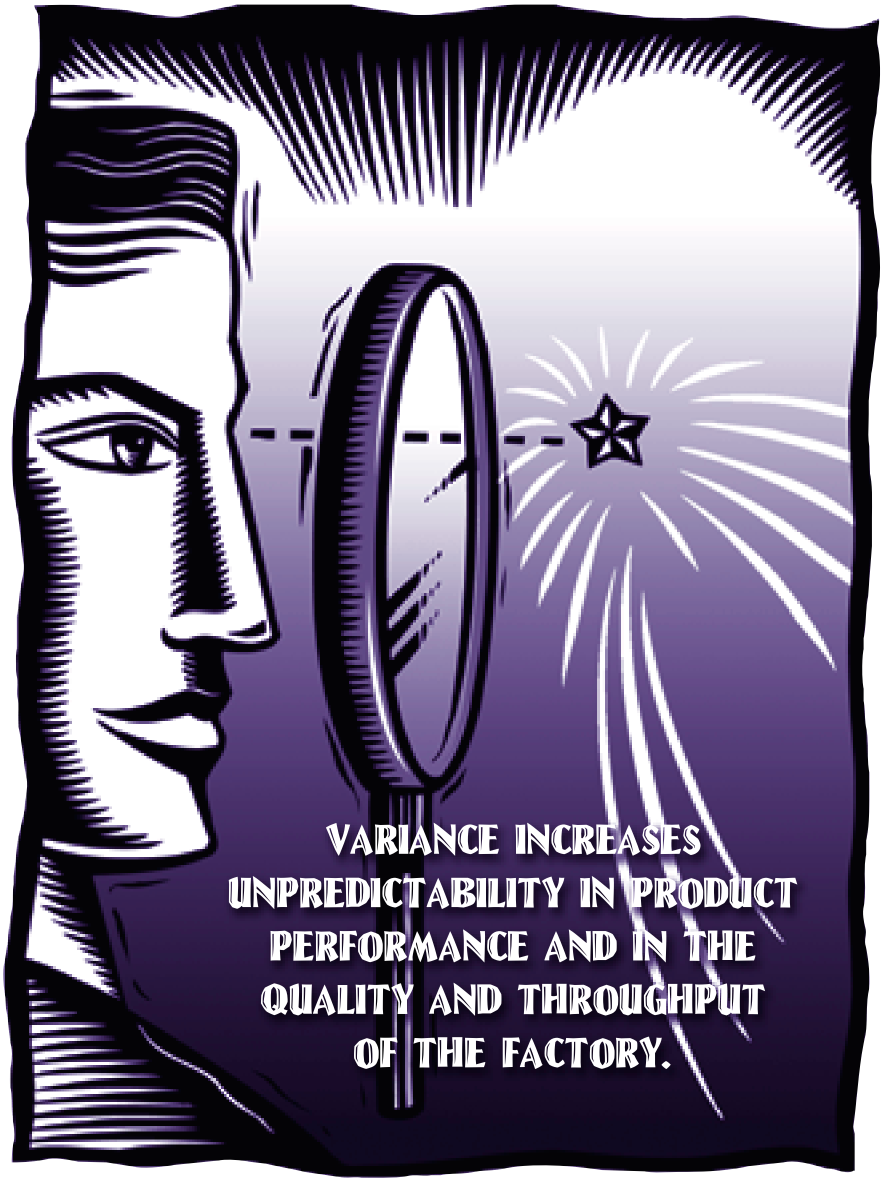
# Introduction to Variability and Variation Reduction

*Bill Motley*




Modern engineering design, manufacturing engineering, and quality assurance embrace variability reduction as a primary means of improving product performance and reducing product defects. In many firms today, a primary goal of engineering efforts is the continuous and systematic reduction of variability in key product features and manufacturing processes. If you are involved in implementing lean production techniques and/or Theory of Constraints and Six Sigma initiatives, you will be involved in identifying and reducing sources of variability in design concepts, manufacturing processes, process cycle times, and test/measurement systems. Product features, manufacturing processes, or material characteristics whose variations can very adversely affect performance, safety, or mission execution are increasingly denoted by the terms "key" or "critical" on drawings and specifications. SAE Standard AS9100B defines a key characteristic as "the features of a material or part whose variation has a significant influence on product fit, performance, service life, or manufacturability." There is still not a consistent use of the terms key and critical, so it is important that a manager know what specific definition is being used.

"Variation" can be defined as any unwanted condition or as the difference between a current and a desired end-state. Both product performance and manufacturing processes exhibit variation. To manage and reduce variation, the variation must be traced back to its source. Variation occurs in all natural and man-made processes. If variation cannot be measured, it is only because the measurement systems are of insufficient precision and accuracy.

## Problems and Their Results

Variation creates numerous problems. If we assume our performance and manufacturing specifications have been

**Motley** *is a professor at DAU and program director of the production, quality and manufacturing career field. He is a former chair of DSMC's manufacturing management department. Motley is certified by the Society of Manufacturing Engineers, Institute of Industrial Engineers, and the Project Management Institute.*

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established correctly, any deviation from the target goal will result in degraded system performance and/or defective components. Variance increases unpredictability in product performance and in the quality and throughput of the factory. Process variance reduces the capacity of the factory because processes become either under- or over-utilized. Process variance reduces our ability to detect potential problems and increases the difficulty of discovering the root cause of problems.

The causes of variation in product performance and manufacturing processes will vary by the type of technology, its maturity, and the experience of the organization and its suppliers.

There are four major sources of variability in technical processes:

- Insufficient design margins resulting from poor design practice, unrealistic requirements, and requirements creep. Also contributing are poorly defined operating environments and inaccurate design reference mission profiles.

- The inherent variability of any manufacturing process. Every factor in a manufacturing process (manpower, materials, work methods, machinery, and measurement) possesses inherent variability.

  No two products or characteristics are exactly alike because any process contains many sources of variation. For example, the diameter of a machined shaft is susceptible to variation from the machine, tool, material, operator, maintenance, and environment. Some sources of variation in the process cause very short-run, piece-to-piece differences—for example, backlash and clearances within a machine and its fixturing. Other sources of variation tend to cause changes in the output only over a longer period of time, either gradually as with tool or machine wear, or irregularly, as with environmental changes such as power surges. Changes in ambient conditions (temperature, humidity, and barometric pressure, etc.) also affect manufacturing processes.

- Measurement systems all possess inherent variability, even if properly calibrated. Several large manufacturing firms believe that variability in their measurement systems initially contributed 20–25 percent to the problems and defects found on their shop floors.

- Variable products provided by subcontractors and vendors. Piece-parts and subsystems are all variable for all the reasons presented in this article. As prime contractors continue to outsource more of their systems, the variability of components—to include physical interfaces—becomes increasingly important.

Counters to variability in product performance and in manufacturing processes include:

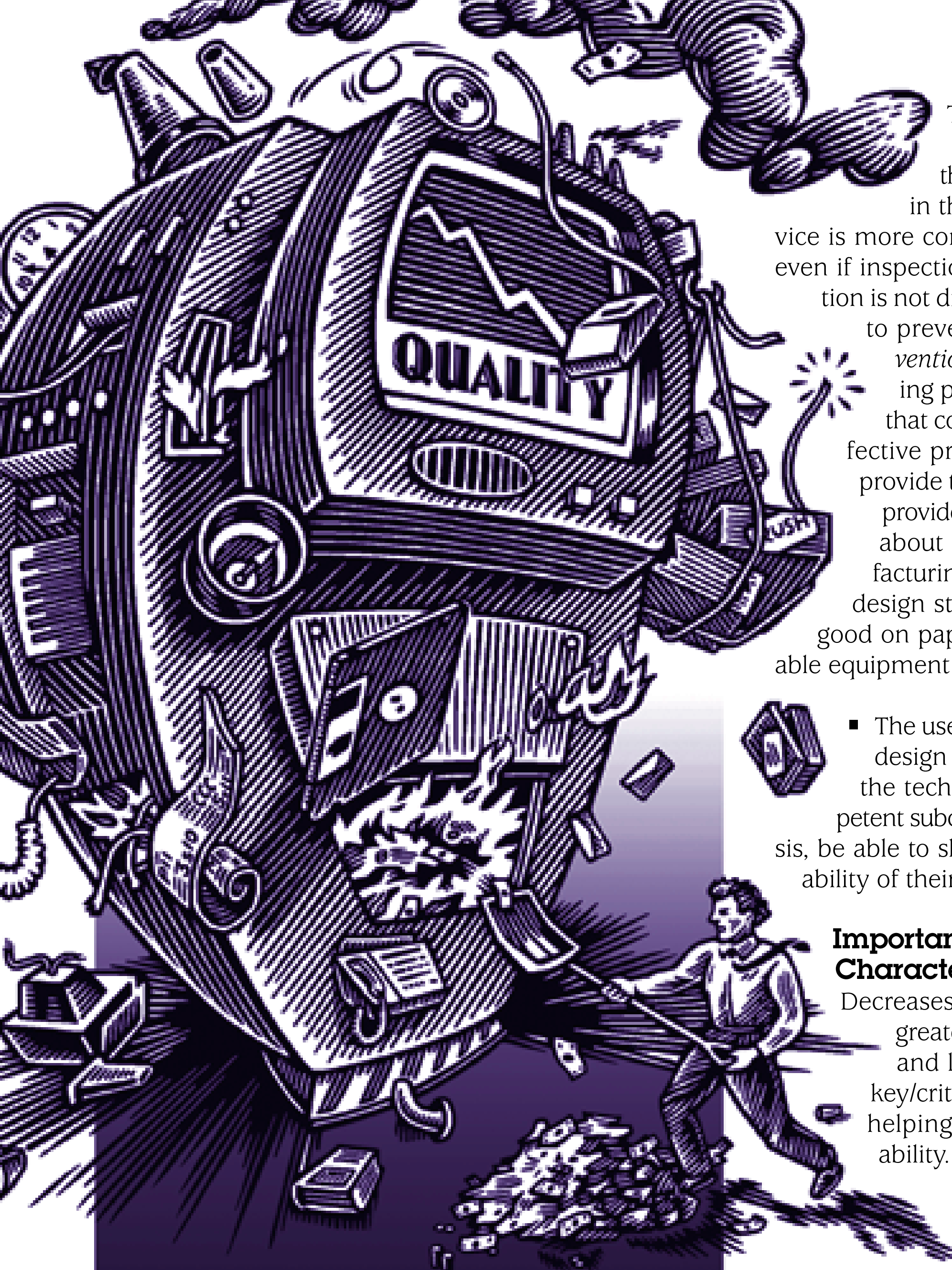
- Stable, realistic requirements, which include well-defined operating environments and accurate design reference mission profiles.

- A design process that includes producibility as a major requirement. Design for producibility focuses on ease of manufacture, which should result in lower piece-part counts and fewer opportunities for defects. Through the use of formal training or integrated product and process teams, design engineers must be made familiar with the capabilities and limitations of the shop floor.

- The use of proven, mature manufacturing processes whose capabilities are well documented, both statistically and empirically.

- The use of statistical tools—such as designed experiments, statistical process control, and analysis of variance—on the manufacturing shop floor. These tools ensure that processes are both capable and predictable.

  The traditional situation depends on production to make the product and on quality control to inspect the final product and screen out defects. This is a strategy of detection. It is wasteful because it allows time and materials to be invested in products or services that are not always usable. In the first place, 100 percent inspection is too expensive. It's an activity that costs money but doesn't bring in any additional revenue from the customer. To put it another way, the customers pay for the parts shipped, and inspections don't result in any additional good parts being shipped. One hundred percent inspection is also limited in usefulness because it cannot contribute to defect prevention and productivity improvements. Inspection activities are always lim-




**INSPECTION ACTIVITIES ARE ALWAYS LIMITED TO REACTING TO THE PAST: THEY CAN FIND DEFECTIVE PARTS ONLY AFTER THEY HAVE BEEN PRODUCED.**

ited to reacting to the past: they can find defective parts only after they have been produced.

Finally, 100 percent inspection is never entirely achievable. A motivated inspector working under good conditions doing repetitive industrial measurement typically fails to take notice of 20 percent of the defective products inspected.

The comment is sometimes made that inspection could be more dependable through use of automation. There is truth in that, since an automatic inspection device is more consistent than a human. Nevertheless, even if inspection is automated, 100 percent inspection is not directed towards controlling the process to prevent defects. What is needed is a *prevention* strategy that provides manufacturing personnel with immediate feedback so that corrective action can be taken before defective product is made. Statistical techniques provide this strategy. Statistical techniques also provide invaluable feedback to the design staff about the abilities and limitations of manufacturing processes. Such feedback helps the design staff avoid producing designs that look good on paper but cannot be built with the available equipment.

- The use of subcontractors and vendors whose design and manufacturing processes employ the techniques discussed in this article. Competent subcontractors will, through statistical analysis, be able to show continuous reduction in the variability of their products and processes.

### Importance of Defining Key Characteristics

Decreases in variability will eventually result in greater product performance, fewer defects, and lower manufacturing cost. The use of key/critical characteristics is a powerful tool in helping identify and reduce sources of variability.

It is important that variation reduction efforts are applied to only those features and processes defined as key or critical based on human safety and/or mission-essential performance. There is a strong tendency by technical managers and engineers to use key characteristics indiscriminately, and when that happens, they lose their meaning and impact.

Key/critical characteristics are a powerful tool for communicating to everyone in the organization what really is important and deserving of increased attention and resources. An increasing number of commercial firms are making key characteristics a non-negotiable technical requirement. If a feature or process is marked “KEY,” there can be no waivers or deviations allowed.

The author welcomes comments and questions and can be reached at bill.motley@dau.mil.