 1994).
2. Geoffrey Boothroyd and Peter Dewhurst, *Product Design for Manufacture and Assembly* (New York: Marcel Dekker, 1994).
3. <http://www.isixsigma.com>
 1. Kerri Simon, ksimon@isixsigma.com. *What is Six Sigma and how does Design for Six Sigma compare to DMAIC.*
4. Kai Yang and Basem S. El Haik, *Design for Six Sigma. A Roadmap for Product Development* (McGraw-Hill, 2003).