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## 0.0. CLOSED-LOOP PROCESSES—THOMAS EAKINS (THE SWIMMING HOLE)

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**With closed-loop processes consisting of sequential functions and associated tools and techniques, we can gain continuous improvement and organizational learning only if humans interact based on mutual trust.**

Figure 0.0. shows *The Swimming Hole* painted by Thomas Eakins during the years 1883 to 1885. The painting is 27 inches high by 36 inches wide and is hung in the Amon Carter Museum in Fort Worth, Texas. Edward Coates, who commissioned the painting, later exchanged it for Eakin's *The Pathetic Song*.

Born in 1844 in Philadelphia, Eakins was financially independent and painted what and how he wanted. He was passionately devoted to the portrait; to him the human being was central. The centrality of the human to the workings of the world and to an organization in particular is the key to the management process today.

During his painting years (1870 to 1910), the world was full of astounding social change, and many people suggested the increasing mechanization would cause people to lose their central place in their own world. (Whenever we consider the meaning of a painting we must consider the artist and where he or she was from, the time in history when the painting was done, and the size and setting of the painting.) Today, we face continuing forces for dehumanization as we gain automation. The question becomes whether we can use automation to humanize the workplace. Within the onward rush of computer and automation breakthroughs, how do we accomplish what Weisbord calls a productive workplace with dignity, meaning, and community?

The people in the painting were Eakin's friends (his art students) who appeared in many of his

paintings. Eakins painted his friends in a setting in which he often saw them. Women weren't in this painting or in one like it because he never saw them naturally in this setting.

A person's underlying philosophy will influence what they have to teach us. Eakins thought of himself as a "scientific realist."

Let's consider the scene in *The Swimming Hole* as representative of any human group activity. I'll obviously draw parallels to organizations as human group activities. The group dynamics are stressed here in that Eakins was interested in the depiction of motion in the figures in the swimming hole. He used motion photographs to help with his painting.

My bet is you'll remember this painting; and, because you remember the painting, you'll remember the points it makes symbolically. You'll remember the painting and the points because of the richness of the information portrayed in visual art. Visual art is a rich but biased form of information. Information and the conversion of data to information is what this class is ultimately about—both building and using tools for providing information for decision making. However, management and measurement to get data to make information depend on the human element—empowerment and trust. Among other things, this painting portrays some critical principles behind the concept of trust. I'll use this painting to discuss management systems.

What's going on in the painting? What are the

people doing? Are we seeing a process, a system, or both? A group of friends are enjoying nature and each other's company in play, or in a work process. (Play is a work process for recreation.) Thomas Eakins has painted himself as the swimmer at the lower right and five of his art students from the Pennsylvania Academy of Fine Arts in Philadelphia together as functions of a work process associated with a system.

What is the system? We'll learn two views of a system—one as a thing and the other as an approach to the world. This system as a thing includes the components of the water, dock, weather, people, and perhaps more. From the system perspective, each component is necessary for the system to meet its purpose.

What's the purpose of the components and their relationship that Eakins has pictured here in his painting? What's the reason for the system being like this? The answers to these questions get to this system as an approach to the world. The aim of the system is most likely one of relaxation and enjoyment instead of exercise or learning how to dive and/or swim. The aim involves the components (The weather is more important for the enjoyment aim rather than the exercise aim. Weather would also be important for an aim to cool off.) but reaches above the components for the meaning of the system. This meaning begets the holistic perspective in the systems approach.

What's the process shown in the painting? The process for play or work consists of a series of steps getting the system toward its aim. The steps get the people into and out of the water in a timely, graceful, and safe way. These steps I'll call functions.

What are the functions for enjoying the swimming hole? The functions include diving, surfacing and swimming, climbing out of the water, resting and relaxing as desired, getting

up, and preparing to dive. Each person in the painting represents one of the steps. Notice how Eakins shows each of the people, or functions, in sequence. (Does the dog participate in a function?) Each function makes the process work. Each function involves different tools and techniques. You can use different tools and techniques to carry out the swimming functions. However, the best tool or technique depends on the process and the system with its aim in which the swimming functions are a part. You can use different tools and techniques to teach someone how to dive if the aim of the system is learning. The management tool for learning how to dive is usually a procedure. However, we would want to observe (measure) and gather data on the characteristics of a particular dive so we will do better for the next try.

Notice how Eakins shows the functions of the process not as a once-through process, more popular in the management of years ago, but as a closed loop, or cyclic process. You have to get in the water before you can swim, swim before you can get out, and get out before you can dive. Closing process loops is what managing quality today is all about. The so-called Plan-Do-Study-Act (PDSA) Cycle is about closing process loops. By closing process loops, we get continuous improvement, a learning organization, creativity, and empowerment. The PDSA Cycle represents the management process. The process in the painting is a closed-loop work process. We would apply the management process, or the PDSA Cycle, to this work process to achieve results like continuous improvement and learning.

If the aim of the system was more to learn to dive and/or swim, we'd see more of the need for observation and feedback inherent in the management process. (Maybe observation and feedback are the functions of the dog.) In management systems engineering, we apply the engineering process to the management

process, which overlays the work process. Since there's no question of improvement either for competition or for self-renewal in the painting, we don't see the engineering process or the management process highlighted. However, both the engineering process and the management process are closed-loop processes. And this painting emphasizes the closed-loop work process.

If the aim of the system was learning or improvement, we'd want to focus on observation to gain data to convert into information to support decision making. Through our decisions, we'd feed back what we learned to the process. And through our conversion of data to information, we'd feed back to the decision maker what the process was doing. Decision making is the key function in the management process.

Now let's consider the situation in this swimming process where the people aren't wearing suits. Why not? People skinny-dip. Why? For the freedom of it. Because they enjoy the weather and the water more without clothes. Now look at the people. Do they look embarrassed or vulnerable? Why not? Because they have mutual trust—perhaps because they've all exposed themselves. We find that empowerment and trust in an organization come through submerging your ego and exposing yourself. We can't get quality in an organization without mutual trust and mutual exposure. While we don't expose ourselves physically in an organization, we expose even greater vulnerabilities. For quality in an organization, we must expose appropriately what we feel and what we think—even if we haven't perfected our feelings or thoughts yet. Through mutual exposure and mutual respect we build trust. The new concept of leadership is built on trust and intimacy, not intimidation and fear.

I've discussed the content of Eakins' painting to help hold the memory of several concepts

important to management systems engineering. Now, let's look at the structure of the painting. What shape is built into the key people in the painting? A triangle or, in three dimensions, a pyramid. What's so good about a triangle? Simplicity, robustness, and strength. We know about these qualities of triangles from studying structures. How about the painting and the message it sends?

Do you see the engineering process in this painting? Do you see the management process in this painting? Do you see the systems approach in this painting? I suspect that at this early stage of the class the answer to all three questions is no. I have more than 80 class periods to get you from not seeing the engineering and management processes and the systems approach in a painting like this into being able to see those processes and approach in this painting and in other group interactions, like in organizations. I intend for the paintings to help highlight and help you remember class concepts I associate with the painting content or style. In this case, the painting content as opposed to style carries most of the class concepts. The concepts I intend for you to remember and I will reinforce during the course are:

- The human being is central in group interactions and in organizations.
- Trust is important to the management of organizations today.
- Exposure is part of empowerment and trust.
- Systems and processes are different.
- Processes include a series of functions, or steps, with their associated tools and techniques.
- Closed-loop processes promote continuous improvement and organizational learning.

- Managers need rich information to make decisions with; and visual art is extremely rich information.
- The pyramid brings both visual and structural simplicity, robustness, and strength and, as such, is useful as a modelling tool.

Eakins achieved a paramount place among American artists "not only because of the novelty of his particular vision of the world or his formidable technique as a painter but because of the penetrating truth of his statements." (Donelson F. Hoopes, *Eakins Watercolors*, Watson-Guptill Publications, p. 12.) "Although, from the beginning, Eakins was recognized as a dedicated and inspiring teacher, his methods were controversial. .... While

Eakins' emphasis on the study of the nude figure was not an unusual part of an academic curriculum, the presence of both male and female students at the Academy as well as Eakins's insistence that the women follow a course of study identical to that of the men—including life-study classes from both nude male and female models—was a constant source of tension." (Darrel Sewell, *Thomas Eakins: Artist of Philadelphia*, Philadelphia Museum of Art, 1982, pp. xiii - xiv.) Because of his unusual teaching techniques, Eakins was fired from the Academy. The outcry from his dismissal resulted in forty of his students forming the Art Students' League in Philadelphia, where Eakins taught without pay until 1892.



**Figure 0.0.** Eakins' "The Swimming Hole" helps us visualize a system of people interacting together through a work (or play) process. An organization is also people interacting through a work process governed by a management process. We apply the engineering process to the work and management processes.



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# **1. BACKGROUND**

## **1.1. INTRODUCTION**

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### 1.1.1. ART AND SCIENCE AS FOUNDATIONS FOR MANAGEMENT SYSTEMS ENGINEERING

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**In management systems engineering we must understand, balance, and blend the human and technical elements of the organization and apply tools and skills to relationships and to work processes based on foundations learned from art and science.**

“Management is an art. You can’t structure or teach good management. You’re either born with it or you aren’t.” These often-stated excuses for not analyzing, learning, and improving the principles and techniques of management are used to justify not putting the needed effort into managing well. Not too long ago, old-time, real-world engineers were making similar statements about engineering. “Engineering is an art.” “You must be a born engineer.” Now in engineering we pretend engineering is all science and no art. This book will emphasize the absolute necessity of balance between art and science, between qualitative and quantitative thinking, and among human, technological, and economic issues in both engineering and management. This book is based on the premise that we can learn and improve management and engineering, that both management and engineering spring from the same root—the scientific method, and that art with science makes both engineering and management work in the real world by bridging imagination and reality.

I’ve found that visual art (paintings, sculpture, photography) has opened doors for better understanding and use of science in the engineering and management processes. Engineers understand the significance of physical science as the underpinning of their engineering courses. Engineers need to know that the application system they’re working on sometimes involves physical science, but always involves other sciences such as life science and especially social science. Leonard Shlain in his book on art and physics gives evidence

of visual art as the precursor to discoveries in physics that are fundamental to engineering. I’ll use engineering principles like the First Law of Thermodynamics and control theory to build bridges between engineering and management, to develop a structured approach to management, and to emphasize the need for engineers and managers to understand both the engineering process and the management process. Shlain’s discussion of art and physics helps open new ways of thinking for understanding management systems engineering.

Leonard Shlain, a surgeon, argues that artists have led physicists in discovering the mystery of nature. As in the profession of medicine, the profession of engineering or the profession of business is done best when we balance art and science. In his book *Art and Physics: Parallel Visions in Space, Time, and Light*, Shlain says, “Art and physics are a strange coupling. Of the many human disciplines, could there be two that seem more divergent? The artist employs image and metaphor; the physicist uses number and equation. Art encompasses an imaginative realm of aesthetic qualities; physics exists in a world of crisply circumscribed mathematical relationships between quantifiable properties. Traditionally, art has created illusions meant to elicit emotion; physics has been an exact science that made sense.” (p. 15)

In management systems engineering we must recognize the emotional component of organizational effectiveness. Culture, motivation, trust, and teamwork are important for stability and synergy in the organization. We must

bring both art and science to the productive workplace.

Shlain further says, “While their methods differ radically, artists and physicists share the desire to investigate the ways the interlocking pieces of reality fit together. .... Émile Zola’s definition of art, ‘Nature as seen through a temperament,’ invokes physics, which is likewise involved with nature. The Greek word *physis* means ‘nature.’ .... The physicist, like any scientist, sets out to break ‘nature’ down into its component parts to analyze the relationship of those parts. This process is principally one of reduction. The artist, on the other hand, often juxtaposes different features of reality and synthesizes them, so that upon completion, the whole work is greater than the sum of its parts. There is considerable crossover in the techniques used by both. The novelist Vladimir Nobokov wrote, ‘There is no science without fancy and no art without facts.’” (p. 16) When Schlain talks of “reduction,” “synthesizes,” and “the whole work is greater than the sum of its parts,” he’s indicating that the artist practices the systems approach and must balance understanding and abilities in analysis, synthesis, and synergy. So should the engineer and the manager.

Shlain further says, “In the case of the visual arts, in addition to illuminating, imitating, and interpreting reality, a few artists create a language of symbols for things for which there are yet to be words. .... When we reflect, ruminate, reminisce, muse, and imagine, generally we revert to the visual mode. .... ‘Imagine’ literally means to ‘make an image.’ .... who then creates the new images that precede abstract ideas and descriptive language? It is the artist. .... Artists have mysteriously incorporated into their works features of a physical description of the world that science later discovers. .... Both art and physics are unique forms of language. Each has a specialized lexicon of symbols that is used in a distinctive

syntax. .... ‘Volume,’ ‘space,’ ‘mass,’ ‘force,’ ‘light,’ ‘color,’ ‘tension,’ ‘relationship,’ and ‘density’ are descriptive words that are heard repeatedly [in art and in physics].” (pp. 17-20) These descriptive words are also extremely familiar to the engineer and, as we get into this book, the manager. An important idea in this quote and in Shlain’s book is that art has often paved the way for science. I believe an important lesson from Schlain’s discussion is: You have to imagine something before you can discover it. Also, the important things in an organization are abstract—unmeasured and immeasurable. We have to measure what can be measured and imagine what can be imagined. Often, we have to blend measurement with imagination.

In talking about how a surgeon could write a book on art and physics, Shlain says, “... a surgeon is both artist and scientist. The craft demands a finely honed sense of aesthetics: A maxim of the profession is if an operation does not ‘look’ beautiful it most likely will not function beautifully. Thus, surgeons rely heavily on their intuitive visual-spatial right-hemispheric mode. At the same time, our training is obviously scientific. Left-brained logic, reason, and abstract thinking are the stepping-stones leading to the vast scientific literature’s arcane tenets. The need in my profession to shuttle back and forth constantly between these two complementary functions of the human psyche has served me well for this project.” (p. 8)

Management systems engineers must shuttle back and forth at a moment’s notice between qualitative and quantitative thinking. You must learn to be good at both and at shuttling. One moment you work on a technical issue, the next a human one. Truly, art and science are complementary foundations of the engineering process. Just ask Leonardo DiVinci, one of the first engineers. The same can be said for the management process.

### 1.1.2. ART, PHYSICS, AND ENGINEERING—IMAGINATION, REALITY, AND ENVISIONING

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**“The history of mankind has taught us that if we can imagine it, we can make it.”**  
(p. 2, Kiyoshi Suzaki, *The New Manufacturing Challenge: Techniques for Continuous Improvement.*)

If you can imagine something, you can do it. Imagination is crucial for successful engineering and for successful management. We must balance imagination and reality so we can make our imagination become reality. When we deal in the art of engineering and management, we’re dealing in imagination. In this book, I’ll balance the art and the science of engineering and management in a discipline I call management systems engineering. To help understand the balance we’ll look at visual art.

I’ll later discuss communication, message content, language variety continuum, and information richness. A primary focus of this book is the conversion of data to information and the use of that information for decision making, where information is converted into action. Visual art exceeds language in information richness. Painting and sculpture exceed photography in information richness because painting and sculpture aren’t limited to reality and because painters and sculptors aren’t limited to a single eye. Art contributes to the ability of the engineer or the manager to think beyond the limit of the rules. Art is also a tool to support people in conceptual blockbusting.

Engineers and managers must be able to envision for problem solving and for leadership. Perhaps the greatest contribution of descriptive geometry is to gain skills in envisioning hidden reality and envisioning possibilities, alternatives that could become reality. When we imagine what the object looks like when we intersect it with a cone, we get a lesson in envisioning. The object and the cone are real.

I used to carve soap to help in descriptive geometry so I could see better what I was supposed to envision. When I got good at descriptive geometry, I didn’t have to carve soap and I could envision what would happen if I built a house or reorganized a group of people. By later comparing the reality of what I built or organized, I improved my envisioning skills.

In summarizing the philosophy of a leader of the quality movement today, W. Edwards Deming, W.W. Scherkenbach says we’re striving for “joy of ownership through joy of workmanship.” Now there’s an emotion that makes sense. When we engineer the management process, we must deal with emotion.

Is emotional energy greater than, or just different from, physical energy? As we deal with synthesis, systems thinking, and synergy in management and engineering, does the First Law of Thermodynamics apply? When we first converted mechanical or chemical energy to electrical energy to light a bulb, we felt like we got so much out of the bulb. The magic of the newly-experienced conversion could imply we got something more out than we put in. The First Law tells us that isn’t so. The energy is conserved even though most of the bulb’s energy is “lost” to heat energy rather than “gained” in light energy. Now we operate computers on tiny batteries. What seemed like a lot in the bulb was new, not more. We weren’t used to or good at electrical energy.

When the members of a basketball team, a symphony orchestra, or a business organiza-

tion gain synergy and the whole seems larger than the sum of its parts, perhaps we're dealing with the conversion of physical to emotional energy—a conversion we aren't used to or good at. We're converting physical exertion to feelings of trust, confidence, and motivation. Just as energy conversion is fundamental to engineering, energy conversion is fundamental to management.

Management systems engineering is about skills for analysis and synthesis. For example, analysis helps us build good management tools and synthesis helps us use management tools well. Management systems engineers must understand both. We readily accept physics as fundamental to engineering. I consider art, other humanities, life science, and social science to be equally important—especially when engineering a management system.

I believe we don't teach either the engineering process or the management process to managers or engineers very well. We've tried to separate the art from the science when they need to be interwoven to the point they're indistinguishable one from the other. I'll discuss our failures in teaching the engineering process in Modules 1.1.11.6.3. through 1.1.11.6.5.—where I discuss the engineering process and its fundamentals and I discuss teaching and learning the engineering process.

To drive home the interplay between art and science in engineering and management, throughout this book I'll use examples of visual art and the artists who did them. Of course, the best I can do is show examples of the art in photographs. Photographs of visual art are as unsatisfactory to those who really want to experience the art as are paintings from photographs. The camera has but one eye and the human has two. Between a camera and a human, the perception is totally different.

Seeing the visual art in person is far superior to what I can provide in this book. The frame of a painting affects what you see and so does the setting of the visual art. Michelangelo's David in front of the Palazzo Vecchio isn't the same as David in the Academia. (I'll prove this point in Module 1.1.19.) The Musee d'Orsay in Paris is new and each painting has been thoughtfully placed in its setting. The result is overwhelming. Seeing science as an art is a function of both the observer and of the context, or setting.

A painting contains a message. I'm not discussing a painting as an art expert but as an art enthusiast. I'll discuss a painting in terms of its message to me—my own interpretation so I can highlight important qualitative concepts of management systems engineering supported by images of rich information. The power of art is its ability to send rich information. As a receiver of rich information, you must develop strong assimilation and interpretive skills to capture and use all that information. The richest information is also the least repeatable, verifiable, and quantitative. My interpretation of visual art, then, is one of many, which I hope adds something to the understanding of management systems engineering.

Visual art is an expression of envisioning. You can envision what a soap carving is to look like, or how you want your new car to look, or the house you're building, or the new structure for your organization. When envisioning your new organization or product, you can envision the result or the steps of the process for getting that result. When you consider building the new house, you can envision how you want to solve the problem of enlarging the living room. The power of envisioning is being able to review many alternatives rapidly in your mind.

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### 1.1.3. BENDING TIME AND SPACE—SALVADOR DALI

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**Managers have to make the most out of time and space; and to do so, they have to envision beyond the laws of Newton, which are so familiar to engineers.**

Albert Einstein developed his special theory of relativity early in the twentieth century. Minkowski used the special theory to define the fourth dimension. Few people have successfully conquered the ideas that seem to violate what we believe about time and space. As a nuclear engineer, the contributions of Einstein were some of my foundations for designing nuclear reactor cores. However, Einstein forever shook our devout faith in the universality of  $F = ma$ . We took  $F = ma$  as absolute truth, something we could clearly build anything from and never have to worry.

About the time of Einstein, there lived another revolutionary by the name of Sigmund Freud and a number of revolutionary artists like Picasso and Salvador Dali. Freud was interested in the unconscious and the meaning of dreams. Dream time doesn't obey sequence and linearity of clock time and dream space doesn't follow Euclidean axioms. "Relativity, Cubism, and psychoanalysis share this feature: Profound distortions of everyday time and space occur regularly in each theory. .... The dream mode soon became the means certain artists used to plumb the depths of their own unconscious, mining them for symbols and juxtapositions that violated all rational sense. In 1917 Apollinaire named this new movement *surrealism*, which means *above* reality. Surrealism worshipped at the altar of the unconscious. Surrealism, Andre Breton, the poet and the movement's chief spokesman, wrote, 'is based on the belief ... in the omnipotence of dreams, in the undirected play of thought.' Despite their apparent lack of connection to the crisp blackboards of science, the dreamlike paintings of surrealist artists reveal many crucial images that can help people understand the vision of reality wrought by

modern physics." (Leonard Shlain, *Art and Physics: Parallel Visions in Space, Time, and Light*, William Morrow and Company, 1991, p. 224.)

As an engineer, how many times can you build a bridge in a twenty-minute nap or daydream? More times than you can count. You can get materials not easily accessible. You can build the bridge right and you can build it wrong—and you can learn from your dream mistakes. As a manager, how many times can you reorganize your unit in a twenty-minute dream? Related to dreams is your imagination—about real things and unreal things—and your ability to envision. If you can't have a vision, you can't lead well, you can't manage well, and you can't engineer well. Your descriptive geometry course helps you learn to envision. Engineers and managers don't get enough courses in how to envision and how to break conceptual blocks and old paradigms. Without these skills, you can't create and you can't innovate. We're entering a time in history where we need the creative juices of every person. Our big problems with the environment, transportation, housing, and other engineering-related problems won't be solved with old approaches. We'll have to dream up new ones.

As a manager, two of my most important concerns are time and space. I use facility layouts to figure out where to put people and equipment to streamline the work process (reduce steps). I use Gantt charts and time logs to help deal with the elusive resource of time (save time). I redesign information formats and information processes (reduce paperwork).

We teach courses on time management, which

can't be done by the way. Time refuses to be managed—it marches on. We deal with management approaches like Just-In-Time. In their book, *Competing against Time: How Time-Based Competition Is Reshaping Global Markets*, Stalk and Hout claim time is the cutting edge; time is the equivalent of money, productivity, quality, even innovation. They introduce the time-based organization. “The characteristics of a time-based company are best explored under three headings:

- How work is structured
- How information is created and shared
- How performance is measured

..... People in time-based—or fast-cycle—companies think of themselves as part of an integrated system, a linked chain of operations and decision-making points that continuously delivers to customers. In such organizations, individuals understand how their own activities relate to the rest of the company and to the customer. They know how work is supposed to flow, how time is supposed to be used. Also, work that is not critical to delivery of value in real time is taken off-line so it doesn't slow down delivery. .... Time-based companies create more information and share it more spontaneously. For the information technologist, information is a fluid asset, a data stream. It is an object itself, something to be carefully measured and handled. But to the manager of a business, information is something less elegant, less separate from the employees who create and carry it. .... Time-based companies go back to basics when they decide how they are going to keep track of their performance. Time is already widely used to measure performance in business. Managers use terms like *lead-time*, *on-time delivery*, and *response time* almost instinctively in describing how well a company is serving its customers. But, time-based companies go a step further. They use time-based metrics as diagnostic tools throughout the company and set basic goals of the operation around them. In effect, they use

time to help them design how the organization should work.” (pp. 172-190, George Stalk, Jr. and Thomas M. Hout, The Free Press, 1990)

A major division of Asea Brown Boveri uses the concept of time-based management as their direction in the quality movement. However, to develop new work structures, share information more readily, and get accurate measures of performance, we must deal with trust, mutual respect, and motivation among people who act out, are responsible for, and support these activities.

I'll consider two of Salvador Dali's paintings. Dali is a surrealist. The first painting is discussed in Shlain's book. “In one of his most famous paintings, *The Persistence of Memory* (1931) [Figure 1.1.3.1.], Dali juxtaposes two ordinary symbols of time: clocks and sand; but in Dali's arresting vision the clocks are melting over a vast and lonely beach that resembles the sands of time. To emphasize the painting's temporal images, he also incorporates a swarm of crawling ants, whose uniquely shaped bodies resemble hourglasses. Sand, hourglasses, and watches all connect below the threshold of awareness till the viewer's mind swings around to focus on the very nature and meaning of time. Dali's gelatinous timepieces, crawling with patient ants, ooze and melt upon an immense beach stretching into the distance. The molasses-like plasticity of his watches suggests the possibility of slowing to sludge the flow of the invisible river of time.

The key revelation enabling Einstein to revise the fundamental constructs of space, time, and light was understanding the nature of time's dilation at close to the speed of light. Had someone asked Einstein or any of his contemporaries to represent the dilation of relativistic time in one visual metaphor, he could not have produced a more strikingly appropriate image than *The Persistence of Memory*. If a work's symbolic content strikes a chord deep within our collective psyche, then it will continue to

resonate for us indefinitely. Mention the name Dali to a sampling of people and more often than not, melting watches will be included in the response. This surrealist painting mesmerizes us because it translates an idea into symbols when conventional words and phrases have never been sufficient.” (pp. 228-230.) Time is a wondrous dimension. Today is yesterday’s tomorrow. Depending on where you stand and which way you look, all time is relative.

Figure 1.1.3.2. is Dali’s *The Sacrament of the Last Supper*, dated 1955. Many paintings from western culture artists, exemplified by the art of Europe and the United States, reflect content from Greek and Roman mythology and from Christianity. Some of the most popular topics are the last supper, the crucifixion, and the resurrection of Christ. The topics provide a wealth of imagery and search for reality and thereby innovative expression. Dali balances reality and imagination in a symmetrical geometric framework. “The Christian subject matter, the simplicity of organization and the lack of shock value separate *The Sacrament of the Last Supper* from almost all of Salvador Dali’s other works. Dali’s reputation from the late 1920s to the mid 1940s was founded on his use of themes reflecting anarchy or agnosticism and interpretations in a surrealist manner derived from subconscious, Freudian dream imagery. .... The Italian High Renaissance of the early 1500s was another major source for Dali’s new classicism. As in the harmonious presentation of Renaissance schemes, the composition here is clearly defined into two main planes: foreground action and background scenery. The placement of men around the table is symmetrical, the same figures being repeated in perfect mirror-image on both sides of Christ. Moreover, the entire nine-foot-long picture is constructed according to complex mathematical ratios devised by Renaissance scientists and such ancient Greek philosophers as Pythagoras.

Dali explained the reliance upon this elaborate geometric patterning just after completing his nine-month labor on the picture:

... I wanted to materialize the maximum of luminous and Pythagorean instantaneousness, based on the celestial Communion of the number twelve: twelve hours of the day—twelve months of the year—the twelve pentagons of the dodecahedron—twelve signs of the zodiac around the sun—the twelve Apostles around Christ.

Thus, *The Sacrament of the Last Supper* is not an attempt to re-create the Passover but a symbolic presentation of the eucharistic ritual. The men at the table, rather than being specific apostles, are idealized participants in the continuing dogma of Christianity. The strange enclosure, part earthly, part celestial, is not the ‘large upper room’ of the Bible but an abstract concept embodied by the dodecahedron, a twelve-sided volume sometimes signifying totality.

Just as the surrounding cupola is only partially real, Christ is not corporeally present because his body is transparent, too. The actual, tangible allusion to Jesus’ long hair: just above his left shoulder, the irradiated strands of hair suggest the silhouette of a perching bird. If indeed, this half-hidden configuration was intentional, it must indicate the dove of the Holy Ghost. The whole Trinity would be represented if the arms outstretched overhead were those of God the Father.

This ethereal torso, however, is much too youthful for the standard conception of the Creator, who is normally portrayed as a patriarch. The all-embracing arms might represent the Resurrected Christ, but the nail holes are absent from the hands, and the wound does not appear in the side. The enigma of *The Sacrament of the Last Supper* might be rationalized if this disembodied presence signifies the en-

compassing spirit of heaven, for Dali maintains that ‘... heaven is to be found exactly in the center of the bosom of the man who has faith!’” (quoted from a handout received during my first visit to the National Gallery of Art in Washington D.C. during 1960).

The concepts I intend for you to remember and I will reinforce during the course are:

- You can imagine, dream about, create a vision for things that don’t exist—and then do them.

- Good engineering requires envisioning.
- Symbols bring out feelings.
- As the world moves faster, we’ll have to bend time and space.
- A model is like a metaphor. Engineers develop models.
- We’ll live up to the expectations of us.
- We can fill empty space with our mind.
- These are treasures in the human mind. We have to tap them.



**Figure 1.1.3.1.** *The Persistence of Memory*



**Figure 1.1.3.2.** *The Sacrament of the Last Supper*

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### 1.1.4. TIME-HONORED, FUNDAMENTAL MANAGEMENT QUESTIONS

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**How do we apply the principles, models, and techniques of the engineering process to time-honored, fundamental management questions and open avenues for significant improvement in management tools and their use?**

All discovery begins with a questioning attitude leading to penetrating, substantive questions. As we begin our discovery of applying the engineering process to organizations, let's sample the questions people responsible for organizations have been asking for years and can't seem to successfully resolve. The fundamental questions are the ones you seem to keep coming back to every time you try to figure out how to manage an organization and its people.

Since we'll be looking at the organization as a management system, the important questions will be systems-oriented. Weisbord says, "For the past forty years productive workplaces on several continents have been evolving another way entirely of thinking and acting. First, they have been moving away from problem solving toward whole-systems improvement as the secret for solving great handfuls of problems at once." (Marvin Weisbord, *Productive Workplaces*, Jossey-Bass Publishers, 1987, p. xiv) .... "A 'whole system' includes *economics, technology, and people*—including all of ourselves. (italics added) I urge students to see the workplace as a 'whole brain' adventure involving values, thought, and action. I would like to see that notion in more academic curricula." (p. xvi) Systems thinking will underpin our understanding of both the engineering and the management processes.

In discussing Frederick Taylor, the creator of the industrial engineering role, Weisbord parallels his notion of whole-system components including economics, technology, and people by saying, "He started a new profession in 1893—'consulting engineer'—because he saw

that captains of industry, caught in a swirl of change, did not know how to untangle *cost, productivity, and motivational* problems (italics added). Taylor was a systems thinker of sorts, the first person to realize that workplace problems must be solved together, not piecemeal, although he never figured out to anyone's satisfaction how to do that." (p. 22)

"It is not generally appreciated how modern Frederick Taylor's core values were. He knew the importance of productive workplaces. He was working on the right problems—*social, technical, economic*—even when he did not have the right solutions." (p. 57) (italics added)

So, the source of time-honored, fundamental questions comes from these problems for which Taylor couldn't find answers and which still are unanswered today. And, what are Taylor's core values, and how do those relate to fundamental questions for managing productive workplaces? Weisbord lists Taylor's core values as "labor-management cooperation, higher output, improved quality, lower costs, higher wages, the rule of reason, questioning old habits, experimentation, clear tasks and goals, feedback, training, mutual help and support, stress reduction, and careful selection and development of people." (p. 59) What a rich place from which to start asking important questions!

I'll use Weisbord's figure for *reward, work, and human systems* (See Figure 1.1.4.) as an analytic tool, hopefully used in a systems approach (I'll develop definitions for analytic and systems approach later.) for developing

categories to show a representative list of time-honored, fundamental management questions. Throughout this discussion, I've used italics to highlight the references to these three systems, because in each case Weisbord has used slightly different terminology. Since we're considering the organization as our system of interest, or, in Weisbord's terms, the whole system, the systems of Figure 1.1.4. are really the important *subsystems* of an organization. The whole system of economics, technology, and people; Taylor's cost, productivity, and motivational problems; and Figure 1.1.4.'s reward, work, and human subsystems all help set up three categories of questions.

As we analyze to help deal with the situation, we must recognize that questions can't be completely separated into subsystem categories because most questions are interconnecting among the subsystems. However, some questions seem to start in one subsystem or another. Consider Taylor's dilemma as a question: How do we untangle cost, productivity, and motivational problems? Perhaps we can untangle the problems to list or discuss them and to ask questions. But we'll have to leave the problems tangled to answer the question. Another broad question is: How do we get high-quality, high-quantity work from people working in a satisfying atmosphere with the least resources and expense? You can see the three subsystems interplaying in this question.

**Reward-subsystem-oriented questions include:**

How do I rate, rank, appraise, recognize, and pay people?

How do I ensure my stakeholders get a good return on their investment?

How do I get the most for my money for materials and facilities?

How do I get the creative and commitment energies from much of the workforce, when the reward system doesn't reflect these priorities?

**Work-subsystem-oriented questions include:**

How do I deal with the crises, surprises, disturbances, or disruptions that seem to keep me from accomplishing my planned work?

How do I know I'm working hard on the right things?

How do I gain visibility of my work?

How do I gain and maintain control of my work?

How do I get useful information (the right, high-quality information on time) about my work to support the decisions I make?

**Human-subsystem-oriented questions include:**

What are successful supervisor and subordinate roles?

What are roles for purposeful meetings?

How do I replace fear with trust and teamwork in the workplace?

How do I motivate people to find joy in the workplace?

How do I get the best out of people without harming their personal and family lives?

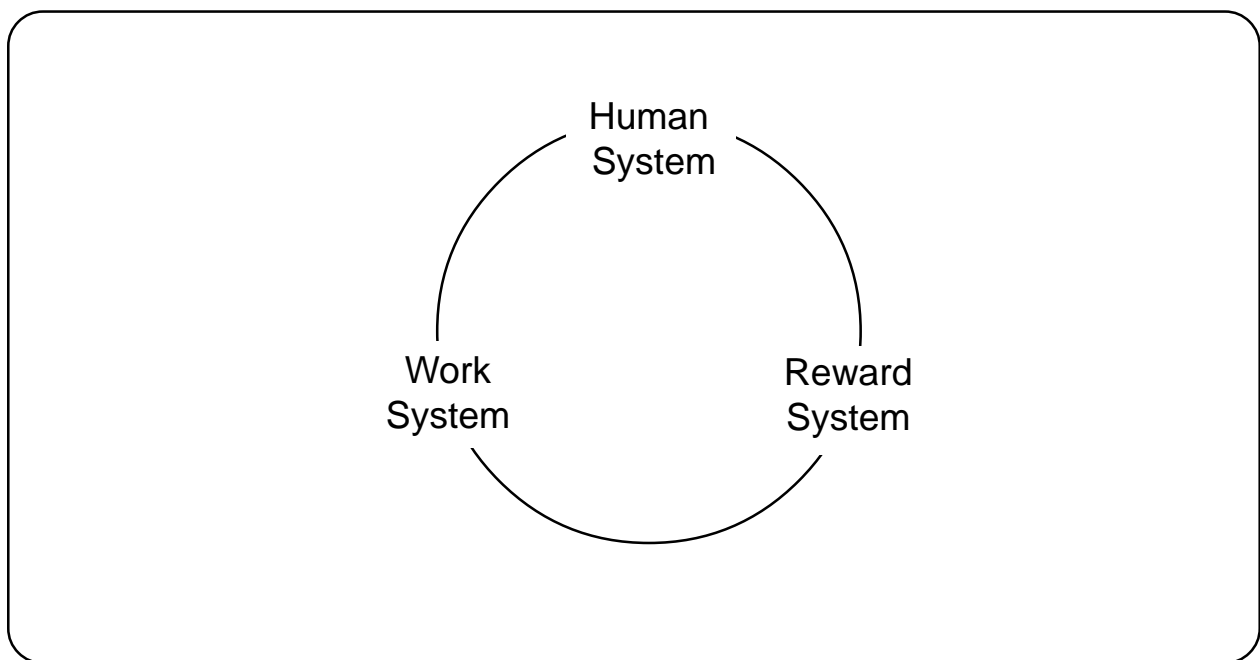
How do I balance toughness with affection in the workplace?

Even though these questions are hard to answer, we must think about the questions and the principles behind potential answers. For

example, consider the question, “How do I know I’m working hard on the right things?” When a supervisor thinks, “I don’t believe that person is working hard,” they mean “I don’t believe that person, who’s working hard, is getting the results I expected,” which translates to “I don’t believe that hard-working person is working on the right things.” Who should know what the right things are? How do we find out what the right things are? Who

sets expectations? Whether or not you think through these questions can make the difference in success in getting the work out, your financial return, and the contributions of you and your subordinates.

You can add to this too-short list. The categorization scheme represented in Figure 1.1.4. and the short list described earlier should start you thinking.



**Figure 1.1.4.** *For whole-systems improvement of management tools and organizations, we must answer management questions that include interrelated aspects of economics, technology, and people shown here as reward, work, and human subsystems. One way to dig into the questions and their answers is to consider the subsystems. (taken from Weisbord)*





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# **1. BACKGROUND**

## **1.1. INTRODUCTION**

### **1.1.5. THE OUTPUT: HOW THE BOOK FLOWS**

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### 1.1.5.1. BOOK DESCRIPTION

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**The five sections of this book will lead you through the theory for management systems engineering into the models you can use to help build and use management tools, the machinery supporting decision making.**

This book scopes management systems engineering as an engineering discipline. The book defines the systems approach, the engineering process, and the management process in language understandable by engineering students, non-engineering students, and practicing managers. The flow of the book starts with background concepts and models and works toward building-tool functions applied to general categories of tools and using-tool functions applied to specific tools for continuous performance improvement. The focus of the book is the machinery to support decision making—management tools. (Examples of management tools include the organization structure, schedules, operations research methods, plans, policies, vision statements, management information systems, and many more. I'll discuss the different management tools at length later.)

Figure 1.1.5.1. shows the structure of the book in five major sections. I've shown the book sections on the left side of the figure with major content listed below each section topic. In the two-semester course using this book, the background takes more than half the first semester (class periods 1 - 34) and the building tools section takes less than half the first semester (class periods 35 - 43). The sections on using tools, synergy from building and using tools, and conclusion takes the second semester.

The concepts of management, engineering, and system; the discussion of the art and science of management; and the research process relating to the discovery of what management

systems engineering is leads to the theory illustrated in the top box on the right of Figure 1.1.5.1. The theory includes the systems approach with its three perspectives as the overarching philosophy for both the engineering process and the management process. We apply the engineering process to the management process to get management systems engineering. All of the processes are developed and understood within the context of balance, the proper mix of the issues being balanced.

Based on these concepts, I develop a series of models that I offer together with models developed by others to help us understand how to build and use management tools. I'll describe the frameworks used to diagnose an organization in terms of the needed management tools in the next group of modules. These models and frameworks yield a coordinated set of models shown in the middle box on the right of Figure 1.1.5.1. Based on the Management System Model, management system analysis (MSA) and management system synthesis (MSS) lead us to the models in the engineering process and management process frameworks.

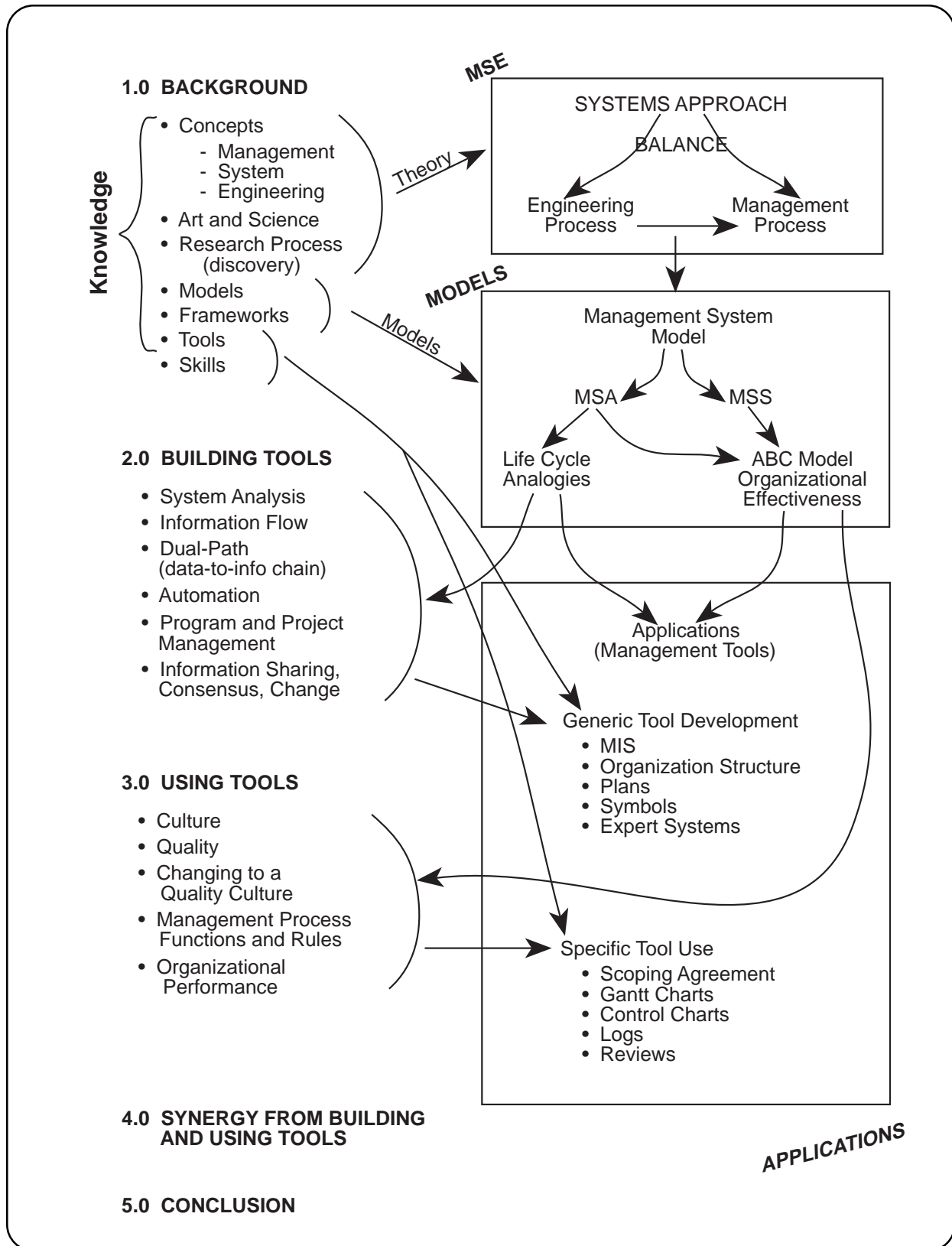
The tools with their guides (e.g., a procedure or set of instructions can be a tool or can be a guide for another tool, like procedures for a management information system.) and the skills for using the tools fit within the frameworks for the engineering and management processes and apply to the work management systems engineers do. To build and use tools well, we need knowledge, skill, and ability. I can't give you ability in this book. But I will

describe the knowledge and skills you'll need. When you apply the tools and skills to building management tools, you'll develop generic tools, like management information systems, organization structures, and plans. When you apply the tools and skills to using management tools, you use specific tools, like scoping agreements, Gantt charts, and control charts. The situation here is analogous to designing and using an automobile. You design and build a type of automobile, like a Ford Taurus. You use that red automobile parked over there by the curb.

When I talk about building management tools, I'll define categories of management tools,

like guides, and general types of tools within the category, like policies, plans, procedures, or instructions. The topics for building management tools apply to management tools in general, like system analysis and information flow.

When I talk about using management tools, I'll describe how to use specific tools, like an action plan or a scoping agreement. To put the specific tools in context, I'll use culture, quality, and changing to a quality culture to help set the scene for the philosophy and structure of the management process functions and rules for using management tools.



**Figure 1.1.5.1.** The book contains five sections, the first three of which carry you through the theory of management systems engineering to models we'll use to best build and use management tools in given applications.



### 1.1.5.2. USE

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**This book gives you a roadmap and tools with their guides and the skills for using the tools, all to use as you build management tools or manage builders of management tools, and as you use management tools to improve the performance of your organization.**

In Section 1.1. of the book, I'll set out the engineering process and the management process with their respective frameworks and with their underpinnings in knowing the application, or domain or unit of interest, and their philosophical "overpinnings" through the perspectives of the systems approach. These frameworks form a roadmap to use throughout the rest of the book. I'll discuss examples of tools to use to help accomplish each of the 21 engineering process functions and the 14 management process functions. You're apt to lose the forest for the trees. The roadmap lays out the forest.

Like all roadmaps, the scale, or level of detail, dictates whether you can find a specific landmark when you get lost. Sometimes you have to wander a bit until you find a landmark that happens to be on your map. Since your roadmap has more roads than landmarks, you may find a road but not know exactly where you are on the road. In short, the functions I'll give you in your roadmap are large scale. You'll have to fill in some details as you find your way in engineering a management system.

In the later sections of the book, I'll expand some on the roadmap and its concepts, like the Management System Model (MSM) and the ABC Model, but I'll concentrate on discussing tools and skills to use to accomplish the functions of the engineering and the management processes.

In the theory section, I'll give you tools, or frameworks, to help you diagnose your organization or another organization so you can build

or use the right tools successfully. The theory section is to help you develop a wonderful solution to the *right problem*.

The building tool section and the using tool section of the book focus on the tools and the skills for using the tools. An example tool is the scoping agreement used to set expectations on project-like pursuits. Notice that the scoping agreement is one of the outputs of the Survey function (the first function) of the engineering process shown in the framework for the engineering process in Figure 1.1.20.1.1.a. Also, the scoping agreement is a tool for setting expectations, the first function in the using management tool functions of the management process shown in Figure 1.1.21.5. I'll discuss scoping agreements in great detail in the using management tool section of the book. I'll describe the scoping agreement and give a guide for using the scoping agreement.

Communication is an example skill for building and using the scoping agreement and for building and using almost all the tools. I'll discuss communication skills (writing, reading, speaking, and listening) in some detail in the building management tool section of the book. Clearly, the placement of the discussions of tools and skills in the book is a bit arbitrary. The skills are pretty universal and the tools can be widely applicable. Soon, I'll develop frameworks to identify and classify tools and skills. Then, I'll develop a matrix to show the tools and the skills and where they're discussed in the book and where they're useful in the engineering and management processes.





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# **1. BACKGROUND**

## **1.1. INTRODUCTION**

### **1.1.6. SOLVING THE RIGHT PROBLEM**

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### 1.1.6.1. COLOR—PERCEPTION AND REALITY—PAUL CÉZANNE

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**If you put the right color on things, form becomes substance and perception becomes reality—in management as well as in art. In management, these ideas can work for or against you, and as you gain skill you must use these ideas with conscience.**

Artists understand the importance of light in portraying and perceiving information. Color is the vehicle they use. In science, light is quantifiable reality. Color is a specific wavelength of light, and the speed of light is our prevailing constant.

In James M. Carpenter's *Color in Art: A Tribute to Arthur Pope*, Howard Fisher's introduction states, "Color is a psychological phenomenon. It exists exclusively in the mind of the beholder. There is no color as such in nature. Just as there is no sound when a tree falls or lightning strikes in an uninhabited land, so there is no color when the sun rises and flowers open.

The sensation of color is usually caused by variations in the length of light waves radiated by self-luminous sources, reflected from objects, or transmitted through them. The rays enter the eye and through receptors in the eye their nature is communicated by the optic nerve to the brain. Because no two eyes and no two brains may operate in exactly the same way, no two persons are likely to sense color in exactly the same way." (p.13, Fogg Art Museum of Harvard University, 1974.)

If we consider color to be a form of information, the information has a portrayal vehicle and a perception vehicle and, until we match the two, we have no information. Since managers use information to make decisions with, we'll have to worry about both portrayal and perception to get information.

Without light we have no color. Color is light. Shlain puts into perspective the importance of light in relating the constructs of reality, we as

engineers write and solve equations for every day. "In our present paradigm we still acknowledge four basic constructs of reality: space, time, energy, and, matter. Space and time constitute the gridwork within which we conduct our lives, while inside their frame, energy, matter, and various combinations thereof create our world of appearance. These four elemental constructs form a mandala of totality. All perceptions created in the dream room of our minds are constructed from these four building blocks. ....Whether it was the miracle of fire or the life-giving rays from the sun, light in and of itself has always been the most mysterious element. ....In some strange way light is the link connecting space, time, energy, and matter. The symbol for the speed of light in physics,  $c$ , plays a prominent role in the key equations connecting the other four." (p. 26.)

In discussing color, Shlain continues, "Until the mid-nineteenth century, materialist scientists like Newton, who only described color, affirmed that it was a unique property of matter. Idealists like Goethe, who wrote a treatise on color's effects on the emotions, propounded the opposite view: that it existed chiefly in the mind of the beholder. By the early nineteenth century, scientists strengthened the position of the materialists by demonstrating that color is light of varying wavelengths, thereby reducing to number what had always been a sensation. ....Infants respond to brightly colored objects long before they learn words or even complex purposeful movements.

Most evaluations of reality depend upon a synergy of two or more senses. Sound can be heard and felt. Mass can be seen and touched.

Liquid can be tasted and smelled. Color alone defies corroboration by a sense other than sight. Color cannot be described to someone who has been blind all his life. I cannot even be sure that the color I call green is the same color you call green. While a consensus can be built about most other features of the world, there is only an uneasy, unspoken agreement among people about color. It is both a subjective opinion and an objective feature of the world and is both an energy and an entity. Color is tied to emotions as well as being a fact. ....There are many [examples] throughout history of those in authority harnessing the power inherent in color and using it in the service of their policy. One has to think only of the patriotic surge of emotion that is evoked by the red, white, and blue for Americans. Observing how the spectators respond to a home team's colors or counting the lives of young men who sacrifice themselves in battle to protect their battalion's colors are just three examples of color's potency." (pp. 170-172.) (I prefer to use pronouns and other references to people that reflect both genders unlike the author of this statement; eg., the discussion of men in battle or the pronouns he or she and him or her. I also prefer to quote other authors directly. So, quotes may or may not reflect my first preference, depending on the preference of the author quoted.)

How do we characterize color so we can use it? "In 1898, an artist and teacher named Albert A. Munsell organized the information discovered by Isaac Newton by creating a color charting system that not only allowed us to see the colors of the spectrum but to use them for planning, mixing, etc. Since we can now see these colors by referring to the Munsell System, a complete understandable sequence of color study can be developed. Today the Munsell System is the most widely accepted system in the world. It is accepted by the Bureau of Weights and Standards and is used by artists and colorists throughout the world. Through the years there have been many varia-

tions of color organization conceived, but almost all of them are based on the principles of the Munsell System. (William F. Powell, *Color and How to Use it*, Walter Foster Publishing, 1984, p. 8.)

Powell defines the three qualities of color as 1) hue: the name of the color, 2) value: the lightness or darkness of color—add white to get tint and add black to get shade, and 3) intensity: the purity or strength of color. He says, "The three qualities above are known as the three different dimensions that can be applied to each color. These were discovered by a scientist named Helmholtz and were later used as a basis for the Munsell System." (Powell, p. 8.)

So, what does color have to do with management systems engineering? What one person sees in conceptualizing ideas like management, engineering, system, process, data, or information is a matter of perspective and perception. When you see blue, do I see blue or do I see red? Since we agree to call what we each see blue, we can talk to each other with some measure of consistency. But each of our realities is different. The issue of reality is crucial to communication. Communication is crucial to management and leadership. We'll find that distinguishing one person's reality from another person's reality is necessary to truly communicate.

Go ahead and define management. Then have someone else define management. Compare your definitions. Chances are the definitions will be different. Therefore, you each have a different reality about management. You can't communicate about management until you understand both realities.

Management is such a common term, I'll have a hard time getting you to convert your sense of reality about management to agree with mine. I'll define management as decision making. I may be able to get you to accept my definition and have some feeling of what I

mean when I use the term management. But, will you perceive what I perceive when I look for management in an organization? Can you apply the qualities of hue (name), value (degree), and intensity (strength) to the idea of management?

The form of what is management to you depends on how you perceive management. The form of what is in a painting depends on how you perceive color.

An important issue in solving the right problem is knowing the perception and the context of the problem. To the person who has the problem, perception is reality and the context in which the problem fits makes a difference in determining whether this problem is the right one to deal with.

We'll find that the biggest part of solving a problem is knowing whether the problem is a technical, social, political, economic, esthetic, or other type of problem. We want to spend our energy on the right problem, not the wrong one. When we solve the problem, our effort usually requires a balance, or mix, in perspectives and we usually have to mix, or blend, our activities so the activities are indistinguishable one from the other.

As we discuss problem identification and resolution in effective management, we'll raise the issues of perception, context, balance, and blending. For now, we'll consider these issues in terms of color and in terms of a person's perception being that person's reality. In management, perception is critical.

I'll use Paul Cézanne to illustrate the use of color to create perception and communicate reality. "Color is perspective,' Cézanne once said, and its function was to structure space. ....He discovered that warm colors advance and cool ones recede, and so was able to create a sense of depth and mass without using line or perspective. ....He was able to show how pure

color without an outline could create a sense of something's existence in space, which implied the subversive idea that light was the preeminent element of reality. ....Cézanne substituted color for the crucial elements of line, shading, and perspective." (Shlain, p. 176.)

And what's the relationship between color and form? "For the painter colour is therefore also form. This is the meaning of Cézanne's famous equation 'form = color.' Linear design in itself must not exist, for it does not exist in nature. Line is implicit in the rounded form. The more colour grows and gains in precision and harmony, the more the 'line' of objects will appear, but it must appear through form. The painting of Cézanne cannot therefore be graphic or linear, but is a painting of volumes. His urgent need to 'produce form' resulted in that flat, dry, structural brushstroke which is one of the basic elements of his style, and in the slowness of execution which has become legendary." (Mario de Mecheli, *Cézanne*, Thames and Hudson Ltd., London, 1968, p. 21.)

"Less concerned than Monet or Pissarro with the scintillation of light or haze of atmosphere, he stressed the tangible substance of objects and gave a more definite compositional structure to his paintings. ....[Cézanne was] deeply absorbed in the search for a way of painting that would combine the luminosity of impressionism with the grand stability and harmony of classical art. ....He painted landscapes, still lifes, and figure compositions that rank among the highest achievements of 19th-century painting. ....Like the impressionists, Cézanne needed the experience of nature; unlike them, he did not try to record momentary visual sensations, fleeting effects of light and atmosphere. Instead, he studied the permanent structures and relationships of objects." (Bernard S. Myers, *Dictionary of Art*, Volume 2, McGraw-Hill Publishing Co., pp. 3-4.)

Figure 1.1.6.1. is Cézanne's *Marseilles Bay seen from L'Estaque*. Do you see anything in

the bay? If you answer “boats,” look closely. Cézanne meant for you to see his simple white shape as a boat. The sail is the right color and the right form and in the right context to be a boat. You fill in the missing information in your mind. Perception is reality. You see reality according to your perception. The form becomes substance. What else do you see in the painting? How does Cézanne use color to separate foreground from background?

What people perceive to be the truth becomes their reality. As an engineer and a manager, you must make sure that the information you portray is perceived the way you wanted to communicate the information. Don’t just think that because you portrayed the information, you’ll make your audience understand the essence of your communication. Much of management is communication and being ever-vigilant of the interface between information portrayal and information perception will spell the difference between failure and success.

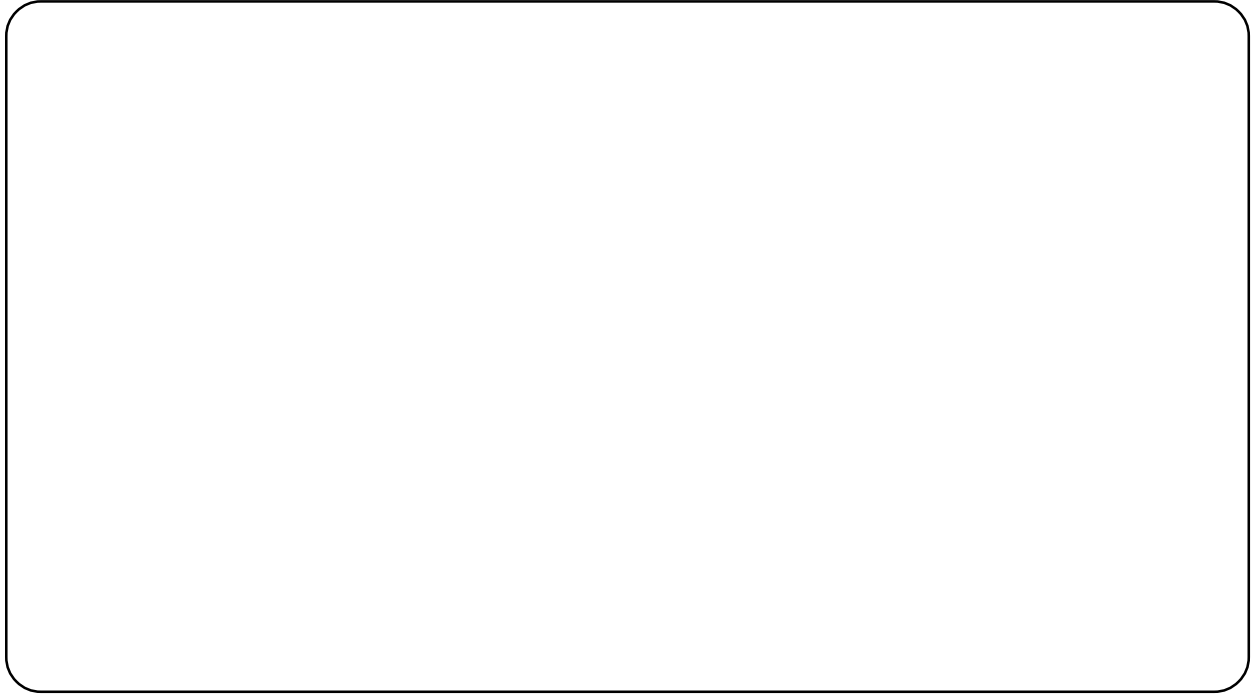
I learned a great lesson from a Department of Energy contracting officer by the name of Don Drennon. I was justifying a research grant overrun. He explained how he wanted me to prepare the cost figures. When I returned with my justification document, he decided not to reject the request for funds out of hand but rather to give me another chance. He wrote down the form he wanted for the justification. He told me to put my numbers and explanation in exactly that form. “That’s the form we use,” he said “and, in that form, I’m more apt to believe your numbers and justification. Remember form becomes substance.” Can you apply this lesson to your classes in terms of how you act and dress and how you prepare your homework? How do you feel about that? Do you think some people abuse the ideas of form and substance and perception and reality for their own selfish gain?

How do we get the right color and the right understanding from a painting? We blend the

color from the fundamental (primary) colors. We can do that physically or visually. I’ll talk about visual blending later. In physical blending we lose the original colors, never to be retrieved from the mix. This absolute blend represents how management systems engineers need to mix the principles of the systems approach, the management process, and the engineering process. You can start with the components but must end up with the blend.

The concepts I intend for you to remember and I will reinforce during the course are:

- Form becomes substance.
- Perception becomes reality.
- Your context when you observe something influences the reality of what you observe.
- No two people sense things (color) in exactly the same way.
- To get information to support decision making, we must match information portrayal to information perception.
- Without light, we have no color: without information and knowledge, we have no interpretation and decision.
- Color and information have 1) hue: name or type; 2) value: lightness or darkness; 3) intensity: purity or strength.
- Light (and information and knowledge) is the most mysterious element.
- Most evaluations of reality depend on a synergy of two or more senses—measurement of reality takes more than observation.
- What you see or understand depends on your perspective.
- Make sure the information you portray is perceived the way you wanted to communicate the information.
- We have to understand blending to be good integrators.



**Figure 1.1.6.1.** *Marseilles Bay Seen from L'Estaque*



### **1.1.6.2. *PROBLEM STATEMENT*—WHAT'S THE PROBLEM?**

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**The aim of this book is to lay out and demonstrate a structured systems approach and skills for building and using a complete, comprehensive set of management tools to help managers get the information they need about their responsibilities to make good decisions. In doing so, this book defines and scopes the discipline of management systems engineering.**

#### **System Failures Are Often Due to Management Failures.**

Many of our seemingly technical failures today are really management failures. The Three Mile Island and Challenger disasters are good examples. Each had a technical component to the failure. But each was primarily a management failure.

In addition to dramatic disasters like these, the United States' slide in competitive position in the world is more a management failure than a technical one. I believe a major part of this failure comes from not understanding the principles, fundamentals, tools, and skills for managing responsibilities and from not having an integrated, synergistic process for the tools and skills to work through.

As you think about large or small failures in government, business, industry, and academia, scrutinize situations for the types of failures involved. You'll find system failures, often with technical components, but largely due to errors in management. (If you feel failure is too strong a term for the results of the errors you find, try the terms frustration and waste.)

I'll describe systems as comprising components with their attributes and relationships, or interfaces. Components fail because of technology. Systems fail because of management. (The components versus systems idea was given to me by Mike Maddox.) The internal sources of failure come from the components of a management system; the external sources

come from the system's environment. We can describe the types of failure in organizations by considering the interfaces between pairs of components in a management system.

#### **We Can Apply Engineering Fundamentals to Management.**

In business, we want our organization to do something well and to do the thing better than our competitors do. That ability depends on the availability of the right tools and skills and our ability to use them in an effective process. A process interconnects the uses and results of the tools and skills. Whether you're a carpenter, an artist, an engineer, or a manager, to be successful, you must learn the principles, fundamentals, tools, and skills needed for the work you do. In this book, my objective is to lay out and demonstrate how to build and use tools for management. I'll use engineering fundamentals to accomplish my objective. My premise is that the advantages of the engineering process will help us unlock some of the doors to better tools for managers. In doing so, we'll apply the engineering process to the management process under the purview of the systems approach.

#### **Contrast Engineering and the Engineering Process.**

Engineering is a discipline that connects a builder to a user, as shown in Figure 1.1.6.2. The engineer is the builder. Engineering is what he or she does to meet the needs of the user. Any person who builds something using the engineering process is doing engineering.

Only some people get degrees that classify them in the engineering profession. I distinguish between the engineering process and the engineering profession.

My interest is in building and using management tools—tools for providing information to a manager. I believe to practice engineering responsibly, we need to close the feedback loop between the user and the builder to ensure the builder meets the user's needs. The management systems engineer is the builder who practices engineering process fundamentals to meet the needs of the manager. To do so, the management systems engineer must understand how to build management tools, how the manager uses management tools, and how well the user's needs are met so the builder can improve his or her performance.

As the builder, the management systems engineer forms a composite whole (a complete integrated solution) by ordering and uniting ingredients (materials or components) according to a systematic plan (or design) to accomplish a defined purpose (serve an application to benefit people). As the user, the manager needs the result of the builder to accomplish a specific goal or objective.

As I expand my discussion of engineering and the engineering process, I'll expand Figure 1.1.6.2. I'll continually disclose more detail as I develop the ideas behind the additional details about the engineering process and its fundamentals and the application system we apply the engineering process to. The next expansion of Figure 1.1.6.2. is in Module 1.1.9.3.

### **To Optimize a System, We Need Tools and Skills.**

Most people recognize the need to optimize the system, not optimize the component parts. However, they don't understand the principles and don't have the skills and tools that work in their specific responsibilities to help them con-

tinuously improve their work and to get the most out of their organization. To gain this understanding, we need a systems approach. We must apply the systems approach to the work and management processes and to the engineering process. We use tools to help us with our work (operations tools) and management (management tools) processes. We use the engineering process for building and using the tools.

We want to do analysis and synthesis activities on systems and their processes. When we learn analysis and synthesis skills and tools, we might call ourselves systems analysts and/or systems synthesists. Our analysis and synthesis skills and tools will help build good management tools.

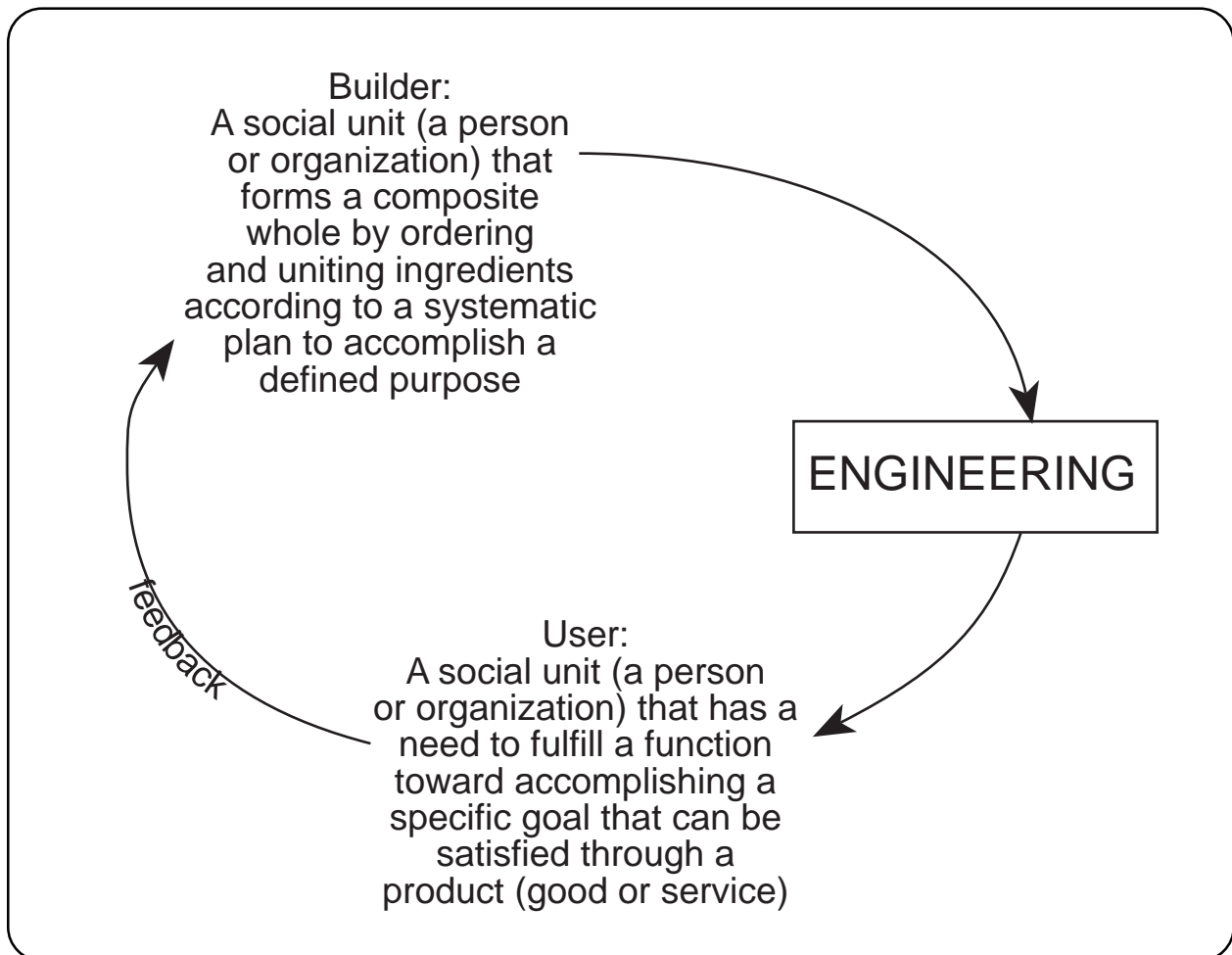
To take on the challenge of giving managers the tools they need, we must use the systems approach. The systems approach requires us to think from system, holistic, and generalist perspectives *in addition* to the analyst and specialist perspectives most of us already practice. The subtle differences among the system, holistic, and generalist perspectives are important to learn for understanding how a system works and can be managed.

### **We'll Consider Management Systems Engineering as a Discipline.**

As an academic discipline, management systems engineering comprises more than management tools. The management tools are part of a system including the manager and the work processes he or she is responsible for. The perspective of this book focuses on management tools within the systems context recognizing the manager's need for information from the tools and the need for the tools to reflect what's going on in the work processes. In this book I'll define and scope the discipline, recognize the manager's responsibilities as a system, and focus on the system from the management-tool perspective. Other management systems engineering approaches

would start with the total system understanding but could focus on the manager's responsibilities as a system from other perspectives,

such as the manager's personal effectiveness or the operation's productivity.



**Figure 1.1.6.2.** *The management systems engineer is the builder who practices engineering to meet the needs of the manager and who determines how well he or she meets that need.*



### **1.1.7. THE *MOTIVATION* FOR AND *RELEVANCE* OF MANAGEMENT SYSTEMS ENGINEERING.**

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**To reduce crises, we need good information from good management tools to help make good decisions so we can convert the energy we spend on crises into creative energy.**

#### **In Your Unit, You Make Decisions about Your Responsibilities.**

For your responsibilities, your job is to make decisions—all kinds of decisions. You make decisions about what to do next, when to do it, what you need to do it, why to do it, and so on. If you make decisions about a responsibility, you manage that responsibility.

You need information to make a good decision. Without information, your decision is really a guess. Management tools can give you information about your responsibilities to help you make good decisions. Good management tools give you accurate, timely, and relevant information.

You don't want to have to make decisions about existing problems. You want to make decisions to head off problems and to move your responsibilities ahead successfully, enjoyably, and effortlessly. You want to be proactive. To be proactive, you have to be able to predict what's going to happen to your responsibilities, not only from your efforts and the efforts of the people you work with but from outside influences. So you need good information about where you are, where you want to be, and how to get there from here.

#### **Can We Head Off Crises of Our Own Making?**

I believe that with the right tools, skills, and process and the knowledge and ability to use them, you can significantly reduce unnecessary effort on crises and replace that frustrating effort with creative, stimulating energy to get more done and feel the joy of your work. Each of us has a number of responsibilities we

manage each day. These responsibilities fall into relatively-convenient groupings—our work responsibilities, our family responsibilities, our community responsibilities, and so on. How often when you look forward to your efforts on any set of responsibilities do you know what you'll accomplish that day and, in fact, accomplish what you expected? The answer I usually get is seldom or never. Clearly, the reason you didn't do what you expected is because something came up you didn't expect. This something, I call a crisis. A crisis is an unexpected occurrence. Even if the unexpected occurrence has a positive effect, I call it a crisis. Other terms for an unexpected occurrence might be surprise, disturbance, incident, problem, and so on.

Crises take up physical and mental energy you planned to devote to productive work. Most of the time this diversion of energy is unnecessary. Usually, directly or indirectly, the crisis is of your own making. (For the responsibilities of a fire fighter, a fire isn't the type of crisis I'm talking about. The fire fighter is prepared for a fire and sees fire fighting as integral to his or her work process. The fire fighter sees improperly given directions to the fire, failure of the truck or communication system, or debilitating interpersonal squabbles as the kind of crisis I'm talking about.)

#### **To Solve Problems in Organizations, We Must Penetrate to the Cause without Threatening People.**

When you have a problem in your work, you first see the result you don't want. The result is a symptom of the problem. To fix the problem, you have to get to the root cause. If you fix the

symptom, the problem will reoccur. Like physicians, engineers find causes using the symptom as a window to the cause. Finding causes is a necessary, but not sufficient, condition for problem solving. The cause is almost always embedded in the process for generating the result. You need tools to penetrate to the root cause, to learn the reason for the cause, and to prevent the cause from reoccurring. You need tools aimed at the process not the result.

In a management system, you almost always need the person doing the process to help you find the cause of a problem. If that person feels threatened, you'll not find the cause. A key question then is: How do I penetrate to the root cause in nonthreatening ways? Penetrating requires an understanding of the work and management processes and the help of the potentially-threatened person. Understanding the work process and the technology behind it gives you the ability or driving force to penetrate. Understanding people and teamwork helps you reduce barriers and resistance to penetration. You move a problem toward resolution by increasing drives or reducing restraints. The latter is better because driving forces attract more restraints while reducing restraints permits existing forces to prevail (Marvin A. Weisbord, *Productive Workplaces*, p. 78).

If you increase the drive of the force of technical knowledge on the problem of penetrating to root cause, you can attract the restraints of fear and covering up. However, if you reduce the fear of being open and honest, whatever technical knowledge you have will prevail and you'll have more success in moving the penetration problem to resolution.

### **We Head off Crises by Being Proactive.**

Being proactive includes heading off crises, or disturbances—those occurrences from inside or outside your control that you don't expect and don't want. Think about the disturbances

you face each day. Most of them are of your own making; you could have kept them from happening. How much time do you spend in rectifying poor communication? When you think of communication problems from your supervisor to you, from you to your subordinates, from your customer to you, and from you to your customer, how much time do you think you could save on misspent effort if the communication had been better? How much time could you save if the communication were more efficient? How much time would you save if you and the people you work with enjoyed working together, trusted each other to share all information readily, and didn't need to explain interpersonal frustrations to yourself or to others?

Think of the time you spend on rework and other consequences of nonconformance to requirements or expectations. (Crosby defines quality as conformance to requirements.) In the United States, most manufacturing operations spend 40% of their time on rework. (Kosaku Yoshida, *Made Wholistically in Japan*, a video tape and Crosby tape) Service operations spend almost as much time on rework. How much time is wasted when we rush around at the last minute trying to meet a forgotten or put-off-to-the-last-minute assignment or milestone? Do you spend time looking for something you misplaced or never received? Do you spend time waiting for someone or something that's late? You don't go to work in the morning saying, "I intend to spend an hour looking for something I forgot," or "I intend to do a job that won't meet expectations and will have to be redone." You want to head off these frustrating, wasteful efforts and do productive work using your creative abilities.

### **The ABC Model Relates the Time We Spend on Crises to What Else We Do.**

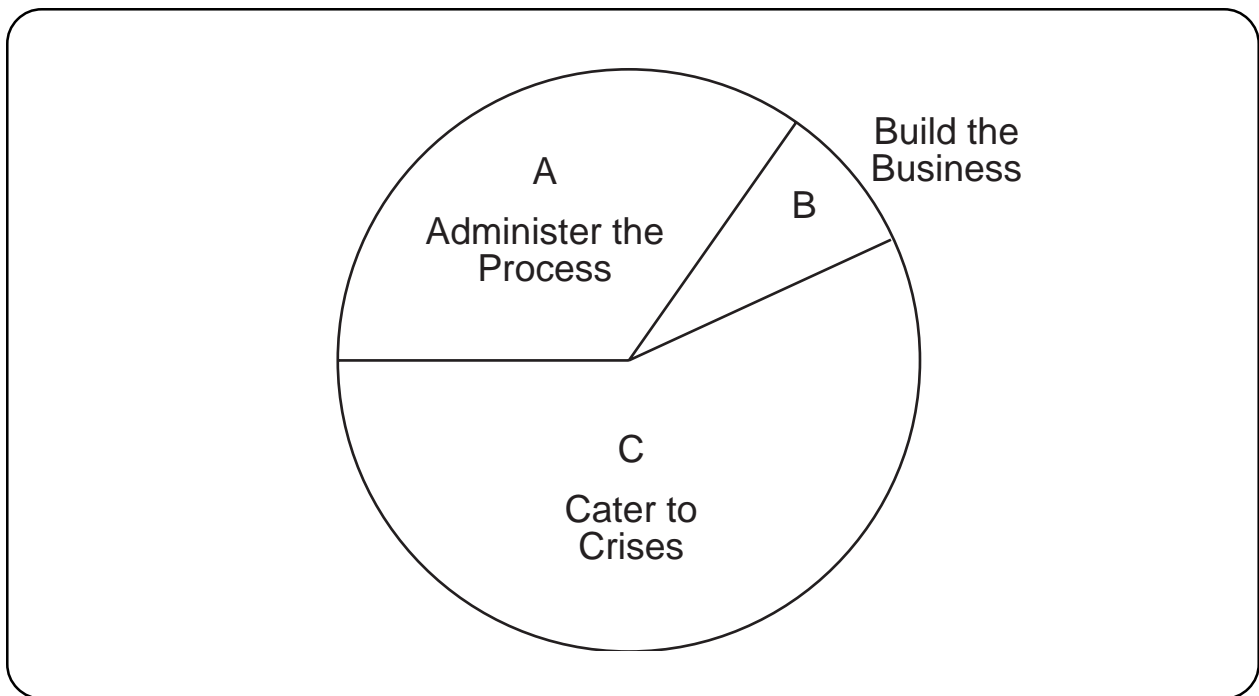
If we start with approximately 40% of our time spent on rework, clearly we spend more time on disturbances, or crises, than we spend on

everything else we do altogether. The crises are shown in Figure 1.1.7. as the large slice of the pie called C, for catering to crises.

Figure 1.1.7. is one simple, but robust, look at our performance or success criteria. I argue that a manager spends all of his or her time administering his or her work and management processes (A), building the business (B), or catering to crises (C). How do you want to spend your time? Surely not catering to crises. Most likely, you want to spend as much time as possible exercising your creativity and using your education and abilities to better serve your customer, add customers and products or services, and learn with your coworkers; that is, building the business. Since we spend most of our time on crises, we have less than half of our time for the A and B slices of the pie. Since A (administer the process) is the time you

spend on your productive work—your work process—and the time you spend on your management process, if you have a large C (cater to crises), you don't get much time to do B (build the business). Doing C is no fun. Doing a good job at A is some fun. Doing B is the most fun. We all want to be creative and build our responsibilities so we can see what accomplishments our abilities, education, and experience will support in our professional life.

Our motivation is simply to reduce crises of our own making. I'll discuss the ABC Model and how to address that problem in Section 1.3. on the ABC Model, which simply says you need to focus on work and management processes to get the business you have under control and reduce crises before you think about expanding the business.



**Figure 1.1.7.** *Given that we spend time on our productive work, when we spend more than half our time on wasteful efforts, we have little time left in our day to be creative. That's why we need good management tools to give managers good information to help make decisions.*



### 1.1.8. THE SOLUTION IS TO ENGINEER THE MANAGEMENT SYSTEM— HOW DO YOU SOLVE THE PROBLEM?

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**We approach management from the systems approach when we understand balance—balance between the art and science of management, balance between the qualitative and quantitative parts of our work, balance between the important and urgent parts of our work, and balance between the technical and human relationship competencies in our work.**

In management systems engineering we engineer a management system, an organization. The system we're engineering has many special characteristics that make management systems engineering challenging. Our outcome is to help managers do their job. The manager is responsible for the management system. For the engineer, the engineering process defines the action they take, which centers around design. For the manager, the management process defines the action they take, which centers around decision making.

Three decades ago, Jay Forrester, in his landmark text, *Industrial Dynamics*, recognized the challenge of the action of management as compared to other actions, such as engineering. In his introduction, he says, "The manager's task is far more difficult and challenging than the normal tasks of the mathematician, the physicist, or the engineer. In management, many more significant factors must be taken into account. The interrelationships of the factors are more complex. The systems are of greater scope. The nonlinear relationships that control the course of events are more significant. Change is more the essence of the manager's environment. .... Management is in transition from an art, based only on experience, to a profession, based on an underlying structure of principles and science. Any worthwhile human endeavor emerges first as an art. We succeed before we understand why. The practice of medicine or of engineering began as an empirical art representing only the exercise of judgment based on experience. The development of the underlying sciences was

motivated by the need to understand better the foundation on which the art rested." (p. 1) "Without an underlying science, advancement of an art eventually reaches a plateau. Management has reached such a plateau." (pp. 2-3.) Forrester's thinking and his models and techniques for industrial dynamics form one of the pillars underpinning management systems engineering.

In solving the problem discussed in Module 1.1.6.2., we must be eternally vigilant of recognizing the balance between art and science in management—and in engineering. We can't yet solve complex systems of equations involving human beings as parts of the machine we call an organization. But we can model the organization, recognize fundamental relationships in it, and study the sensitivity of the cause-and-effect interactions of the organization and its people. Most of all, we can better structure and design the many tools managers use to help them make decisions and we can determine which tool fits a particular situation. You'll find that many of the management tools, especially the computer-based ones, reflect science, and the skills for using the tools reflect art. You must balance the science of the tools with the art of using them.

We can measure variables in an organization and develop better measures, tools, and guides to give managers better data and information to support their decision making. Lord Kelvin said, "When you can measure what you are speaking about and express it in numbers, you know something about it, but when you cannot

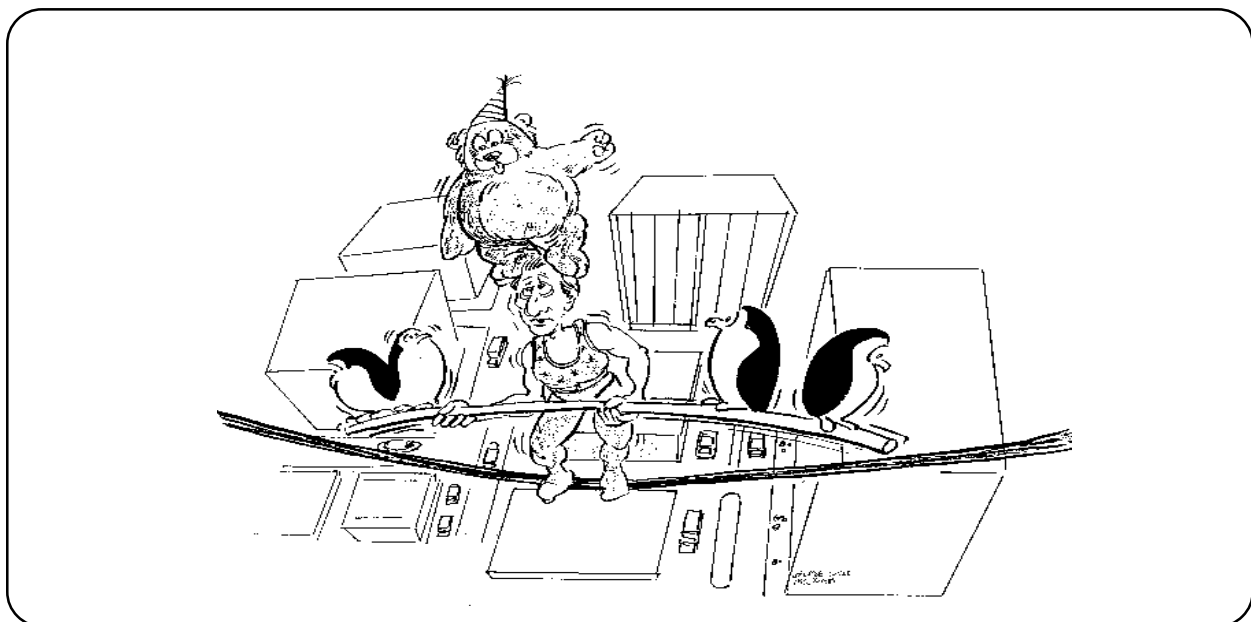
measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind.” (Walter A. Shewhart, *Statistical Method from the Viewpoint of Quality Control*, p. 80.) In management systems engineering, we must learn what to measure and how to measure it.

We face balance issues in everything we do. We all find a tendency to put the urgent in front of the important. Unfortunately, crises or short deadlines don’t define priority. So, you’ll have to work to take some time out for the important. But, you can’t ignore the urgent. The answer again is to find the right mix (balance) in the amounts of time you spend on the urgent and the important. When we figure out the mix, we’ll work on the right things. Figure 1.1.8. illustrates the problem of balance.

To solve fundamental management problems using management systems engineering, you must be able to not only work in qualitative as well as quantitative modes, but you must be able to switch at a moment’s notice. You’ll want qualitative approaches to address the human component of a management system. Typically, engineers feel at home with quanti-

tative analyses and solutions. To engineer a management system, you must feel at home also with qualitative approaches and solutions, because you must balance qualitative and quantitative issues and approaches. Many complex situations are mixtures of qualitative and quantitative issues and approaches. Often, you’ll address a quantitative issue and immediately switch to addressing a qualitative issue. Balance means mix, not equality. How much time should you spend on qualitative versus quantitative issues? The answer is the right mix, not an equal amount of time to both.

From either a management or an engineering perspective, whether we engineer management systems or we manage engineering or technology, we need both quantitative and qualitative skills. Part of the failures (in my opinion) in both management and engineering is that we emphasize the quantitative perspectives and skills at the expense of the qualitative perspectives and skills. If this book seems to emphasize the reverse, it’s not intended but rather an overreaction to what I consider an unbalanced approach to the world. To be successful, we must mix our quantitative and qualitative approaches just right.



**Figure 1.1.8.** *Balance is difficult to achieve, but worth the effort.*



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# **1. BACKGROUND**

## **1.1. INTRODUCTION**

### **1.1.9. MANAGEMENT SYSTEMS ENGINEERING**

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### 1.1.9.1. DEFINE MANAGEMENT SYSTEMS ENGINEERING

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**Even though management systems engineering is the harmonious, robust *blend* of 1) the systems approach, 2) the engineering process, and 3) the management process, people who understand and practice these concepts aren't necessarily in the engineering or management professions.**

*Management systems engineering is concerned with researching, designing, building, operating, and improving a management system, and draws upon knowledge of the natural laws of the physical, social, and life sciences. A management system comprises any person or group of people making decisions about and taking action on a set of responsibilities, the work process for meeting those responsibilities, and the management tools for converting data from measurements of the work process into information for decision making. Management systems engineering applies the fundamentals of the engineering process, which centers on design, to the management process, which centers on decision making and leads to continuous improvement. Management systems engineering integrates principles of human interaction with principles of processes, problem solving, and systems under the purview of the systems approach.*

Much of our effort in understanding management systems engineering will focus on understanding and integrating concepts like engineering, engineering process, engineering process fundamentals, natural laws, principles, management, management process, management tools, work process, decision making, data, information, processes, systems, systems approach, problem solving, and responsibilities with enough depth and precision that we can understand the interplay of these concepts within the framework of a way of thinking. (I discuss engineering and the engineering process in section 1.1.11. I discuss management and the management process in section 1.1.11.)

In management systems engineering, we apply the engineering process to the management process under the purview of the systems approach. I'll describe the engineering process and its fundamentals in Modules 1.1.11.6.3. and 1.1.11.6.4. I believe we don't teach the engineering process in the engineering schools today. (I also believe we don't teach the management process in the business schools today.) I'll discuss that concern in Module 1.1.11.6.5. I define management in Module 1.1.11.2. and outline the framework for the management process in Module 1.1.11.4. Sections 2. and 4.3. of this book describe the management process in detail. I describe the systems approach in Module 1.1.16.2.

We're comfortable with the idea of engineering a chemical system, or process, or a mechanical, transportation, or electrical system. To learn how to generalize engineering for any system, we study systems engineering. In management systems engineering, we learn how to engineer a management system.

Once you understand the management tools and how to use them and learn the skills for using the processes, functions, tools, and rules, you can get better and better at using the management tools well and using them in the right places. (Later, I'll discuss organization structure, management information systems, plans, and many more examples of management tools.) However, to be truly successful at management systems engineering and at the engineering and management processes, you must be able to do more than practice the skills

for using the tools and guides as a mechanical walk through the steps of a process. You must live by the rules and exhibit (manifest) the systems approach.

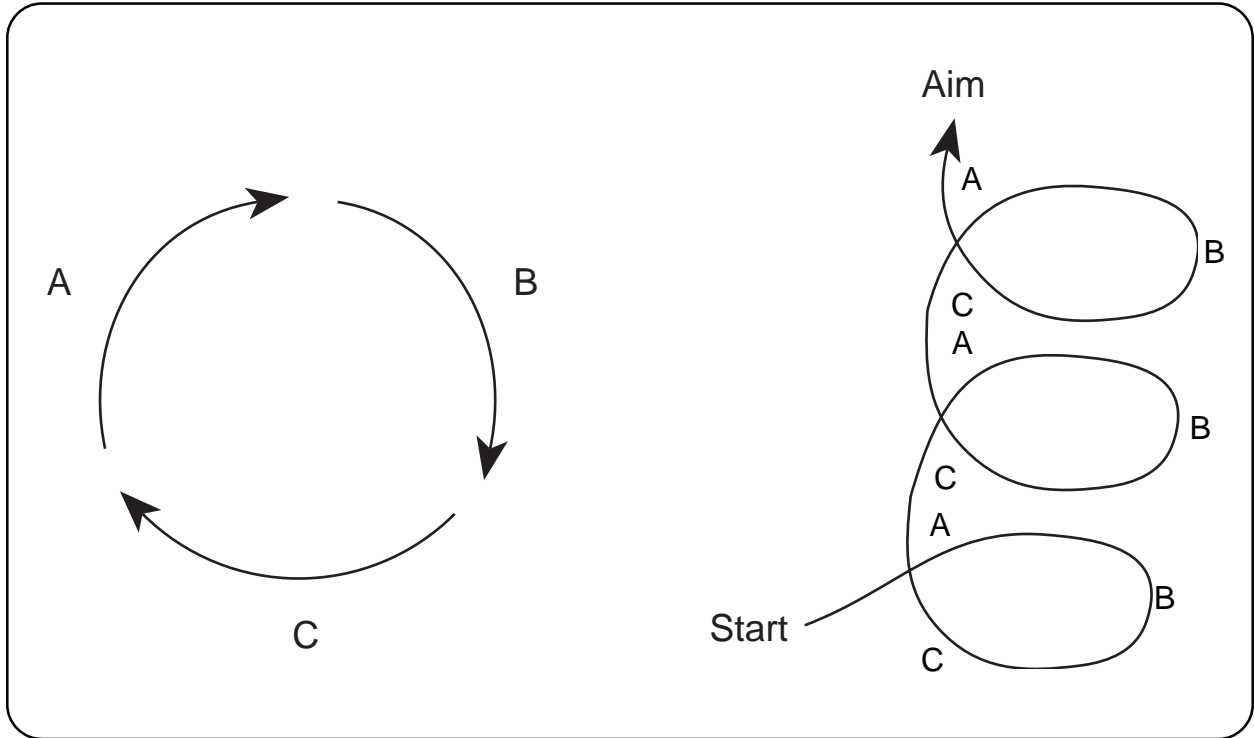
In this book, I'll lay out 14 management-process functions, five to make sure management tools are designed and built right and nine to make sure management tools are used right. The nine using-management-tool functions reflect Deming's Plan-Do-Study-Act cycle. I'll also lay out 22 engineering-process functions.

In scoping management systems engineering as a discipline parallel to chemical, mechanical, civil, or electrical engineering, I'll address the systems approach, both the engineering and management processes, and the functions, rules, and ways of thinking of the two processes. I'll show both processes as learning, cyclic processes capable of continuous improvement. I'll also show that in practicing management systems engineering we recognize frequent bridging between the two processes so we can learn from one process to improve the other.

Figure 1.1.9.1. shows first the idea of a simple, three-step cyclic process and second how repetitive cycling through a learning process provides for continuous improvement toward

the aim of the system the process is associated with. In the past, we've exercised our processes typically as linear processes. In engineering, when we designed a system, we were interested in its installation. We didn't follow through to the end of implementation to include the engineering process steps of upgrade, obsolescence and replacement, and/or clean-up, restoration, and remediation. We never closed the cycle. We never took full advantage of how to learn the lessons of our practices and how to use what we learned to do better the next time. Both the engineering and the management processes have more than the three process steps shown in Figure 1.1.9.1. Therefore, its easy to neglect follow-through steps. But there's more to learn from taking the steps.

Management systems engineering is extremely broad. After setting the stage for management systems engineering, this book emphasizes the tools and guides and skills needed for building and using the tools and guides. Many of the approaches of engineering and management are the same or overlap, making our job of understanding management systems engineering somewhat easier and implying that the management and engineering processes aren't too different. We'll find both the management and engineering processes are rooted in the scientific method.



**Figure 1.1.9.1.** *Processes for learning and improving tend to be cyclic sequences of steps toward an aim.*



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### 1.1.9.2. BLENDING CONCEPTS OF MANAGEMENT SYSTEMS ENGINEERING

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**To do management systems engineering well, you must blend the engineering process, the management process, and the systems approach so the concepts are indistinguishable one from the other.**

Management systems engineering is the harmonious, robust *blend* of 1) the systems approach, 2) the engineering process, and 3) the management process. The sequence is important in that the systems approach is the glue among the functions and we're working with engineering management systems here, not managing engineering or technology. All three involve ways of thinking. Processes are more conducive to analysis and defining functions and sequences of steps or stages. Approaches are more conducive to synthesis than processes and drawing ideas together into a direction or objective, but also support analysis.

Project management is a combination of engineering and management that exemplifies the overlap. As a result, project management is the career step most engineers go through in transforming from engineering activities to management activities. Project management heavily intermingles the management and engineering processes. Usually people enter project management educated and trained in either engineering or management and have to deal with the other through hard knocks. In working toward an understanding of both management and engineering processes, this book intends to structure the tools and guides and the skills for using them so the reader can perform engineering and/or management activities in the context of management systems engineering.

Trying to develop an integrated model combining the systems approach, the engineering process, and the management process to get a conceptual model for management systems engineering isn't as useful as we'd hope. Just

like you won't find an integrated model or process including both the engineering process and the chemical process in chemical engineering, I won't try to integrate the engineering and management processes into an overall model. Rather I'll model first the engineering process and then the management process and keep the models separate. Both of the processes include functions. I'll intermingle the functions as I discuss them.

When I think about how to blend the systems approach and engineering and management processes of management systems engineering, I think of blending colors in a painting. We don't connect the colors and show their linkages like components in a mechanical system. We blend yellow and blue to get green. There's yellow and blue in green, but to look at the green you can't separate the yellow from the blue. Depending on how you blend yellow and blue, you get a different green. And you want just the right green (the right blend) to capture what you envision to be reality. An artist knows the technique for blending to get the green that best represents the image he or she wants the audience to see. As we blend colors in art, we blend the approaches and processes in management systems engineering.

We blend to get crisp images, not to get fuzzy ones. At first glance, you might think an artist blends color to give a general fuzzy image of the subject being painted. In Tucson, I met a watercolorist who showed me that the detail is in the color. He'd put a brushstroke of green on his paper and you'd see a cactus. He didn't paint in detailed outlines or texture or compo-

nents. When the color was right within the context of the entire painting, you saw a cactus. Likewise blending the management and engineering processes and the systems approach doesn't make things fuzzy. Rather the blend brings out the contributions of all three. The detail is in the blend.

In management systems engineering, you must not only have profound knowledge of systems, engineering, and management, you must understand how to blend the three to get the harmony that makes the mix work and the robustness that makes the mix work well.

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### 1.1.9.3. COMPARE MANAGEMENT SYSTEMS ENGINEERING TO OTHER ENGINEERING DISCIPLINES

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**Like traditional engineering disciplines; management systems engineering applies the engineering process to an application system, in this case to an organization. The engineering process has advantages to help us manage better than ever before. Other management-related engineering disciplines practice the opposite approach by applying management principles to technological enterprise.**

#### Traditional Disciplines

How do we engineer a management system? Consider a management system to be like a mechanical, electrical, or chemical system. How do we engineer those other systems? Your answer will lead you to the answer for engineering a management system. First, we must understand thoroughly the system where the solution we're engineering fits into—the application system. Whereas we don't know what the solution looks like, we must thoroughly understand the body of knowledge governing the use and benefit of our solution, which I will call the object of our engineering effort. For chemical engineering, we must understand chemistry, chemical processes, and tools and facilities for operating the chemical processes. For management systems engineering, we must understand organizations, the management process, and tools for managing the organization. Second, we must understand thoroughly how to engineer. Just as successful chemical engineering requires us to understand both the chemical process and the engineering process, successful management systems engineering requires us to understand both the management process and the engineering process.

Recall Figure 1.1.6.2., which shows the cycle between the builder and the user, where engineering connects the beneficial effort of the builder to the need of the user. In Figure 1.1.9.3., I've expanded the idea of engineering into the engineering process and the object of

the engineering process—the application system. The application system converts capital, labor, equipment, and materials (CLEM) and energy and information into beneficial orientations to meet the needs of the user. The builder forms the beneficial orientations. Any system produced by rational people has an aim; and every system is associated with a process. (I'll discuss and contrast systems and processes later.)

For chemical engineering, the application system is a chemical plant or plant component. The chemical plant has an associated chemical process including the functions of the plant and an associated management process for managing the chemical process. The chemical engineer applies the engineering process (I'll describe the engineering process and its fundamentals later.) to the chemical process under the purview of the systems approach. The management systems engineer applies the engineering process to the management process under the purview of the systems approach. Unfortunately, when we teach an engineering discipline, we focus on the application system to the detriment of both the engineering process and the management process—both of which are needed to engineer the system. In Figure 1.1.9.3., I've extended the ideas from Figure 1.1.6.2. I'll expand Figure 1.1.9.3. further to continually disclose the details of the engineering process and the application system. The next expansion of Figure 1.1.9.3. is in Module 1.1.11.6.1.

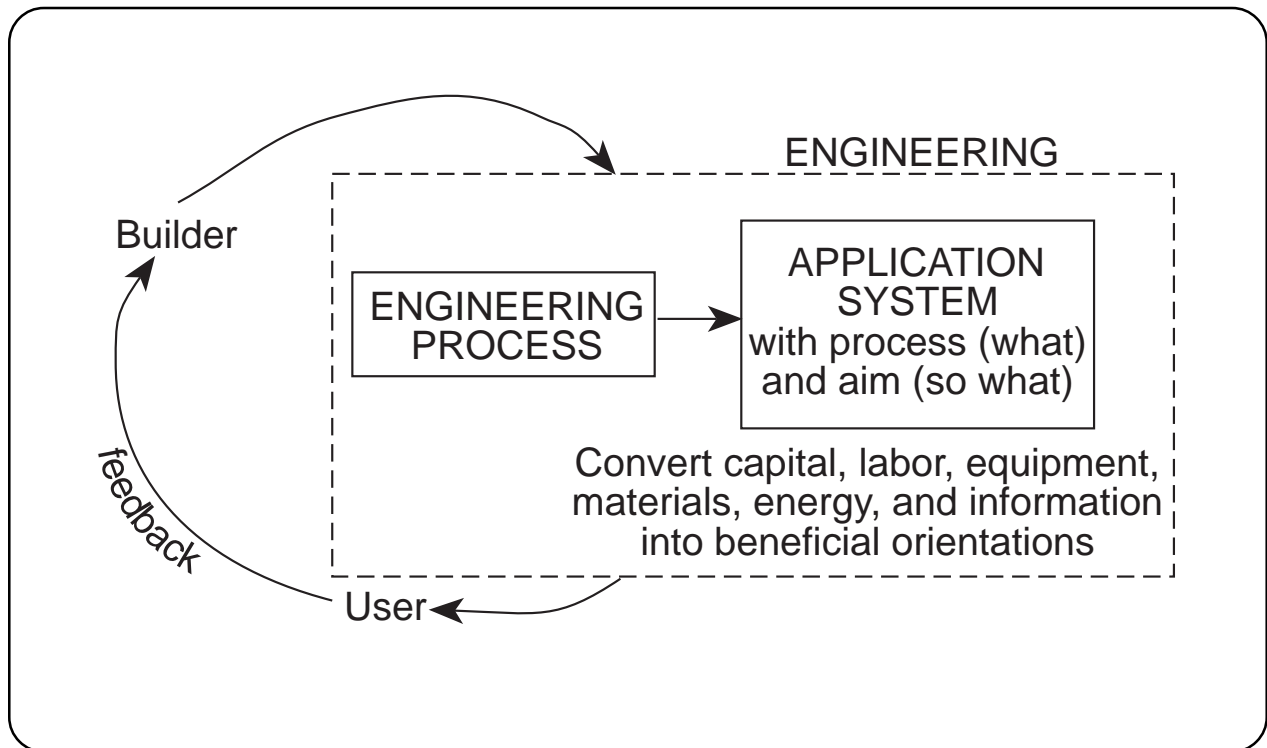
In chemical engineering, the engineer participates both in designing the application system and its components and in operating the application system. (The engineer can be the chemical plant manager.) In management systems engineering, the engineer participates both in designing the organization and its components and in operating the application system. If the organization—the application system—were a chemical plant, the engineer could be the chemical plant manager. I believe that understanding the management process overlaying the chemical process in the plant—the management system—requires knowing the management process and the engineering process in addition to the chemical process. In this example, I call the chemical process the work process, or the core application system.

### **Non-Traditional Disciplines**

In management systems engineering, we engineer a management system; that is we apply the engineering process to the management process. We apply engineering principles and techniques to organizations. This point of view is different from engineering management where we manage engineering, typically thought of in terms of technology. In engineering management we apply management principles and techniques to engineering or technology firms. People in the business schools consider engineering management to be managing technology. So, if we have to consider departmental barriers, I claim engi-

neering management is part of the management perspective, whereas management systems engineering is part of the engineering perspective. In management systems engineering, we're considering management engineering, *not* engineering management.

Fabrycky and Blanchard introduce the idea of another term—systems engineering management—by saying, “[Systems engineering management] is the management of systems engineering functions that leads to the successful birth of a system.” (Benjamin S. Blanchard and Wolter J. Fabrycky, *Systems Engineering and Analysis*, Prentice-Hall, Inc., 1990, p. 20.) They list the systems engineering functions as 1) system planning, 2) system research, 3) system design, 4) production and/or construction, 5) system evaluation, and 6) system use and logistic support. (p. 25-30.) They say, “There are variations in the application of engineering functions to the system life cycle, depending on the size of the system and the extent of new design and development required.” (p. 25.) Managing these functions is managing engineering or technology and therefore is more like engineering management. It's a matter of perspective. Systems engineering management and engineering management see engineering or technology as the object of management activities. Management systems engineering sees management as the object of engineering activities. The nomenclature isn't important. The perspective is.



**Figure 1.1.9.3.** *In engineering, we must understand how to apply the engineering process, not just how the application system with its processes works.*



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**1.1.10. PERSPECTIVE THE ENGINEER'S WAY—LEONARDO DAVINCI**

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# **1. BACKGROUND**

## **1.1. INTRODUCTION**

### **1.1.11. A NEW (OLD) DISCIPLINE**

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### 1.1.11.1. WHAT'S UNIQUE ABOUT MANAGEMENT SYSTEMS ENGINEERING?

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**Management systems engineering is a structured systems approach, based on engineering principles, to building and using means to help organizations improve their performance.**

Applying the engineering process to the management process represents a new discipline. Or, if we look closely at the beginnings of industrial engineering, perhaps management systems engineering re-initializes the original meaning of industrial engineering.

Management systems engineering is centered on systems thinking and systems integration. In management systems engineering, we apply engineering fundamentals of design and gathering, conversion, and conservation of energy to an organization, whose key ingredient is its human resources. Management systems engineering stresses the perspective of the generalist in balance with typical engineering specialties.

As engineers, we work to improve the performance of the system of interest. Instead of a bridge, engine, electrical generator, automobile, heat exchanger, or other system commonly thought of in the engineer's domain, our system of interest is the organization. If we consider a given organization, the manager of that organization is responsible for that system and its performance and, in fact, is part of the organization. The manager is an important component of the management system. As engineers, we work to design means to support the performance of all organizations and to work with the manager to apply those means to improve the performance of his or her organization. (In patents, the word *means* refers to the mechanism employed to carry out the purpose or objective of the patent. Here, I intend means to be the theories, tools, techniques, or skills the engineer develops for the organization to use or the organization to im-

prove its performance.) To be successful, we must be able to think like an engineer and like a manager and to integrate the two.

Let's put our objective in perspective using Figure 1.1.11.1. The focus of our attention is the organization, in the center of the figure. The engineer and the manager want to make decisions and act on the organization in ways to improve its performance. As engineers, we'll want to represent the organization in ways we can observe it, learn about it, and work on it. We'll represent the organization by using one or more models. We can model the organization in a variety of ways. In engineering terms, the organization looks like a transfer function for converting interventions into performance changes.

We evaluate the performance of an organization through performance criteria. Performance criteria are shown as the output of the organization in Figure 1.1.11.1. We'll learn about a number of sets of criteria; however, the A, B, and C criteria for how we spend our time is one such set. Note that the output of the organization in the figure is data or information, not the product or the service of the organization. Obviously, the product or the service is an output of the organization; however, this figure focuses on data and information about the organization and about the organization's work process and its product or service. Information is the stuff we use to make decisions with.

We act on the organization through any number of means. These means include management tools and their guides and the skills to use

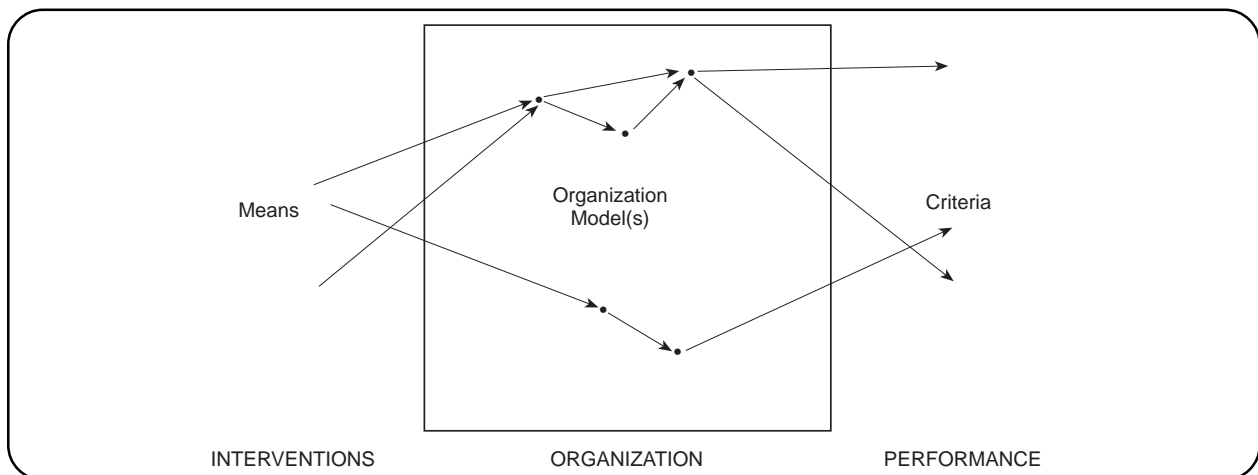
the tools well. In Figure 1.1.11.1., I show the means acting on the organization yielding performance criteria. As engineers, we contribute by analyzing, designing, building, implementing, and following up on the means for improving the performance of the organization. The arrows in the figure show that different means affect parts of the organization in ways to change certain performance criteria. By developing the details in the three sections of Figure 1.1.11.1., we can trace cause-and-effect through the system. Knowing cause and effect we can learn from what we do and continually improve our interventions.

One way to use Figure 1.1.11.1., is to view the organization from inside. From the inside view, a person uses management tools as interventions on the organization's work process. The work process is in the organization block in the figure. Alternatively, you can view the organization from outside as the person building management tools so you can intervene on the entire organization, including the manager, the work process, and the management tools. To do management systems engineering well, you must be good at both views. Then you can make sure the right tools are built, the tools are used right, and the tools are built better based on what we learn from their use.

Figure 1.1.11.1. gives us a global view of the organization. Figure 1.1.11.1. also gives us a framework to tie in our contributions to help manage the organization. As we look toward building and using management tools, we need a complete, comprehensive package and roadmap for showing how those tools and other interventions affect the organization and its performance. The means we use for interventions includes tools and guides and skills for building and using tools and guides so we'll get continuous performance improvement.

As I expand my discussion of the management process, I'll expand Figure 1.1.11.1. I'll continually disclose more detail as I develop the ideas behind the additional details about building and using management tools to support the management process. The next expansion of Figure 1.1.11.1. is in Module 1.1.11.4.

Figure 1.1.11.1. was first shown to me by Betty Koball in relation to developing the structural equation model, or the holistic construal, for doing path analysis for organizational research. I've borrowed the figure to show the relationship between the interventions we make in an organization and the results we hope to achieve through the interventions.



**Figure 1.1.11.1.** *The contribution of management systems engineering is to take a broad systems view of the organization and how interventions affect performance so we can build and use means to help the organization improve its performance.*

### 1.1.11.2. DEFINE *MANAGEMENT*

---

**“Decision making [is] synonymous with managing.” (Herbert A. Simon, *The New Science of Management Decision*)**

Management is one of those words that you can get as many definitions for as you ask people to write definitions. However, the definition we choose will underpin our understanding of the management process. I choose the definition made by Nobel-laureate Herbert A. Simon on page 1 of his landmark book, *The New Science of Management Decision*. I choose this definition because it gives us a foundation upon which we can build a discipline and because we can use it most easily to observe and document the action, or behavior, of management.

Managing is decision making. Decision making involves a process that reflects the scientific method and ends in an observable behavior of choosing among alternatives. We string a series of related decisions together to do problem solving. The people we look to for management engage in functions and activities to prepare for, carry out, and evaluate their decisions. The processes for decision making and problem solving make up the management process.

In the end, managing comes back to the act of decision making. Who makes decisions? Everyone. You’ve been managing since the day you were born. We’ll talk about how well you’ve been managing later. When a one-year-old child uses information to decide which toy to play with, he or she is making decisions. If you will, the toy is one of the physical things in the child’s set of responsibilities, and the child’s decision results in an action affecting that toy. Either they chew on it or they don’t.

Simon says, “In treating decision making as synonymous with managing, I shall be referring not merely to the final act of choice among

alternatives, but rather to the whole process of decision. Decision making comprises three principal phases: finding occasions for making a decision; finding possible courses of action; and choosing among courses of action. These three activities account for quite different fractions of the time budgets of executives. The fractions vary greatly from one organization level to another and from one executive to another, but we can make some generalizations about them even from casual observation. [Simon uses the word *executive* for *decision maker*, or *manager*. He, of course, is writing for decision makers with extreme sets of responsibilities, not for a one-year-old child. So do Peter Drucker in his book, *The Effective Executive*, and Chester Barnard in his book, *Functions of the Executive*.] Executives spend a large fraction of their time surveying the economic, technical, political, and social environment to identify new conditions that call for new actions. They probably spend an even larger fraction of their time, individually or with their associates, seeking to invent, design, and develop possible courses of action for handling situations where a decision is needed. They spend a small fraction of their time in choosing among alternative actions already developed to meet an identified problem and already analyzed for their consequences. The three fractions, added together, account for most of what executives do.” (pp. 1-2.)

Compare the economic, technical, political, and social environment comment of Simon to the reward, work, and human subsystems we discussed in module 1.1.4.

Simon further says, “The first phase of the decision-making process—searching the en-

environment for conditions calling for decision—I shall call *intelligence* activity (borrowing the military meaning of intelligence). The second phase—inventing, developing, and analyzing possible courses of action—I shall call *design* activity. The third phase—selecting a particular course of action from those available—I shall call *choice* activity.” (pp. 1-2.)

Notice the centrality of the design activity in decision making. In Module 1.1.11.6.2. I’ll discuss the centrality of the design activity in engineering. In that both the engineering and the management processes come out of the scientific method, they show similarities. The decision making process is cyclic and recursive.

Simon continues, “Generally speaking, intelligence activity precedes design, and design activity precedes choice. The cycle of phases is, however, far more complex than this sequence suggests. Each phase in making a particular decision is itself a complex decision-making process. The design phase, for example, may call for new intelligence activities; problems at any given level generate subproblems that, in turn, have their intelligence, design, and choice phases, and so on. There are wheels within wheels within wheels. Nevertheless, the three large phases are often clearly discernible as the organizational decision process unfolds. They are closely related to the stages in problem solving first described by John Dewey, (*How We Think*, New York: D.C. Heath & Company, 1910, chapter 8):

- What is the problem?
- What are the alternatives?
- Which alternative is best?

It may be objected that I have ignored the task of carrying out decisions. I shall merely observe by the way that seeing that decisions are executed is again decision-making activity. A broad policy decision creates a new condition for the organization’s executives that calls for

the design and choice of a course of action for executing the policy. Executing policy, then, is indistinguishable from making more detailed policy. For this reason, I shall feel justified in taking my pattern for decision making as a paradigm for most executive activity.” (pp. 3-4.)

Note the cyclic, recursive nature of the decision-making process. Clearly, the management process is cyclic and recursive. Note also the similarity between decision making and problem solving. Sequences and hierarchies of decision making processes make up the problem solving process. Many would argue that the engineering process must reflect the problem solving process. The engineering and management processes come from the same roots. They employ different functions.

Simon further says “A good executive is born when a man with some natural endowment (intelligence and some capacity for interacting with his fellow men) by dint of practice, learning, and experience develops his endowment into a mature skill. .... There is no reason to expect that a man who has acquired a fairly high level of personal skill in decision-making activity will have a correspondingly high skill in designing efficient decision-making systems.” (pp. 4-5.)

Simon’s work provides another pillar for management systems engineering.

When Barnard, Simon, Drucker and others focus on executives, they’re addressing an audience of managers who have broad responsibilities. As long as they equate executives and the act of decision making, I see beyond the glamour of the word executive and call each of us an executive. I believe that when we look into what Deming and others say about quality, we look to everyone in the organization to be an executive. No one really should be considered more glamorous than any other in our mutual responsibility to make good

decisions together in our organization. We each make decisions about our responsibilities and wherever possible we make decisions together about our mutual responsibilities.

In his book *Industrial Dynamics*, Forrester says, “Management is the process of converting information into action. The conversion process we call decision making. Decision making is in turn controlled by various explicit and implicit policies of behavior.

As used here, a ‘policy’ is a rule that states how the day-by-day operating decisions are made. ‘Decisions’ are the actions taken at any particular time and are a result of applying the policy rules to the particular conditions that prevail at the moment.

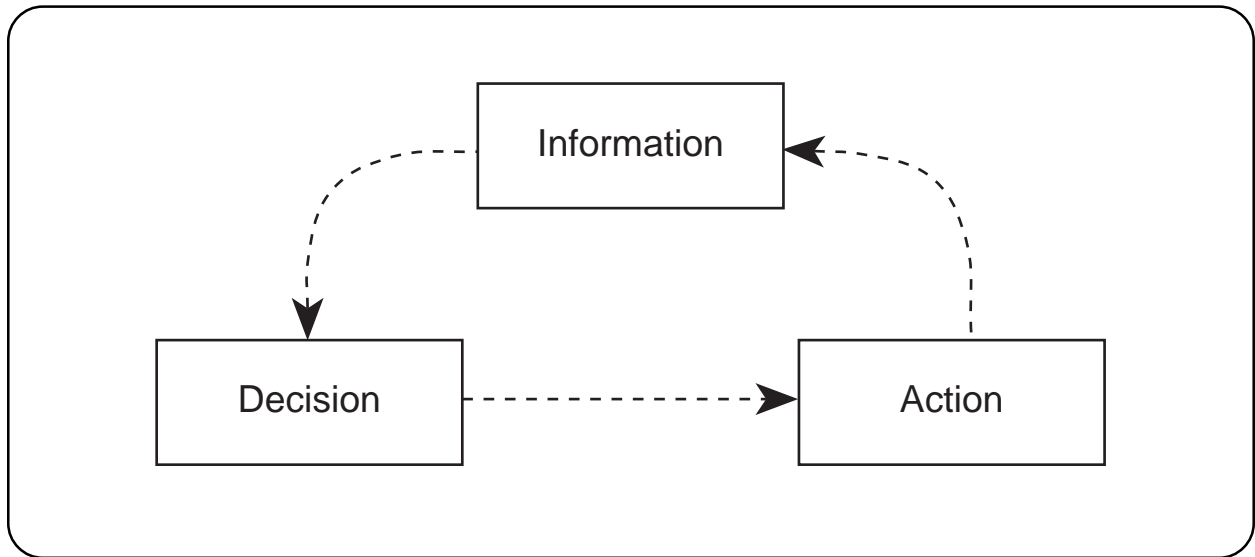
If management is the process of converting information into action, then it is clear that management success depends primarily on what information is chosen and how the conversion is executed. The difference between a good manager and a poor manager lies at this point. .... The manager sets the stage for his accomplishments by his choice of which information sources to take seriously and which to ignore. When he has chosen certain classes of information and certain information sources to carry the highest priority, the manager’s success depends on what use is made of this information. .... In this book we shall look upon the manager as an information converter. .... He receives incoming information flows and combines these into streams of managerial

instructions. .... An industrial organization is a complex interlocking network of information channels. .... Every action point in the system is backed up by a local decision point whose information sources reach out into other parts of the organization and the surrounding environment. .... Figure 1.1.11.2. shows a decision stream in the simplest framework of an information-feedback system.” (pp. 93-94.)

Figure 1.1.11.2. was taken directly from Forrester. I see the manager as occupying the decision box in the figure. The manager receives information from management tools to make decisions with and generates actions from the decisions to affect the work flow, or operation, of his or her responsibility.

You’ll see Figure 1.1.11.2. again as several of the ingredients in the Management System Model described in Module 1.1.18.1. Both the components and the feedback loop are important foundations of a model that describes a management system. In Module 1.1.11.5., when I describe a system, you’ll find the need for identifying the components and the relationships among the components in a system.

As we think about Forrester’s words, we deal with the issue of good decisions—how to do decision making well. Clearly, a necessary, but not sufficient condition for good decision making is good information. Another necessary condition is a good decision making process that acts on good information.



**Figure 1.1.11.2.** Forrester's figure shows a decision stream in the simplest framework of an information-feedback system. He places the decision maker squarely between the information the manager needs and the action resulting from the decision.

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### 1.1.11.3. CONSEQUENCES OF DEFINING MANAGEMENT AS DECISION MAKING—OTHER DEFINITIONS.

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**Of the dozens of declared definitions of management, managing equals decision making is most useful to us; yet we must know the other definitions to understand and communicate management systems engineering concepts.**

The consequences of defining managing as decision making are important. Because of this definition, we can't contrast management and leadership as many authors do—just like we can't contrast apples and automobiles. Managers make decisions. Decisions, when made in a certain role I'll define later provide leadership. Other roles we play as we make decisions include administration, liaison, figurehead, and many others developed by Henry Mintzberg in his landmark paper, *The Manager's Job: Folklore and Fact*, in which he says, "The classical view says that the manager organizes, coordinates, plans, and controls; the facts suggest otherwise." (p. 49.) "... I [define] the manager as that person in charge of an organization or one of its sub-units. .... The manager's job can be described in terms of various 'roles,' or organized sets of behaviors identified with a position. .... formal authority gives rise to the three interpersonal roles, which in turn give rise to the three informational roles; these two sets of roles enable the manager to play the four decisional roles." (p. 49, HBR 53:4, 1975)

I support Mintzberg's idea of the roles we play as we make decisions. I disagree with Mintzberg's definition of manager. I believe a manager is a decision maker. A supervisor is in charge of an organization. Supervising is another role we play as we make decisions. When supervisors make decisions, they are then managers.

By defining managing as decision making, I lay the foundation for a structured or engineering approach to management. Through the

structured approach, you can easily identify the act of decision making and then link decision making acts together in problem solving processes to analyze, design, implement, and follow-up—the activities of engineering. Notice the relationship between and the difference between decision making and problem solving. I'll discuss problem solving in detail in Module 1.5.5.6.

As is the case with Mintzberg, not all authors define management as Simon does. Deming defines management as prediction. (Notes from *Quality, Productivity, and Competitive Position*, a workshop by W. Edwards Deming, September 1992.) Deming's roots begin in the teachings of Walter Shewhart. Shewhart sees prediction (or Deming's management) as one of the components of knowledge. Shewhart says, "In line with the statement quoted from C.I. Lewis at the beginning of this chapter ('... knowing begins and ends in experience; but it does not end in the experience in which it begins.' C.I. Lewis, *Experience and Meaning*, *The Philosophical Review*, vol. xliii, p. 134, 1934.), I shall assume that knowledge begins and ends in experimental data but that it does not end in the data in which it begins. From this viewpoint, there are three important components of knowledge: (a) the data of experience in which the process of knowing *begins*, (b) the prediction P in terms of data that one would expect to get if he were to perform certain experiments in the *future*, and (c) the degree of belief  $p_b$  in the prediction P based on the original data or some summary thereof as evidence E. .... Knowledge begins in the original data and ends in the data predicted, these

future data constituting the operationally verifiable meaning of the original data. Since, however, inferences or predictions based upon experimental data can never be certain, the knowledge based upon the original data can inhere in these data only to the extent of some degree of rational belief. .... What has just been said about the three components of knowledge may appear to the practical engineer or statistician as being abstract and somewhat formal until he considers how they are met in everyday experience. For example, I might say, 'It's going to rain the day after tomorrow.' That statement has a definite predictive meaning in the sense that you can test it in the future. However, it doesn't convey much knowledge, since I have no standing as a weather prophet. You may therefore ask what makes me think that it's going to rain the day after tomorrow. That is, you *ask for my evidence*. Given the evidence, there is presumably a certain degree of belief  $p'_b$ , however small, that may rationally be held in my prediction. *The evidence as well as the prediction must be considered.*

This simple example shows how one may make a perfectly definite scientific statement—one that is meaningful—without conveying much if any knowledge. In fact, I should say that the statement that it is going to rain the day after tomorrow, free of any supporting evidence and the source of the statement, conveys no knowledge at all. The results of experimental work may also be summarized in terms of meaningful statements that do not transmit knowledge, in that the one who reads the summary may not know how much belief to place in it. Likewise one may present a set of original data without making any interpretative statements. Hence, in what follows we must consider ways and means for presenting experimental data in three different ways: (a) as original data, (b) as interpretive predictions, and (c) as knowledge.” (Walter A. Shewhart, *Statistical Method from the Viewpoint of Quality Control*, Dover Publications, 1986, pp. 85-86.)

Shewhart's work and the follow-on work of Deming and Juran provide another pillar for management systems engineering. Now we're not only talking about managing but we're talking about managing well. To make good decisions, you'll need good information based on good data in a foundation of knowledge.

Many people like to equate managing with supervising. I don't. When you have people, whom you hire, fire, and adjust salary for, who report to you to spend your defined budget to meet the objectives of the organization your title reads you're the head of, I say you're supervising. You're the supervisor and those who report to you and those who report to them are your subordinates. Those who report directly to you are your direct reports. When you make decisions, you're managing. When your subordinates make decisions, they're managing. When you organize, direct, and control people, you're supervising. Supervising is a role you play as you make decisions; and organizing, directing, and controlling involve making decisions.

Peter Drucker says, “A man who knows only the skills and techniques, without understanding the fundamentals of management, is not a manager; he is, at best, a technician.

Management is a practice rather than a science. In this, it is comparable to medicine, law, and engineering. It is not knowledge but performance. Furthermore, it is not the application of common sense, or leadership, let alone financial manipulation. Its practice is based both on knowledge and on responsibility.

The management boom has proven that the manager must be more than a *technocrat*. He cannot be confined to his discipline, cannot be content with mastery of his skills, his tools, and his techniques.

Management is not culture-free, that is, part of

the world of nature. It is a social function. It is, therefore, both socially accountable and culturally embedded.” (Peter Drucker, *Management*, Harper and Row, Publishers, Inc., 1973, pp. 17-18 .)

Drucker seems to contradict Forrester when he says management is a practice rather than a science. Forrester says management is moving from an art to a science. Because in management we must deal with people, I believe management will always be a mix, or balance, of art and science. As we understand the science more, we can devote more energy to the art. That’s what we want to do in management systems engineering. We want to apply science where science fits so we can gain time and resources to apply art where art fits. Drucker further says, “The question, *What is management?* comes second. First we have to define management in and through its tasks.

There are three tasks, equally important but essentially different, which management has to perform to enable the institution in its charge to function and to make its contribution:

- [defining] the specific purpose and mission of the institution, whether business enterprise, hospital, or university;
- making work productive and the worker achieving;
- managing social impacts and social responsibilities.” (pp. 39-40.)

Drucker implies the possibility of a fourth task when he says, “One complexity is ever-present in every management problem, every decision, every action—not, properly speaking, a fourth task of management, and yet an additional dimension: time.” (p. 43.)

Drucker adds the dimensions of administration and entrepreneurship to managerial performance. (p. 45.)

He comes closest to a specific definition when he says, “Each of these tasks and dimensions has its own skills, its own tools, its own requirements. But the total management task requires their integration. And this too requires specific work and its specific tool. The tool is management; and the work is managing managers.

The tasks—economic performance; making work productive and the worker achieving; managing social impact and social responsibilities; and doing all this in a balance between the demands of today and the demands of tomorrow—are the things in which the public at large has a stake. The public has no concern with—and only mild interest in—what managers have to do to accomplish their tasks. It rightly is concerned with performance. But managers must be concerned with the means to the accomplishment of their tasks. They must be concerned with managerial jobs, with the work of the manager, with the skills he needs, and with his organization.

Any book of management that does not begin with the tasks to be performed misconceives management. Such a book sees management as something in itself, rather than as a means to an end. It fails to understand that management exists only in contemplation of performance. It treats management as an independent reality, whereas management is an organ which derives existence, identity, and justification from the function it serves. The focus must be on the tasks.

To start out discussing management with the work of the manager or with managerial organization—as most books on management do—is the approach of the technocrat, who soon degenerates into a bureaucrat. But it is even poor technocracy. For, as will be stressed again and again in this book, management work, management jobs, and management organization are not absolutes, but are deter-

mined and shaped by the tasks to be performed. *Structure follows strategy* is one of the fundamental insights we have acquired in the last twenty years. Without understanding the mission, the objectives, and the strategy of the enterprise, managers cannot be managed, organizations cannot be designed, managerial jobs cannot be made productive.” (pp. 47-48.)

We must separate in our minds the act of decision making and the corresponding action from roles the people with responsibilities play and the tasks they do within their work and management processes. Decision making is the key ingredient in all the roles and the tasks and is the fundamental act in the roles and tasks. The roles and tasks then define the decisions to be made. Drucker is asking not that we just make decisions as management but that we make the right kinds of decisions. This point is very important. I, however, want to separate the decision making act from the roles, tasks, and processes. The reasons are that we don't force management on only a few people playing certain roles and we can easily identify a decision (the act of management) through the consummation of the decision process—a choice.

Montana and Charnov have a much shorter definition of management in their book, *Management*. “In 1969, the President of the American Management Associations (AMA) used this definition of management: ‘Management is getting things done through other people.’

Now look at a current definition: ‘**Management** is working *with and through* other people to accomplish the *objectives* of both the organization and its members.’

What are the differences between the two?

There are three key differences that should be highlighted. The more recent definition

1. places greater emphasis on the human being in the organization
2. focuses attention on the *results* to be accomplished, on objectives, rather than just things or activities
3. adds the concept that accomplishment of the members' personal objectives should be integrated with the accomplishment of organizational objectives.

In looking at the current definition, we come to the conclusion that management is both a science and an art. We also have to view the manager as an individual.” (p. 2.)

Once I limit management to the act of decision making, I also emphasize the significance of the decision maker and the decision making process. I consider supervision as the act of working with and through other people. In fact, one of the pillars of the management process is the relationship among people. In this regard, Autry's definition of management is crucial and ties directly to what I choose to call supervision. Autry says, “*Management is, in fact, a sacred trust in which the well-being of other people is put in your care during most of their working hours. It is a trust placed upon you first by those who put you in the job, but more important than that, it is a trust placed upon you after you get the job by those whom you are to manage...A promotion to manager can give you authority, but not power. It is the people you are to manage who will give you power; by their actions and response, they will bestow power on you, but only if they trust you to use it well.*

So management is a matter of being ‘in relationship.’ This is one of the most overlooked and misunderstood principles in management.

Wherever did we get the notion that, in man-

agement, there is a reasonable and acceptable separation of the intellect and the spirit—that, in our work-world terms, the intellect controls the rational work life and the spirit is relegated to the soft stuff of romance, family, and religion? Where did it come from, all this hiding of emotion, of the spirit, of passion, behind some cool mask of macho detachment? I wonder if it is that business is considered too important to be diluted by all those feelings, or is it that business is not considered important enough to deserve them? Either way is wrong.” (James A. Autry, *Love and Profit: The Art of Caring Leadership*, Avon Books, 1991, p. 19.) So, you'll not manage (or in my terms, supervise) if you don't have trust. You won't get trust if you aren't trustworthy.

In considering the several definitions and what managers do, be careful to distinguish results, performance, objectives, tasks, and process. I'll discuss these ideas later as we get into successful management and engineering.

In his article on the management theory jungle, Harold Koontz describes six major schools of management theory. (Harold Koontz, *The Management Theory Jungle*, *The Academy of Management Journal*, December 1961, pp. 174 - 188.) His first school, the management process school is the traditional or universalist school of Fayol and Taylor and mixes the art and science of management. His second school, the empirical school relies on experience and anecdotal evidence as viewed through cases. These two schools support the idea of a management system, which I'll model in Module 1.1.18.1.

Koontz's third school, the human behavior school, recognizes the importance of people as individuals in organizational settings. His fourth school, the social system of March and Simon and of Barnard sees people acting in groups. These two schools relate to the importance of people and their social system in

organizations. People both manage and are managed in organizations.

Koontz's fifth school, the decision theory school focuses on the decision process and is the center of the management process associated with a management system. His sixth school, the mathematical school is the foundation of operations research and management science and supports at least one category of management tools managers use to support their decision making.

In his discussion on disentangling the management theory jungle, Koontz's says, "...I have come to the conclusion that management is the art of getting things done through and with people in *formally organized groups*, the art of creating an environment in such an organized group where people can perform as individuals and yet cooperate toward attainment of group goals, the art of removing blocks to such performance, the art of optimizing efficiency in effectively reaching goals.”

I'll end what could become an indefinitely long discussion of other definitions of management by quoting Babcock's discussion. “McFarland traces the meaning of the words *manage* and *management* as follows:

The word *manage* seems to have come into English usage directly from the Italian *maneggiare*, meaning 'to handle,' especially to handle or train horses. It traces back to the Latin word *manus*, 'hand.' In the early sixteenth century *manage* was gradually extended to the operations of war and used in the general sense of taking control, taking charge, or directing .... *Management* was originally a noun used to indicate the process for managing, training, or directing. It was first applied to sports, then to housekeeping, and only later to government and business.” (Dalton E. McFarland, *Management: Foundations and Practices*, 5th ed., New York, Macmillan Pub-

lishing Co., 1979) *Mane* means with your hand. *Giare* means guiding. Then *maneggiare* means guide with your hand as in training horses. (Personal communication with Gery Patzak.)

McFarland continues by identifying ‘four important uses of the word *management*, as (1) an organizational or administrative process; (2) a science, discipline, or art; (3) the group of people running an organization; and (4) an occupational career.’ Sentences illustrating each of these in turn might be (1) ‘He practices good management’; (2) ‘She is a management student’; (3) ‘Management *doesn’t really believe* in quality’; and (4) (heard from innumerable college freshmen) ‘I wanna get inta management.’ Of these four, most authors of management textbooks are referring to the first meaning (the *process*) when they define ‘management.’ According to some of these authors, management is:

- The work of creating and maintaining environments in which people can accomplish goals efficiently and effectively (Albanese)
- The process of achieving desired results through efficient utilization of human and material resources (Bedeian)
- The process of reaching organizational

goals by working with and through people and other organizational resources (Certo)

- The process of planning the decision making, organizing, leading, and controlling an organization’s human, financial, physical, and information resources in an efficient and effective manner (Griffin)
- The process by which managers create, direct, maintain, and operate purposive organizations through coordinated, cooperative human effort (McFarland)
- The process of acquiring and combining human, financial, informational, and physical resources to attain the organization’s primary goal of producing a product or service desired by some segment of society (Pringle, Jennings, and Longbecker)” (*Managing Engineering and Technology*, Prentice-Hall, 1991, pp. 8-9.)

Notice the frequency with which these authors classify management as a process. I consider management to be decision making within a process I call the management process. The management process contains a series of functions, some for building management tools and some for using management tools.

In this book, managing is decision making—nothing more, nothing less.

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### 1.1.11.4. THE FRAMEWORK FOR THE MANAGEMENT PROCESS

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**When we act on the organization, we change its performance and we should monitor that change and feedback what we've learned to improve our interventions.**

The management process is keyed to the decision making of the manager. The management process is a cyclic, recursive set of steps for continuously improving performance. Figure 1.1.11.4. shows the framework for the management process. In Figure 1.1.11.4., I've extended the ideas from Figure 1.1.11.1. I'll expand Figure 1.1.11.4. further to continually disclose the details of the management process and building and using management tools. The next expansion of Figure 1.1.11.4. is in Modules 1.1.21.2., 1.1.21.4., and 1.1.21.8. in preparation for the illustrative model in Module 1.1.29.1.

The framework in Figure 1.1.11.4. has a dual personality. Understanding the dual personality is crucial for dealing with the management process. The center block of the figure is the organization. The duality comes from the question of whether the organization (center block) is just the physical operation of the organization or, on the other hand, includes the physical operation, the manager, and his or her management tools. The first view is good for studying the productivity and the work flow of the organization. The second view is good for studying decision making and the conversion of data to information to support decision making. In a way, the second view is from outside the organization (the view of a consultant using consulting interventions) and helps work on the organization. This view helps build management tools for the decision maker. The first view is from inside the organization (the view of the manager using management interventions) and helps work within the organization. This view helps use management tools by the decision maker.

Building management tools isn't just an out-

side job. Building tools is a cooperative effort between the user/manager and the information specialist (expert), with the information specialist playing a key role in between the analysis and implementation stages of building tools. For building management tools, the manager provides understanding of himself or herself and of the physical operation of their responsibilities. To do this well, the manager with the information specialist view the organization from outside. Likewise, using management tools isn't just an inside job. Using tools is also a cooperative effort between the user/manager and the information specialist (expert), with the information specialist playing more a monitoring, evaluation role.

As you look at Figure 1.1.11.4., you'll see dual views by placing yourself on the feedback arrow in the figure. The feedback arrow closes the loop between performance criteria and interventions for continuous performance improvement. When I discuss the 14 management process functions, they'll be in the organization block. You'll view the five building-management-tool functions from outside the organization and see the functions as being inside the organization block. For building management tools, the interventions of the left block are aimed at everything in the organization, including the decision maker and the tools of interest. The performance criteria of the right block for this view are organizational performance, a synergistic combination of operational, personal, and tool performance.

You'll view the nine using-management-tool functions from inside the organization and, as in the case for building tools, see the functions as being inside the organization block. For using management tools, the interventions of

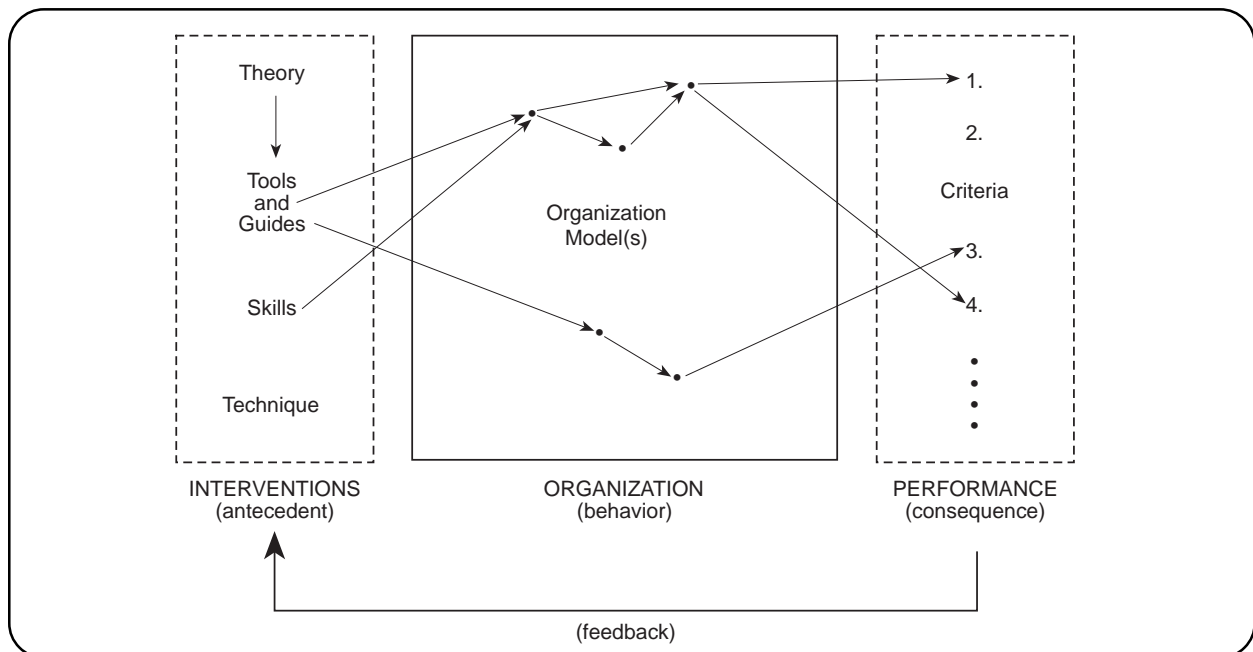
the left block are aimed at the physical operation (capital, labor, equipment, materials), not including the decision maker and the management tools. The performance criteria of the right block for this view are operational performance criteria.

Figure 1.1.11.4. is the fundamental system or input/output model, where the input is interventions (not capital, labor, equipment, or materials) and the output is data and information (not capital, labor, equipment, or materials). The left block for interventions has been expanded to show that theory, tools and their guides, rules for using the tools, skill for using the tools, and technique for putting theory, tools, and skill together are the interventions we'll apply to the organization. The arrows from the interventions show that the tool and skill we apply affect the organization in different ways in different places. The effect of the intervention can have a rippling effect in the organization. The intervention can affect one part of the organization, which, in turn, can affect another part of the organization. The arrows from the organization to the perfor-

mance criteria show that effects on the organization will affect the performance of the organization, which is the objective of making the intervention. Later, I'll discuss a number of different sets of performance criteria. For now, the figure just shows the criteria as numbers.

In Figure 1.1.11.4. we should consider interventions to be decisions and actions affecting the organization. The performance criteria start as indicators, reference points, and standards. To accomplish the feedback, we'll need to measure the indicators to yield data and information for decision making. Note that the cycling of decisions, actions, and information as shown in Forrester's model in Figure 1.1.11.2. is preserved in this figure.

The cycling replicates the psychologist's ABC (antecedent, behavior, and consequence) model. This consistency reinforces the working of the management process framework. The organization model(s) embody the functions of the management process and the behavior of the organization.



**Figure 1.1.11.4.** The management process framework is a traditional system or input/output model with interventions as input and data on performance as output. The manager converts the data and information into improved interventions for the organization. Depending on viewpoint, the manager/decision maker can be the builder or the user of the tools and guides.

### 1.1.11.5. DEFINE SYSTEM

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**The organization is a system involving one or more processes for changing input into output, resulting in throughput, with all components working toward a common aim and with performance measures to determine progress toward the aim.**

Systems understanding is a way of thinking, involving the closely related but subtly different concepts of a system, a process, and the systems approach. In management systems engineering, we're looking at the organization as a system. I'll define a system here and flesh out the systems understanding in later modules when I discuss a process and the systems approach.

In their book, *Systems Engineering and Analysis*, Blanchard and Fabrycky define systems. "A *system* is an assemblage or combination of elements or parts forming a complex or unitary whole such as a river system or a transportation system; any assemblage or set of correlated members such as a system of currency; an ordered and comprehensive assemblage of facts, principles, or doctrines in a particular field of knowledge or thought, such as a system of philosophy; a coordinated body of methods or a complex scheme or plan of procedure, such as a system of organization and management; any regular or special method or plan of procedure, such as a system of marking, numbering, or measuring. (This definition was adapted from J. Stein, ed., *The Random House Dictionary of the English Language*, New York: Random House, Inc., 1966.) Not every set of items, facts, methods, or procedures is a system. A random group of items lying on a table would constitute a set with definite relationships between the items, but they would not qualify as a system because of the absence of unity, functional relationship, and useful purpose." (Benjamin S. Blanchard and Wolter J. Fabrycky, *Systems Engineering and Analysis*, Prentice-Hall, Inc.,

1990, p. 2.) The inclusion of purpose is especially applicable for systems made by people. Experts debate whether natural systems are purposeful.

Blanchard and Fabrycky describe the elements of a system. "Systems are composed of components, attributes, and relationships. These are described as follows:

1. *Components* are the operating parts of a system consisting of input, process, and output. Each system component may assume a variety of values to describe a system state as set by control action and one or more restrictions. [I prefer *represented by* to *consisting of* in the definition of components.]
2. *Attributes* are the properties or discernible manifestations of the components of a system. These attributes characterize the parameters of a system.
3. *Relationships* are the links between components and attributes.

A system is a set of interrelated components working together toward some common objective. The set of components has the following properties:

1. The properties and behavior of each component of the set has an effect on the properties and behavior of the set as a whole.
2. The properties and behavior of each component of the set depends upon the properties and behavior of at least one other component in the set.

3. Each possible subset of components has the two properties listed above; the components cannot be divided into independent subsets.

The properties given above ensure that the set of components comprising a system always has some characteristic or behavior pattern that cannot be exhibited by any of its subsets. A system is more than the sum of its component parts. However, the components of a system may themselves be systems, and every system may be part of a larger system in a hierarchy.” (pp. 3-4.)

Figure 1.1.11.5. illustrates a system. You can see the general form for Figures 1.1.11.1. and 1.1.11.4. in this figure. The previous figures had specified inputs and outputs. In Figure 1.1.11.5., you see the system as a box acting as a transfer function from the inputs to the outputs. Within the system, you see three subsystems, or components, depending on your perspective. Each of the subsystems has inputs and outputs and with a defined purpose meets the definition of a system. The relationships are the arrows and the only defined attribute of the components in the figure is their number. If they had color, size, age, or responsible person defined for them, those would also be attributes.

For organizations, we often characterize the inputs and outputs as CLEM, for capital, labor, equipment, and materials. Some people add information and energy as inputs and outputs. Because of our interest in management tools, we’ll focus on information within the system, so we’ll handle that particular input with care. For example, we’ll distinguish between information generated internal and external to the organization.

Blanchard and Fabrycky also talk about purpose, function, and hierarchy of systems. “The objective or purpose of a system must be explicitly defined and understood so that sys-

tem components may provide the desired output for each given set of inputs. Once defined, the objective or purpose makes it possible to establish a measure of effectiveness indicating how well the system performs. Establishing the purpose of a man-made system and defining its measure of effectiveness is often a most challenging task.

The purposeful action performed by a system is its *function*. A common system function is that of altering material, energy, or information. This alteration embraces input, process, and output. Some examples are the materials processing in a manufacturing system or a digestive system, the conversion of coal to electricity in a power plant system, and the information processing in a computer system. ....

Every system is made up of *components*, and yet any of the components can be broken down into smaller components. If two hierarchical levels are involved in a given system, the lower is conveniently called a *subsystem*. For example, in an air transportation system, the aircraft, terminals, ground support equipment, and controls are subsystems. Equipment items, people, and information are components. Clearly, the designations of system, subsystem, and component are relative, since the system at one level in the hierarchy is the component at another.

In any particular situation it is important to define the system under consideration by specifying its limits or boundaries. Everything that remains outside the boundaries of the system is considered to be the *environment*. However, no system is completely isolated from its environment. Material, energy, and/or information must often pass through the boundaries as input to the system. In reverse, material, energy, and/or information that passes from the system to the environment is called *output*. That which enters the system in one form and leaves the system in another form is usually

called *throughput*.” (pp. 4-5.)

When dealing with continuous performance improvement in organizations, W. Edwards Deming treats the organization as a system. He says, “A system is an interconnected complex of functionally related components that work together to try to accomplish the aim of the system.

A system must have an aim. Without an aim, there is no system. The aim of the system must be clear to everyone in the system. The aim is a plan for the future. The aim is a value judgment. [Of course, I consider an organization to be a system made by people.]

There will be a conflict of interests in setting the aim of a system. The buyer of an automobile seeks low cost, safety, economy of operation, comfort, room, speed, style. There must be judicious compromises in settling on the aims of the system that consists of the maker of the automobile, his suppliers, the customer that buys the automobile, regulations of speed and traffic signals.

Every living being has two aims. Does the tiger [have] an aim? Yes. He has two aims: 1. the good life for today; 2. propagate—ensure that there will be tigers in the future. He is accordingly a component in a system. In fact, he is the only component, if we think of only the tiger. If we think of tigers as one member of wildlife, then he belongs to a larger system. With human intelligence, might translate into English his aim for the good life today:

1. To become a great hearth-rug.
2. To stabilize the number of deer in the forest.
3. To stabilize the number of inhabitants of the village.

Is your organization a system? A company or other organization may have buildings, desks,

equipment, people, water, telephones, electricity, gas, municipal services. But is it a system? In other words, is there an aim?

With some companies, because of short-term thinking, the only aim is survival for the day, with no thought about the future. They fall short of the aims of the tiger.” (pp. 35-37, handout from *Dr. Deming’s Plan for Action for the Optimization of Service Organizations*, May 1992, Washington, D.C.)

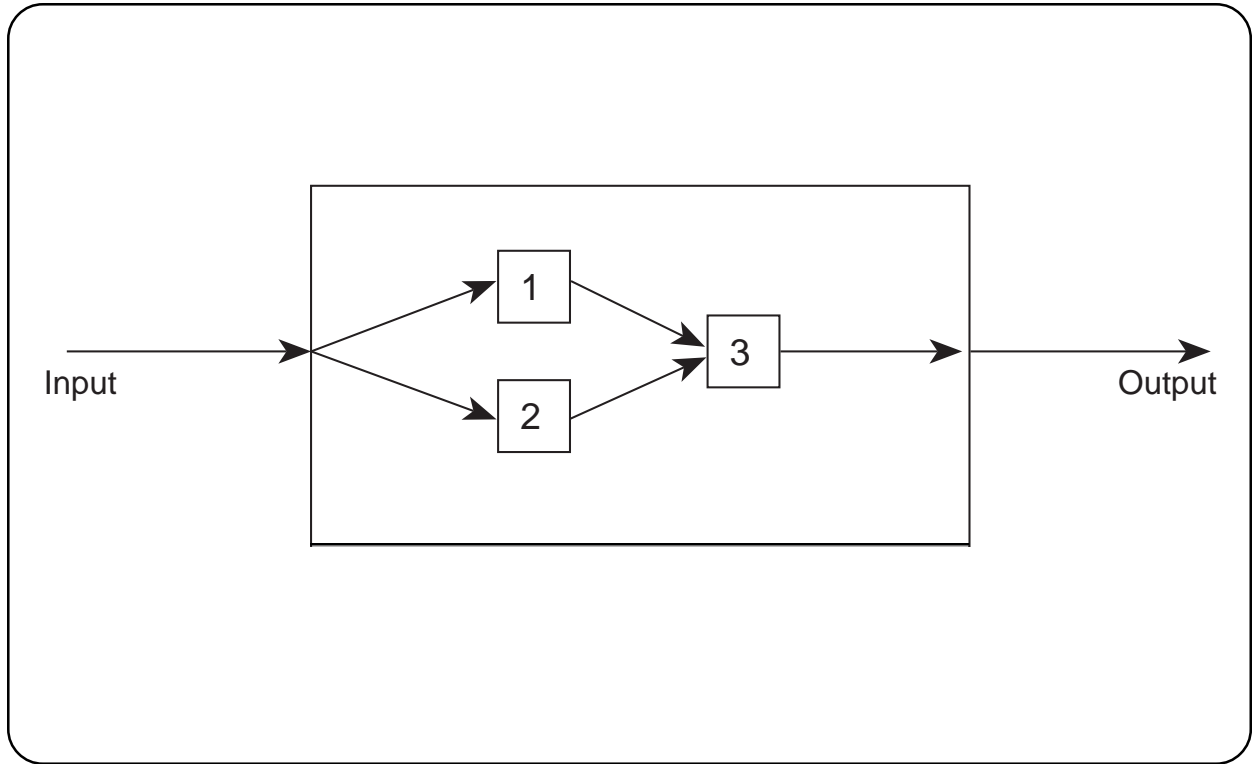
Deming also says, “A system must be managed. The bigger the system, the more difficult it is to manage it for optimization.

The performance of any component within a system is to be judged in terms of its contribution to the aim of the system, not for its individual production or profit, not for any other competitive measure.” (p. viii, Deming’s foreword in Sherkenbach’s *Deming’s road to Continual Improvement*.)

In discussing systems, components, and optimization Deming says, “If the parts are optimized, the system will not be. If the system is optimized, the parts will not be.” (notes from *Instituting Dr. Deming’s Methods for Management of Productivity and Quality*, January 1992.) This idea of optimization has profound effects on how to manage an organization as a system.

In this book, we’re going to look at the organization as a system, with its components, attributes, relationships and subsystems. We’re also going to look at the organization with the systems approach, including process, purpose, and models.

The definition of a system isn’t all there is to understanding systems. I’ll round out (add to) our understanding of systems later when I discuss the complementary notions of the systems approach and a process.



**Figure 1.1.11.5.** *A system converts input into output and contains subsystems or components with attributes and relationships. The aim of the system is hard to show in a diagram, but the aim is important too, especially for a system made by people.*



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# **1. BACKGROUND**

## **1.1. INTRODUCTION**

### **1.1.11. A NEW (OLD) DISCIPLINE**

#### **1.1.11.6. RELATE ENGINEERING TO THE ENGINEERING PROCESS**

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### 1.1.11.6.1. DEFINE *ENGINEERING*

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**Engineering is a profession involving people who profess the engineering process for analyzing, designing, implementing, and following-up applications for the benefit of people based on natural laws and structured procedures for collecting, converting, and conserving energy.**

Engineering is a profession. Engineering also defines a process based on using natural laws to create, understand, describe, and be responsible for application-oriented products and services from which people derive benefit. Someone in the engineering profession should be able to engineer something. We need to distinguish between the profession and the process at least to the point we can determine if those people we know in the engineering profession are in fact practicing the engineering process. Simply stated, someone in the engineering profession has a degree in engineering or is certified as an engineer. An important question is whether or not the person is good at the engineering process.

Engineering is providing a new solution while science provides more insight into the world. Science deals with discovery and engineering deals with creation of solutions for applications.

All engineers deal with energy or its related variables—force, power, and work. For electrical engineers, it's electrical energy. For mechanical engineers, it's mechanical or thermal energy. For chemical engineers, it's thermal or chemical energy. For management systems engineers, it's motivational or human energy. As a result, we can consider forces on an organization, power within an organization, and work of an organization. As engineers, we understand the natural laws so we effectively collect, convert, and conserve energy.

Descriptions of engineering include derivatives from ingenuity to engines. The Random

House Dictionary defines an engineer as, “a person versed in the design, construction, and use of engines or machines, or in any of the various branches of engineering; a person who manages an engine or a locomotive; a skillful manager.” The verb is “to arrange, manage, or carry through by skillful or artful contrivance.” Webster's Ninth New Collegiate Dictionary adds, “to guide the course of.”

The action of engineering implies a process for doing that action. We would assume anyone in the engineering profession to be proficient at the engineering process. But this isn't always the case. For this reason, I've separated my discussion of engineering (the profession) from the engineering process. I'll discuss the engineering process in Modules 1.1.11.6.3. and 1.1.11.6.4.

Figure 1.1.11.6.1. extends the ideas from Figure 1.1.9.2. In Figure 1.1.11.6.1., I've expanded the representation of the application system, because I believe the engineer focuses on the application he or she intends to benefit people. I believe the engineer focuses on the application system to the detriment of the engineering process. I believe the benefit to the application system would be greater if the engineer put more energy into the engineering process. If the application system is a mechanical system, the natural laws and science are most likely those of physical science. If we expand the mechanical system to include its environment or the people involved in building or operating the system, the natural laws and science include the life or social sciences. The human-made system has an aim related to meeting the needs of the user. In Figure

1.1.11.6.1., I've shown a process associated with the application system. The process brings steps or functions containing components, parts, tools, and guides to work together to meet the system's aim. (The dotted lines for boxes representing some of the steps signify that not all processes are cyclic; but the best ones are.) I'll further expand Figure 1.1.11.6.1. in Module 1.1.11.6.3.

To describe engineering, I'll start with definitions and statements from a standard engineering fundamentals textbook: Arvid R. Eide, Roland D. Jenison, Lane H. Mashaw, and Larry L. Northup, *Engineering Fundamentals and Problem Solving*, McGraw-Hill Book Company, 1979. They say, "In the 1963 Annual Report of ECPD, the following definition of engineering appears.

*Engineering is the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice, is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind.*

In the National Council of Engineering Examiners' Model Law, the following statement is found.

*Engineer shall mean a person who, by reason of his special knowledge and use of mathematical, physical, and engineering sciences and the principles and methods of engineering analysis and design, acquired by education and experience, is qualified to practice engineering.* [The problem with this definition is that it's circular. As such, we don't learn what engineering is all about from it.]

Both the engineer and scientist are thoroughly educated in the mathematical and physical sciences, but the scientist primarily uses this knowledge to acquire new knowledge, whereas the engineer *applies* the knowledge to design and develop *usable devices, structures, and*

*processes.* (italics added) In other words, the scientist seeks to know, the engineer aims to do." (pp. 6-7.)

Definitions of engineering always stress the application orientation of the profession and the aim to benefit humankind. They also always stress the practice of design. The focus of this book on management systems engineering is on the design and development and the implementation of management tools and processes to benefit organizations and decision makers.

Eide et al further say, "You might conclude that the engineer is totally dependent on the scientist for the knowledge to develop ideas for human benefit. Such is not always the case. Scientists learn a great deal from the work of engineers. For example, the science of thermodynamics was developed by a physicist from studies of practical steam engines built by engineers who had no science to guide them. On the other hand, engineers have applied the principles of nuclear fission discovered by scientists to develop nuclear power plants and numerous other devices and systems requiring nuclear reactions for their operation. The scientist's and engineer's functions frequently overlap, leading at times to a somewhat blurred image of the engineer. What distinguishes the engineer from the scientist in broad terms, however, is that the engineer often conducts research, but with a definite purpose in mind." (p. 7.)

Disciplines and professions are based on fundamentals. Fundamentals are the ideas, principles, and vision of the discipline. I believe the fundamentals of engineering relate to the engineering process. I'll describe the engineering process fundamentals in Module 1.1.11.6.4. I think the profession doesn't practice the fundamentals of the process very well.

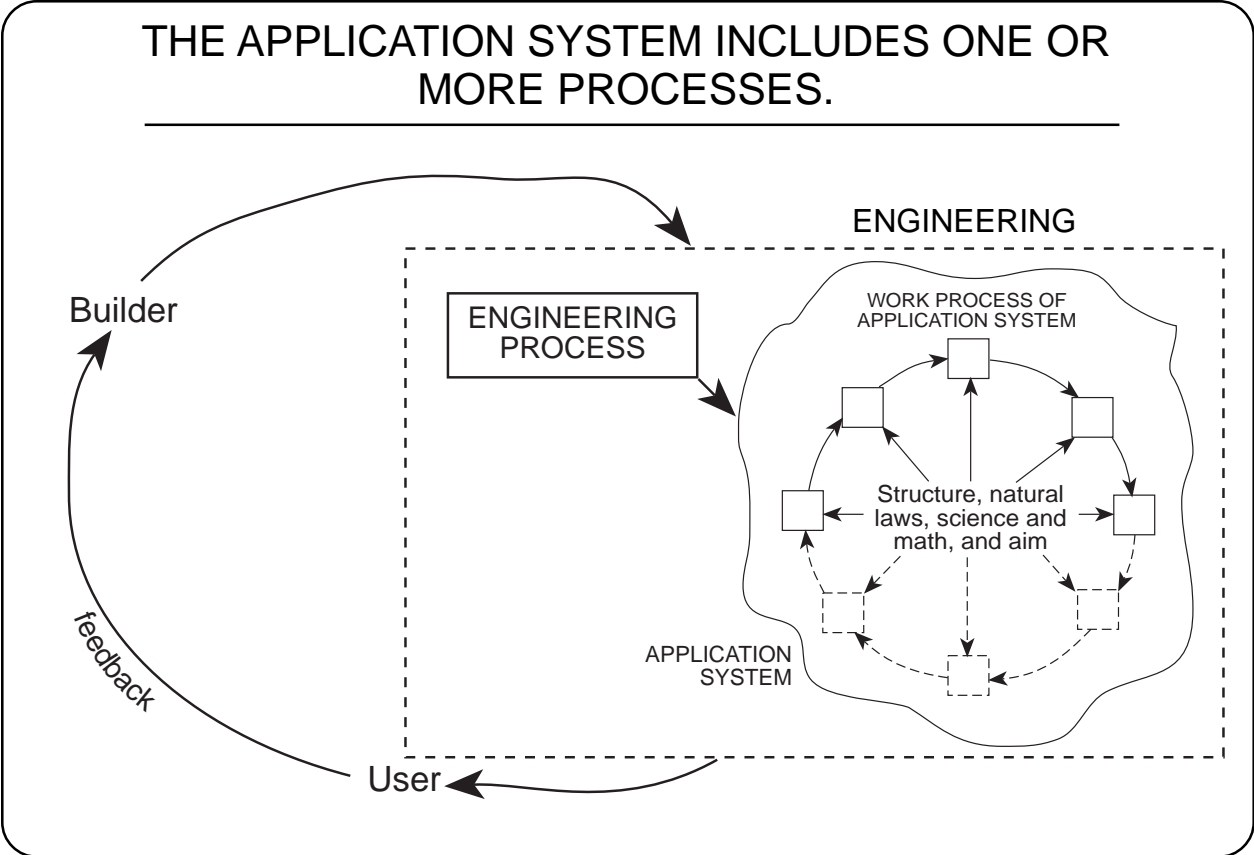
The fundamentals and the need for dealing with energy are generally similar but specifi-

cally different among a nuclear reactor, an automobile assembly plant, and an insurance company. The fundamentals, structure, natural laws, science and math, and aim you need to learn are those of the domain, or the application system. In a petroleum refinery, you need chemistry and physics. In a controller's office you need finance, psychology, and sociology.

The technical specialization and the application characteristics of the traditional image of an engineer can be constraining to people who want to practice engineering. This constraint is highlighted in a paper by Frederick Nils Bennett, when he discusses what he calls the engineering career trap and says, "Engineering is an honourable, and for some, fully satisfying profession, but for others it can be a career trap. I have often found engineers without other strings to their bow to be in the position of the 'expert' on tap, but not on top. To fulfill their potential or to satisfy their

ambition many engineers will have to go beyond engineering into management or administration. To climb to the top of the business or government ladder they will find it necessary to make the transition to management and management is a multi-disciplinary activity; no task for a 'Johnny One Note' engineer.

'That is no problem' you may say. There are any number of engineers who have successfully made the transition to management of large business enterprises and government agencies. It is true that some gifted and highly motivated persons succeed in that way but for every one of those there are a dozen more trapped in their specialization, frustrated that their advice is not accepted, and complaining bitterly that in their field of work important decisions are controlled by the dreaded 'bean counters'." (Frederick Nils Bennett, "Beyond Engineering", *The Australian Project Manager*, vol. 12, no. 1, February/March 1992.)



**Figure 1.1.11.6.1.** *The engineer focuses on the application system distinguishable by its structure, aim, and the natural laws, science, and math needed to understand cause and effect within the application.*

### 1.1.11.6.2. THE CENTRALITY OF DESIGN

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**At the centers of both the engineering process and the decision making process, the design process is a cyclic, recursive process based on the scientific method allowing for learning and continuous improvement.**

Many engineers believe the end result of their effort is design—both the process and the product. However, engineers do much more. First, if there is an end result, I believe the result must involve the satisfaction of the user’s need. Second, if the engineering process is cyclic and recursive, like the process shown in Figure 1.1.9.1., then design is a step, or function, in the cycle. I will say that design is central to the engineer’s activities. Design is what engineers do. The rest of the functions in a cyclic engineering process, which I’ll describe in Modules 1.1.11.6.3., 1.1.11.6.4., and 1.1.11.7., prepare for design, apply the design, follow up on the application, and learn from the application.

The design process within the engineering process is similar to the decision making process within the management process. Each is central to the other functions in a learning cycle for continuous improvement. Just like engineers do design, managers do decision making. Recall my discussion of the centrality of decision making in management in Module 1.1.11.2. Recall also Simon’s discussion of the centrality of design in the decision making process, also in that module.

Eide et al say, “The end result of an engineering effort—generally referred to as design—is a device, structure, or process which satisfies a need. A successful design is achieved when a logical procedure is followed to meet a specific need. The procedure, called the *design process* (italics added) is similar to the scientific method with respect to a step-by-step routine, but it differs in objectives and end results. The design process encompasses the following ac-

tivities, all of which must be completed.

1. Identification
2. Definition
3. Search
4. Establishment of criteria
5. Consideration of alternatives
6. Analysis
7. Decision
8. Specification
9. Communication

In the majority of cases, designs are not accomplished by an engineer’s simply completing the nine steps shown in the order given. As the designer proceeds through each step, new information may be discovered or new objectives may be specified for the design. If so, the designer must backtrack and repeat steps. For example, if none of the alternatives appear to be economically feasible when the final solution is to be selected, the designer must redefine the problem or possibly relax some of the criteria to admit less expensive alternatives. Thus, because decisions must frequently be made at each step as a result of new developments or unexpected outcomes, the design process becomes iterative.” (pp. 7-8.)

Later, I’ll place the design process within the engineering process. In dealing with systems and processes, we’ll always deal with subsystems and subprocesses. The design process is similar to the engineering and the management processes in the cyclic, recursive nature of the process.

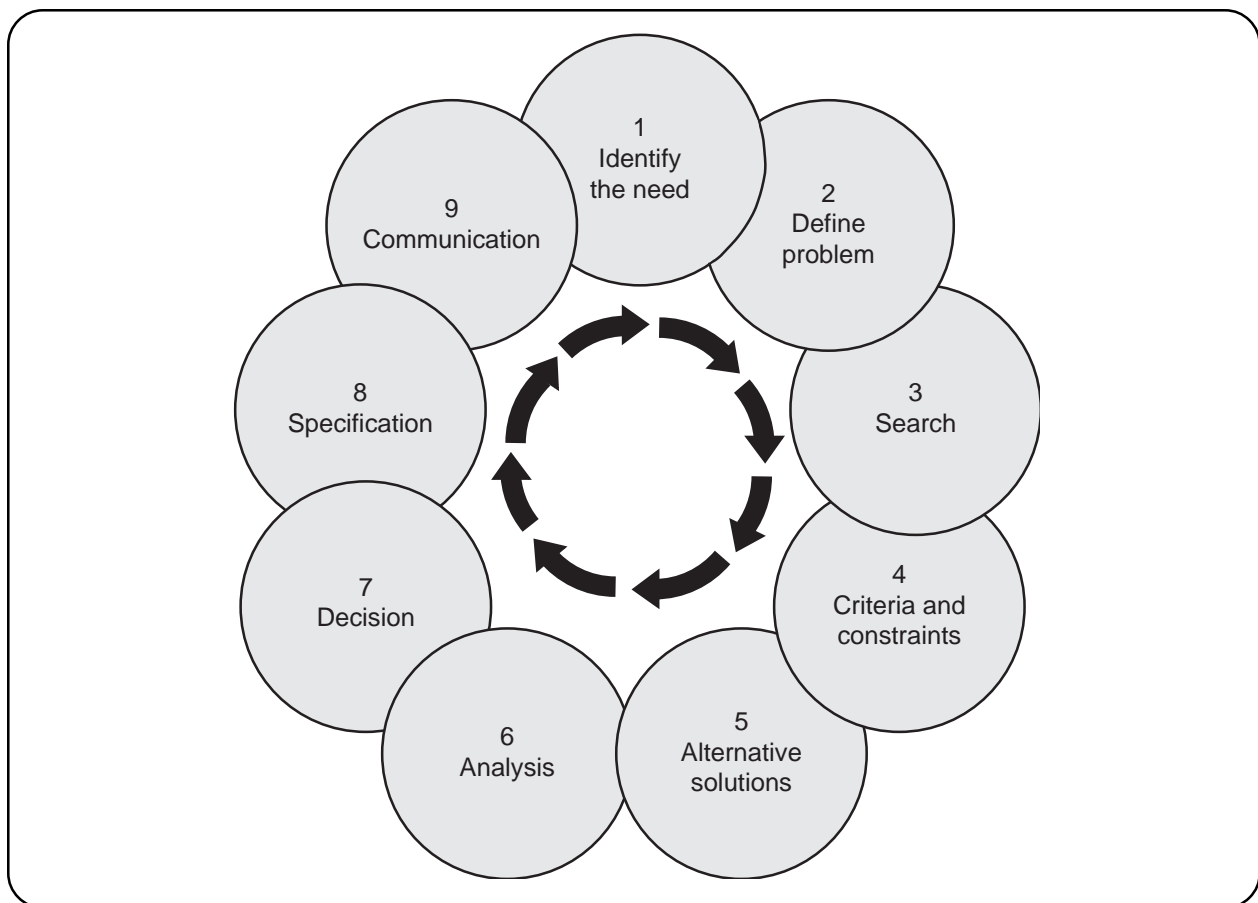
Eide, et al list the functions of an engineer as: research, development, design, production and

testing, construction, operations, sales, management, consulting, and teaching. (p. 17-22.) You'll find some overlap with my functions of the engineering process. However, I consider the engineering process to consist of more than just functions. Also, notice that design is but one function of the engineer.

Eide et al define design and process by saying, "A simple definition of design is: to create according to a plan. A process, on the other hand, is a phenomenon identified through step-by-step changes that lead toward a required result. Both these definitions suggest the idea of an orderly, systematic approach to a desired end. Figure [1.1.11.6.2.] shows the design process as continuous and cyclic in nature.

This idea has validity in that many problems arise during the design process that generate subsequent designs. You should not assume that each of your design experiences will necessarily follow the sequential steps without deviation. Experienced designers will agree that the steps as shown are quite logical; but on many occasions, designers have had to repeat some steps or perhaps have been able to skip one or more." (pp. 326-327.)

I've used Eide et al's figure for the design process here as Figure 1.1.11.6.2. to show the cyclic, iterative nature of the processes in engineering and management. The engineering and management process are similar in that they both relate to the scientific method.



**Figure 1.1.11.6.2.** *The engineer's design process shows the cyclic, iterative nature of processes we use for continuous improvement in meeting a system's aims. (taken from Eide et al)*

### 1.1.11.6.3. THE ENGINEERING PROCESS

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**There's a difference between the engineering profession and the engineering process.  
The same can be said for management and the management process.**

#### **The Engineering Process and the Total Application System**

Engineer is used here as a verb. Engineering is something we do to analyze, design, build, use, improve, and retire systems. All systems should be engineered with a balanced approach. Management systems especially need to be engineered with a balanced approach because the key components of the management system are human beings. To carry out the action of engineering, we can develop and use a generic process—the engineering process—tuned to the type of system we're engineering.

The application system is the object of the verb. We always engineer a system. The question is: What kind of system are we interested in, how does it differ from other systems, and what does the difference mean in terms of natural laws and applicable science (e.g., physical, life, and social sciences)? We must understand what we're working on. What is the unit of interest? That is, what is the system we're going to engineer? We don't want to suboptimize or misoptimize by engineering a part of the system of interest or by engineering some other system than the system of interest.

Management is the adjective telling us the kind of system we intend to engineer. The solution this book proposes for addressing the time-honored, fundamental management questions described in Module 1.1.4. is to recognize and characterize the organization as a management system, or an application system, and to apply the engineering process to that system and to the management tools used in that system. This book proposes manage-

ment systems engineering.

In Figure 1.1.11.6.3., I expand the concept of the application system I showed in Figure 1.1.11.6.1. I've highlighted the difference between the management process and the work process. The work process is what you manage and the management process is what you do to manage. Therefore, the plant components of a chemical process, including capital, labor, equipment, and materials (CLEM) working according to natural laws form functions, or steps, of a chemical process we manage to produce products. I call the work process the core application system, because I'll argue later that we want to apply the engineering process to more than just the work process. We want to apply the engineering process to the management process too. So, I've shown the management process acting on the work process, or the management process acting on the core application system, all comprising the total application system. The point of Figure 1.1.11.6.3. is that to do the engineering process right we must apply that process to the entire system we're trying to benefit—the total application system.

Note the following considerations from Figure 1.1.11.6.3. 1) You'll have systems within systems. 2) The core application system specifies the structure, natural laws, science and math, and aim of the object of the engineering process. 3) The example chemical system has one or more chemical processes and, like other systems in other disciplines, can, and should, include environmental system processes. 4) The example chemical system is a component of a management system, which has a management process. 5) You apply the engineering

process to the core application system or the management process, depending on the unit of interest. I'll discuss the importance of the unit of interest in Module 1.1.14.3.

The engineering process aims to convert matter and energy guided by fundamentals and governing natural laws into beneficial orientations within the application system to serve a user by supporting, joining with, and assuming the nature of the application system.

Just as the chemical process includes a number of operations, which we can neatly categorize into functions, the management and engineering processes also include functions. Learning the functions of a process is a necessary but not sufficient condition for becoming good at the process. To complete our understanding of these processes, we must learn about ways of thinking, like the systems approach, and we must learn the rules for conducting the functions. Processes include functions and rules guiding the functions and a way of thinking oriented to the aim of the process.

The functions of the management process involve both management tools and the guides for using the management tools. The work process, or the physical operation you manage, also includes tools: operations tools. What we do in the management and engineering processes is supported by tools. The rules and the functions, embodying the tools and guides, are conducive to steps of a process, the most effective of which are cyclic, recursive steps to promote learning and improvement. You'll find both the engineering and management processes involve cyclic, recursive steps. Figure 1.1.9.1 illustrates the cyclic nature of the management and engineering processes that is so important for learning and continuous performance improvement. Sequences of steps are relatively easy to visualize and draw and to scrutinize for repeatability, completeness, and validity. The rules and approaches that em-

body or overlay the functions aren't as easy to visualize, and take dwell time to absorb as part of our understanding.

My job in this book is to include an understanding of both the engineering and management processes, their functions, rules, and their ways of thinking. In management systems engineering, you don't first do a management process and then an engineering process, or vice versa; the functions and approaches of both are intertwined. Therefore, I'll disclose the functions and approaches of the management and engineering processes in the sequence I feel best supports learning management systems engineering.

### **The Difference between The Engineering Profession and the Engineering Process**

I claim there's a difference between the engineering process and the engineering profession (and a difference between the management process and the management profession). Many people not in the engineering profession practice the engineering process very well and many people in the engineering profession don't practice the engineering process very well. Of course, I feel this situation is unfortunate. Engineers ought to be very good at the engineering process.

Lou Middleman, the author of the writing text, *In Short*, likes to tell the story that one time I told him he was an engineer. When he tells the story, he feels he needs to explain why I would call a person with degrees in math and English an engineer. He says, "Harold thinks anything dealing with engineering is good. He likes me and thinks I do good work. Therefore, he calls me an engineer." The truth is: Lou Middleman practices the engineering process but he isn't part of the engineering profession.

Some of the people who are best at the engineering process are physicists. I feel the reason they're so good at the engineering process

is because they understand the laws of nature in their gut. They really learned sophomore physics. As a consequence they could walk through a plant and smell out the relationships and consequences of the many laws and principles intertwined at play in the workings of the plant. They could design, build, and follow-up with tools and equipment based on the principles to meet the needs of the plant. They practice the engineering process but aren't part of the engineering profession.

A good engineer, and also a good manager, must be able to walk the workplace and see how natural laws work together to get the best performance from the application system. This engineer or manager must understand cause and effect among all the system's parts and between the parts and the whole. Understanding cause and effect requires profound knowledge.

I believe there are sociologists, psychologists, and teachers who can walk through an organization and smell out the relationships and consequences of the many intertwined laws and principles at play in the human-oriented workings of the organization. When they apply these principles through the scientific method to the design, implementation, and follow-up of improvements in the organization within the context of the systems approach, they're practicing the engineering process.

I had a dentist who practiced the engineering process. I've known artists, clergy, physicians, and farmers who practiced the engineering process. In my heart, I believe the engineering process is more important than the engineering profession. I would like for this book to contribute to making the engineering process more a part of the engineering profession and to convince engineers they can learn and practice the engineering process in cooperation with people of different educational

and certification backgrounds.

In the engineering process we holistically mix (balance) the system life cycle functions guided by the systems approach. The systems approach is based on a deep-rooted understanding for and appreciation of the laws of nature (both science and environment) under the objective of making application for the benefit of people. We consider the application throughout its life cycle.

The problems we address in the world are complex combinations of many factors. We can identify a number of good solutions to the problem. Because of the complexity of the problem, finding the very best solution is difficult if not impossible. In practicing the engineering process, we know the balance for choosing one of the short list of good solutions and for searching for the best solution. Often, we can use a good solution and solve a problem for less time and energy than we would spend finding the best solution.

Who has an understanding of and appreciation for the laws of nature? Under the risk of generalizing, I'll argue I've met three groups who excel at the laws of nature. First, the indigenous people, and then physicists and farmers.

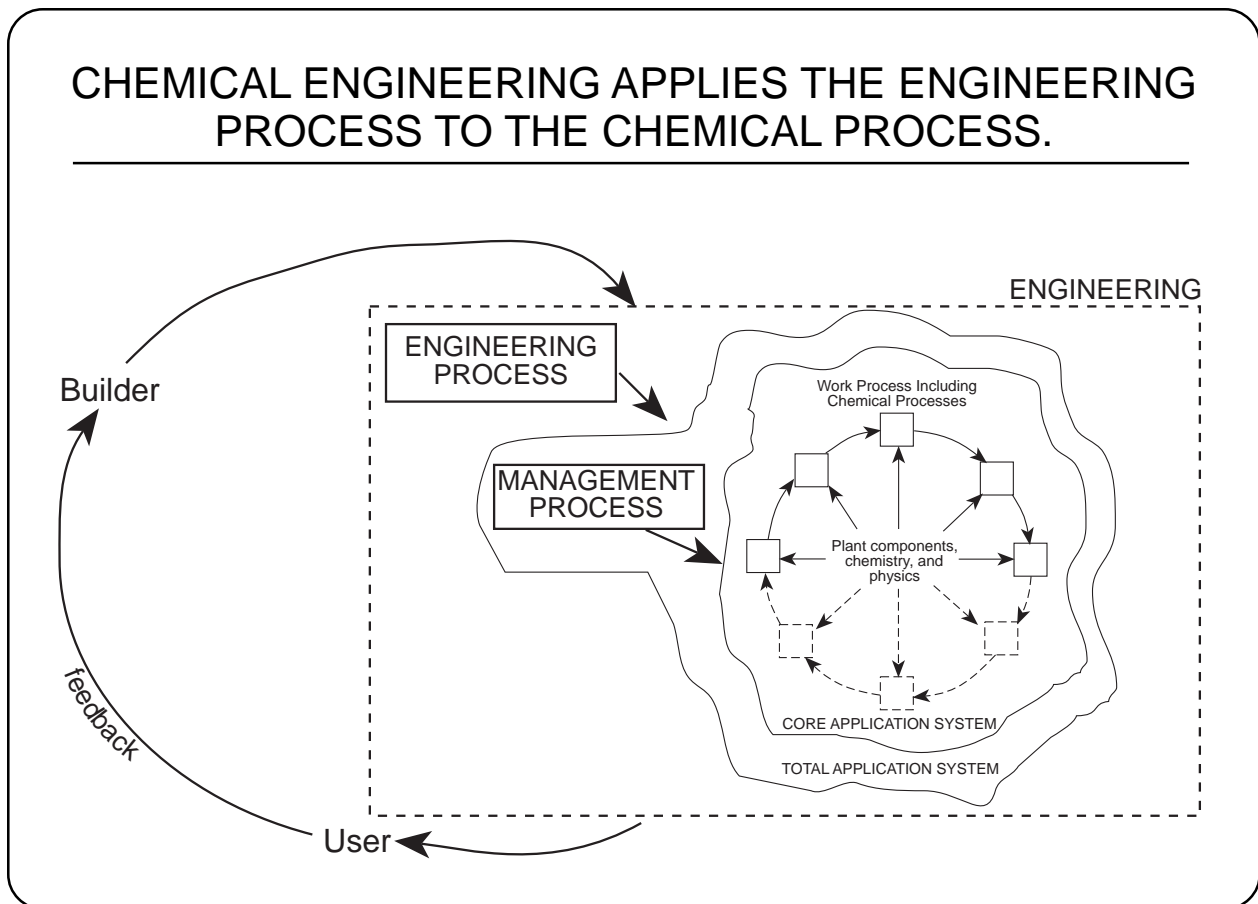
I'm learning of the artists from Leonardo to Cézanne to my oil painting teacher who understand that before you can paint a tree well you must know how a tree works and how and why trees differ among species, during seasons of the year, during their life cycle, what grows in and on them, and so on. To paint a building, bridge, automobile, or person, you have to have the same depth of understanding of the laws of nature applying to what you're painting. Now we know why artists like Rembrandt, Leonardo, Durer, and Michelangelo studied and painted cadavers—so they could learn the workings of the human body and paint live people.

### Apply the Engineering Process Properly to the Right Thing

I discuss the domain of responsibility as a management consideration and the unit of interest, or application system, as an engineering consideration. They're really similar issues. Both are intended to ensure you focus on the system, subsystem, or component you're responsible for. You don't want to work on the wrong thing.

Understanding the aim of the application system and how all the components of the system

fit together to serve the whole and the cyclic, recursive relationship of all the functions in the engineering and management processes are prerequisites for applying tools and techniques effectively and efficiently. If you don't know the fundamentals of the engineering process, the structure, natural laws, science and math, and aim of the core application system; and the fundamentals of the management process, you'll confuse techniques with principles and not use the technique based on a principle that reflects the needs of the user.



**Figure 1.1.11.6.3.** We must apply the engineering process to the total application system we're working to benefit, comprising both the work process, or core application system, and the management process that overlays the work process.

#### 1.1.11.6.4. FUNDAMENTALS OF THE ENGINEERING PROCESS

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**You must know and practice the fundamentals first, most, and best to practice the engineering process because the fundamentals are the threads that weave throughout the fabric of the engineering process.**

Webster defines a fundamental as, “one of the minimum constituents without which a thing or a system would not be what it is; serving as a basis supporting existence or determining essential structure or function.” (Webster’s Ninth Collegiate Dictionary) The Random House College Dictionary adds, “a basic principle, rule, law, or the like, that serves as the groundwork of a system; essential part.” The fundamentals of the engineering process are the building blocks, without which we wouldn’t have the engineering process. We can’t practice engineering without understanding the fundamentals of the engineering process.

One way to characterize engineering is through its fundamentals. We use the fundamentals to understand specialties we synthesize through the design process. We use the fundamental of an energy balance to understand thermodynamics we synthesize with mechanics and other specialties into the design of a steam engine.

What are the fundamentals of the engineering process? Or, what knowledge and skills do you need to practice the engineering process? I list twelve: 1) language for communication, 2) problem solving and the scientific method, 3) drawing and understanding connections, 4) the systems approach as a way of thinking, 5) walking the workplace (application system), 6) the system life cycle as the framework of the engineering process, 7) envisioning and imagination, 8) the collecting, converting, and conserving of energy, 9) knowledge of the lessons of the past, 10) the philosophy of the aims of the engineering process and the application system, 11) teamwork, professionalism, and

empowerment, and 12) dedication to continuous, vigorous, life-long learning. I’ll expand on each of the fundamentals in the following paragraphs.

##### **Language for Communication**

We learn language through mathematics and English (I’ll include art as a language for us in this book.) We also learn graphics (engineering drawing) and computer languages for communication. Language is a system we use in conjunction with the process of communication, whose aim is the transfer of information. Language is the system by which you capture ideas and information and transfer the ideas and information to others.

Because you’re applying natural laws for the benefit of humans and their environment, you must understand language for communication. Engineering is the link between the builder and the user as shown in Figure 1.1.6.2. And the user must provide feedback to the builder for evaluation and improvement of the application system. The engineering process, which is crucial to the practice of engineering as shown in Figure 1.1.11.6.1., requires a cycle, and the cycle requires communication. You must be able to communicate using mathematics and models, graphics and other visual displays, computer programming, and verbal sending (writing and speaking) and receiving (reading and listening). This thread is the largest (We spend the most time on it.) and most tightly interwoven of all threads in the fabric.

In communication, you must be able to “write it down and write it up.” When you use words

(text) or symbols (math) to think through a situation, you're "writing it down." When you use words or symbols to communicate a situation, you're "writing it up." Because they have different purposes, "writing it down" and "writing it up" are quite different activities. "Writing it down" takes a good deal of "scaffolding" to set up and hold up ideas until you get the kernel built. When you find and complete the kernel, you must strip away the "scaffolding" before you can communicate what you have ("write it up"). Communication is itself a process. Language is a system we use in conjunction with the process of communication, whose aim is the transferring of information. "Writing it down" is transferring information from the recesses of your mind into some more-tangible form and "writing it up" is transferring information from you to someone else.

### **Problem Solving and the Scientific Method**

Because you're making things better by taking action, you must know how to diagnose and solve a problem, know how to use the scientific method and design experiments, and practice and balance deductive and inductive reasoning (including strong inference). In diagnosing a problem, you have to identify and define the problem. Most "problem solvers" work up elegant solutions to the wrong problem. The user prefers a mediocre solution to the right problem over an elegant solution to the wrong problem. The engineering process requires the ability to focus on the application system and distinguish the problem to be solved. To be this kind of problem solver, you must have a responsible attitude, be open minded, and have an open and honest approach. The Arizona State report on engineering education plays on Peter Drucker's distinction between effectiveness and efficiency by saying "engineering undergraduate curricula prepare engineers to deal almost exclusively with [the question 'Are we designing the thing right?'] while seriously neglecting [the question 'Are we designing the right

thing?']" (*Engineering Education: Preparing for the Next Decade*, A Study by The Engineering Curriculum Task Force, p. 47.).

### **Drawing and Understanding Connections**

Through connections you can integrate and synthesize. The ability to consider technical, social, economic, environmental, and many other aspects of a problem is valuable. To see relationships and decipher cause-and-effect relationships among the aspects is even more valuable. Most valuable is to be able to connect components or ideas at an even deeper level. In her book *Leadership and the New Science*, Margaret Wheatley tries to shift our focus from things toward connections and systems. "Donella Meadows, a systems thinker, quotes Sufi teaching that captures this shift in focus: 'You think because you understand *one* you must understand *two*, because one and one makes two. But you must also understand *and*' (1982, 23). When we view systems from this perspective, we enter an entirely new landscape of connections, of phenomena that cannot be reduced to simple cause and effect, and of the constant flux of dynamic processes." (Margaret J. Wheatley, *Leadership and the New Science: Learning about Organizations from an Orderly Universe*, 1992, Berrett-Koehler Publishers, San Francisco, p. 9.) To be a generalist or think like a generalist, you must start by drawing and understanding connections. (I discuss the generalist perspective in modules 1.1.27.7. and 1.1.27.8.)

In the engineering process you must integrate as well as differentiate. You must synthesize as well as analyze. The systems approach involves both analysis and synthesis, both the Newtonian model of the world and the new holistic view of the world. (See my discussion on the role of integrator in Module 1.1.27.2.).

### **The Systems Approach as a Way of Thinking**

Because all applications are systems, you must know how to think in systems terms, including

the system, holistic, and generalist perspectives. The system perspective emphasizes the components, their relationships, and the necessary role each plays in meeting the system's aim. The holistic perspective emphasizes the gestalt in the system and its aim. The generalist perspective emphasizes consistency among systems and the transferability of lessons learned from one system to another. In practicing the systems approach, the three perspectives are harmoniously blended into one integrated way of looking at the world. With the three perspectives, we recognize the importance of each component, the supremacy of the aim or purpose, and the significance of learning. Under the systems approach, you must perform both analysis and synthesis activities and you must balance synthesis with analysis. (By balance I mean get the right mix, not make equal). The engineer must see the total system and be able to strip out the confusing, non-essential complexity to get to the essence of the situation.

### **Walking the Workplace (Application System)**

Because the application system embodies the aim of the engineering process, you must know the structure (components, attributes, and relationships), natural laws, science and math (physical, life, social, mathematical sciences), and purpose (or aim of the application system) of the application system so well you can "feel" the cause-and-effect relationships of the application processes.

### **The System Life Cycle as the Framework of the Engineering Process**

Because we always engineer a system, the system life cycle is important. Everything is a system with a process. The framework of the engineering process shows the steps, or functions, you must be able to do to carry out the engineering process. The framework is supported by rules and ways of thinking that show how to do the functions. The framework

includes the system life cycle functions and the design process functions. Design is the stage of the system life cycle the other stages support. The closure of the cycle allows the concepts of re-engineering and green engineering in the engineering process. To do the framework functions of the engineering process, you must know project management. Project management is required for application process and for performance improvement. Completion and improvement of the application process and its performance is the reason for the engineering process. You must be able to design an application system or its products and services to perform throughout the system life cycle. You must design the system to operate. You must design the system to manufacture. And you must design the system to decommission, disassemble, decontaminate, restore, and remediate.

### **Envisioning and Imagination**

Because the engineering process requires ingenuity, innovation, and creativity, you must be able to envision and to imagine. When we learn descriptive geometry, we learn to envision. We have to see in our minds what the intersection looks like when we intersect an object with a cone, for example. Suzuki says, "The history of mankind has taught us that if we can imagine it, we can make it." Envisioning and imagination are needed throughout the engineering process.

### **The Collecting, Converting, and Conserving of Energy**

All application systems function by collecting, converting, and conserving some form of energy. Mechanical systems include mechanical and thermal energy. Chemical systems include chemical, mechanical, and thermal energy. Biological systems include these forms of energy. Organizational systems include motivational energy. By viewing energy in its broadest context, no system functions without energy. For example, in the engineering pro-

cess, you have to be able to transfer the idea of entropy and the First Law of Thermodynamics to biological and organizational systems. Consider also that collecting, converting, and conserving energy should be extended to mass, momentum, electrical charge, etc.

### **Knowledge of the Lessons of the Past**

You perform the functions of the engineering process better because of knowledge of lessons of the past. That's why experienced users of the engineering process are better problem solvers. You gain lessons of the past through history, case studies, and anecdotes related to both the engineering process and to the application system. When you learn from history, you understand more than events; you learn societal perspective of the impact of technology and the engineering process and you learn the economic perspective of financial issues related to events. In short you balance technical, societal, and economic perspectives.

### **The Philosophy of the Aims of the Engineering Process and the Application System**

If you don't know the purpose, aim, or meaning of the application system, you can't improve it. You'll most likely work up an elegant solution to the wrong problem. Without the philosophy of the engineering process and the application system you can't diagnose the problem.

### **Teamwork, Professionalism, and Empowerment**

Because the engineering process seldom is an individual activity, you must know and practice teamwork, professionalism, and empowerment. Teamwork carries the need for interpersonal skills and an understanding of group dynamics. A successful team functions as a cooperative community exhibiting team spirit and mutual goals. (See, for example, James A. Autry, *Love and Profit: The Art of Caring Leadership*, Avon Books, 1991, pp. 79-81.)

For success in teams, you must work well with diversity and have a sense of grace, style, and civility. You must feel a genuine caring for and intimacy with the work, the user, nature and its laws, and, most of all, the people involved in the application and its engineering. Caring and intimacy relate to affection for, and trust of, people and nature. You must be able to distinguish and balance cooperation and competition, especially in relation to quality. You must know and practice professional and ethical standards, requiring an understanding of social, ethical, political, and human responsibility. To succeed at these practices, you must display integrity, maturity, judgment, responsibility, and caring.

For teamwork and empowerment, you must be able to confront issues with yourself and others. You must be able to understand and resolve conflict (between one person and another, one workflow and another, or one material and another).

You must achieve balance between your relationship competency and your technical competency. You must exercise passion and intimacy in balance with your competence and integrity.

### **Dedication to Continuous, Vigorous, Lifelong Learning**

Because the engineering process must be cyclic to be successful through continuous performance improvement, you must have a motivation and capability to continue the learning experience on the job and through extracurricular readings, meetings, workshops, and degree programs. The concepts of quality and total quality management enter the engineering process through the cycle of continuous learning and improvement.

### **How Well Do We Know or Teach the Engineering Process?**

If you accept all or part of my twelve funda-

mentals of the engineering process, the question now is whether anyone can do the engineering process without them. Or at least do the process well. Can a person only learn these fundamentals on the job through experience, or can we supply the principles and knowledge behind these fundamentals in college so the learning curve isn't so steep on the job? Consider the fifth fundamental: the framework of the engineering process. I believe we can teach the system life cycle and its 21 functions. I believe we can teach the basics and the tools of project management. Sure, you'll learn these faster on the job; but I remember my embarrassment and frustration when I found a book on project management after I'd spent two years being a project manager and learning the hard way. With the principles and basics in hand before I started, I believe I'd have learned more and faster on the job.

I've listed a series of questions below to test whether we now produce graduates who have any understanding of the engineering process.

- 1) Can he or she envision (for problem solving and for leadership) and imagine (prerequisite for doing)?
- 2) Can he or she communicate—both “write it down” and “write it up?”
- 3) Can he or she do synthesis as well as he or she does analysis?
- 4) Can he or she make connections among things or ideas and see beyond cause and effect?
- 5) Can he or she design for disassembly and clean up as well as he or she designs for assembly (for operation and manufacture)?
- 6) Can he or she practice the systems approach (system—with integration and differentiation, holistic, and generalist thinking)?
- 7) Does he or she understand system concepts like: “If the parts are optimized, the system won't be.”
- 8) Can he or she figure out what problem to solve so he or she solves the right problem?
- 9) Can he or she intelligently select when to go with a good solution rather than putting more time and energy into searching for the best solution?
- 10) Can he or she walk the workplace and understand cause and effect (government offices, banks, hospitals, and insurance companies as well as manufacturing plants and chemical processing plants)?
- 11) Can he or she logically construct an approach to a problem founded on basic principles stemming from the laws of nature in addition to transferring the experience of solving a similar problem to the problem at hand?
- 12) Can he or she manage a project to improve a process or performance?
- 13) Can he or she balance art and science?
- 14) Can he or she figure out the system of interest so he or she doesn't suboptimize or misoptimize the system by engineering the wrong thing?
- 15) Can he or she rapidly switch between working in qualitative modes and quantitative modes?
- 16) Does he or she understand the effect of the management process on the application system, thereby affecting the engineering process (e.g., increasing the amount and rate of change and the diver-

sity of the problems)?

- 17) Does he or she understand, or have the potential to understand, human nature and the beauty and laws of nature?
- 18) Can he or she contribute to a team working as a community, bound by a fellowship of endeavor, committed to goals, and dedicated to the quality of commitment and effort in which people take care of one another?
- 19) Can he or she think and act on an ethically moral level?
- 20) Can he or she see useful purpose in what he or she is doing?
- 21) Can he or she balance lessons of history or experience with theory, innovation, and imagination?
- 22) Does he or she practice standards of ethics and professionalism?
- 23) Does he or she intend to continue learning forever because he or she is excited and enthusiastic to do so?

If we understand and can practice the fundamentals well, we can learn to do well at the engineering process, which requires the integration and synthesis of the fundamentals. I'll argue that the same twelve fundamentals are the ones for the management process, although the techniques might be different. Instead of converting mechanical or electrical energy, supervisors convert human energy in the form of motivation. Supervisors see human energy dissipate from friction in the form of conflict. The fundamentals are the same and the processes are similar. However the functions and the application systems are different. When we learn the fundamentals and the application system and their sameness for engineering and management and when we learn the functions of the engineering process and of the manage-

ment process, we'll be able to fulfill our potential or satisfy our ambition as engineers, managers, or management systems engineers.

The twelve fundamentals and associated skills are diffuse and are best suited to teach throughout the curriculum, starting with freshmen. Possible exceptions to this diffuseness include project management skills, which can be taught as a course as well as throughout the curriculum. In either case, the relationships among and the principles behind the project management tools as they work in a complete project management process are more important than training the use of specific tools. When the skills for the twelve fundamentals are taught, they're spot taught and students forget them after a semester or two because they're not reinforced throughout the curriculum. People learn them better on the job because the organizational culture reinforces them. To teach the engineering process, we must overcome compartmentalized learning.

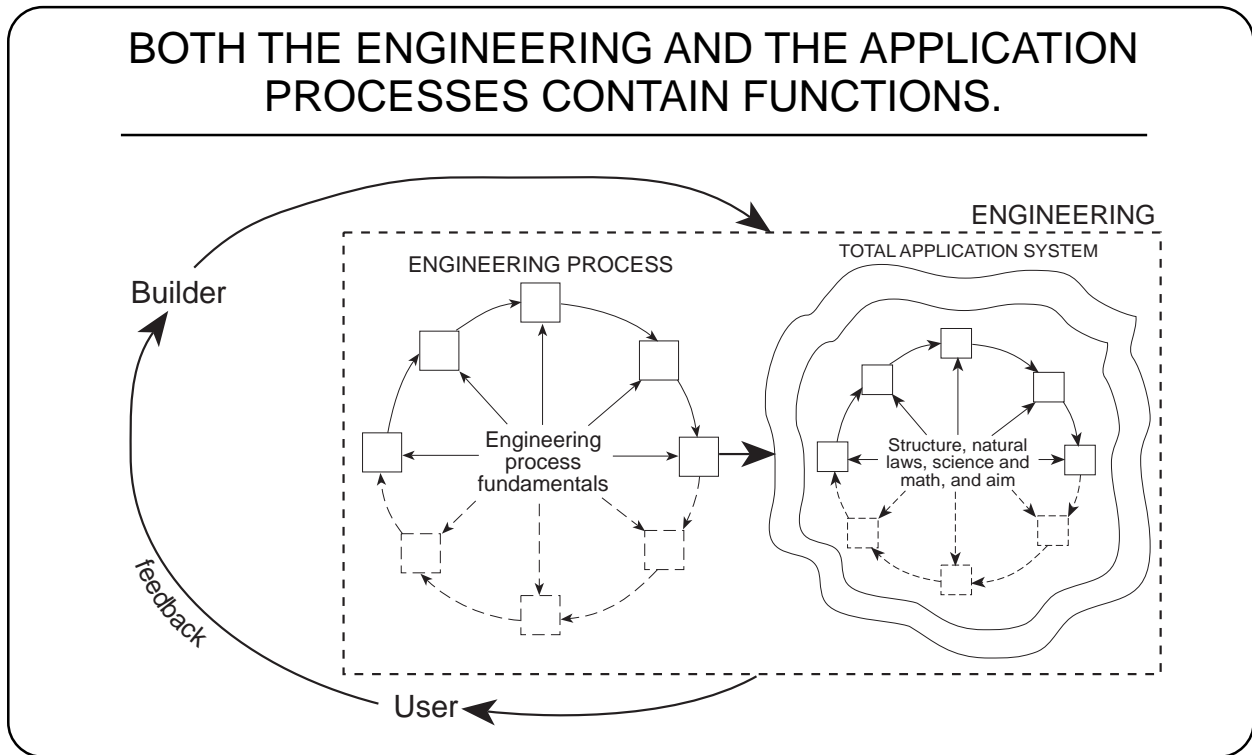
The fundamentals of the engineering process are the roots of the tree. We use the roots for stability and sustenance. If we build a good root system, the tree will bear fruit. The engineering process can be applied to any application system. Instead of concentrating only on the core application system, graduates will be stronger and more productive if they understand the engineering process fundamentals.

Where do you see the fundamentals of the engineering process practiced? If you answer activities like scouting, the hospitality industry, school systems, and other practices considered to be outside the engineering profession, you can see how much we have to learn from others about our discipline.

Figure 1.1.11.6.4. extends Figure 1.1.11.6.3. by showing the engineering process as a cycle of functions, all being driven by the engineering process fundamentals. By applying the engineering process through its fundamentals

to the total application system, we can engineer either applications of traditional disciplines like chemical and mechanical engineering or the management systems by which we manage the core application systems. In Module 1.1.20.1., I'll describe the 22 functions of

the engineering process as a closed cycle. In Module 1.1.11.7., I'll group the engineering process functions into five categories showing the ability of the engineering process to achieve continuous improvement.



**Figure 1.1.11.6.4.** *Through its fundamentals, we apply the engineering process to the application system to benefit the user. The engineering process, the application process, and the builder-user feedback loop provide for learning and improvement.*



### 1.1.11.6.5. TEACHING AND LEARNING THE ENGINEERING PROCESS AND MANAGEMENT SYSTEMS ENGINEERING

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**Unfortunately, engineers aren't necessarily educated or trained to be good at the engineering process or to understand management systems engineering.**

Given the amount and importance of technology in our daily lives, engineering should be the liberal education of today. But engineering won't be if we teach engineering more as a profession than as a process balancing art and science. I believe a liberal education is one where we prepare a student for the world they'll inherit by instilling a thirst for the learning process and introducing them to a comprehensive understanding of fundamental laws and principles behind people, technical, and economic systems. The world they'll inherit surely includes technology and everything from the refrigerator at home to the computer in the workplace. In engineering we're requiring courses in humanities. The only problem is that we don't show the connection and importance to the engineer's world and we don't practice the connections as role models.

In education in the United States, we do too much training of the discipline as a professional school and not enough education of the approach and the process as an evolving stage of thinking in dealing with the world and its problems and opportunities. The engineering approach is today's liberal education and needs art for engineers and technology for social scientists to be implemented successfully by people in those professions.

In chemical engineering, we learn both about the chemical process and the operations making up a chemical process and about the engineering process. In management systems engineering, we must learn about both the management process and about the engineering process. I claim (with some degree of support

in the literature) that management schools don't teach management students the management process very well and engineering schools don't teach engineering students the engineering process as well as they should. The consequence is that the people we expect to have profound knowledge of these crucial processes don't. I believe we have to support and learn from those who do know and practice the processes. We also need to make sure we don't neglect the fundamental processes when we teach engineering and management. I worry that in our effort to teach the fundamental knowledge and practices we fail to teach the process.

I'm concerned that our design courses don't adequately teach the fundamentals of the systems approach. One of the tenets of a system is that it must have an aim—a purpose. The aim carries us beyond the *what* to the *so what*. The aim is philosophical. All our systems ultimately involve people; that's where the application part of engineering is consummated. We need to know the psychology and sociology of people as individuals and in groups.

The issue of focusing on the right unit of interest, or right application system, is a huge issue. I believe as engineering faculty most of us turn out extremely bright, hard-working young people who go out into the world and work diligently to produce perfectly elegant solutions to the wrong problem. We never teach young professionals how to figure out what the problem really is or what to focus on. So they reach into the quiver of solution techniques we teach them and pull out the arrow

that they understood best in school or the arrow that was the favorite of their best teacher.

For the most part, engineering faculty do teach tools and techniques for solving a wide range of problems. However, we don't teach how to select the right technique based on determining the absolutely right problem and how to integrate the right tools and techniques to solve the more-complex problems of today. We depend on on-the-job-training to teach these things. But what about the education behind the on-the-job-training? We have to teach the principles and fundamentals behind figuring out the right problem and using the right techniques. We won't be able to teach this understanding of the right problem, selecting the right technique, and integrating tools and techniques until we teach the systems approach, the engineering process, and the management process.

Management systems engineering is a discipline, like electrical engineering, and as such needs courses focusing on the core application system—the organization, the management system, the management process, management tools, and performance improvement. When these discipline-oriented courses are combined with the traditional mathematics, physical science, and applied with math and science courses of engineering and with management, social science, and applied statistics and business courses, we have a management systems engineering discipline. However, these courses or this type of instruction doesn't improve our understanding of the engineering process.

The fundamentals of the engineering process are best learned when integrated—really when they are subsumed or dominate—into the existing courses of the engineering (or other disciplines) curriculum. The system life cycle should be learned early and continuously. The cycle applies to everything. Learning how to communicate comes when we change the way

students participate in class and on homework and tests. The systems approach must be disclosed continuously throughout all courses. Most engineering process fundamentals won't be learned well without effective role models. You can't help a person learn a way of thinking or a way to approach the world if you don't think or approach the world that way yourself. Most engineering process fundamentals aren't recipes to follow (Plug numbers into this formula and get the prescribed answer.) or tasks to do. The fundamentals are ways of being that must be shown through attitudes and behavior in all facets of our life. Those who are good at the engineering process don't just practice those fundamentals part of the time in their office or on the job in the field.

As we consider the way to teach the engineering process, I must share a lesson I learned from my father. He said, "We can't teach anything. We can only help people learn." Today I recognize there's more to the story. If we help someone do something, we can cause more harm than good. Therefore, I say we must *support* people as they learn. Peter Senge, in his book, *The Fifth Discipline* (The book introduces organizational learning; but the fifth discipline is systems thinking.) quotes Bill O'Brian of Hanover Insurance, who says, "[Hunger for learning] is as fundamental to human beings as the sex drive." (p. 14.) If people are driven to learn, our job is to support them and to remove barriers. When we help them we stifle their hunger, their individuality, and their self-empowerment. When we teach them, we do nothing. (I learned the concept of supporting versus helping from Kellie Wells of First Union Bank.)

How do we support people as they learn? Most of all we set good role models and demonstrate the fundamentals through our attitudes and behaviors. Then we provide information and experiences from which people can derive their own understanding of the fundamentals. Then we provide opportunities for people to

try out the fundamentals so they can study the results and the process of what they tried.

The consequences of not supporting people as they learn the engineering process and its fundamentals are frightening. In engineering education, we fixate on the core application system to the detriment of everything else. We ignore the management process. Therefore, we don't understand the total application system we're dealing with. We short-shrift the engineering process. The consequence of these practices is that engineers have trouble switching core application systems. That is, aeronautical engineers can't switch to mechanical engineering applications when the aeronautical industry is depressed. Chemical engineers wouldn't think of applying their abilities and experience to manufacturing engineering needs. Mechanical engineers and electrical engineers don't see the similarities between the control systems they work on and the organizational systems that are trying to deal with disturbances and optimize their operation. (I'll discuss the organization as a control loop in Module 1.1.21.9.) If we emphasize the engineering process and its fundamentals, we empower the flexibility to apply that process to any application system.

I believe management systems engineering tends to emphasize the engineering process

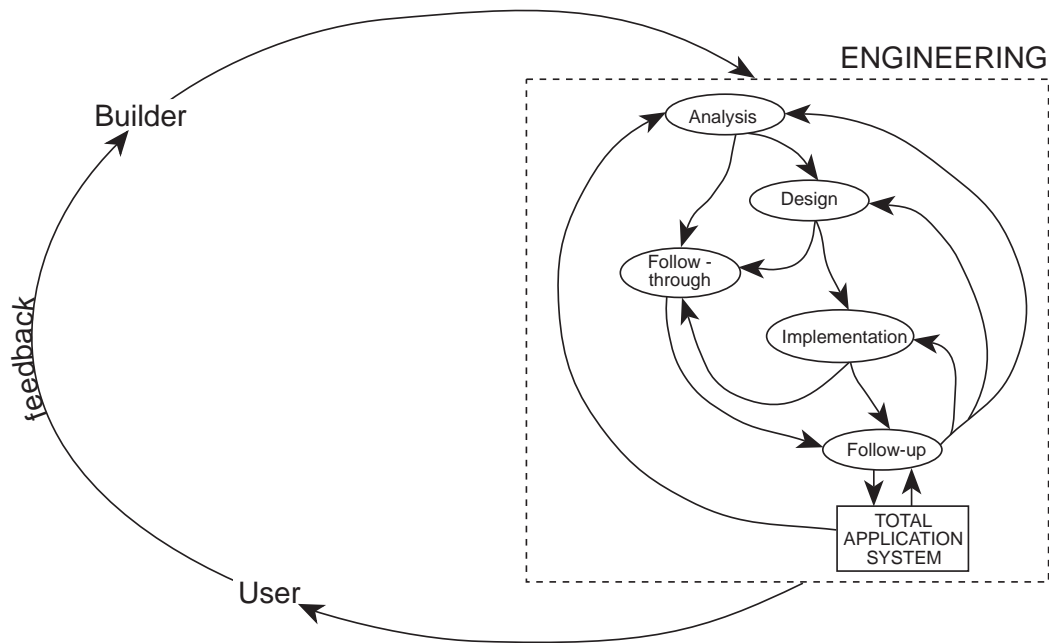
because of the wide range of seemingly different application systems we deal with. While banks, chemical plants, government offices, and manufacturing plants are all organizations with similar characteristics, they seem different because of their markets and products. Also, management systems engineering is influenced by the more-qualitative and social science differences in the application system, thus focusing attention on the broad nature of the engineering process fundamentals.

In Figure 1.1.11.6.5., I've emphasized the engineering process by indicating the groups of functions in the engineering process framework. The framework doesn't show the fundamentals or the philosophy behind the process. We see the process here as a series of steps. Since the steps are shown as a cycle, we see that we never finish the sequence. We continually improve. We stop when we abandon the process.

I wasn't taught about life cycles for bridges or sanitation plants in civil engineering and I wasn't taught about life cycles for nuclear reactors or nuclear fuel in nuclear engineering. In short, I was never taught the framework for the engineering process. I wasn't taught the systems approach either. I was another engineering professional who didn't know the engineering process.

YOU NEVER FINISH THE ENGINEERING PROCESS,  
YOU ONLY ABANDON IT.

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**Figure 1.1.11.6.5.** *The steps of the framework for the engineering process show the functions for the engineering process but don't show the fundamentals or philosophy of the process. Traditionally, in school we learn about analysis and design, but all the rest is left to on-the-job training.*

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### 1.1.11.7. THE FRAMEWORK FOR THE ENGINEERING PROCESS

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**Many people with varied backgrounds practice the engineering process when they use fundamental principles to analyze a need and convert the analysis into the design, implementation, and follow-up of a solution to meet that need within the context of the systems approach.**

The engineering process is part a way of thinking and part a series of functions as steps toward an end guided by rules. The functions display a cyclic, recursive nature. I can show the functions in a framework. The rules and the way of thinking must be discussed and thought through. I'll show an overview of the framework now. I'll develop the engineering process in later modules.

Figure 1.1.11.7. shows as ovals five categories of functions of the engineering process. I'll expand the categories into 21 functions later. In Figure 1.1.11.7., notice how each category of functions is tied to the other functions. The engineering process isn't something you start at the beginning and end at the end. The engineering process is a continuing flow of learning, doing, and improving steps. When we apply the engineering process, we never finish it, we only abandon it—hopefully only for a short time to be picked up and worked yet again.

The engineering process, as I've shown in Figure 1.1.11.7. and will expand later, reflects a model I call the system life cycle, Blanchard and Fabrycky's system engineering functions listed in Module 1.1.9.2., the design process in Figure 1.1.11.6.2., and the project management process. The functions of the framework are important to the user and the builder of the result of the engineering process. The people involved are shown as rectangles in the figure. The engineering process is as important to the user of the result as it is to the builder of the result. In management systems engineering,

we'll apply this engineering process to the management process.

Figure 1.1.11.7. identifies categories of functions of the engineering process. Figure 1.1.11.7. is a framework because it shows neither the rules governing the functions nor the overarching philosophy directing the functions. In the engineering process, we analyze a need and design and implement a solution. We've learned that implementing a solution isn't the end of the process. We must follow-up with maintenance, upgrade, retirement, or cleanup. Also we must follow through as we work the other categories with documentation, evaluation, and project management. The framework emphasizes the cyclic and highly-recursive nature of the engineering process. We never absolutely finish the job. We sometimes put the process on hold for a time, especially after a new implementation, to come back to continue the job later.

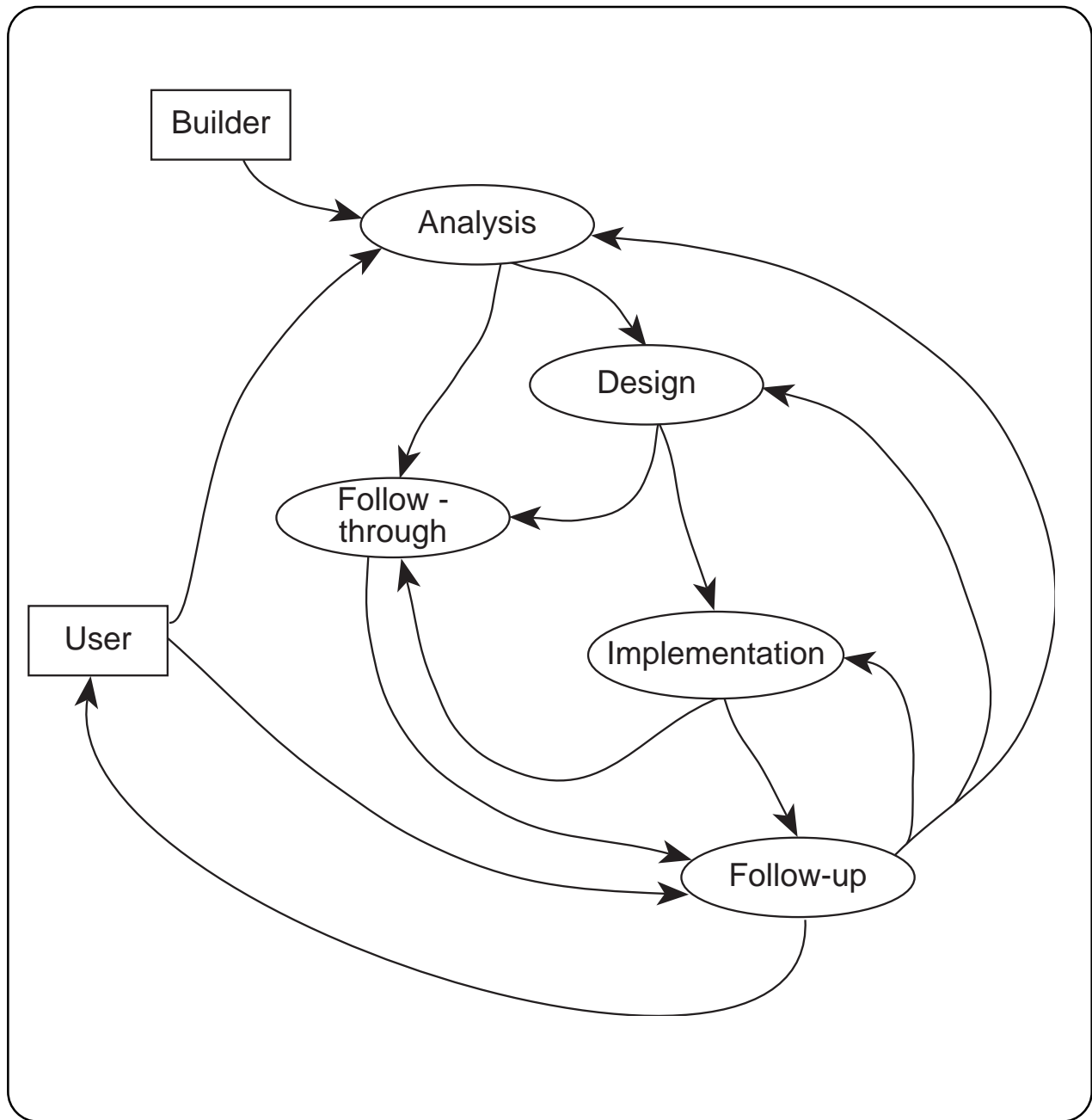
Figure 1.1.11.7. includes the analysis and design steps (actually groups of functions) many people think constitute engineering. The process also includes the implementation step to study the results of our design and the follow-up step to use the lessons learned from our study to do better analysis and design. The follow-through step includes documentation and project management functions that we do throughout the other steps. I'll provide details for the general framework in Module 1.1.20.1. When we consider the design step as what engineers do, the analysis (plan), design (do), implementation (study), and follow-up (act)

steps of the engineering process parallel the famous plan-do-study-act steps of the management process. The parallel is reasonable since both cycles derive from the scientific method.

One of the most complete published versions of the system life cycle is that of Blanchard and Fabrycky. I've listed their functions in Module 1.1.9.2. They allude to follow-through type activities and follow-up type activities in their discussion. For follow-through they ask, "How is the system to be supported throughout its life cycle? This includes a definition of levels of maintenance, functions at each level, and anticipated logistic support requirements (i.e., test and support equipment, supply support and spare/repair parts, personnel and training, transportation and handling requirements, facilities, and technical data)." (Benjamin S. Blanchard and Wolter J. Fabrycky, *Systems Engineering and Analysis*, Prentice-Hall, Inc., 1981, p. 23.) I see follow-through functions as those you do for each of the other functions in analysis, design, implementation, and follow-up to make sure you support or follow-through on all the steps of the life cycle. I'll include functions like project management, documen-

tation, and evaluation in the follow-through step because you need to perform each of those functions continuously throughout the life cycle.

For follow-up, Blanchard and Fabrycky ask, "When the system becomes obsolete and/or when items are removed from the inventory, what are the requirements for disposal? Can specific items be reclaimed and recycled? What are the effects on the environment?" (p.23.) In their diagram of the life cycle they include a dotted box for "phase-out, disposal, reclamation, and/or recycling" (p. 22.), but don't include that box as one of the functions they list for the life cycle. I see follow-up as perhaps the most important step, because it's the learning step. With follow-up, we learn from functions like operation; maintenance; upgrade; obsolescence and replacement; and clean-up, restoration, and remediation so we can continuously improve our analysis and design and to better serve the user. To me, follow-up means after we install the object of our analysis and design we must continue our attention to meeting the needs of the user and follow-up to ensure we do what is needed.



**Figure 1.1.11.7.** *The cyclic, recursive nature of the engineering process serves the user of the results of the process as well as the person who conducts the process, whom I call the builder. The process serves the user and builder over the life of the need or the solution.*



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**1.1.12. PERSPECTIVE THROUGH ILLUSION—SANDRO BOTTICELLI**

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### 1.1.13. *PURPOSE OF THE APPROACH—THE VISION*

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**I intend for this book to describe and explain a systems-oriented paradigm for understanding and implementing processes for engineering and management, focusing on the role and improvement of management tools and their use within a discipline having the ability to do and teach 1) describing and evaluating the organization as a system that incorporates management tools, 2) determining what tools will work, 3) prescribing how to get or build the right tools, 4) prescribing how to use the tools best for that organization, 5) predicting the resulting organizational performance from using the tools, and 6) practicing the skills and techniques to get the most out of the tools and the organization.**

#### **Background**

For a total of 35 years, roughly equally divided between university research and industrial involvement in management systems, processes, and tools, I've worked with managers frustrated by unsuccessful tasks trying to fix their situations. The great lesson learned is, no matter what the industry or agency, unless management tools fit each other, the manager, and what is managed, they overwhelmingly fail. And unless the manager, the managed, and the tools reflect the internal and external forces on the organization, the organization cannot meet its goals and objectives. The fit is a function of the tool and associated guide and of the process the tool works through. The tools must work together and support the manager or they work at odds with each other and against the manager.

Anecdotal evidence, corroborated by reaction from managers and information specialists, indicated that, unfortunately, 70 percent of all management tools fail. MIS's are unused, plans sit on the shelf, and no one believes the organization structure chart. Furthermore, the people in the organization don't buy into the tool or the process using the tool. The result is a loss in confidence in the tool(s), the process, the manager, the organization, and the organization's aims.

#### **Foreground**

Private and public sector managers need tools to do their job. What they have are tools that work both against one another and collectively against managers. Indeed, many managers are slaves to some modern management tools. Today's computer-based tools or participative management techniques don't work equally well (if at all) in every situation. To manage today's uncertain, rapidly-changing organizations, we must evolve the science of building effective tools and the art (skill) for applying them. The future manager will apply tools across interdependent groups of highly-specialized professionals in a world with immediate communications involving huge amounts of rapidly-changing data and with international, if not interterrestrial, scope. The concept of interdependency carries the idea of and the need to manage cooperation for continual performance improvement. The environment, work force, and technology are changing to force success or failure based on our ability to build and use management tools.

What we need is a paradigm (engineer's systems approach to management) with associated methodologies (integrated sets of tools for representation, analysis, and prescription consisting of models, frameworks, theories, and procedures); operational strategies (gen-

eral sequences of activities designed to achieve some end); and techniques (discrete procedural sequences resulting in outcomes of a pre-specified form) with which any manager can evaluate any set of responsibilities and prescribe with predictable levels of confidence the best management tools, guides, and processes, and from which an academic discipline of management systems engineering can be taught—all within the future world just described.

The individual, old-time furniture maker folds art into his or her work, but his or her basic tools have been painstakingly understood, documented, taught, and improved for generations. The science of the right tool for the piece being worked, fitting comfortably in the carpenter's hands, will get the prescribed results. The master craftsperson can make a tool work in less-than-optimum situations, whereas for the rest of us, put the wrong tool in the wrong hands and the piece gets butchered or the handler injured.

Today's furniture maker is different. He or she doesn't use one-person tools to completely make one piece of furniture by himself or herself. He or she works in teams, sharing tasks, tools, and information to make large numbers of pieces of furniture. Much is automated where he or she deals more with information about what is being done to the furniture rather than doing that thing to the furniture himself or herself.

Carpentry tools can be grouped by function, with dozens of different saws, for example, to ensure the right one fits each nuance of the function. We also can master our management tools and leave room for the creativity and flexibility of the artist. Like the carpenter, we can understand our work so well that we know all the nuances before they arise and are prepared with just the right tool to do the job.

Without the luxury of generations of time for evolving tools and teaching their use—and with breakthroughs in terms of years as opposed to centuries—we also must group our management tools by function and perfect each one for its specific purpose. Building or using a tool for the tool's sake doesn't lead to a successful application. For success, each tool must be built and used as part of a process in a productive system.

The skill by which the master carpenter applies the proper technique is learned and performed by the carpenter alone, for the object of his or her skill is mere matter—albeit for a human customer. Management skills and techniques, however, must be learned and applied by both the supervisor and his or her subordinates—human beings. Thus, the variables of interest increase geometrically as we consider the relationships between the supervisor and the subordinates.

Today's (and especially tomorrow's) manager is less apt to work alone. With modern data and information sharing tools (e.g., networks and shared data bases) and participative management, the manager works with and makes decisions with others. Working together requires reaching consensus on many broad-ranging and diverse issues affecting many different people with many different agendas. An understanding of the various organizations managers deal with and their cultures helps managers understand the processes, rules, and precedents that guide organizational behavior and decision making. The complex and dynamic nature of the information needed to support these decision-making processes requires a thorough understanding of the organization's stakeholders and systems to assemble, integrate, and portray this information effectively to managers. This information gathering, manipulating, and portrayal becomes especially important when managing in

situations of large, rapid change.

### **Vision**

Imagine a management systems engineer in the future addressing a new set of responsibilities that needs improvement. By asking the right questions and observing the right indicators, the management systems engineer scopes the situation and classifies the organization according to a number of parameters that will characterize the organization in terms relating to management tools and their use. Based on the classification of the organization and its decision maker, the management systems engineer identifies which management tools are working well and which aren't and why. Then the management systems engineer determines which new management tools can be selected

and which need to be built to help make the needed improvement. The management systems engineer helps select the right person to build the new tools or builds them himself or herself. The management systems engineer supports the manager in prescribing how to use the tools in that unique situation. Then the management systems engineer predicts the resulting organizational performance from using the tools and the extent of other improvements directly or indirectly affecting performance. The management systems engineer either helps find or provides training and advice to identify and teach the needed skills and techniques to get the most out of the new and continually improving set of tools and out of the organization.

