# Quality Driven by CAE

**Advanced CAE tools** enable companies to **design quality** into their products.

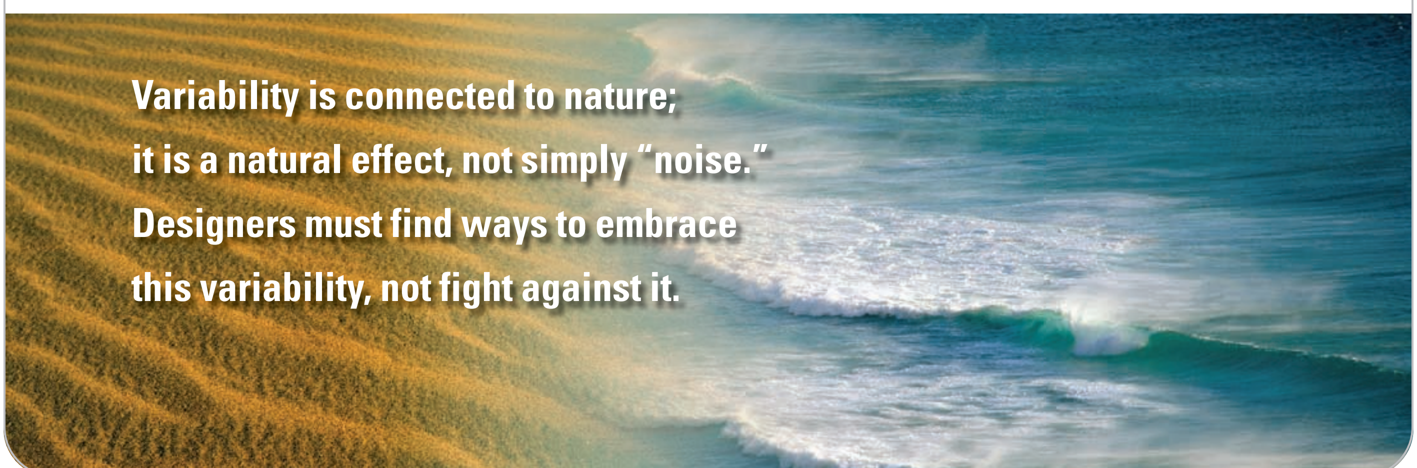
*by* **Massimo Fariello**

Bringing a new product to market is a challenging endeavor, and consistently successful product launches are an indicator of a rare class of companies.

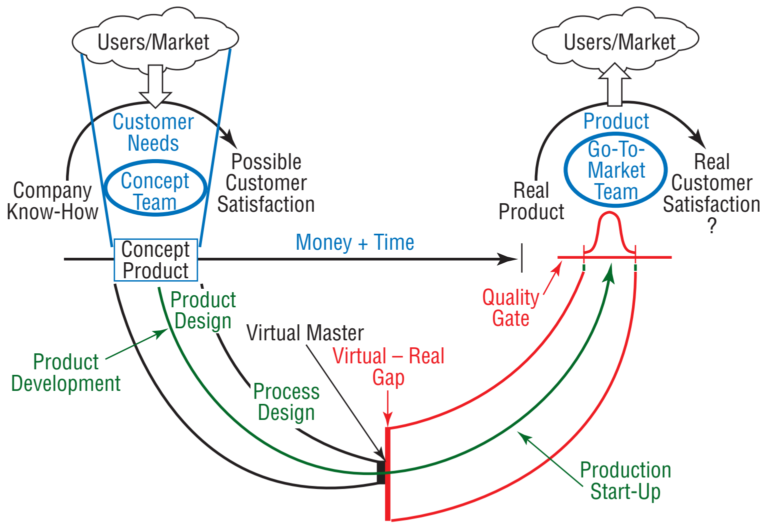
Customer-focused product development teams involve cross-functional personnel from a variety of areas to support conceptual design efforts. Teams can include representatives from marketing, R&D, style, design, sales, supply management, production and finance. Merging knowledge of the company's products and processes with an understanding of customer needs, competitors and market trends, these teams develop a set of product functionalities and performances. The intended result of their efforts is to satisfy customers and increase revenue and profitability.

If the "Concept Product" could be released to the market immediately, the chances of its success would be quite high. For example, consider the excitement and allure created by visionary concept vehicles. Imagine the demand that could be created if production could be synchronized with the unveiling.

The product development process is often complicated, however, and getting from Concept Product to "Real Product" requires time and money. Product development complications often result in the Real Product being close to – but not exactly the same as – the Concept Product. This is because design and manufacturing compromises are made during product development.



**Companies begin with a perfect Virtual Master and end up with a Real Product embedding its statistical distributions.**




**Quality plays a pivotal role in bridging the gap between product development and production start-ups.**

Successful product launches can be characterized by three factors:

1. Good interaction with users and the consumer market early in the concept phase;
2. A Real Product that closely matches the Concept Product; and
3. An accurate feedback loop from users to the product design team to evaluate customer satisfaction.

There is a fourth factor, however, that can lead to sustained enterprise success. That factor is "Quality."

## From Concept to Reality: The Virtual Master

Quality is the ability to deliver what is promised to customers in terms of functionality and performance over time and for each individual product sold. Note that this is a customer-oriented definition of Quality and does not necessarily relate to internal measures of variability.

Quality is measured (and is attempted to be controlled) for Real Products in what we call "quality gates." These gates represent a fixed level of required product and process testing – 99.38 percent for Three Sigma and 99.99 percent for Six Sigma, for example.

The path from a Concept Product to a Real Product that is characterized by a statistical distribution includes two convergent processes: product development and production start-up.

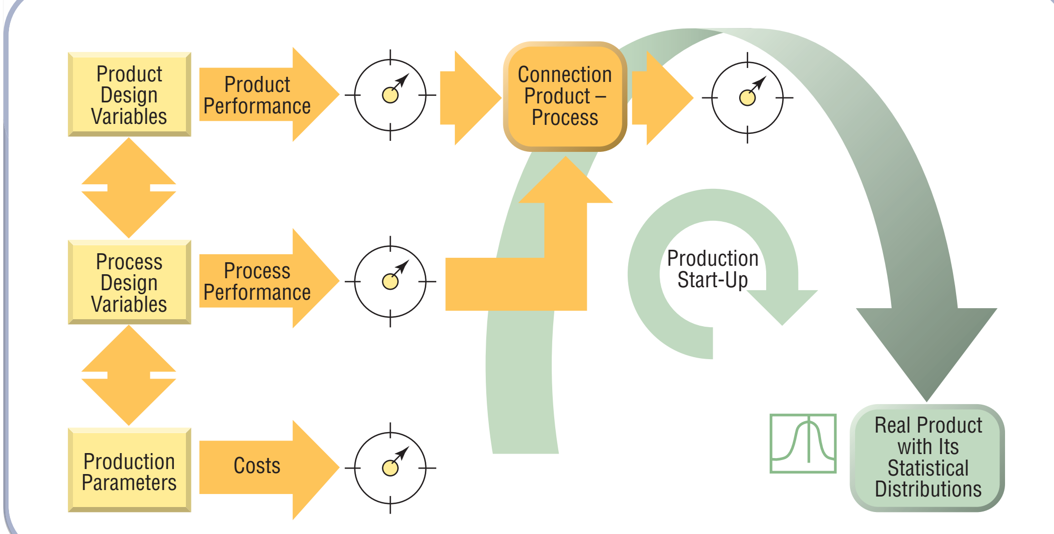
Product development that utilizes product lifecycle management (PLM) tools starts with a Concept Product and ends with a complete definition of the "Virtual Master." The Virtual Master is the complete set of all design variables and their connected performance predictions in a digital environment.

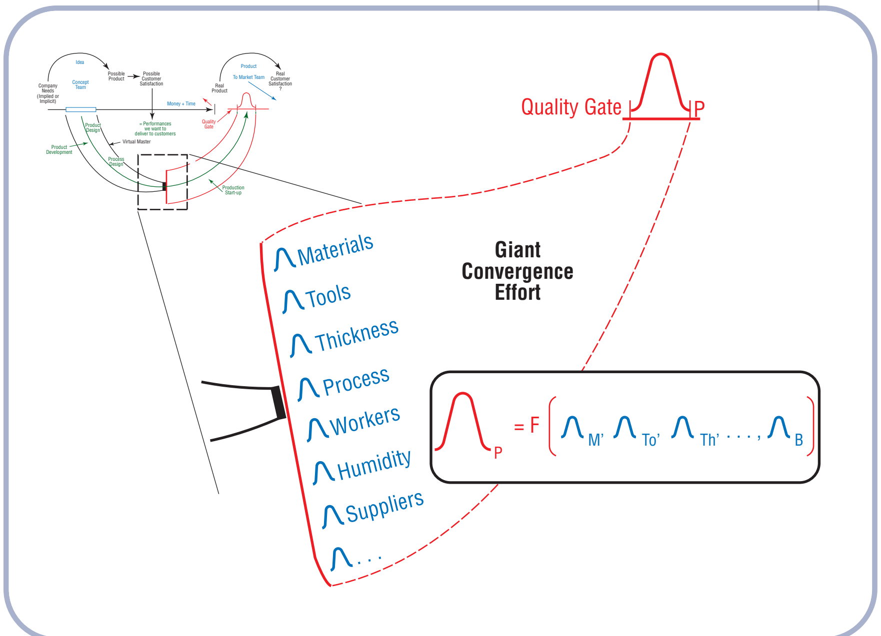
Computer-aided engineering (CAE) tools are used to evaluate product design variables, with a goal of predicting and improving product performance. All factors are deterministic, that is, all facts and figures exemplify natural laws. For example, a nominal value defines each variable or performance measure.

Cost is always a key consideration, and to evaluate cost feasibility, production plant process variables must be connected to the nominal production conditions.

Effective use of CAE technology will allow the connection of information between process and performance simulation, leading to a better estimate of the real nominal product performance.

The Virtual Master, in conjunction with CAE simulation, digitally represents the complete product. At this point in the design cycle, the Real Product may be different from the Concept Product, depending on the level of innovation and the compromises made. But it is still regarded to be within the intent of the product development effort's original scope. Following organi-






zational approval, significant investment in capital equipment, facilities and tooling is made to support production start-up.

## From Virtual Master to Production Reality

The reality of production start-up is the introduction of variances and statistical distributions inherent in a Real Product as compared to the perfect, clean and impeccably nominal Virtual Master.

This variability becomes evident as soon as the virtual product meets the "real" world. Every variable that was considered as nominal – thickness, material characteristics, process variables, tools and hundreds of others – introduces variability by natural distribution.

To successfully pass quality gates, it is necessary for the product to perform satisfactorily, as related to a series of single variables and their production process distribution. This often results in an expensive convergence process to control input and output variability.

## Different Efforts to Achieve the Same Quality

Given that the product distribution is a nonlinear function of the input variables' distribution, the most natural way to improve product quality is to narrow the appropriate input distribution until the output is back within acceptable limits. This is the right approach if desired process controls are efficiently within available capabilities.

However, trying to push variability distributions to their nominal values is not the correct approach, especially if doing so comes at an inordinate cost. Variability is connected to nature; it is a natural effect, not simply "noise." Designers must find ways to embrace this variability, not fight against it.

Cost-effective Quality is dependent on the methods chosen to pass the required quality gates, and making the convergence effort easier is an effective way to spend less money during product launch.

A key point is that the function is dependent on the product design itself serving as a function of design parameter variability in production.

Consider the design of a steel U-channel that is going to be produced by a stamping press.

The designer sets its geometry and thickness (see page 18), and then wants to take into account the stamping process. A design rulebook might direct the designer to add a draft angle of three degrees to account for the spring back.

The blue geometry is now the nominal one, and a normal distribution around that mean geometry is accepted.

Now, imagine that a revolutionary, new high-strength steel is available, and the company wants to use it because it can reduce thicknesses (and thus cost and weight). However, at production tryouts, the average spring back is now found to be higher (e.g., five degrees). This new spring back behavior was not covered in the design rulebook, as it comes out of an unanticipated innovation (the new steel), and the production processes are all designed around the three-degree spring back value.

One way to compensate for an offset mean value like this is to place tighter controls on the process variability than would normally be required. This can be expensive, however.

In contrast, CAE can be used to evaluate the natural behavior of processes and provide feedback to design prior to production. In this U-channel example, a stamping simulation with the new steel and the existing tool could be performed to discover that the mean value for spring back is now 4.8 degrees. Then, the nominal design can be aligned to the mean value of the

**Product performance is a function of all the variables – and is dependent on the product design itself.**

geometry distribution resulting from the stamping process. CAE thus represents an efficient pre-production means of designing while simultaneously taking process parameters into account.

## The Virtual Production

All the methodologies and tools that contribute to define the Virtual Master can be imagined as a connected "simulation engine." To assess the effects of variability resulting from the real production world, this engine can be run several times on samples obtained through input distributions.

The result is a special kind of simulation – "Virtual Production" – whose main result is to evaluate the connection between input distribution and the quality gates in a pure digital environment.

Now, the design parameter variability function can be identified and is available in the design phase.

Knowledge of this function includes all of the sensitivity effects, thus allowing for a much easier problem diagnosis. Moreover, quality gate failures can be remedied with focused corrective actions. Most importantly, this function knowledge allows Quality to be part of the design.

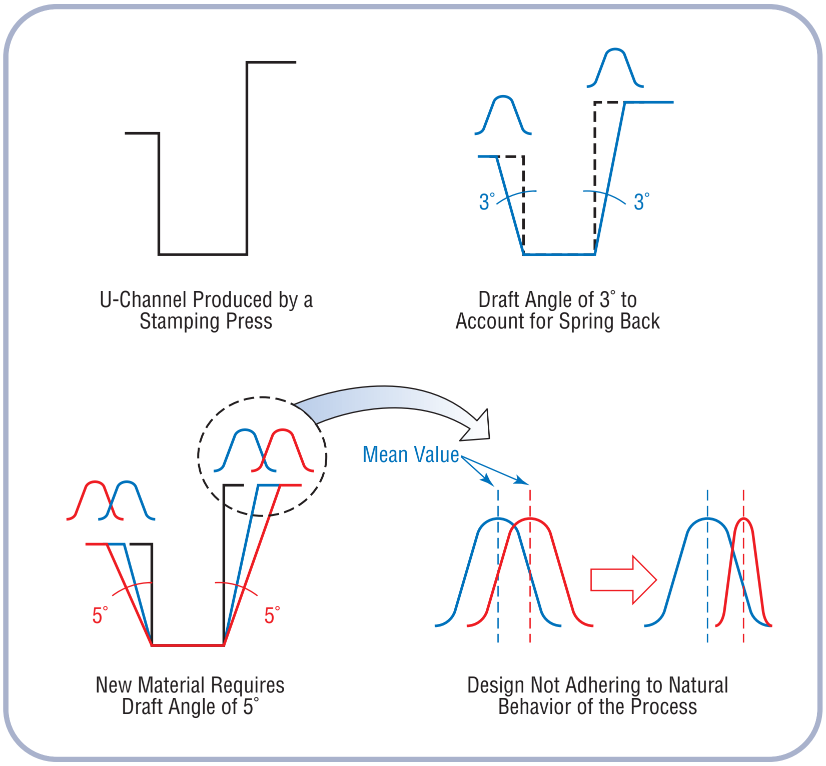
By starting from the target Quality, natural variances can be introduced and accounted for. Controllable input distributions can then be set to the minimum level necessary to reach Quality targets.

This efficiently places the Quality effort only where it is really needed and avoids setting impossible targets for the final product. It also avoids the expenditure of inordinate resources to control input distributions that have little effect on the global product.

Another good example of Virtual Production can be found in a statistical assembly simulation of a car body-in-white (BIW) that takes into account the flexibility of its components. The nominal simulation engine takes a set of stamped components, as well as the assembly rules and sequence, and then assembles the group, using a CAE tool that takes into consideration the physical behavior of the components and their contact interfaces.

This is very different from what is usually done with CAD systems. With a CAE simulation engine, the compliance, component interactions and material characteristics are all taken into account to represent real physical behavior.

The next step is to define a statistical 3D geometry distribution for each of the input components and simulate the assembly process as many times as necessary to obtain the resulting statistical 3D assembled geometry. Quality targets for the assembly have been analyzed, and their sensitivity compared to the single component distribution has been assessed.




**CAE simulation enables engineers to evaluate the natural behavior of processes and feed it back to design.**

## Back to the Customers

Are we designing Quality into our products in a way that ensures customer satisfaction?

Yes and no.

As indicated earlier, true Quality is related to product performance that the production processes can actually deliver. Quality gates can be good indicators of the performance distributions, but they are geometry- or threshold-based, compared to being tied to actual customer response.

The reliable "performance evaluation engine" methodologies developed by the CAE community over the past few decades can now be linked to Virtual Production, with the goal of assessing the performance of each product coming out of Virtual Production lines.

This represents a true Virtual Master, connecting all aspects of design (yellow), production (blue) and the resulting product performance (green). It can be used from any direction to explore alternatives and connections from every different perspective.

Having the ability to test every design and process variable choice as it relates to the effect on product performance (including cost) can help organizations anticipate problems, create positive cross-functional discussion, prevent costly manufacturing launch problems and enable product development organizations to focus on developing innovative and market-leading products.

This is Quality driven by CAE. C2R

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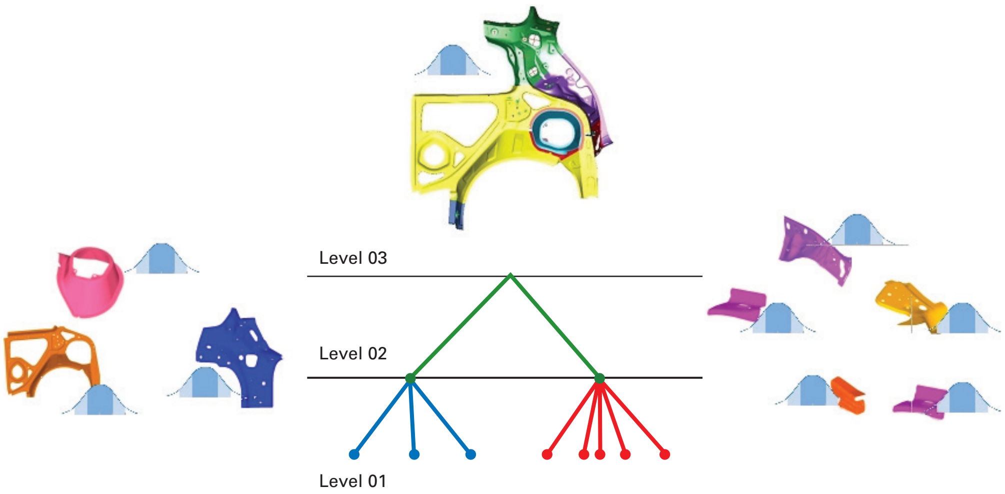
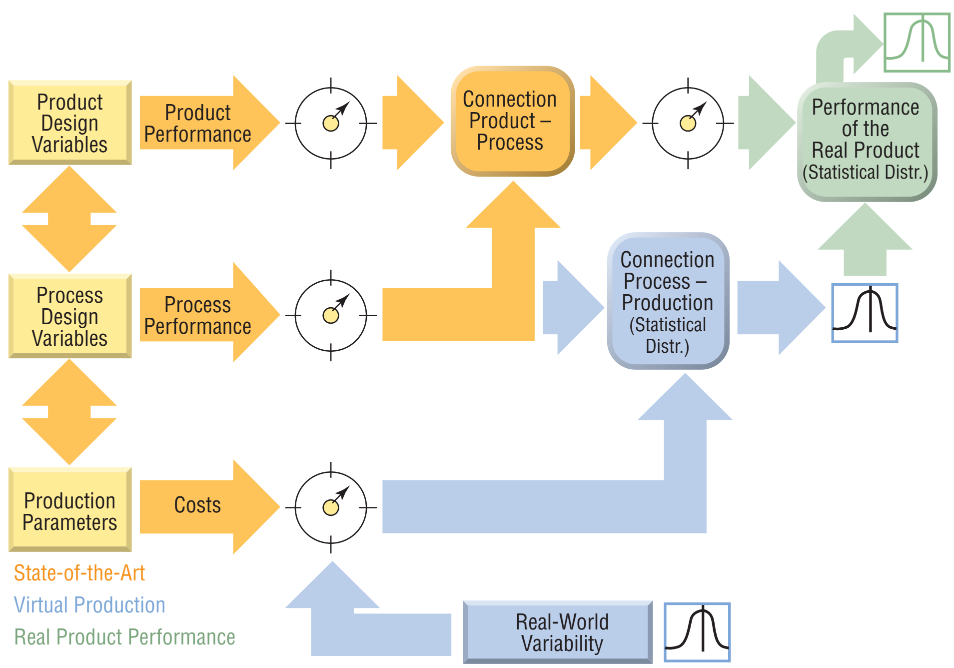



**CAE enables engineers to define the statistical 3D geometry distribution for each input component and can simulate the assembly process multiple times to obtain the resulting statistical 3D geometry.**

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**To learn more about designing for quality with Altair technologies, visit *www.altair.com/c2r* or check 04 on the reply card.**