The Knowledge Mapping Application: Ford's Robust Engineering Process

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Need to simplify and fully integrate quality methods in new product development

In the spring of 1995, the top 100 managers in Ford's Powertrain division met to determine their breakthrough initiatives for the year. They wanted to decide on what vital few processes could be worked on, so that if breakthrough was achieved in these processes, Powertrain could obtain a breakthrough in results.

Some of the discussion centered around quality methods. One Chief Engineer remarked that there were too many quality tools, and that the tools were too complex. He said, "Today someone might come and talk to me about implementing Taguchi's methods of robustness. Tomorrow someone will ask me to better implement reliability methods; the day after: customer focused engineering. There are too many quality methods and they are too complex. We need them simplified and integrated into one common actionable sequence."

After listening to and thinking about these comments, a breakthrough initiative was forged that is now called the Robust Engineering Process. The Robust Engineering Process is a straightforward, iterative pattern of team-oriented actions to design and manufacture products that consistently satisfy customers, despite changing environmental circumstances and the passage of time.

A fractal approach provided the overall framework

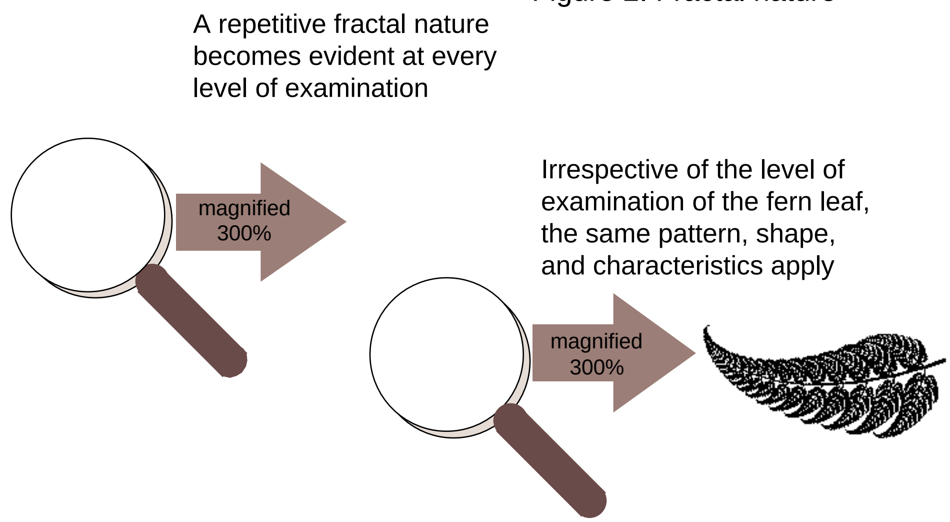
The Robust Engineering Process was developed by a cross-functional team over an 18 month period of time. A fractal-based approach was used to provide a framework to integrate and simplify the various quality initiatives used in new product development. This is best explained with illustrations. Consider the fern leaf drawing shown in Figure 1. This fern has such an intricate shape; it could take a large number of instructions (detailing the various dimensions) to explain to someone how to reproduce this shape.

Figure 1. A Complex Fern Leaf

A fractal approach provided the overall framework, continued

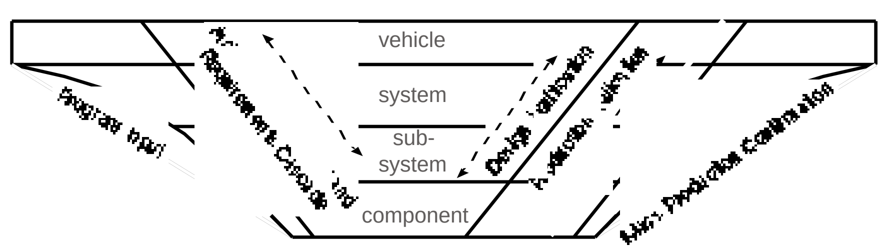
The task becomes even greater when we consider that within each element of this drawing, the overall detail is replicated at smaller levels of scale. As illustrated in Figure 2, characteristics that replicate patterns at lower levels of scale are called fractals.

Figure 2. Fractal nature



Fractals are commonly found in nature and also show up in the product development process! Consider the systems engineering aspect of new product development as shown in Figure 3. George Box, the well-known Quality statistician from the University of Wisconsin, said that, "All models are wrong, but some are useful." This model is useful to illustrate system engineering principles associated with cascading requirements and integrating system elements in new product development. Although the product development process is also very complex (it takes many instructions just to describe the system architecture part of new product development), lets use this simplified model to illustrate the fractal nature of new product development.

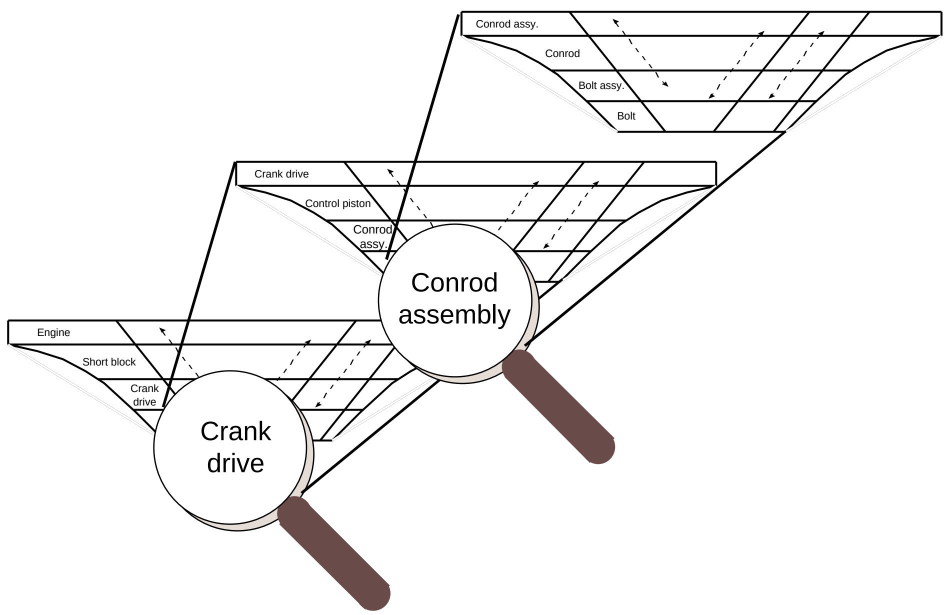
Figure 3. Complexity in Product Development—A System Engineering "V" Model shows cascading requirements and system integration



A fractal approach provided the overall framework, continued

Typically, systems engineering begins with a definition of system architecture, functions, and requirements for the system (vehicle), the subsystem elements (such as a powertrain), and components (for example, an engine). However, Figure 4 shows that systems engineering activity conducted on the vehicle level can be replicated on the engine. In other words, the engine can be treated as a system in its own right, cascading requirements to subsystem elements (such as a short block) and components (for example, a crank drive). However the crank drive can be considered a system in its own right, with the conrod assembly as a component. But the conrod assembly is a system …and so it goes with vehicle level actions replicated at smaller levels of scale for each fractal element.

Figure 4. The Fractal Nature of Product Development



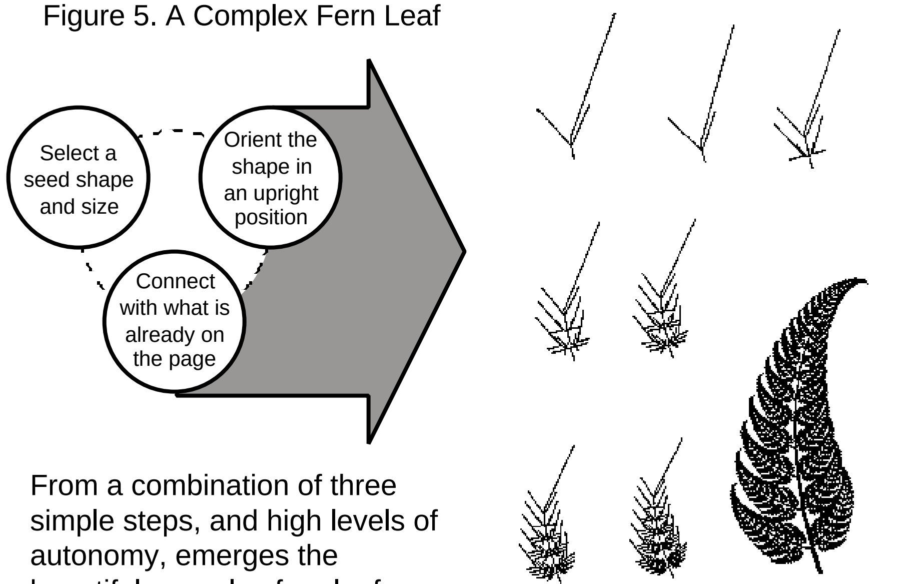
Let's explore the fern leaf example a little more. Even though the fern leaf shape is intricate and complex, the shape can be completely reproduced by iterating three simple rules:

1. Begin with a seed shape and select a seed shape size
2. Orient the shape in an upright direction
3. Connect with what is already on the page.

Iteration among these simple rules, and a high level of autonomy, will generate the complex fern leaf, as shown by the drawing in Figure 5, made with a computer programmed with these rules.

A fractal approach provided the overall framework, continued

Figure 5. A Complex Fern Leaf



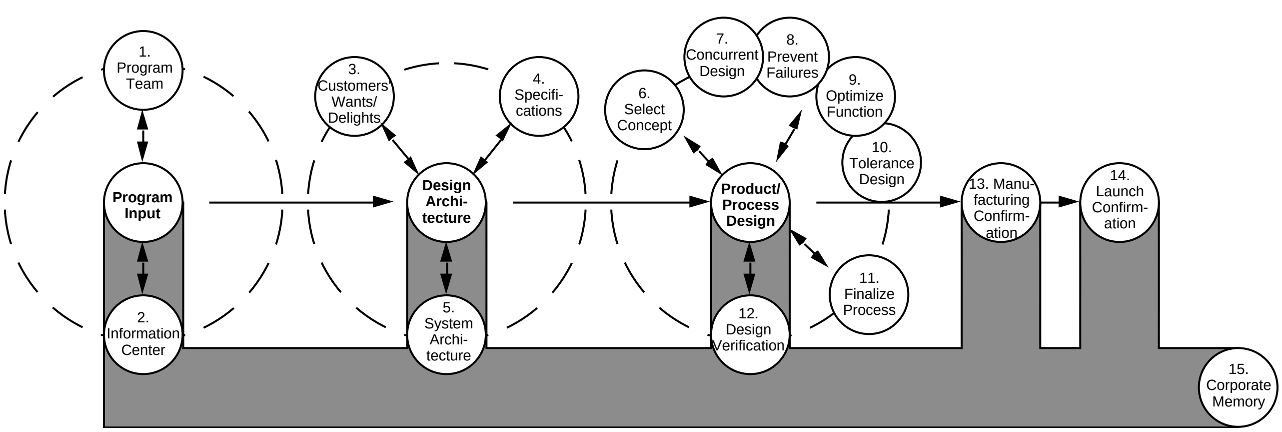
From a combination of three simple steps, and high levels of autonomy, emerges the beautiful, complex fern leaf.

Fern drawing excerpted from Garcia, Linda, *The Fractal Explorer*, Dynamic Press, Santa Cruz, CA, 1991.

At Ford, our Robust Engineering Process utilized a similar, fractal based, approach to simplify and integrate quality and reliability methods in new product development. Using the iterative framework shown in Figure 6, the Robust Engineering Process identified fifteen ways of thinking (big ideas that make big differences) that link to common sense engineering:

1. Program team
2. Information center
3. Customer wants / delights
4. Specifications
5. System architecture

Figure 6. An Iterative Framework of Actions and Ways of Thinking



Dotted lines indicate iteration

A fractal approach provided the overall framework, continued

6. Select concept
7. Concurrent design
8. Prevent failure
9. Optimize function
10. Tolerance design
11. Finalize process
12. Design verification
13. Manufacturing confirmation
14. Launch confirmation
15. Corporate memory

When engineers think, and then act this way, robust and reliable products with great customer satisfaction will be the result.

Once the overall framework for the Robust Engineering Process was developed, the team treated these fifteen ways of thinking as an iterative strategy, and began to develop suggested actions, or how-to alternatives to assist engineers with implementation. These actions were developed using Knowledge Maps, a combination of Mind Mapping and Moderation Techniques.

Knowledge Mapping was used to generate suggested actions within the fractal framework

Mind Mapping was developed by Tony Buzan [2,3,4]. Tony reasoned that the brain is composed of right and left halves. The left part of the brain tends to be very analytical. Logic, language, and numbers are primarily left brain activity. The right part of the brain is more associated with emotion and creativity. Relationships, shapes, and colors are primarily right brain activity. Tony developed a format, called Mind Maps, which combined logic and language, with colors, shapes and relationships. When this format is used, both halves of the brain are intentionally stimulated. Tests conducted found that brainstorming with this format tended to provide a richer solution set; and learning with this format tended to have a longer retention span.

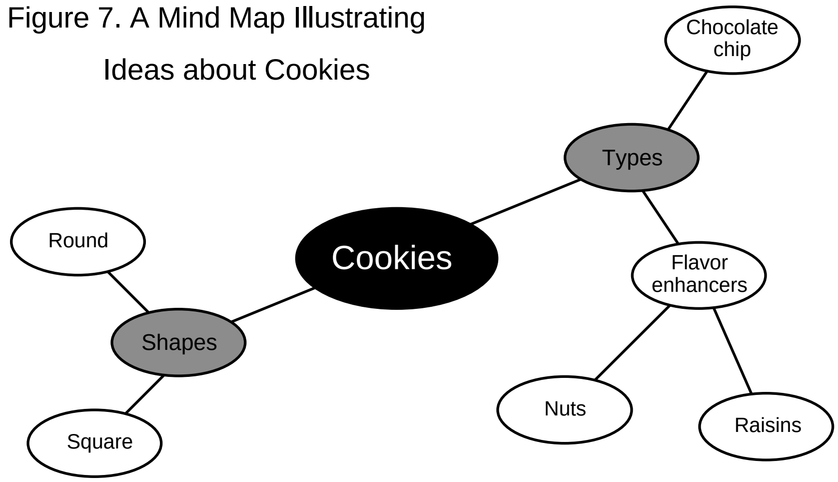
The facilitator for our team was from Ford of Germany, and was trained in the use of Moderation Techniques. Moderation Techniques utilize portable pin boards with a variety of different sizes, shapes and colors of paper. This paper is used by the facilitator and team members to record notes and thoughts on the pinboards.

Moderated Knowledge Mapping came about as our team began to use Moderation equipment and techniques to create Mind Maps for each of the fifteen strategic steps. An example of what such a map might look like is shown in Figure 7.

Figure 7 represents our team's emerging thoughts about chocolate chip cookies. If you are going to design a great cookie you should think about shape (alternatives could be round or square), and type. Type could involve the use of a flavor enhancer (such as nuts or raisins) and whether the chocolate is in chips or chunks. By the way, this chocolate could be dark, white, or milk. This represents another idea that should be added to our Knowledge Map — I bet you can think of others. Give it a try!

Knowledge Mapping was used to generate suggested actions within the fractal framework, continued

Figure 7. A Mind Map Illustrating Ideas about Cookies



Knowledge Maps are Mind Maps that are used to document knowledge and "how to" alternatives. In addition to stimulating both sides of the brain, Knowledge Maps are easy to update when new knowledge becomes available. They are also fun! Our team initially used them for brainstorming (not all team members were in favor of this when we started). As we developed and used the Knowledge Maps, the team liked them so much we kept them in the finished product.

The Robust Engineering Process currently consists of Knowledge Maps and Write-ups. Knowledge Maps exist at a high level for each of the fifteen steps, and then at lower levels to provide additional detail. Write-ups are organized by categories such as: Suggested Readings; Suggested Actions (Inputs/Outputs); Definitions; Overview; and Purpose/Value of Step. The Knowledge Maps and Write-ups work together to provide useful information to engineers (in printed form, each page of Write-up has a facing Knowledge Map).

In the Robust Engineering Process (REP), engineers are responsible and accountable to implement the strategy. How they implement the REP strategy is determined by the engineer. Knowledge Maps document the alternatives. Engineers in teams consider the alternatives and have the opportunity, flexibility, and responsibility to select any approach that makes the most sense for their situation. Consider the following high level Knowledge Map (Figure 8) from Step 8:

Step 8 involves improving a product or process design after it has been engineered, by taking action to reduce failure modes and variability. The key thoughts involved in this are: work in cross-functional teams, thoroughly understand previous product and process work, ask "what can go wrong?", modify the product and/or process to prevent this from happening, and then ask, "now what can go wrong?" The team continues to iterate until they have improved the product and/or process as much as possible. Suggested actions for this process are provided in lower level Knowledge Maps, such as the one shown in Figure 9.

Knowledge Mapping was used to generate suggested actions within the fractal framework, continued

Figure 8. Detail of a Knowledge Map

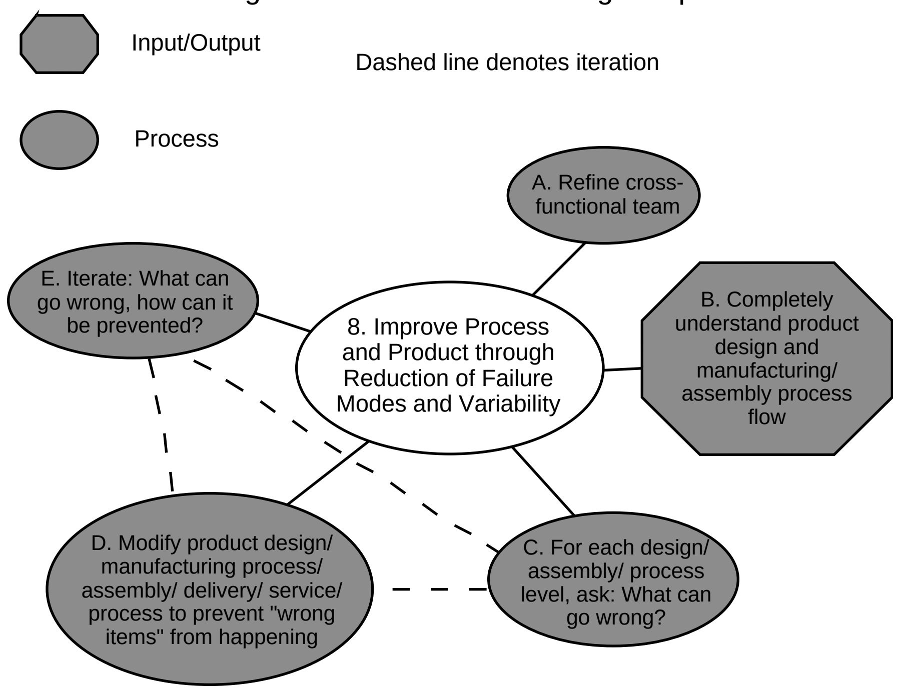
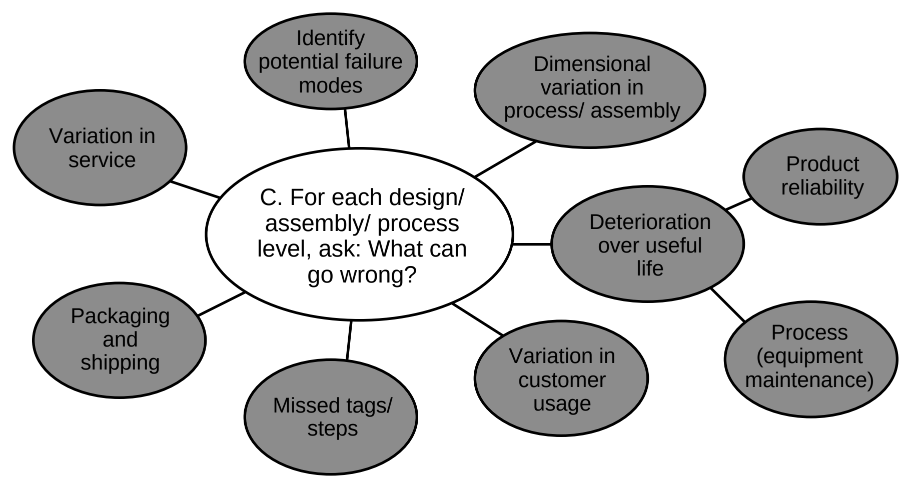


Figure 9. Further Detail of a Knowledge Map

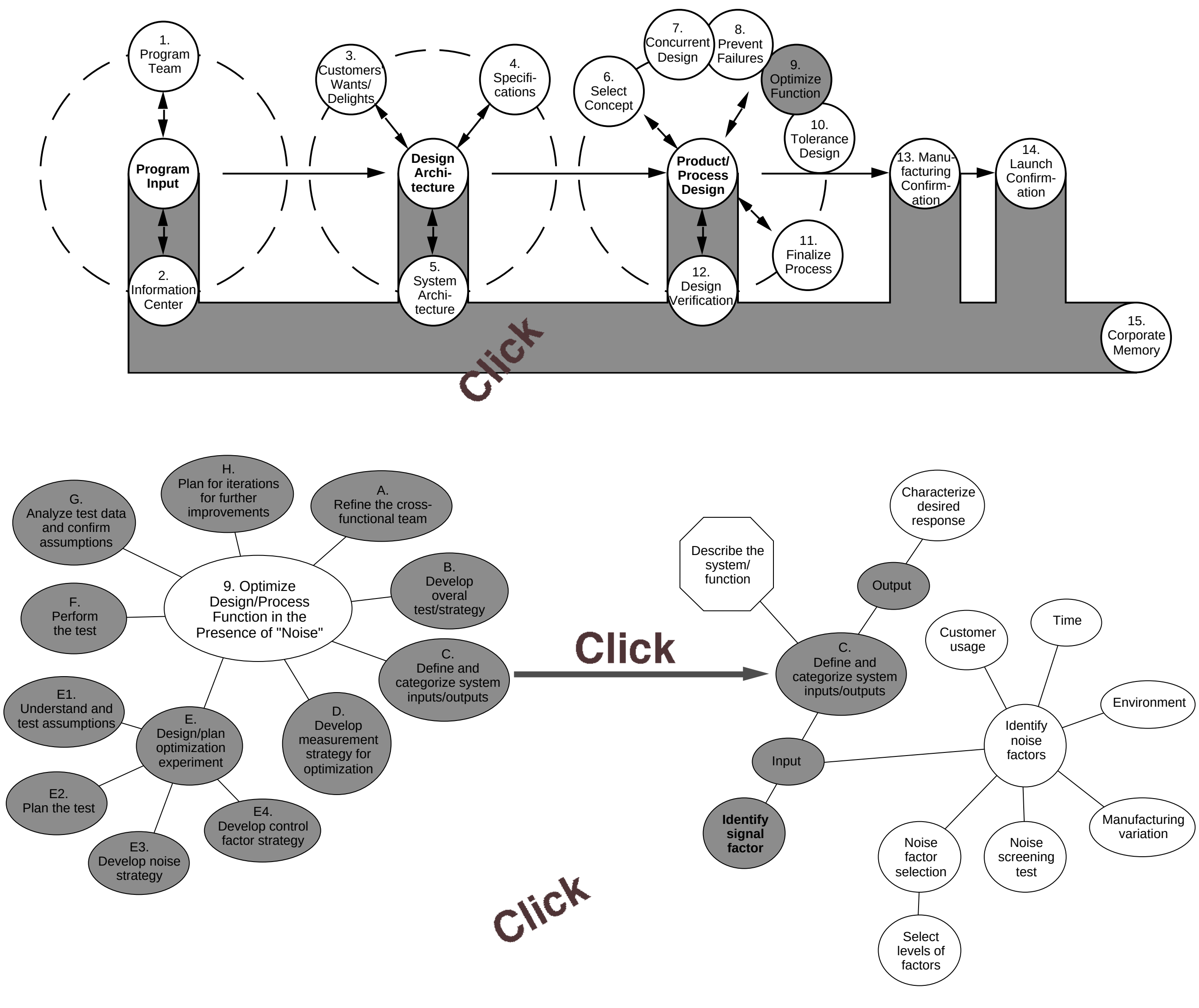


The Knowledge Map in Figure 9 provides additional detail for the higher level Knowledge Map shown in Figure 8, part C. In this portion are suggestions for teams working on "what can go wrong?" Teams may want to consider such actions as: identifying potential failure modes, dimensional variation in manufacturing process and/or assembly, and deterioration over useful life. Tools are then referenced appropriately as possible approaches. In this case, tools used by teams to accomplish this strategic element in the past include: Failure Mode and Effects Analysis, Fault Tree Analysis, Dynamic Control Plans, Process Decision Program Charts, and Ford's Energy Control and Power Lockout procedure.

Knowledge Mapping provides an ideal medium for internet hypertext linkages

A very powerful benefit of using Knowledge Maps became readily apparent when the Robust Engineering Process was uploaded to the Ford Intranet. Knowledge Maps provided the perfect application for internet hypertext linkages. From the Ford intranet website, an engineer can access the overall strategic model, click on the model to obtain information about one of the fifteen steps, including purpose of the step and value. Lower level detail can then easily be accessed by clicking to detailed Knowledge Maps with associated Write-ups (see Figure 10).

Figure 8. More Detailed Information can be Accessed by Clicking Parts of the Knowledge Maps



Identify Signal Factor:

A Signal Factor is a parameter controlled by the customer or user of the system to express the intended value for the system's response. Part of the engineer's role in optimization is to identify the Signal Factor based on engineering knowledge of the system, knowledge about how the system is to be used, and by consideration of physical laws which express and characterize the system's functional behavior and input engergy.

Knowledge Mapping provides an ideal medium for internet hypertext linkages, continued

On paper, the Robust Engineering Process is over six hundred pages of material. On the web, the engineers never see the magnitude of the material. They easily browse to select the information that is useful to them at this moment in time, and can print that relevant information at their workstation.

Web based Knowledge Maps can provide linkage in a variety of ways. In REP they are cross-linked to each other, linked to Write-ups with figures, linked to real examples, linked to definitions of tools and terms, and linked to other related web sites. The potential exists to provide further linkage to more specific web-based tool training and tool software. Since Knowledge Maps are relatively easy to update, even when they are on the web, the REP Knowledge Maps can be continually evergreened with new learnings for use in future programs.

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Author information

Larry Smith is a Quality Reliability Manager for full-size pickup and utility vehicles in Ford Motor Company's Truck Vehicle Center. He has extensive experience applying statistical and quality methods for improved customer satisfaction, with an emphasis on Quality Engineering and Product Development. He served as team leader for the development of Fords' new Robust Engineering Process. He has worked at Ford as a design engineer, statistical specialist, manufacturing quality supervisor, casting operations manager of quality systems and training, powertrain manager of quality strategy and planning, and powertrain reliability new methods manager.

Larry has published several case studies and papers in the area of designed experiments, quality function deployment (QFD), and culture change. He currently teaches courses in statistical methods and designed experiments for Wayne State University and Cast Metals Institute. Larry has master's degrees in physics and metallurgical engineering from the University of Michigan and in industrial engineering from Wayne State University. He is also a member of GOAL/QPC's Board of Directors.