Two Definitions of Trouble

Donald J. Wheeler

In the past there was only one criterion required to be a good supplier: you had to ship very few nonconforming items. If your proportion of nonconforming items took a turn for the worse then you would be “in trouble,” and you would stay in trouble until your fraction nonconforming dropped back down to “an acceptable level.” Based on this one criterion most suppliers would alternate between being in trouble and operating okay. As long as you were operating okay you could have an attitude of benign neglect toward your operations. But when you were in trouble you would have to bring in the problem-solving team to fix the process. The world of the manufacturer was characterized by alternating periods of benign neglect and intense panic which could be summarized by a single dimension, as shown in Figure 1.

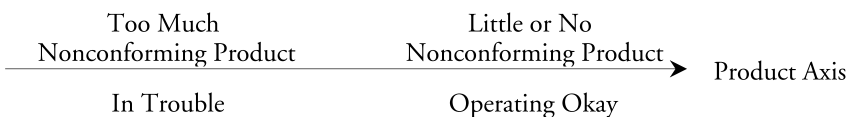

Figure 1: The Old Definition of Trouble

Walter Shewhart gave us a new definition of trouble. This second definition of trouble focuses on the production process rather than the product. According to Shewhart, if your production process is operating up to its full potential, then you are operating okay, but if your production process is not operating at full potential, then you are in trouble. And the only methodology for determining if a process is operating at full potential is the process behavior chart. Thus, the new definition of trouble would look like Figure 2.

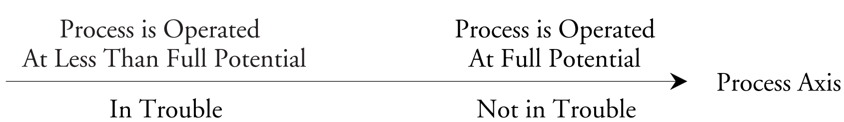

Figure 2: The New Definition of Trouble

While both definitions of trouble are valid, neither one is sufficient to fully characterize a production process. Hence we need to combine these two definitions to get the full picture. When we do this we end up with four distinct categories that may be used to characterize any process.

1. Conforming Product and a Predictable Process (*no trouble*),
2. Nonconforming Product and a Predictable Process (*product trouble*),
3. Conforming Product and an Unpredictable Process (*process trouble*), and
4. Nonconforming Product and an Unpredictable Process (*double trouble*).

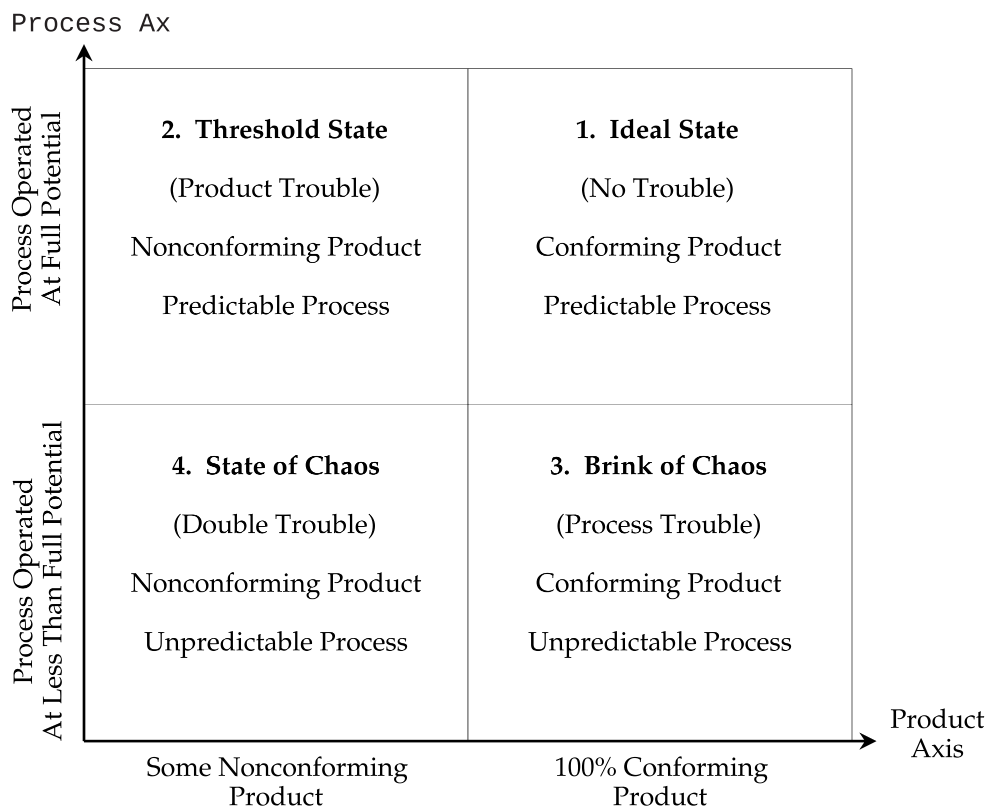

Figure 3: The Four Possibilities for Any Process

THE IDEAL STATE (NO TROUBLE)

For lack of a better name, denote the first of these four categories as the "Ideal State." A process in this state is predictable and is producing 100 percent conforming product. The predictability of the process will be the result of deliberate efforts on the part of the manufacturer. A predictable process is an achievement, requiring constancy of purpose and the effective use of process behavior charts. The conformity of the product will be the result of having natural process limits that fall inside the specification limits. When your process is operating in the Ideal State you will usually find that the Centered Capability Ratio C_{pk} will be close to, or greater than, 1.00.

When your process is in the Ideal State both you and your customer can expect the conformity of the product to continue as long as the process behavior remains predictable. Since the product stream for a predictable process can be thought of as being homogeneous, the measurements taken to maintain the process behavior chart will also serve to characterize the product produced by the predictable process.

How does a process get to be in this Ideal State? Only by satisfying four conditions:

1. The process must be inherently predictable over time.
2. The manufacturer must operate the process in a predictable and consistent manner. The operating conditions cannot be selected or changed arbitrarily.

3. The process average must be set at the proper level.
4. The natural process limits must fall inside the specification limits for the product.

Whenever one of these conditions is not satisfied, the possibility of shipping nonconforming product exists. When a process satisfies these four conditions, the manufacturer can be confident that nothing but conforming product is being shipped. The only way that a manufacturer can know that these four conditions apply to his process, and the only way that he can both establish and maintain these conditions day after day, is by the use of process behavior charts.

A process that is in the Ideal State is one that does not need further improvement.

THE THRESHOLD STATE (PRODUCT TROUBLE)

Again, for lack of a better name, denote the second of these four categories as the "Threshold State." A process in this state will be predictable, but it will be producing some nonconforming product. When your process is operating in the Threshold State the Centered Capability Ratio C_{pk} will be less than 1.00.

As before, the predictability of the process will be the result of deliberate and persistent efforts on the part of the producer—a predictable process does not occur by accident. Moreover, because the process is predictable, it must be thought of as operating as consistently as it currently can operate. Nevertheless, the existence of some nonconforming product will be the result of one or both of the Natural Process Limits falling outside the specification limits.

The fact that the process is predictable puts a new twist on product trouble. First of all, as long as the process remains predictable, the nonconforming product will persist. Therefore you cannot wait for things to spontaneously improve. Second, the ultimate solution to the problem of nonconforming product will require you to move this process up to the Ideal State. This will only happen when you either change the process or change the specifications.

If the Capability Ratio C_p is greater than 1.00, then the process has enough elbow room to operate in the Ideal State and the nonconforming product is likely to be due to a faulty process aim. In this case the manufacturer will need to tweak the process inputs to adjust the process aim. Here the process behavior chart can be used as a feedback loop to help to determine how various adjustments affect the process average.

If the Capability Ratio C_p is less than 1.00, then the process is not likely to have enough elbow room to meet the specifications even if it is operated on target. Here there will be a need to reduce the process variation. Since a predictable process is already operating as consistently as it currently can operate, the reduction of the process variation will usually require a major change in the process itself. As you experiment with major process changes the process behavior chart will allow you to evaluate the effects of your changes. Thus, process behavior charts will not only help you achieve a predictable process, but they also help in moving the process from the Threshold State to the Ideal State.

Therefore, a process in the Threshold State is one that needs to be reengineered. Thus, we can see that the conventional wisdom is correct when it is applied to a predictable process. However, as we will now see, it breaks down when applied to an unpredictable process.

As always, a short-term solution to the existence of nonconforming product is to use 100% nondestructive testing. As has been proven over and over again, 100% screening of product is imperfect and expensive. The only way to guarantee that you will not ship any nonconforming product is to avoid making any in the first place. Sorting should be nothing more than a stop-gap measure rather than a way of life.

THE BRINK OF CHAOS (PROCESS TROUBLE)

The third state is the "Brink of Chaos." Processes in this state are unpredictable even though they are currently producing 100% conforming product. With the traditional view the existence of 100% conforming product is considered to be evidence that the process is "operating okay." Unfortunately, this view inevitably leads to benign neglect. Processes in the Brink of Chaos will usually have a Centered Performance Ratio P_{pk} value that is close to, or greater than, 1.00.

Shewhart's characterization of process behavior emphasizes that processes on the Brink of Chaos are unpredictable—in spite of the current 100% conformity, the process is changing unpredictably, and the 100% conformity can disappear at any time.

Any unpredictable process is subject to the effects of Assignable Causes. So while the conformity to specifications may lull the producer into thinking all is well, the Assignable Causes will continue to change the process until it will eventually produce some nonconforming product. The producer will suddenly discover that he is in product trouble, yet he will have no idea of how he got there, nor any idea of how to get out of trouble. The change from 100% conforming product to some nonconforming product can come at any time, without the slightest warning. When this change occurs the process will be in the "State of Chaos."

There is no way to predict what an unpredictable process will yield tomorrow, or next week, or even in the next hour. Since the unpredictability of such processes is due to Assignable Causes, and since Assignable Causes are dominant causes that are not being controlled by the manufacturer, the only way to move out of the Brink of Chaos is to first eliminate the Assignable Causes. Since the only technique for identifying Assignable Causes is the process behavior chart, any attempt to exit the Brink of Chaos will require the use of process behavior charts.

A process in the Brink of Chaos is often incorrectly perceived to be operating okay, even though it is in need of being operated predictably.

THE STATE OF CHAOS (DOUBLE TROUBLE)

The State of Chaos exists when an unpredictable process is producing some nonconforming product. The unpredictable process means that the producer is confronted with a changing level of nonconformity in the product stream. So even though the producer may know that he is making nonconforming product, he cannot reliably predict the percentage nonconforming from hour to hour. Here the Centered Performance Ratio P_{pk} will usually be less than 1.00.

A manufacturer whose process is in the State of Chaos knows that he has a problem, but he usually does not know what to do to correct it. If he tries to address the problem of nonconforming product directly he is likely to be frustrated by the random changes in the process which result from the presence of the Assignable Causes. When he makes a needed modification to the process, the effect will be short-lived because the Assignable Causes continue to change the process. When he makes an unnecessary modification, a fortuitous shift by the Assignable Causes may mislead him. No matter what he tries, nothing works for long because the process is always changing. As a result, he finally despairs of ever operating his process rationally, and he begins to speak in terms of "magic" and "art." One client actually had daily yields that would swing from a high of 90% to a low of 10%, and he never knew why. A production process in the State of Chaos is simply a mystery where the clues keep changing.

The only way to make any progress in moving a process out of the State of Chaos is to first eliminate the Assignable Causes. This will require the use of process behavior charts. Whenever a process is in either the Brink of Chaos or the State of Chaos the first step should always be to learn how to operate that process predictably. A process is operated up to its *full potential* only when it is operated predictably. Predictable operation is not something that is beyond the capability of your process. It is merely the realization of operating a process as it could and should be operated, nothing more, and nothing less.

A process in the State of Chaos is in need of being operated predictably.

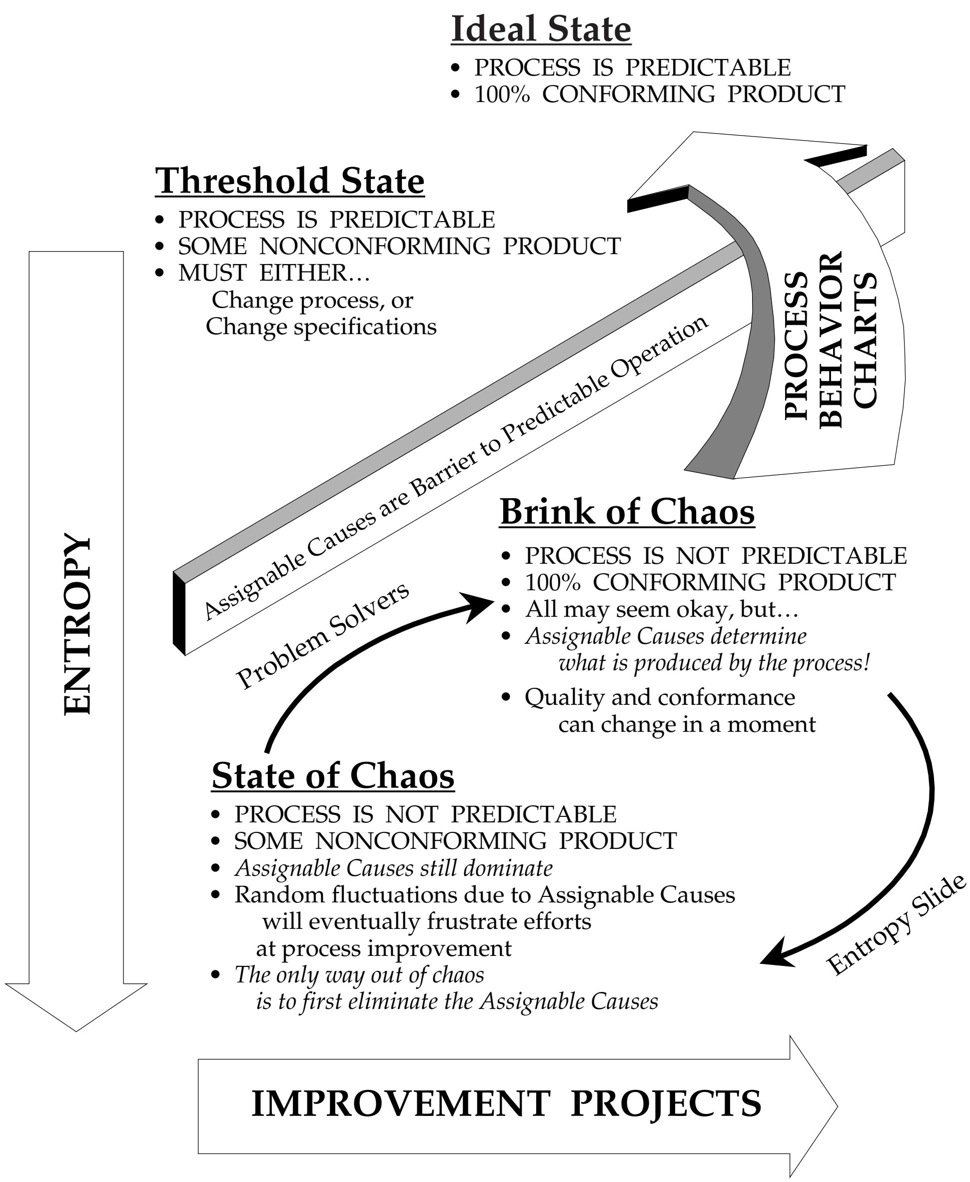

Figure 4: The Four Possibilities and the Cycle of Despair

THE EFFECT OF ENTROPY

All processes belong to one of these four states. But processes do not always remain in one state. It is possible for a process to move from one state to another. In fact there is a universal force acting on every process that will cause it to move in a certain direction. That force is entropy. It continually acts upon all processes to cause deterioration and decay, wear and tear, breakdowns and failures.

Entropy is relentless. Because of it every process will naturally and inevitably migrate toward the State of Chaos. The only way this migration can be overcome is by continually repairing the effects of entropy. Of course this means that the effects for a given process must be known before they can be repaired. With such knowledge, the repairs are generally fairly easy to make. On the other hand, it is very difficult to repair something when one is unaware of it. Yet if the effects of entropy are not repaired, it will come to dominate the process and force it inexorably toward the State of Chaos.

THE CYCLE OF DESPAIR

Since everybody knows that they are in trouble when their process is in the State of Chaos it is inevitable that problem-solvers will be appointed to drag the process up from the State of Chaos. With luck, these problem-solvers can get the process back to the Brink of Chaos—a state which is erroneously considered to be "out-of-trouble" in most operations.

Once they get the process back to the Brink of Chaos the problem-solvers are sent off to work on another problem. As soon as their backs are turned, the process begins to move back down the entropy slide toward the State of Chaos.

New technologies, process upgrades, and all the other "magic bullets" which may be tried can never overcome this Cycle of Despair. One may change technologies—often a case of jumping out of the frying pan and into the fire—but the benign neglect which inevitably occurs when the process is on the Brink of Chaos will allow entropy to drag the process back down to the State of Chaos. This is why focusing solely upon conformance to specifications will condemn you to forever cycle between the State of Chaos and the Brink of Chaos. In the words of one engineer, "I spend my working life on project teams whose average half-life is two weeks, implementing solutions that have an average half-life of two weeks."

No matter how well intentioned your improvement efforts, no matter how knowledgeable you may be about your process, any improvement effort that does not address the issue of operating your process predictably can do no better than to get your process up to the Brink of Chaos. Operating a process predictably is a discipline that must be practiced. It cannot be implemented.

THE ONLY WAY OUT OF THE CYCLE OF DESPAIR

There is only one way out of this Cycle of Despair. There is only one way to move a process up to the Threshold State, or even to the Ideal State—and that requires the effective use of process behavior charts.

Every producer is confronted with this dual problem. Entropy places a process in the Cycle of Despair. Assignable Causes doom it to stay there. Thus, manufacturers must identify both the effects of entropy and the presence of Assignable Causes. The only way to do this is to use process behavior charts. No other tool will consistently and reliably provide the necessary information in a clear and understandable form on a continuing basis.

The traditional chaos-manager, problem-solving approach is focused upon conformance to specifications. It does not attempt to characterize or understand the behavior of the process. Therefore, about the best that it can achieve is to get the process to operate in the Brink of Chaos some of the time. This is why any process operated without the benefit of process behavior charts is ultimately doomed to operate in the State of Chaos.

THE NEW MANTRA

It is important to operate a process to meet requirements. But the fact that some processes are operated up to their full potential, while others are not, makes the issue of operating to meet requirements more complex than the traditional wisdom of upgrading the bad processes and ignoring the good processes.

Traditional process upgrades are focused on moving from the left side to the right side of Figure 4. Operating a process up to its full potential is focused on moving from the bottom to the top of Figure 4. Economic operation requires that we do both.

Predictable Process	**Threshold State** ***Product Trouble*** Adjust Process Aim or Redesign Process	**Ideal State** ***No Trouble*** Ignore or Gently Tweak Process
Unpredictable Process	**State of Chaos** ***Double Trouble*** Find Assignable Causes & Remove Their Effects	**Brink of Chaos** ***Process Trouble*** Find Assignable Causes & Remove Their Effects
	Some Nonconforming Product Produced	**100% Conforming Product Produced**

Figure 5: The Basis for the New Mantra of Process Improvement

Thus, when we combine the two definitions of trouble we end up with a new mantra for improvement. The new mantra may not be as simple as the original mantra, but it does a much better job of reflecting reality and describing appropriate courses of action.

Find Assignable Causes for Unpredictable Processes and remove their effects;
Upgrade or adjust Predictable Processes in the Threshold State; and
Ignore or tweak the Predictable Processes in the Ideal State.

The first line of this new mantra defines how to operate your process with minimum variance. When a process is operated on target with minimum variance it is operating up to its full potential. The second line deals with what you have to do when that is not enough. Thus, this new mantra is one that will guide you through the complexities of improving an existing process. It uses the four possibilities as a matrix to triage your process improvement efforts.