FROM MEGAMACHINE TO LIVING MACHINE®:

AN EVOLUTION OF MACHINES AS DESIGN MODELS

by

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(Under the direction of William L. Ramsey)

ABSTRACT

Machines are a pervasive societal element, now, and to some extent, throughout mankind's history. Their influence may be viewed as positive or negative across any human population. Human design has certainly been affected by the machine's algorithmic nature. The task is to determine how machines influence design arts, such as architecture and landscape architecture, and to question whether that influence is valid, and is understood by designer and user. To accomplish such a determination, we must first understand the genesis of human design, and also design's basic intentions. Further, we must understand the machine's attraction to mankind. By examining a collection of design thinkers whose design is somehow guided by machine aesthetics, it becomes clear that each designer may bring a unique machine conception to design. These unique conceptions provide an evolution in the manner in which mankind perceives the machine, culminating in a unique, ecologically-based machine conception: the living machine®.

INDEX WORDS: Machines, Design theory, Ecological design, Living machines, Modernism, Error.

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B.A., Fairfield University, 1993

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial

Fulfillment of the Requirements for the Degree

MASTER OF LANDSCAPE ARCHITECTURE

ATHENS, GEORGIA

2002

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August 2002

ACKNOWLEDGMENTS

This thesis could not have been completed without the help and support of many people. My sincere thanks to Bill Ramsey, my major professor, who has steered my journey and veered my thoughts towards a final product that I had not even imagined six months ago. Thank you to my reading committee, Marianne Cramer, David McKenna, and Dr. Amy Rosemond, for your commitment and expertise; it will not be forgotten. Thanks to Ian Firth for helping me muddle through the early gestation of my disparate thoughts, and for providing a real path to investigate. My deepest thanks to my family, especially my wife Anne, who often suffered as much as I did during this process, and to our daughter Olivia.

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INTRODUCTION

We live in a world saturated with machines. Many of us sit in front of one type of machine or another for a majority of every day, from computers to dye-casters to automobiles to television sets. Machines and a machine-like conception of the world have influenced the great writers, artists, and critics of human society. Designers have certainly been influenced by the power that machines exercise over the societies in and for which they design. But can a machine generate the dynamic process of design? To answer that question we must clarify what makes designers choose the solutions that they do. We can placate ourselves by saying that a design comes from a constructivist discipline, or that it represents a Post-Modern ethic. But really design comes from an intention, personal to each designer, and that intention has been part of mankind since his earliest cognizance.

This paper will clarify the ways in which the machine has manifested itself in human design. It will ask, does man, as designer, understand the models used in generating design, especially when the model is a machine? In addressing that concern, it will question certain terminology and definitions associated with machines and their use in design. *Chapter One* initially focuses on the origins of human design, noting that human beings originated in the direct image of that which already existed - the surrounding environment, with functioning landforms, animals, plants, and climate. It then examines design concepts which necessarily follow from these origins. Failure, for example, is examined in relation to the evolutionary process of design. Further, ubiquitous error in design, a phrase of unknown origin, introduced to me by William L.

Ramsey, professor of design in The University of Georgia's School of Environmental Design, is defined as elementary to design and not to be ignored.

A significant portion of these origins originates from the writings of the generalist, Lewis Mumford (1895-1990), mainly from *The City in History* (1961) and *The Myth of the Machine* (1966). In fact, Mumford's conception of the megamachine, a conglomeration of human laborers dictated by a ruling minority towards the accomplishment of outlandish tasks (such as the construction of the Great Pyramids of Giza), plays a central role in the development of the paper. Mumford's conception of this machine is defined as the first manifestation of a modern machine, that is, of our contemporary conception of the production machine, which would become a leader in the Industrial Revolution.

Chapter Two discusses a natural world model alongside of a machine model for design and reiterates the utility of error and failure in either model. Perfection is addressed as a potential destroyer of the design process. In this chapter, contemporary ecological design is introduced via the work of biologist John Todd. Although having progressed well beyond Paleolithic man copying an animal's behavior in order to survive, ecologically-based design re-emerges in the latter half of the twentieth century, returning design conception to the use of nature as a guide. The inherent question is, "How may ecological designers resolve the positive with the negative aspects of omniscient technology in their design solutions?"

To elucidate the precarious pertinence of that question, the appeal of machines is addressed in *Chapter Three.* We must know why machines have so thoroughly infiltrated virtually every crevice of human society. In understanding our attraction to them, designers may be able to more clearly understand machines' relevance to design. Should we design with the machine as a model, or shouldn't we? Why?

Chapter Four examines the work of several designers who demonstrate various manners in which the concept of the machine influences design. The examples included demonstrate an evolution in designers' perceptions of machines, not a universal evolution, but one that is evident across a particular design stratum. What becomes clear is that across history, designers display different conceptions of what a machine is and what it does. Obviously differing machine definitions generate different interpretations of the machine's value and place in design. Also in those examinations, certain design motivations will be evaluated, which range from an idolization of machines as the element which will propel man out of what T.S. Eliot called *The Wasteland* in his 1922 poem of the same name, to a reaction against the reign of the machine age, to a refinement of the way in which we conceive of the machine.

It is difficult to ignore the presence of machines in our fast-paced, progress-oriented society. Whether we place a positive or a negative connotation on that presence is irrelevant; our concern is the reality of the influence. We must consider how machines influence our lives, and further how our lives may influence machines. This information can be used to conceive of design strategies which fully recognize machines – their benefits and shortcomings, their failures and successes, their history and future. It may also be used to display the machine's remarkable evolution as a valuable design tool, whose breadth extends far beyond a machine's form and actions, and into its origins and nature.

CHAPTER 1

DESIGN AS DECISION

Conception to Decision: The Designer's Flaw

This is a thesis about design. Its purpose is, in part, to examine the origins of human design, not merely historical origins, but unique inspirations that designers have used to resolve problems of any intensity or breadth. Specifically it will investigate motivations for using the concept of the machine to generate design, and it will evaluate the validity of using machines as design models. In considering machines as generators of a specified thought process, it is appropriate to ask whether design solutions are ever products of mechanically derived formulas. As sentient beings, we design almost constantly, whether we are aware of it or not. At the core of our humanity, our activity, and our development is design, from the earliest decision to live where prey led, to the resolution to remain where soil was productive, to the construction of the simplest shelter, to fortification and the waging of war.

Design requires making choices. Helen Marie Evans states that it is about selection: "Selection can lead to appreciation of self and to the realization of man and his daily functioning as an integral part of comprehensive design" (Evans, 3). When a woman wakes up on a January morning in New England and selects a heavy wool sweater as part of her daily outfit, or when a man waits at an intersection, searching for the safe break in traffic, design is in progress, and the designers place themselves within the framework of a designed society, the comprehensive design. Within a comprehensive life design, however, unique choices are made which reflect accommodation to a condition in constant flux. On an August morning, the aforementioned woman will not likely choose the same sweater – the wool would be inappropriate for the warmer climate. Her formula for dressing is not fixed, but rather it evolves, changing with daily and even hourly progressions in the weather. We do not know what will happen from one minute to the next, and consequently our design must accommodate that uncertainty through flexibility.

Although inextricably tied to a comprehensive design – dressing before entering society and work, for example – each designer's personal journey of discovery is key to a design's progression. The journey contains recognition, defined by Krome Barratt as, "the positive comparison of any new experience with information held in a memory bank,…most intense when…personal and apparently unique to the individual" (Barratt, 8;9). We recognize warm weather and choose a t-shirt from the drawer rather than a sweater. Our formulas of behavior change constantly, accordingly, and unpredictably. Designers, likewise, react to their experiential base and are guided by behavior-directing formula. Through experimental resolution of form or of circumstances, a designer designs personal peculiarities into each solution. Therefore no two designs are identical, even those created by the same designer. Consequently the machine, with its capacity for precision and standardization guided by algorithm, might conflict with the art of conceptual design.

For a comprehensive definition of design, again we reference Barratt's words:

> …design is about the making of things: things that are memorable and have presence in the world of the mind. It makes demand upon our ability both to consolidate information as knowledge and to deploy it imaginatively to creative purpose in the pursuit of fresh information. (Barratt, 2).

Making things requires selection, or a decision which defines the thing. The things about which Barratt speaks take various forms – baskets, dams, hats, spoons, strategies. Their conception evolves with the designer's mind, as knowledge is created from information. If we receive information asking for a spoon, we design a spoon. What happens if after the spoon is fashioned and used, we realize that a slotted spoon is needed? If materials allow, holes may be drilled in the existing spoon, or a slotted spoon may be made. Either way, action is taken in response to the introduction of knowledge.

Human beings react – if a hand is placed on a hot burner, we pull it away instinctively. We do not attempt to plug the painful experience into an equation to define appropriate behavior. We do not ask why the burner is hot, or what it means for the burner to be hot. We need no justification for pulling the hand away – we just do it. If we consider the reaction to be natural, or in response to self-preservation, we must also consider that our ancient ancestors could have reacted in the same manner, because the reaction does not seem to be learned and fire has always been hot. If instincts such as pulling a hand out of fire are innate, it follows that other instinctual self-preservationist behavior may also be innate. This in mind it is reasonable to imagine that the design inspirations of Stone Age man, for example, may be akin to ours on some, or many, levels. Henry Petroski, in *Design Paradigms* (1994) comments:

> …in its most fundamental stage conceptual design involves no overt modern theoretical or analytical component, [so] there is no reason to believe that there is any essential difference in the way our most ancient ancestors conceived and we still do conceive designs. (Petroski, 16).

Design may be as simple as solving a problem by searching available knowledge and choosing a solution. The choice is, in effect, the design, and it narrows an infinite number of conceivable solutions down to one.

The application of one solution to a given problem – the design – necessarily introduces a flaw, but not to the detriment of the design. In order to produce anything, a designer must choose a single solution from a myriad of options – the decision to select one automatically requires the rejection of others. However, without committing to that choice the designer's ideas would simply float around, muddled in potentialities, never producing a tangible solution to the problem. The solution chosen will either be satisfactory to a degree or unsatisfactory; but it will be only one of many solutions.

From *The Nature and Aesthetics of Design* (1978) David Pye offers, "nothing we design or make ever really works" (Pye, 13), because, "all useful devices have got to do useless things which no one wants them to do" (Pye, 14). The goal of any design is to satisfy more design criteria than not – all that can be achieved is a design that works as well as is possible. With one solution, comes a set of useless things. Responding to Pye, consider that a glass implies the ideal form for containing and drinking liquids, and that the form has survived for hundreds of years. It strives toward perfection and arguably reaches it. But then the glass is dropped, leaving a pile of dangerous shards – an imperfection, a useless thing. What utility is there in the unintended design – the broken glass? Very little in the shards themselves; however information is gained, which may be deployed imaginatively to fresh creative purposes.

Devices like the canoe, which have satisfactorily solved one problem over millennia, also imply perfection. In truth, the canoe optimizes rather than perfects. Michael Wahl defines optimization as guided by unity, appropriateness, and economy

(Wahl, 36). The inclusion of economy, in part, distinguishes optimization from perfection in that it suggests frugality. Inherent to economy is adaptation, or chasing the best result using the resources currently available. The resources available change regularly, so there is dynamism in optimization, finality in perfection.

Failure as a Learning Tool

Imagine the problem of designing a vessel for short, quick water transport. If immediately the image of a canoe comes to mind, it is necessarily presumed that the design problem has but one resolution, firmly achieved in the construction of the canoe. Such precocity ignores the evolutionary process of designing the canoe. It also forgets the solutions that sank to the sandy riverbed or disintegrated in the whitewater; it forgets the failures.

We learn from the failures. Design, by the nature of its art, contains error and uncertainty. This error is sometimes called the ubiquitous error in design (Ramsey, Interview). Regardless of the intended result of a design, a number of unintended results will follow its creation. Whereas the number of possible solutions to a problem is almost infinite, it only takes one mistake (error) to nullify a design. Because of the impossibility of satisfying all criteria for a design, every design can be said to contain an error (ubiquitous). As in the example of the drinking glass, a pile of dangerous shards was never intended in its design. However, latently, that result existed. Similarly, and tragically, the design of a super skyscraper like New York City's World Trade Center was never imagined as a gaudy target of terrorism. That is the ubiquitous error in design – one never knows.

A dynamic design process allows error to be utilized in redesigning the thing, wherein error is encountered and knowledge gained from it is used to amend the design.

However, in the circumstance of an algorithmic design, where X must equal Y plus Z, for example, error is discounted. An error in an algorithm causes a complete disintegration of the formula and a whole new formula must be crafted. Algorithm defies the unexpected; it is a mental concept represented by a *set of rules* for getting a specific output from a specific input (Ramsey, *Program*). Bill Ramsey lists two characteristics of algorithm. The first is that vagueness has been eliminated…rules are so simple and clear that a machine can perform the operations described (Ramsey, *Program*). Pye insinuates that vagueness is integral to all design, in that it is impossible to ascribe a single task to a design. Alongside the primary task of a design lies a collection of unintentional, unavoidable results. The second characteristic of algorithm is that it must terminate after a finite number of steps, because algorithm demands an output; it demands termination (Ramsey, *Program*). If one conceptualizes design as an evolutionary process, a final output is not considered, because the design is a continuum.

In *Design Paradigms*, Petroski proposes that the concept of failure is central to the design process, and it is by thinking in terms of obviating failure that successful designs are achieved (Petroski, 1). Obviating failure can be simply reassessing previous designs, after, for example, the boat sinks the first time, or the second, or the third. If, like a machine, a design is based upon a strict formula, when vagueness, or error, is introduced, the design is nullified. Rather than learning from error, such design resists it.

Failure prompts revelation, and often it is in the refinement of an unwanted result that exploration and development are initiated in both designer and user. Creativity goes beyond initial conceptualization, evolving in perpetuity. Petroski's *Design Paradigms* examines several catastrophic bridge failures around the globe, wherein the concept of design error looms dramatically. Bridge design must conform to an algorithm; the bridge must span a finite distance, be able to carry a specific load under specific stress, and do so until the bridge is no longer required. In this manner, bridges offer clear analogy of 'algorithmic vs. dynamic' design, because when error is introduced into the engineer's design for a bridge, the result is usually the bridge's demise – the formula disintegrates. Knowledge gained in failure may not be utilized in the design that failed because the bridge is gone. It is instead used in subsequent designs. Computer programming is another example of design which must succumb to algorithm. A program is a step-by-step procedure, a statement of a set of rules relating to an algorithm, wherein the action A causes the response X, or the action B causes the response Y. No flexibility will allow action A to bring about the response Y. This would mean that the program failed.

Typically, however, ubiquitous error is an integral part of each design, and an indomitable force of invention throughout the continuing design process. It was critical to the development of early human beings. Take for example the conception of Stone Age shelter. In addition to the cave – a natural element whose value was doubtlessly realized by accident – man found shelter in many natural accidents: beneath a thicket of felled tree limbs, in the scour gullies of overland erosion, or beside a hefty boulder that streamed down an unstable slope. After taking shelter from the rain under a thicket of limbs, a wet Stone Age man surveyed the situation and conceived of a more solid and dry solution. In failure the design was mended. In Petroski's words, "[there is no] reason to believe that there is any essential difference in the ways in which our ancestors erred and we can err in our conception…." (Petroski, 16). We must, however, recognize the error.

A progression of cold, wet nights spurs the invention of solid shelter, for man, mouse, or bird. Similarly, hours wasted fashioning a watercraft that all but melts once out in the river channel, create new possibilities, materials, and forms. What was the foundation upon which ostensibly obvious decisions like seeking solid shelter were made? Were such solutions simply instinctive, reactionary? Let's briefly address instinct. Instinctive reaction ostensibly follows a formula – hot burner equals move hand for example. Without thought, the action occurs; it is like a defense mechanism. Instinct however becomes complex in its gradation of action. Rather than reacting identically in every case, we exhibit different intensification levels of reaction. Imagine if our reaction was programmed to be the same when touching a flame as when touching an ice cube – we would suffer innumerable burns. The same is true in design. The designer may be burnt in designing algorithmically, ignoring ubiquitous error.

Barratt notes "we have been programmed to be curious, to question, to probe and to seek to solve riddles. And as part of the process we attempt to imitate and parallel nature's wonders and its creativity" (Barratt, 302). In primitive times, man followed the indomitable rules of the environment: sun and moon cycles, seasonal and micro- climate changes, and water flows. For these natural laws were the only direction available, and they offered flexibility.

Anyone who has planted a seasonal crop garden will attest to the constant amendments required to produce healthy crops each season. Although following a general formula, by planting similar seeds at about the same time every year, in the same place, the gardener often discards the written directions on watering and spacing and waiting. Whatever is necessary to make the crops grow becomes the evolving process by which the garden is designed. This dynamic design is reminiscent of natural process, upon which the earliest human design was modeled. If we consider the garden as a device of man, David Pye comments:

> All the first antecedents of man's devices were given him by Nature. Every one of his devices is traceable back to something in nature, which suggested the first remote and primitive beginnings of its evolution. And every feature in art that man's mind conceives is conceived by a mind that has evolved as a part of nature: that grew out of nature. (Pye, 110).

Nature as a Guide

Imagine the following experience in the life of Paleolithic man. In executing a normal day's routine, a man observes two animals, both of the same species, and the same size. One is grazing on an unknown yet distinct low growing plant, the other on a common weed. Soon after, the animal that chose the distinct plant lies dead after a violent death, while the other frolics and continues to feed on the nondescript weed. The observer notes intently the difference between the plants eaten by the two animals, fearing the poison of the one plant. Imagine the power of experience when, sometime later, similar circumstances repeat a second time, and a third. Recognition creates understanding in the observer: do not eat that plant because it kills animals, and may kill me. A good design decision.

Mankind's origins are filled with similar design decisions, and human development is undoubtedly indebted to the mimicry of nature. Lewis Mumford notes, "being imitative as well as curious, [man] may have learned trapping from the spider, basketry from the birds' nests, dam-building from beavers….Unlike most species man did not hesitate to learn from other creatures and copy their ways…." (Mumford, *Myth*, 101). It requires no genius to understand the natural derivation of man's early actions and devices. As already mentioned, the earth and her systems were the only examples from which to generate a scheme for proper Stone Age living, and primitive man diligently followed her lead. David Pye comments:

> It would be surprising, then, if the things men make were of a fundamentally different order, aesthetically, from those which all the other constituents of nature make:…everything he used was taken as he found it or but slightly modified, and everything he made was from components which he found, not manufactured…. (Pye, 110).

But are we surprised by the design of the machine, a manufactured and fundamentally unnatural thing? No, because man's curiosity also led away from a dependence upon natural process. Mumford introduces the importance of the carrying vessel. Probably a replica of bird nests or bee-hives, a basket or other carrying vessel may be called, "an apparatus consisting of interrelated parts with separate functions, which is used in the performance of some kind of work," as *The American College Dictionary* defines 'machine'. The basket's parts are pieces found in nature, slightly modified, and the basket solves a problem: how do I get this load over there as quickly as possible? A key to basket design is its natural derivation, which offers flexibility. If a load larger than others must be moved, a basket can made to accommodate the new experience. The basket is still a basket; however the design evolves with the requirements placed upon it.

What is the significance of fashioning the basket after the bird's nest, or formulating diet based on animal behavior? Lewis Mumford offers some answers in two works which focus on human development, *The City in History* (1961) and *The Myth of the Machine* (1966). In the basket-making era, Neolithic man (c. 7500 – 3000 BC) no longer merely gathered natural elements from the environment; he fashioned things which made gathering easier. This phase of human development included the comprehension of natural cycles. For example, plant cultivation marked a significant change - from tool making and copying to the management of process and cycles. People embarked upon, "the permanent occupation of an area, prolonged enough to follow the whole cycle of growth" (Mumford, *City,* 11).

Through settlement, man grew accustomed to specific surroundings, to place. He observed changes occurring in and around that place – vegetation, blooming patterns, animal and bird migration routes, seasonal characteristics – and learned to anticipate outcomes based on those observations. Mumford states, "Under these conditions his exceptional curiosity, his retentive memory, were put to work and tested. Constantly picking and choosing, identifying, sampling, and exploring.…all this did more to develop human intelligence than any intermittent chipping of tools…." (Mumford, *Myth*, 101). Mumford affirms the importance of human design, of making choices, in an evolutionary, accommodating manner. He implies that beyond simple instincts like hunting, the human brain's development, through incidents of design, was the most powerful tool propelling man from "chronic nomads" (Mumford, *City*, 11) to domesticated society-bound creatures.

Mumford traces the origins and evolution of human societal organization in an attempt to understand the contemporary state of society. He recounts that as Neolithic man recognized and copied natural processes, and did so more systematically, simultaneously a clearer understanding of the brain's faculties emerged. For example, plant cultivation became more regimented, and agriculture developed formally in several distinct stages, from simple annual production to the domestication of cereals (Mumford, *Myth,* 130). Human settlements grew in size and organization around the productive farming sites. Mumford makes the crucial point, "domestication in all its aspects implies two large changes: permanence and continuity in residence, and the exercise of control and foresight over processes once subject to the caprices of nature" (Mumford, *City,* 12). With this exercise of control came "the beginnings of large-scale, open field, clean-crop agriculture" (Mumford, *Myth,* 130). Beyond mimicry, in clearing land for crop fields, man deployed accumulated knowledge in creative ways that must be classified (in the strictest terms) as unnatural. Although clearly perpetuating a natural growth cycle, man in this era, determined where, when, and how abundantly that cycle would replicate, and which plants would undergo the forced cycle of growth. Such planning practices placed man on a path towards algorithmic design.

<u>From The Daily Grind to the Megamachine</u>

In a bit of cynicism, one might offer that from that point forward, mankind exhibited little more than an evolution of the manner in which, as a species, it exercised dominion over the earth's natural processes. Similarly cynical, Mumford introduces the concept of "the daily grind" (Mumford, *Myth*, 137), a familiar term to contemporary society, but one which he imposes upon the Neolithic village culture. In Mumford's terms: "Only groups that were prepared to remain long in the same spot, to apply themselves to the same task, to repeat the same motions day after day, were capable of gaining the rewards of Neolithic culture" (Mumford, *Myth,* 137). Replacing the word "Neolithic" with the phrase "twentieth century" would not alter this message, which is laden with machine terminology. Growing grains and grinding them into useful elements became the daily task, and a "ritualization of work" occurred (Mumford, *Myth*, 139). Village culture depended upon the ceaseless coordination of all its parts (the growers, the carriers, the grinders, the mothers), coming together to maximize production year after year. Continued success meant village growth, and growth meant the need for stricter organization and an enduring power structure.

For brevity, the multiple phases of early human societal organization will be omitted from this study. It will suffice for the reader to grasp that as villages grew into civilizations, "a different kind of social organization arose: no longer 'democratic' …but authoritarian, centrally directed, under the control of a dominant minority" (Mumford, *Myth*, 164). The dominant minority, or kingship as Mumford calls it, quickly evolved into the unyielding entity upon which fledgling human society depended for direction. The kingship aimed at "the expansion of collective power" (Mumford, *Myth*, 164), and it achieved its goal, in part, by "turning human beings into 'things,' who could be galvanized into a regimental kind of cooperation by royal command, to perform the special tasks assigned them, however stultifying to their family life…" (Mumford, *Myth,* 183). Humans were relegated to a cog-like existence in a minority-dominated system of "progressive mechanization" (Bertalanffy, 10). Whereas village survival so recently depended upon successful cultivation of produce, the village member soon found survival in satisfying the will of the royal command. That command's creation of a malleable, thoughtlessly driven, perpetual work force is the design of the first modern machine, a machine made of human parts, Mumford's megamachine. This mechanization represents a significant formulation in human design intention, wherein the exercise of control and foresight over natural processes once governed by nature is replaced with the exercise of control over the creation of processes that never existed naturally.

The megamachine "was an invisible structure composed of living, but rigid, human parts, each assigned a special office, role, and task, to make possible the immense work-output and grand designs" of the kingship (Mumford, *Myth,* 189). Although the megamachine is Mumford's own construct, not realized as a machine in its time, it epitomizes the contemporary machine. It was programmed toward work output, and worked without vagueness until reaching that output. Similar to the machines of the Industrial Revolution, production was a priority and failure was disdained.

As will be shown in Chapter Two, error and failure are integral parts of both design and natural systems. Algorithmically derived designs ignore ubiquitous error, and are finite and mechanistic designs which terminate when error is introduced. A focus of this thesis is to determine, through the work of various design thinkers, the validity of using machines, unnatural processes, as models for design. Do designers properly comprehend the term 'machine' when proclaiming machines as a foundation for their design? And has anyone demonstrated (historically or currently) the validity of the machine as design model?

CHAPTER 2

A NATURAL MACHINE

The Natural World

Following natural processes as models, primitive man designed shelter, food production, tools, and routines. Like the natural processes themselves, designs experienced failures and were periodically amended to achieve higher levels of satisfaction. As humans became domesticated and civilized, kingships of the late Neolithic age manipulated and quickly learned to exploit human masses, galvanized into a production-driven, regimented order. This order followed more unnatural than natural processes. However, nature remained a primary model for human adaptation, simply overshadowed by a model that allowed for a previously unattainable level of production – the megamachine. To understand the significance of a shift in design models from mimicry of natural systems to the idolization of ceaseless, machine-like production, both models must be examined. We ask, what does it mean to copy natural process?

Addressing the mimicry of natural processes, consider our observer from Chapter One. In studying the environment, he learned a valuable lesson regarding the design of his diet, and accident was central to his understanding – his accidental observation and the doomed animal's choice of menu. Accident comes in response to error, and error is inherent in all design. David Pye implores, "our dinner table ought to be variable in size and height, removable altogether, impervious to scratches, self-cleaning, and having no legs" (Pye, 14). Of course our dinner tables are nothing of the sort. What they are is a place to eat dinner, and they have satisfactorily accomplished that end for hundreds of years. A period of unchallenged prosperity, like that enjoyed by the dinner table, often introduces a "myopia that can occur in the wake of prolonged and remarkable success, and that is endemic to the design process itself" (Petroski, 162). We forget about the unwanted results of dinner table design – the troublesome table legs, the weight, or the restrictive size. In forgetting, we ascribe perfection to our tables, and effectively terminate the design process. The moment that a designer believes a design to be near perfection, the designer admits to a finite, algorithmic design. Perfection cannot be attained without the creation of a fixed definition of its form – a mental picture of perfection. The designer in effect formulates an output, like an algorithm might. Natural systems, however, optimize in a constant evolutionary process of design, which aims at equilibrium, but can never be maintained with the simplicity of X = Y.

Natural systems are sometimes romantically attributed with perfection. For example, we think that because an estuary ecosystem provides diversity, stability, and maintenance to the earth, and has been doing so for millennia, it is a perfect design. This is a flawed terminology. Design displays a progression from inception to solution, and then to construction and beyond. What, then, may be said of estuary design, whose prolonged existence relies upon constantly evolving processes of reparation? It cannot be called perfect; perfection insinuates a final, error-free, product. An estuary may be called an evolving design. According to ecologist Eugene Odum, "a 'nutrient-trap' produced by the mixing of waters of different salinity and the favorable action of oscillating tidal currents in transporting nutrients, food and waste materials" (Odum, E., 364-5) is the key to the productive effectiveness of an estuary. Odum's language is full of motion and transformation; he implies no finality, as perfection does. And in fact neither does the estuarine system, whose cornucopia of activity maintains a progression of natural design in perpetuity (unless disturbed by man).

In the estuary, or the forest, nature's balanced design, the manifested form, is deferential to the evolving continuum of the design. In other words, a forest is not ultimately a valuable design model in freeze-frame visualization; here it is only a postcard, an aesthetically perfect treat at one moment in time. However, forests as systems, "control erosion, moderate seasonal pulses in hydrological flows, buffer climatic extremes, and provide fuel, food, and wildlife habitat" (Todd, 29-30), and that conglomeration of dynamic functions makes the forest a valuable model, but not a perfect design. Frank Golley, an ecologist and professor recently retired from The University of Georgia's Institute of Ecology, states, "…ecological systems are characterized by complexity, by continual change in response to environmental influences, by internal adjustment to selective forces… " (Golley, 224).

From Golley's statement it may be inferred that he considers natural systems to be antithetical to the machine; he speaks of complexity, change in response to stimuli, internal adjustment, and implies no static perfection. Along with Odum's dynamic language, Golley's statement implies an anti-machine ethos. The phrase anti-machine is not a judgment of the two ecologists' philosophies. Rather, it stresses an implicit distinction, which both profess, between natural systems and machines. Golley offers further:

> Using the word *system* might lead us to think that nature is like a machine and that we can approach it from a machine point of view. Living in the modern world where we have almost no contact with nature makes machine thinking inevitable and normal. But that is *not* how I am using the word here! (Golley, 15).

Odum further emphasizes the distinction between nature and the machine by speaking of the productivity of ecosystems: "Biological productivity thus differs from 'yield' in the chemistry or industrial sense. In the latter case the reaction ends with the production of a given amount of material; in biological communities the process is continuous in time…" (Odum, 69). The statement echoes the contention that algorithm seeks an end, while design engages a process.

Further, Odum's statement affirms the intent of the megamachine as antithetical to that of primitive human development. Think of the megamachine as the industrial producer, looking only toward the finished product, the ends. Next consider the self-preservationist design of primitive man as modeled more closely after biological production, which Odum defines as "the rate at which energy is stored…in the form of organic substances which can be used as food materials" (Odum, 68). Biological design progresses with the production of goods which are used to perpetuate the design, to feed it. Production and the process of production are inseparable, whereas in the megamachine (the industrial producer), the finished product renders the design process meaningless – ends overshadow the means. The most obvious distinction between machines and ecosystems, then, provided by these ecologists affirms this paper's assertion that machines are governed by the finite capacity of algorithms and that natural systems are in constant flux.

Biologist John Todd offers a unique extension, and partial opposition, to this assertion. In his book, *From Eco-Cities to Living Machines* (1994), he defines nine emerging precepts of biological design, all based generally on the first precept that the living world is the matrix for all design. In addressing the precepts, Todd exposes his philosophy of ecological design, which implies that machines can be living systems and that living systems are somewhat machine-like (See Appendix A for all precepts). What does he mean? As his philosophy is integrally tied to his invention of Living Machine® technology, a brief history of the Living Machine® is in order.

In the early 1970's The New Alchemy Institute, headed by John Todd, began working with food production on their property in Woods Hole, Massachusetts. On their small hopelessly infertile plot, using a methodology similar to the earliest human cultivators, the group developed intensive composting methods which rendered their soil fertile in two seasons. More importantly, greenhouse food production was enhanced. Using a structure called a bioshelter the Institute created a new way to produce food reliant only upon the sun and the wind. Inside the bioshelter, alongside vegetative food crops, tanks were set up to grow fish. The tanks were part of a simple passive solar heating / cooling system which, along with the plants, maintained a suitable growing temperature inside the bioshelter.

Soon the ubiquitous error in the design was discovered - the fish tank water was too quickly becoming saturated with fish excrement. So in an effort to conserve water in the production process, bacteria was added to the tanks to feed on the excrement. The bacteria not only fed on the nutrient-rich excrement, but also converted ammonia to nitrates, which fed algae, which then fed the fish. Cleaner water led to a constant food supply for the fish, and the fish became a healthy human food supply. This inter-relatedness is exactly the type of product which is impossible to achieve by algorithm.

To further the capacity of their new food production process the New Alchemists sought to deploy their happy coincidence toward new applications. Todd collected thousands of organisms, from microbial bacteria to algae to fish to oysters, and placed them into translucent tanks, approximately 5 feet in diameter by 4 feet high. Atop the tanks, “rafts” of plants were floated. The plants were mostly tropical and subtropical water plants, which would prosper in the year-round warmth of the bioshelter. The Institute’s first test of their new wastewater treatment system, the first Living Machine®, occurred on a site in Cape Cod. At the site, septage, a concentrated waste sludge which is pulled directly from septic tanks, was to be treated alongside the typical treatment facility. Septage, because of its consistency and concentration, is often pumped into open lagoons where it is allowed to decompose.

The New Alchemists set up 21 tanks alongside their own lagoon (which was more of a trough, 120 feet long). The tanks were connected with tubing and used gravity to feed water from one to the other. The septage entered at the high end and trickled its way down through the tanks, leaving the tanks and spending some time in the trough at the halfway point, before finishing the cycle through the lower tanks. All tanks and the trough were housed in a bioshelter. Ten days after the initial batch of septage was sent into the Living Machine®, the purified water was tested at the bottom. Fourteen of the fifteen volatile compounds had been removed from the water, the fifteenth being 99% removed (Todd, xviii). All fats, grease, and heavy metals were gone, and amazingly, the livers and flesh of the fish in the lower tanks were free of toxins. The Living Machine® had far surpassed its expectations, and it had done so through the self-corrective capacity of living systems. Since then many Living Machines® have been implemented and tested across the globe, all meeting or exceeding the goal of wastewater treatment, and in most cases producing useful by-products like high quality natural fertilizers, livestock feed fish, herbs and other food crops, and recycled water.

Todd believes that Living Machine® technology can generate the fuels we will need in the future, transform our wastes, culture our foods, regulate our climates, and integrate our buildings with the larger world (Cousineau & Zelov, 172). At the core of his belief is the notion that natural systems provide a clear model for human design, and that machines of the Next Industrial Revolution (a concept of Amory Lovins and Paul Hawken signifying a wholesale ecological refinement of industry) must not only be modeled upon them, but must actually be living systems themselves. Rather than distinguishing natural systems from machines, he wants the two to become one, as is the case in the Living Machine® – ostensibly a unique hope. In describing the composition of these machines John Todd offers:

> So you get thousands of different species of organisms from all kinds of aquatic environments….They begin to recombine in ways to adapt to our waste. It can be deadly as hell. They'll figure it out. You can't. But you must honor the system by making sure the cast of characters is there. (Cousineau & Zelov, 172).

Todd displays complete faith in the dependability of the aquatic system to perpetually adjust and accomplish the task of cleaning the water. It seems paradoxical to attribute dependability to a system in constant flux, to say that a natural system, while maintaining its capacity for self-correction and regeneration, can also be a dependable machine. Todd's definition of a machine would include classic terminology – accomplishment of a task, dependability, repeatability. However his combination of the machine and natural system is revolutionary because he describes his machines as engaging in a process of self-design (Todd & Todd, 170). Self-design is impossible for the algorithmically driven machine. The implications of Todd's philosophy will be discussed in the last chapter, it will suffice for now to consider the unique fence-post position, between nature and the machine, which his Living Machines® hold.

The Machine: From Basket to Megamachine

With natural systems providing dynamic, self-correcting models for human designs, and with the new machine manifestations witnessed in the Living Machine®, why does man seek an alternate model? That question is one that delves into the deepest chasms of human development. An explanation of man's desire for unnatural design models is offered in part by Mumford's conception of the astoundingly productive megamachine. However, before the appearance of megamachine design, primitive human minds constantly conceived of and built machines. Many sources, namely Barry Brummett's *Rhetoric of Machine Aesthetics* (1999) and Cheney and Cheney's *Art and the Machine* (1936), ignore the reality that man created machines thousands of years ago rather than hundreds. Others, like Mumford's *Myth of the Machine* (1966) refuse to call most Stone Age human devices 'machines.' Yet Stone Age culture sought the dependability of repeatable processes to help in their daily routines.

By dictionary definition, even the simplest basket is a machine. However, of tools and machines, Mumford states, "the essential distinction between a machine and a tool lies in the degree of independence in the operation from the skill and motive power of the operator: the tool lends itself to manipulation, the machine to automatic action" (qtd. in Brummett, 10). Mumford's distinction suggests that a basket is merely a tool; but, in the Neolithic age, for example, a time bereft of our conception of automatic, a full basket carried some distance and then set down on the ground was automatic. Whereas an axe laid on its side no longer provides utility to its user, the basket, even while sitting on the ground, solves the problem of confining its load. By this automatic action the basket is a machine.

Nevertheless the primitive basket is not the machine that begs discussion at this time; for it is an organic design copied from nature, in the same manner that mankind's earliest shelters were fashioned in mimicry of, say, a fallen thicket of tree branches. What must be examined are designs whose models strayed from Mother Nature, designs like the megamachine. Historically, human designs focus on improved production, as in the case of the basket or in agricultural yields, but these increases are accomplished toward the survival of the species. By contrast, the design intent of the megamachine included the refinement of ceaseless, uninterrupted production process.

Megamachine design focused on a static product built using a strictly conceived mechanism of human labor. The emphasis was placed on the process of construction, which implied that, in terms of form, the pyramid would be perfect at its completion. The formula was set: X number of bodies working in various combinations will construct Z, the massive pyramid. Brummett suggests that perfection is an ability to do exactly what the machine was designed to do, with no detectable variation (Brummett, 39-40). The completed pyramid satisfies Brummett's perfection. Similarly, in describing megamachine design, Mumford references a classic machine definition given by Franz Reuleaux: a collection of resistant parts, each specialized in function, operating under human control, to utilize energy and perform work (Mumford, *Myth*, 191). The key phrase in this definition is 'operating under human control'. Machine design epitomizes man's attempt to dominate nature, to be in control. We must however consider the validity of this concept in contrast to Living Machine® technology, which places faith in nature to run the machine.

The issue of dominance over nature is critical to determining the machine's value in design. It must be determined whether dominance is preferable to integration when making things in this world. Machines offer reliable production; natural systems may offer reliable self-correction. Designers engage in an evolutionary process which learns from and reacts to failures, or follows a dependable formula, which may offer longevity, but a longevity that is reliant upon the execution of a man-made formula. Mumford notes that with the efficiency of the megamachine, operations that once could hardly have been finished in centuries were now accomplished in less than a generation (Mumford, *Myth,* 190), and therein lies the attraction of the machine.

CHAPTER 3

THE MACHINE'S CLEVER APPEAL

The megamachine introduced mankind to the potential power and dependability of machines. From this introduction, the machine has steadily progressed, evolving in form and function from the Roman aqueducts and the Colosseum, to medieval war machinery, to Da Vinci's mechanical sketches from the Renaissance. The concept of the machine survived the ideological eighteenth century of revolution, and like a lion, entered the nineteenth. The nineteenth century is the first century of the machine, wherein the Industrial Age blossomed and defined itself in machine terms. What is it about the machine that allowed for its proliferation into virtually every crevice of societies around the globe?

The machine's appeal to mankind may be examined under the broad rubric of machine aesthetics. Why do we like machines? This paper has been written on a dozen different machines; I have communicated with people via telephone and computer. Along my daily nine-mile commute to and from campus, machines cut grass, spin the neon signs in front of gas stations, transport passengers, make other machines in the industrial zone, and allow for easy ticketing of my car when I try to sneak a better parking space. One trait common to all these machines is an ability to expedite the accomplishment of a task - automation.

We like the automatic, that which is easy and productive. A = B, with no variations. Such automation inspires awe. People generally respond to an aesthetic of algorithms. We are in awe of things that work just as they were designed, at their dependability. We punch 273.45 times 65 into our hand-held calculators, and are virtually dependent upon receiving an unquestionable answer. There is finality in the machine that is seldom found in life. The machine's automation can be directed toward a plethora of tasks and this flexibility is highly attractive to us. In *The Failure of Modern Architecture* (1976), a thorough dismantling of the basic tenets of Modern Design, Brent Brolin offers in regards to the latter Industrial Age:

> Machines held magical appeal for the mind and the eye. They captivated the mind because, in an age that worshipped perpetual progress, they were the visible signs of that progress. They leveled mountains, spanned seas, and conquered time. (Brolin, 48).

The magical appeal of which Brolin speaks comes from two levels: performance and form. Performance has been discussed in reference to the productive capacity of megamachine design; it doesn't change much in modern times. Performance can stand alone and speak loudly. If the majority of an ancient population, for example, thought the kingship mad for proposing the Herculean pyramids or the Great Wall of China, imagine their reverent awe whilst standing before the finished product. Even in the primitive form of a megamachine, the machine's productivity was inspiring and magical to both kingship and worker.

The appeal grew stronger with the appearance of the modern form of the machine - metal, gear-grinding machines of the eighteenth century. The machine took its recognizable form during this era. Cheney and Cheney, in *Art and the Machine* (1936), capture the machine fervor of the Industrial Revolution this way:

> The water turbine, the high-pressure steam boiler, the fabrication of steel, perfection of the motor and the dynamo: these were factors….Inventions,

> discoveries, experiments, with always greater consolidation of capital, greater efforts toward industrial expansion, with more inventions, more discoveries, more experiments following each advance, ultimately inspired that first colossal dream of the machine in which it became instrument of unparalleled material power, a national dream of an empire of steel and concrete. Men – machines – money: these were the components. (Cheney & Cheney, 24).

More, more, more! That was the goal of this particular revolution, and the machine is the instrument of constant and unparalleled power whereby man achieved that goal. The achievement of unparalleled power resembles that of achieving perfection; it implies finality, an end to the design. The appeal of progress as completion, not progress as process is strong in the Industrial Age.

Let us return to defining machine aesthetics. In *The Rhetoric of Machine Aesthetics* (1999) Barry Brummett claims, "aesthetics can be a systematic way of thinking about something" (Brummett, 4). So machine aesthetics are the machine's universally recognized qualities. They are the qualities most often visualized when thinking of a machine; they go beyond the definition. In describing machine aesthetics Brummett recounts a passage from Joris-Karl Huysmans novel *A Rebours* (1880):

> Does there exist anywhere on this earth, a being conceived in the joys of fornication and born in the throes of motherhood who is more dazzling, and more outstandingly beautiful than the two locomotives recently put into service on the Northern Railroad? (Brummett, 12).

The narrator feels an attraction, a sense of beauty so powerful that this seemingly absurd metaphor translates effortlessly to the reader. Whether positively attracted to locomotive aesthetics or not, in lieu of their awesome power, the reader can empathize with the narrator's attraction. The image of the dark metal locomotive, driven by man and coal into the wild frontiers is virtually unmistakable. Many people of Huysmans' era understood this new machine beauty. What is at the core of the attraction – is it purely the machine's form, is it the concept of newness that its form announces, or does the attraction lie wholly in productive capacity?

Let's examine each possibility. What of the form itself? Examples of form-derived machine aesthetics are sleekness, streamlined form, light-weight, and standard. The industrial age machine was typically made of steel, was immense in some capacity (either in size or power generation), and revealed its inner workings – no screening facades were used. In *Art and the Machine*, Cheney and Cheney define three primary formal values of the machine:

1. Materials are used honestly. Sheet metal is not artificially grained to look like wood.
2. Simplicity is observed in the number and kinds of materials employed, and in the form given to the object.
3. Functional expressiveness is the artist's foundation. The bed is not to be disguised as a bookcase. The anatomy of the bed is the basic design fact, and the artist's undertaking is to bring out of this fact a characteristic and expressive experience, an appearance that is beautiful in its own machine-age way….   (Cheney &Cheney, 15).

These values satisfy the Modern credo of design. But what do they mean to the general public? For the most part honesty of materials and functional expressiveness are not major influences on the machine's appeal to the majority, especially during the Industrial Revolution. An age of luxury widely experienced by the general population had not begun. People used wood when it was available, and metal the same. The average working class nineteenth century citizen had little concern for ornament or artificial graining. Similarly, if a barn was needed, a barn was built, and not one that looked like a house or a sculpture. Without luxury, functional expressiveness is a given.

Simplicity on the other hand greatly appealed to a population which was overworked, and tired. In fact, most people at one time or another seek immediate completion, and this desire for resolution is primary in the development of machines. It is at the core of such designs as the megamachine, the basket, the locomotive and the computer. In completion lies simplicity. Of the Industrial Age, Brolin states, "the aesthetic qualities of the machine - simplicity and geometry – became desirable in themselves…." (Brolin, 33). In *Machine Beauty* (1998), philosopher and computer programmer, David Gelernter defines machine beauty as the happy marriage of simplicity and power (Gelernter, *Machine*, 2). Since the Industrial Revolution an increasing number of people seek some semblance of order in everyday affairs - we need day runners, automatic coffee makers, and computerized driving instructions on the dashboard, all to simplify the goal of getting somewhere or something. Although extra things like a day runner seem to add complexity to our jumbled lives, they actually provide simplicity by producing a result. They become a guide which automates action, free from analysis – one look down and we are off to the noon meeting, or out to our child's baseball game. Power married to simplicity equals machine beauty (Gelernter, *Machine*, 4).

Let us consider the machine's productive capacity as reason for its appeal. Progress was crucial to the frenzied youth of the capitalist Industrial Revolution. During this era, "machines embodied the most highly esteemed ethical values of the time; they were the essence of efficiency and economy. They were as simple as possible, geared to produce the most from the least and were the product of a methodical, rational approach" (Brolin, 48). Again the concept is more with less, not a bad design credo. However machine aesthetics like simplicity, regularity, standardization, and replaceability (Brummett, 40-2) contradict our conception of the design process. If designs resemble natural processes because they formed in direct mimicry of them, then designs may not successfully achieve the aforementioned aesthetics. For example, in nature a monoculture is doomed to destruction, the seasons change regularly but never follow exactly the same calendar, no two trees or snowflakes are the same, and plankton could never be replaced in their crucial role to a food web.

The machine's embodiment of all that is Modern, what Paolo Portoghesi calls the "theology of the new" (Portoghesi, 7), is a final consideration of its appeal. After World War I a significant community of artists and designers vigorously sought inspiration which was wholly devoid of romanticism. They wished to disavow the past in favor of a Modern world; they became the pioneers of Modern design. In *The Bauhaus and America* (1999), Margret Kentgens-Craig notes the importance of, "The maturation of one specific idea among many that had arisen from the experience of the war: that older values had proved inadequate to resisting collapse, and that radical reform was imminent" (Kentgens-Craig, 37). It is revolutionary to proclaim that design must be disassociated from the past. As has been declared in this paper, the past (that being nature's past), has provided essentially all of the tools with which we have designed and do design. Considering a disassociation with the past, Simone Weil writes:

> It is useless to turn away from the past to think only of the present. It is a dangerous illusion to even think that this would be possible. An opposition between present and past is absurd. The future doesn't bring us anything; doesn't

> give us anything; it is for us to build it, we must give ourselves to it….But to give it is necessary to possess, and we possess no other life, no other lymph, than the treasures inherited from the past, and digested, assimilated, recreated by us. Among all the needs of the human soul none is more vital than the past. (qtd. in Portoghesi, *After,* 27).

With Weil's words in mind, it is possible that in disavowing the past, a designer necessarily creates a restrictive formula. Formula eliminates the value of experience, experience that designers accrue. Remember Barratt's description of design as making a presence in the world of the mind. The mind is a memory bank filled with experience. Memory is past experience. A machine assures completion based on material input, without a need for reference – the fiftieth widget will exist without reference to the first; it is merely the first all over again. The assembly line churns out a product as thoughtlessly as one would rubber stamp a stack of library books. This kind of simple, repetitive production attracted the Modernists. In it they saw the machine as the element with which design must come to terms. In design however it is inadvisable to work without an intense comprehension of the past, even if only the past of one current design. What if the Stone Age man had disavowed the past in the design of dry shelter, would he not forget the failures which led to cold, wet nights and be doomed to repeat them? How can we get anywhere if we have been nowhere? The past represents the failures and ubiquitous error discussed in the first two chapters, which are integral to the dynamism of the design process.

CHAPTER 4

POST-INDUSTRIAL AGE CONCEPTIONS OF THE MACHINE AS DESIGN MODEL

Machines and Modern Design

Having discussed the origins of human design next to those of the machine, it is obvious that the two are distinct. Human design developed out of copying the environment; the machine from a desire to control it. For millennia, this duality has created innovative designs, provided useful tension, and created innumerable problems. Over the latter portion of those millennia, man has been increasingly attracted to the machine's simplicity, as the world has evolved into a machine age and strayed from the natural world.

Machine aesthetics, found in the machine's form, function, and in its newness, appeal to a significant stratum of the population. So significant is this stratum that designers in the machine age have turned *en masse* to machine aesthetics (or at least a semblance of them) as the foundation for their designs, formally and ideologically. The machine has become that which is Modern, and a new manifestation of it is always available to mitigate staleness. Departure from tradition in generating form is often attributed to the revolution of the machine age. The amorphous landscape designs displayed by Garrett Eckbo (1910-2000) in numerous residential designs, or by Roberto Burle Marx (1909-1994) in the gardens around his home and across Brazil, for example, fell under a category of revolution because they were not reminiscent of the French, the English, or of any tradition. Although the kidney shape of an Eckbo pool or a Burle

Marx planting bed is ostensibly a long way from the rigid, binary nature of a machine, critics described it in machine terms because it was Modern, because it seemed to disavow the past. Did a Modern designer like Garrett Eckbo use the machine as the foundation for a new *ism* of design? I will not seek answers to that question, but rather I will seek determination of whether various design thinkers like him comprehend the machine's algorithmic nature, and design accordingly, especially when the machine is used as explanation for the origins of a design.

The next section of this paper will explore the work and philosophies of representative designers of roughly the last century. I neither proclaim that these are the most useful examples, nor that they are the only examples, rather that they are representative of an evolution in the machine's value to design thinkers. After viewing these personal conceptions of machines, it will become evident that there neither is, nor was, a single incorporation of machines into design theory and application. Rather, there has been a plethora of incorporations, and their manifestations change notably over time and across designers, bringing varied designs with the change.

The last century has witnessed the wildest transformation of the general perception of machines, from idolization to fear to dependence to disdain. In fact, in the twenty-first century, no general conception of the machine exists (if one ever did), owing partly to the profound breadth of information currently available. Because a general perception of the machine is unlikely today, does not imply that during the height of the Industrial Revolution a general perception could not exist. The newness of machines was real then, and a smaller catalog of machines allowed for easier classification. Authors and the public alike were enamoured of the locomotive or the steam engine. Brolin's magical appeal was in full swing, and designers, like the public, were often swept up in the magic.

While designers like American Frederick Law Olmsted (1822-1903) and Englishmen William Robinson (1838-1935) experimented with organic forms and processes, towards the end of the nineteenth century, a design movement emerged which proclaimed the machine as a focal point of its vision. Whether he knew it or not, a pioneer of this movement was Henry Hobson Richardson (1838-1886). Mumford claims, "Richardson was the first architect of distinction in America who was ready to face the totality of modern life" (Miller, 52). One of Richardson's contributions to design came in the 1880's, during a commission to build railroad stations. He understood that nothing in the nature of a suburban railroad station was reminiscent of any existing architectural style (Miller, 52). This forced him to boldly abandon sacred architectural tradition, like the use of ornament, and look toward the modern world for inspiration (the Modernists would soon follow). Avoiding a safe, traditional form for the depots, Richardson created a new sensibility in his designs, which captured the essence of the railroad station and not, for example, that of a cathedral. By paying attention to the waiting areas and using windows in a useful rather than decorative manner, Richardson executed a functional design (Miller, 53).

Pye offers an especially salient critique of functionalism. Not only does he refute the concept, but he also provides a parallel analogy to the task here at hand:

> Now plenty of people do really believe that form can follow function; that if you thoroughly analyse the activity proper to the thing you are designing, then your analysis will provide all the information needed, and the design can be derived logically from the function. Plenty of people still believe that 'purely functional'

> designs are possible, and believe that they themselves produce them, what is more! But none of them has yet divulged what an analysis of a function looks like and what logical steps lead from it to the design. All you get from them is talk about the purpose of the thing, which…is a statement of opinion and can never be anything else. (Pye, 12).

Pye's statement can be viewed as a refutation of algorithmic design. He infers that to ascribe one function to something limits its potential and effectively ignores beneficial unintended results. Functionalist design then limits the design process. Pye claims that functionalism is impossible on the grounds that one function (purpose) cannot be definitively attributed to a thing.

A machine's purpose is often defined as the performance of a single task (Brolin, 48; Brummett, 40). A universal problem in relating designers to machines is that their products are incompatible. By our understanding of design, a design must be a living, evolving process, and not a fixed product. Conversely, our understanding of machines tells us that they aim to produce a single product or task. This incompatibility surfaces throughout human design, and designers have often displayed a misunderstanding of design in relation to the simple production of a machine. Most often, they forget or ignore that machines cannot engage in the evolving process crucial to design.

Let us briefly examine a contemporary of Richardson's – Louis Sullivan (1856-1924) – to illustrate a mechanized design conceptualization popular at the end of the nineteenth century. Often credited with coining the phrase 'form follows function', Sullivan explored what materials and functional expressiveness meant to design. Cheney and Cheney proclaim that he asked for organic architecture, and also, "that there is to be constructed out of industrial forms such an expression of industrial America's life as will become the American machine-age architecture" (Cheney & Cheney, 30).

Sullivan's buildings, often exquisitely crafted, experimented with steel and sought to create a unique identity based upon their confrontation with a modern world, ready to embrace the "steel skeleton as a load-bearing structure" (Joedicke, 24). His primary pertinence to this paper comes in his design methodology. In creating a recipe for office building design, he made the skyscraper a uniform entity, and contended that it should be designed uniformly to follow that function. Towards a definition of the architect's problem in office building design, he offers his recipe for them in *Kindergarten Chats*:

> Wanted – 1st storey below ground containing boilers, engines of various sorts, etc….2nd, a ground floor, so called, devoted to stores, banks, or other establishments requiring large area, ample light, and great freedom of access. 3rd, a second storey readily accessible by stairways – this space usually in large subdivisions….4th, above this an indefinite number of offices piled tier upon tier, one office just like all the other offices….5th, and last, at the top of this pile is placed a space or storey that, as related to the life and usefulness of the structure, is purely physiological in its nature…. (Joedicke, 28-9).

Sullivan's recipe is his algorithm for office building design, complete with a call for uniform office size throughout. Just like Sullivan's parts of the office building, "the machine's motions and processes are uniform; but of equal importance from the point of view of production is that what it produces is uniform" (Brummett, 41). Human sensibility, unlike the machine, is rarely able to stomach uniformity – we are all too different, like snowflakes, and as such demand change rather than afford compromise. Cheney and Cheney state, "Sullivan had embodied in his philosophy an aesthetic of all things that man contrives in mass for man's uses, with only a difference of degree between airplane and ash tray, streamline train and toy cart, vanity case to skyscraper" (Cheney & Cheney, 31).

Standardization is implicit to Sullivan's philosophy – it suggests a rationalization of mass production, of design by formula. In an essay from his novel *The Brown Decades* (1931), Mumford recounts this tale about Sullivan's education:

> Sullivan's mathematics was at first inadequate, and he studied it under a French master. This man, M. Clopet, scanned the mathematical textbook that Sullivan had purchased in advance and said, 'Now observe: here is a problem with five exceptions…here a theorem, three special cases; another nine and so on and so on, a procession of exceptions and special cases. I suggest you place the book in the wastebasket; we shall not need it here; for our demonstrations shall be so broad as to admit of no exceptions! (Miller, 60).

Sullivan applied a no-exceptions ethic to skyscraper design, and consequently created a static design model. Being swept up in the magical awe of the machine it was easy to forget about the origins of human design, of the trial and error, and more importantly how successful those origins have been to human development, and are to human design. What happens, for instance, if fifty years pass in the life a Sullivan office building and its function must change to living quarters? Sullivan asserts that where function does not change, form does not change (Joedicke, 27). If however function does change, or as Pye suggests, no one function may be attributed to any one thing, Sullivan's recipe must be flexible enough to accommodate the change.

In describing Sullivan's highly formulaic office building design, the term 'machine' is avoided. Instead we see 'functionalism'. Not until the emergence of the

European Modernists do designers openly claim the machine as inspiration for design. Brolin comments, "In the early twentieth century an architectural revolution took place. All traditional styles were declared null and void – to the point where putting ornament on a building was regarded as a criminal act" (Brolin, 14). Brolin's hyperbole shows the extension of Modern design beyond the nineteenth century.

A clear extension of functionalism is seen in the work of Walter Gropius (1883-1969). After a grueling tour of duty fighting for Germany, Gropius returned to his bewildered homeland to resume what had been a successful architecture career. However his country had changed after World War I, and a new frontier offered by the machine became a leader in a design revolution. Four years after founding the seminal Bauhaus in Weimar, Germany, Gropius wrote in *The Theory and Organization of the Bauhaus* (1938):

> We want to create a clear, organic architecture, whose inner logic will be radiant and naked, unencumbered by the lying facades and trickeries; we want an architecture adapted to our world of machines, radios and fast motor cars, an architecture whose function is clearly recognizable in relation to its forms. (Bayer et. al., 29).

Gropius calls for an appropriate technology to come out of the Bauhaus projects. Rather than pander to an existing or outdated style, or to copy French formalism, for example, Gropius wants to disregard existing styles and create new ones. The problem of course is that as soon as one style is created, it admits to the flaw inherent to that choice (the ubiquitous error), and subsequently becomes outdated and may be amended by subsequent designs. In lieu of Gropius' proclamation, a central concern of the Bauhaus is human adaptation to a world of machines. Should we adapt to such a world or rebel against it? A middle ground, which recognizes the transience of any style and seeks to acquire knowledge from the failures of previous styles may be the most suitable methodology. But Gropius and his ilk embrace the machine age as a frontier toward which design must race; conversely there are those, especially toward the end of the twentieth century, who impugn the need to adapt to mechanization.

Using Gropius as a quintessential European Modernist, let us examine some of his work in order to satisfactorily evaluate his conception of a machine-model for design. In the Bauhaus manifesto Gropius wrote, "The Bauhaus believes the machine to be our modern medium of design and seeks to come to terms with it." (Bayer et. al., 29). In Gropius' era, labeled *The Wasteland* by T.S. Eliot, the machine represented a new world to those sickened by the drudgery, decadence, and failing traditional values of the old one. Gropius and the Modernists could not ignore the machine as a model for revolutionary design. In question is the machine's appropriateness as design model and the designer's understanding of it as a model.

Prior to World War I Gropius found success in designs like his seminal Fagus Building (1911), which exhibited a new method of construction, pulling the corner beams in toward the interior, thus leaving the corners seemingly open, covered only by a glass skin, supported by cantilevering the floor beams (Fitch, 19). In describing Gropius' functionalism, critic James Marston Fitch writes, "Science and technology appeared to [Gropius'] generation as much safer paragons than human passion" (Fitch, 15). It is hard to argue that science and technology are *not* ideal models for the creation of machines; however they may not be ideal models for designing improvements to non-quantifiable qualities of life, which the Bauhaus claimed in part to be doing.

When Gropius names the simple, geometric machine as his design model, he attempts to marry incompatible concepts by creating a formula for his design. The formula is especially visible in some of his house designs, namely in Dessau (1925), in Lincoln, MA (1937), and in the Howlett House (1949). They represent what may be called a standard white Modernist house – cube-like form, smooth exterior white walls, flat roof, open floor plan – and can hardly be distinguished from a house designed by De Stijl (The Style) member and pioneering Modern designer Theo Van Doesburg (1883-1931), Le Corbusier, or even a young, and still Modern Michael Graves (1934-present). Gropius notes, "architecture went hand in hand with technology and had developed a characteristic appearance that deviated from the old craft of building. Its identifying traits are clear, well-proportioned lines from which all unnecessary ingredients have been removed – the same traits characteristic of the modern engineered products of the machine." (Kentgens – Craig, xvii). It is acceptable for design to exhibit identifying traits. But when those traits appear on multiple projects, spanning time and the globe, and are rooted in the standardization of machine production, they seem to exist for themselves, not for the design, and they become a style. Following a style, requires following a formula, therefore, in designing to a style, even the rebel designer may compromise the design process – form follows formula.

A similar style recipe may be found in the contemporary example of the *Charter of the New Urbanism* (1998), a document produced by the Congress for the New Urbanism. Although the twenty-seven principles defined in this charter are broad statements directed toward the reclamation of livable societies, they seem to be playing a dictatorial role in the final style of New Urban neighborhoods. Regardless of location, the New Urban neighborhood follows a strictly defined formula, to which the constitution of its inhabitants is expected to adhere. Like Gropius' white house which often fits neither a land nor regional aesthetic, the New Urban neighborhood, while following its criteria for livable communities, often isolates itself from, rather than integrates itself into a region.

Another figure synonymous with Modern design is Le Corbusier (1887-1965). In *Towards A New Architecture* (1927), he proclaimed, "Architecture is stifled by custom. The 'styles' are a lie." (Le Corbusier, *Towards,* 9). With that proclamation Le Corbusier hints at an organic conception of design, one not held to custom. However in the same book is the infamous quote, "The house is a machine for living in" (Le Corbusier, *Towards,* 10), explained this way by architectural critic Jurgen Joedicke: "In its original context it simply means that the programme for a home should be set out with the same exactitude as the programme for building a machine" (Joedicke, 90). Note that Joedicke uses the term 'home' which signifies a place, even a feeling, and not simply a structure. To equate the design of a home to that of a machine implies that a home may be schematically generated. The inhabitants of a dwelling create a home, and with a human-derived form, it cannot be predicted by the algorithm of a machine schematic. In framing the central problem of house design Le Corbusier adds:

> If we eliminate from our hearts and minds all dead concepts in regard to the house, and look at the question from a critical and objective point of view, we shall arrive at the 'House Machine,' the mass production house, healthy…and beautiful in the same way that the working tools and instruments which accompany our existence are beautiful. (Le Corbusier, *Towards,* 12-13).

This is a functionalist statement and represents a Modernist conception of design. Rather than valuing human needs and a unique sense of beauty, Le Corbusier imposes a machine aesthetic upon humanity. At the core of his statement is the notion that humans are mere cogwheels in a state of progressive mechanization (Bertalanffy, 10) and further that they are privy to machine aesthetics. Barry Brummett notes:

> To think of aesthetics in terms of a faculty of appreciation raises the possibility that not everyone will have the faculty to appreciate an aesthetic dimension of every experience….we should note here that not everyone has a faculty with which to appreciate machine aesthetics. (Brummett, 7).

Brummett's comment questions Le Corbusier's statement that a house is beautiful in the same manner that a hammer is beautiful. Human sensibility follows no rules, and subsequently, we may not all understand the beauty of a hammer strike. In reference to Pye's argument against functionalism, a house has more than one function, not all of which are envisioned by the designer, but may be experienced by the inhabitant.

Le Corbusier implies otherwise. His language is full of mechanization, especially the mechanization of human life. Lauding his contemporary French architect Auguste Perret's dream plan for a City of Towers, Le Corbusier states, "In these towers which will shelter the worker, till now stifled in densely packed quarters and congested streets, all the necessary services…will be assembled, bringing efficiency and economy of time and effort, and as a natural result the peace of mind which is so necessary" (Le Corbusier, *Towards,* 56). In these machine-like terms we see one of Le Corbusier's misconceptions of the machine as design model. He proposes that a non-quantifiable sensation – peace of mind – may be the product of formulaic design – the City of Towers. This cannot be. Designing for peace of mind is analogous to designing a computer to love via artificial intelligence, which is impossible by the very nature of the incompatibility of machines and human emotion.

Echoing a similar reliance upon the machine is Le Corbusier's utopia *Ville Radieuse,* or the Radiant City. Le Corbusier's motivation for designing the city was individual liberty (Le Corbusier, *Radiant,* 90), and his explanation of it is "technical and vigorously precise" (Le Corbusier, *Radiant,* 94). He leaves little room for interpretation in the design, by defining the components of the Radiant City with imperatives containing the terms 'no', 'never', and 'all'. He falls prey to the lure of perfection when he says, "…if we wish to save industry and throttle the growing unemployment, we must rebuild the country by constructing prefabricated houses in factories" (Le Corbusier, *Radiant,* 96). By allowing a standard design to be replicated, that design is attributed with perfection and the vital design process ends. Production and design are two different things.

The Radiant City is a formulaic design that ignores the importance of adjustment. The occupants are to be uplifted and liberated by its sincerity, yet it offers little adaptation to personal idiosyncrasies. Each inhabitant is afforded fourteen square meters of living space, in much the same manner that buyers were afforded with a black Model-T in 1909. Commenting on the appropriateness of Le Corbusier's Radiant City, Modernism critic Peter Blake introduces the city of Zagreb, Yugoslavia, which he states, "is an updated version of Le Corbusier's *Ville Radieuse*" (Blake, 85). Old Zagreb, he notes lies to the north of the River Sava, and the Radiant Zagreb to the south. The characters of old and new Zagreb illustrate an important danger in formulaic design:

> Every evening the people of Zagreb gather in the streets of the old center of town…The center of town is jammed with pedestrians, its sidewalks crowded with cafes, its streets closed to automobiles and opened wide to young and old alike…Meanwhile, to the south of the River Sava, those great expanses of

> greenery between the concrete and glass apartments are deserted. No one ventures out…People stay inside their modern apartments – unless, of course, they have taken off in the general direction of the old town center, to join their fellow citizens. (Blake, 85).

New Zagreb's emptiness reveals the town's ubiquitous error. We can neither predict nor dictate human behavior with any design. The danger in succumbing to a style is that when one person (the author of the statement above) can describe the design (new Zagreb) with disdain and mockery, the design admits that it is not suitable for everyone. By defining the new Zagreb as a utopian city, its designers ignored the ubiquitous error of the design. Blake names several unwanted results of Zagreb's design: "In the Vertical City, your neighbor is your enemy, the person who hammers nails into the other side of your wall…interior ventilation ducts convey to you the breakup of a marriage in Apartment 27D and the despondency of a poodle in 30G" (Blake, 80). New Zagreb's designers perhaps never envisioned such useless things that their design had to do, yet the design does them. Consequently it is not universally suitable, and ought not be proclaimed as such.

Another contemporary example illustrates the concept of the ubiquitous error in design. In 1982, while with SWA, landscape architect George Hargreaves designed Harlequin Plaza outside Denver, Colorado to an array of praise and awards. His design transformed a "50,000 square-foot roof of a parking garage between two reflective-surface office buildings" (Thompson, 96) into an *Alice in Wonderland*-esque dream-like hardscape solution, arguably devoid of human feeling or comfort. Sixteen years later the building was sold, and the new owners wanted change. Citing a need for a more people-friendly space, where employees could eat lunch, they sought a new design from EDAW of Denver in 1998. Today only slight remembrances of Hargreaves' original design remain on-site. In its place is a tree and bench-heavy design that adequately pleases new design criteria.

No one knew that, so soon after its creation, the original design would fall prey to a new sensibility – in this case user-friendliness over land art. But it did, and rather than being tweaked in response to new design criteria, the whole design was essentially scrapped. It is not within the confines of this paper to critique the reasons why the design failed, but it can be surmised that somewhere Hargreaves' design process ended, thus bringing the demise of the design. Unbeknownst to Hargreaves, his design, in part, resulted in people not using his space. The dilemma of Harlequin Plaza brings to mind a quote of unknown origin that goes something like this: "It is quite difficult to build a space which is uncomfortable to the vast majority of people; what is amazing is how often it is accomplished."

Maybe Hargreaves thought the design was perfect and did not pay attention to information gained after its construction. In other words, maybe he ended the design' evolution himself. Perhaps human sensibilities changed and Hargeaves' design, which challenged and shocked upon installation, became unattractive. We simply do not know why things change, or what any thing might evolve into.

<u>A Post-Modern Model</u>

After describing a Modernist conception of machines, I will use the idea of the Post-Modern as another example of the dangers of algorithmic design. Rather than examining specific Post-Modern designs, or attempting clarification of the broad Post-Modern ideology, I will explore circumstances which led to a Post-Modern sentiment and show how they themselves illustrate ubiquitous error and the dangers of designing based on formula.

Following the early decades of the twentieth century, Modernism was the omniscient *ism* in design. As with all revolutions, the freshness of its ideology had to pass, its error had to become apparent, and subsequently bring a correction. The reason for any revolution includes a need for change (a correction) felt by a sufficiently large enough population to affect that change. In a collection of essays entitled *Form Follows Fiasco* (1977), Peter Blake displays the reactionary sentiment of the Post-Modernists:

> …the problem that the Modern movement really wants to solve, judging by its performance to date, is the infuriating anatomy of the human race: nothing, dammit, is going to function –Bauhauswise – unless all men are redesigned as cubes, and all women redesigned as spheres. Once that is accomplished, everything else will fall into place with a barely audible click…. (Blake, 144).

Blake's sarcasm is aimed at Modernist ideology, an ideology that, to him and many others, required that mankind adjust to it rather than the opposite. Design must accommodate a problem. It cannot expect that a problem will accommodate it. Writing in response to Jurgen Joedicke's Modernist-friendly *A History of Modern Architecture* (1959), Phillip Johnson pleaded, "There is only one absolute thing today, and that is change. There are no rules, absolutely no given truths in any of the arts" (Portoghesi, 33).

Johnson captures the essence of my argument. (I would however add that the word 'today' in his statement ought to be changed to 'always'.) If one considers design as a manifestation of Johnson's use of the word 'arts', it is understood that nothing in that artistic realm is final. Ideology may not be considered final because a new transient truth will come in response to it. It is historically evident that man reacts ideologically, that one concept inevitably leads to another. Helen Marie Evans notes that dissatisfaction is a strong force behind human design (Evans, 5). The moment that a design exhibits a weakness, a flaw, we search for a correction, just as a natural system does internally, and just as the design process necessitates. The Modernist movement had to produce a reaction which led to a reactionary movement – Post-Modernism, for one. Although many classic Modernists write as if they found the answer to design, they found but one solution amongst an infinite number of possibilities.

Take for example this command offered by Le Corbusier, "The great problems of modern construction must have a geometrical solution" (Le Corbusier, *Towards,* 36). His work is filled with imperatives. Imperatives are necessary in making a point just as algorithms are in making a machine. The creativity of design however allows for few absolutes, due to its evolutionary nature. David Gelernter conveys useful ideas regarding the origins of creativity with these three facts about it:

1. The core achievement of restructuring and creativity is the linking of ideas that are *seemingly unrelated.*
2. Inspiration comes as a bolt out of the blue. It occurs as a moment of sudden awareness. It is not something to which you work up gradually….
3. Hard work does not pay….Inspiration occurs *not* when you are concentrating on the problem to be solved, but exactly when you are *not* concentrating. (Gelernter, *Muse,* 84).

From these facts, one may deduct that creativity might not be the product of a well-defined formula, but rather that it is the product of chance, in familiar terms, a product of unwanted results, of experimentation and realization. The transition from one *ism* to another, then, comes from ubiquitous error inherent in the prevailing *ism*. The transition is spontaneous and does not necessarily stem from a concise formulation of the problem.

Ecological Design and the Machine

> [Reference to the environment] was absolutely categorically rejected in the International Style, where the assumption was that there was a generic architectural solution which was appropriate to all people, in all places, at all times, which, of course, has been demonstrated to be inappropriate for all people, and all places, at all times! - Ian McHarg (Cousineau & Zelov, 54).

McHarg condemns design by formula in this reaction to Modernism. The statement provides transition into another design arena which addresses the concept of the machine – ecological design. Designing in accordance with general ecological principles has gained momentum over the latter half of this century. When McHarg's opus, *Design With Nature* was published in 1969, society was tumultuous and rebellious. The reactionary activism of the sixties and seventies aided a blossoming of the 'rights of nature', Roderick Nash's phrase connoting an acceptance of nature as an entity worthy of ethical consideration. As man disassembled the Cartesian duality of man and nature, many design thinkers searched for appropriate corresponding design solutions. It was the era of Todd's New Alchemists, landscape architect Ian McHarg's (1920-2001) ecological suitability analysis stemming from his opus *Design With Nature* (1969), and arguably the pinnacle of an understanding and application of inventor/philosopher/mathematician R. Buckminster Fuller's (1895-1983) unique contributions.

Roderick Nash comments, "One of the most characteristic ideas of the 1960's concerned the need for fundamental changes in American life and thought. At its deepest level, the so-called counterculture advocated a new morality and the wholesale dismantling of many established institutions" (Nash, 166). Nash evokes a Modernist credo popular some decades prior. He describes a group of people, and an era, in active reaction, but in reaction to the earth's degradation by a prolonged reign of the Industrial Age. Popular culture echoed Nash's organic ideology. Examples include Stanley Kubrick's mesmerizing films, *2001: A Space Odyssey* (1968) and *A Clockwork Orange* (1971), which display a general fear and loathing of the manipulative power of machines. Similarly, Aldous Huxley's novel *A Brave New World* (1932) enjoyed a resurgence of influence amongst the era's youth and many critical thinkers. The war machine in Vietnam was a powerful element as well. A general anti-machine sentiment was visible in a segment of the population, and astute designers were often affected by this conception of the machine.

Yet what is so interesting about design during this era is that many of the so-called ecological designers, such as The New Alchemists and Bucky Fuller's disciples (like J. Baldwin, inventor of the Pillow Dome, and Stewart Brand, founder of the Whole Earth Catalog), and a collection of fractal / chaos experimentalists, display an underlying idolization of mathematics and technology. Take for example some of the inventions of Buckminster Fuller – geodesics, the dymaxion car, and dymaxion houses - homes which were prefabricated for mass production a la Le Corbusier. Fuller's work was socially just and ecologically sound, while relying almost wholly upon technology, and a new mathematics called Synergetics. The New Alchemists similarly experimented with one new material after another in hopes of finding a usable solution to the restrictions of their land. Paolo Soleri, designer of the utopian eco-community, *Arcosanti,* states, "[Buckminster Fuller] saw technology as the resolution of our problems, and I tend to agree with him, but it has to be a technology-to-come" (Cousineau & Zelov, 240). Soleri captures the essence of revolutionary design over the last several decades. Implicit in design of that period, is a reluctance to vociferously side with technology as a resolution to society's ills, yet many designers have cleverly adapted technology-to-come into their ecological design solutions. Unless aided by some form of a new machine, designers showed little faith in natural systems, or mimicry of them, as dependable models upon which to solely base design.

William McDonough and John Todd are representative ecological designers who directly address the machine and also incorporate a new technology into their design. In his strive toward the elimination of waste from the industrial process, McDonough exemplifies the tenuous position of the twenty-first century ecological designer, in that much like the Post-Modernists, he exhibits a strong reaction against the Industrial Age, but in his design, must rely heavily upon technology, or "technology-to-come" in Soleri's words. The machine is truly unavoidable today and McDonough must use some manifestation of it to complete his ecologically-driven projects. John Todd, while also loathing a 'mechanocentric theory of the universe' (Todd & Todd, 15) conversely, attempts to redefine the machine altogether, and use that new manifestation - the Living Machine® - to ecologically enhance the world.

McDonough's value to this thesis lies in part within his coherent argument for ecological design. Listening to McDonough assail the "strategies of tragedy" which plague human design throughout history, one becomes swept up in a unique magical awe. Unlike the awe Brolin describes, McDonough's assault places the machine upon a pedestal of scorn, and one wonders if its power as a design model lies wholly in an example of what ought not to be done. His lectures are powerfully convincing in their simplicity and offer a structured assault on 'remaking the way we make things' (the subtitle of his first book). Beyond a well-crafted philosophical platform lay McDonough's physical contributions to design.

Toward understanding his philosophy, consider this statement McDonough made in an address entitled, "Design, Ecology, Ethics, and the Making of Things,":

> If we understand that design tends to be the manifestation of human intention, and if what we make with our hands is to be sacred and honor the earth that gives us life, then the things we make must not only rise from the ground but return to it, soil to soil, water to water, so everything that is received from the earth can be freely given back without causing harm to any living system. This is ecology. This is good design. (Calmenson, 2).

His first book, *Cradle To Cradle* (2002), co-authored with his ecological chemist partner, Michael Braungart, echoes the ecological sentiment of the statement above, in that it posits an anti-machine ethic. Rather than designing for ends, for products, McDonough believes that designers ought to design in harmony with cyclical and on-going natural processes. His cradle-to-cradle theory contrasts the standard cradle-to-grave design approach, wherein a thing is used until it is no longer capable of production, at which time it is discarded. Cradle-to-cradle design assures an evolutionary cycle, and thus gives production new meaning. McDonough shifts the idea of industrial production to one of metabolic production. He calls it the revelation of the two metabolisms: "There is the biological one and the technical one. So things should be designed to either go back to the soil safely…or designed to go back to industrial cycles forever, without contaminating the natural cycles" (Griscom, 2). This effectively eliminates waste.

Following the two metabolisms, McDonough's philosophy returns design to mimicry of nature. Effectively McDonough sees waste as the ultimate ubiquitous error in all design. He suggests that buildings, like trees, should produce more energy than they consume and purify their own water, that factories should produce effluents clean enough to be drinking water, and that products, after their useful life is over, should not be tossed onto a junk pile, but rather should decompose, going back to the soil (Braungart & McDonough, *Cradle,* 90-1).

To McDonough, design is a manifestation of human intention. If human intention is to honor the earth's complex cycles, then necessarily we may not design using the consumptive, polluting, and simple machine as a design model. Without speaking directly about machines, McDonough's philosophy rants against them:

> That there could be an international style where one size fits all is a joke, it's dangerous. Nature is an intricate system made up of millions of organisms, no two of which are alike. The fact that they aren't alike is what keeps the system going. That's biodiversity and we must apply this kind of diversity to [design]. (Calmenson, 4).

Intricacy and diversity are antithetical to machines. They may in fact be considered errors in algorithmic design, often representing the failure of a mechanistic design. McDonough places importance on the naturalness of systems as a design model. By naming uniqueness and diversity as systems generators, McDonough sets a standard to which his design must conform.

After the drafting of the Hannover Principles (1992) for sustainable design, one might think that McDonough had initiated a new style, that he had begun to follow a formula directly, reminiscent of Sullivan's office building or the Charter for the New Urbanism. However in reading the principles (see Appendix B), one realizes their inherent call to flexibility in design, and their recognition of design's ubiquitous error.

Rather than defining a strict course of action with commanding phrases like, 'no' and 'always', McDonough asks that attention be given to ambiguous qualities: "recognize interdependence"; "rely on natural energy flows"; "accept responsibility for the consequences of design" (McDonough, *Hannover,* 4). The postscript to the principles includes, "the Hannover Principles should be seen as a living document…so that they may adapt as our knowledge of the world evolves" (McDonough, *Hannover,* 4). To admit man's incapability to fully determine his own path through formula (domination) would be anathema to many designers, of many eras.

With a glimpse of McDonough's ecological philosophy, let's briefly examine his architecture, to see if, and how, it generally conforms to his philosophy. Although McDonough's philosophy renounces an adherence to formula – "Buildings should be designed to be flexible enough to accommodate many human purposes," (McDonough, *Hannover*, 6). His buildings' exteriors display similar forms and use similar materials across distinct sites. Remembering his call for diversity to generate a system, one may notice that it is difficult to find a McDonough building that does not include Gropius-like glass skins, employed to reap the benefits of the sun and wind. Whether this feature detracts from the aesthetics of the buildings is not a concern. What is of concern is the frequency with which this feature appears in McDonough's buildings, across distinct sites and climates. Another feature of his architecture that appears frequently, but not nearly as often as the glass walls, is the arched roof (or arc-form somewhere else in the design), incorporated to mimic a tree canopy. Understandably, such features are manifestations of McDonough's philosophy; however in viewing various projects it appears as if McDonough occasionally falls prey to a style dilemma, by using the features in a manner dangerously close to frivolity.

Also demanding attention is McDonough's conception of his buildings as living machines, using the term quite differently than does John Todd. A machine must perform a task, so we must ask, what task is a McDonough building accomplishing? Beyond providing shelter and work-space, the building's fecundity is a task. Production of clean air and purified water are ends, but McDonough also believes that he is producing non-quantifiable ends – social justice, ecological intelligence, comfort, well-being. By defining non-quantifiable ends as products of design, McDonough necessarily eliminates algorithms as potential design models. They are incapable of achieving his goals.

In describing a green roof project of his, which illuminates, ventilates, heats both air and water, and protects from rain, McDonough explains:

> So we're leaving something better that the way we found it. In fact, in some cases we can actually try to get beyond a neutral location and get to a fecund location. We can actually design things that produce more than they take in over a long period of time, so they become like a tree. (Cousineau & Zelov, 130).

Fecundity is critical to McDonough's work. His buildings must be, in a sense, alive, regulating their air temperature and quality, reacting to occupancy patterns by automatically illuminating areas as necessary, and with the help of Todd's Living Machines®, purifying their own water. They are meant to produce, not simply sustain, or maintain themselves. However, the buildings' vitality, for the most part, progresses only as far as technology allows. They rely upon automatic lighting, heating and cooling automatically retractable blinds, upon automatic machines. Only ostensibly are the buildings living systems. They are systems mechanically operated; therefore their intricacy is barely real. Rather it is mechanically-controlled intricacy.

Technological mechanism in ecological design is a conundrum of the twenty-first century ecological designer. Technology is so important that it often becomes necessarily integral to a design which aspires toward ecological intelligence and social justice. Although used towards satisfying those aspirations, the technology can be cost-prohibitive and technically confusing. So in using it, social justice may be hindered by limiting use to wealthy clients, and technical precision may outshine mystical organicism in the design.

To battle the conundrum, enter John Todd, whose Living Machines® are living systems effectively transformed into productive machines. Like McDonough and so many others, Todd wants to reverse what he calls a new cosmology, characterized by a clockwork universe, and a natural world functioning mechanistically, machine-like, removed and separate from ourselves (Todd & Todd, 14). Todd's philosophy of ecological design reads like a direct reaction to the degradation caused by the Industrial Revolution. Concerns guiding his design include the mistreatment of water and soil, and biological inequity (an inequity that Noam Chomsky refers to as 'The Prosperous Few and the Restless Many').

At the core of his philosophy is the New Alchemists' empirically-gained "affirmation of the regenerative capabilities of the planet and of the human role as stewards of the earth" (Todd & Todd, 8). To be stewards of it, mankind must oversee nature in some way, which implies a domination ethic. Consider Anatol Rapoport's words in the essay, *The Search for Simplicity* (1972):

> Science is clearly a systematized search for simplicity, a method of making the world predictable. The most conspicuous feature of science, which, in popular estimation, both explains its origins and justifies its existence, is that it represents

> the harnessing of the search for simplicity to other purposes, specifically to gain power over the environment. (Laszlo, 18).

Rapoport's words are ostensibly critical of the scientific world. It is not my intention to further that concept one way or the other. Instead, I use Laszlo's statement to distinguish Todd's ideology from that of a dominion-complex often encountered in science and religion, wherein nature becomes a slave to mankind (Nash, 90). Recall that Todd has faith in his Living Machines® to 'figure out' problems which they encounter. To him, Living Machine® technology ensures complexity, and inventively makes it a tool with which man may accomplish a task while avoiding the domination of natural processes. He embraces the unpredictability of the natural world, and uniquely uses it toward human ends. In effect his product (clean water for example) is achieved with that unpredictability.

He understands that mankind can afford mistakes. "Failures," he says, "can be recycled into more useful forms and tried again, leaving open the possibilities for continual choice" (Todd & Todd, 8). Imagine if a worker, in a building which houses a Living Machine®, dumped two gallons of bleach into a toilet. The bleach would seriously affect the Living Machine®, possibly halting its productive capacity; however with time, nature would fix the problem. Todd relies upon error and a system's subsequent adjustments to it. Part of the stewardship, then, is a full understanding of the evolutionary process of design, complete with ubiquitous error. In lieu of the thoughtless design choices mankind generally exhibited in the twentieth century, an acceptance of past mistakes is critical.

Whereas some designers, like McDonough and Soleri, rely upon a technology-to-come for resolution of the ills caused by the Industrial Age, Todd relies upon existing, living systems to provide a resolution. He proposes that the new technology include a transformation of our conception of machines, from one with mechanical moving parts, noise and exhaust from internal combustion engines, or the silent geometry of electronic devices (Todd & Todd, 171), to one composed of living organisms, housed within in a lightweight casing (Todd & Todd, 167). He wants to create a new machine aesthetic; he wants to redefine the machine.

In explaining his seventh precept of biological design, Todd cites Lewis Mumford: “If we are to prevent [technology] from controlling and deforming every aspect of human culture, we shall be able to do so only with the aid of a radically different model derived directly, not from machines, but from living organisms and organic complexes (ecosystems)” (Todd & Todd, 75). Mumford’s sentiment resembles that which drives many designers toward new technology and ecological design. What is unique in Todd’s application of Mumford’s statement, his radical model, is that he extends beyond merely copying living systems, and lets the living system itself become the evolutionary process which guides the design, which regulates it, and which self-corrects ubiquitous error in the design. Todd’s machine is truly alive. We must ask, then, is it a machine or a living system?

The greatest value in Todd’s invention might lie in its introduction of this machine / nature paradox. By introducing his specifically productive living system, Todd confronts a pertinent conundrum of twenty-first century society, namely how to progress at a suitable rate while sparing enough of the planet to allow for future generations to do the same. In naming his invention the ‘Living Machine’ Todd is prompting society – science, design, industry – to re-evaluate its terms of progress. We have raced through the twentieth century obeying a conception of the machine, which ignores the realities of resource depletion, and which creates mountains of waste. The juxtaposition of 'living' and 'machine' represents a reaction. Machine design contains error and the creation of a living machine is a reaction which recognizes the machine's algorithmically derived error, and offers a solution: to redefine the thing (the machine) and how it is made. The name displays dissatisfaction – with our understanding and definition of machines – which Helen Marie Evans contends is an impetus for design. Historically, machines have led humans to certain points in our development as a species. Without defining those journeys as positive or negative, they, like any other design journey, must learn from error and use the information gained to creatively pursue fresh information.

CHAPTER 5

CONCLUSIVE INSIGHTS

Design is an evolutionary process which seeks resolution of a problem, often a problem which itself is evolving. Primitive mankind ultimately recognized the ubiquitous error in every design, and so too does twenty-first century mankind. Failure is the progenitor of evolution. Design should not be merely the completion of a product; it should be a cycle, an evolution which constantly feeds itself new information. A misconception of design as completion – choosing product over process – is common and often surfaces when designers use the algorithmically-driven machine as a design model. Human design began as mimicry of earth's natural processes; sometime later, the model for human design, in part, became unnatural, mechanistic and product-oriented, whereupon the concept of machines, whether megamachine, jet engine, or computer, influenced the design process, often making it finite and static. The machine's desire to rid designs of error conflicts with the dynamic nature of the design process.

Considering the examples used in this paper, it is difficult to find value in using machines as design models, especially during the early part of the twentieth century. In most cases, machine-derived design strives for a textbook, or perfect, design. Perfection cannot and should not be an option for designers; it may be egotistically sought, but ultimately its paralyzing effect on design must be realized. A lesson learned from Modernism (a lesson learned by some anyway) instructs designers to avoid committing to a universal solution, because universality in design is, as McDonough pointed out, "a joke." Design, like a living organism, evolves, reacts, and progresses unpredictably.

With over a century of post-machine age design history, if little else comes out of the design discipline in the next century, perhaps recognition of design as engagement in a process will finally be accomplished.

Even in the realm of ecological design, wherein the principles of living systems guide design thinkers, and design conception is akin to our earliest ancestors, there exists a machine paradox. In many cases, ecological designers rely upon technology and mechanism to fuel their designs into fruition. Where would McDonough's living buildings be without their automatic window tinting, stairway lighting, and floor heating? Relying upon technology to maintain a design, most often an automatic technology, is dangerous because, in doing so, the design depends upon predictable elements, algorithms of a sort. By its nature, design may not evolve predictably and thus may not depend upon predictability. So, for instance, when a McDonough building is constructed to be alive via the implementation and of dependable mechanization, that building denies its potential to evolve naturally and is alive only as far as its machines will allow. Although of admirable intentions, design which is dependent upon technology-to-come may inadvertently help steer society toward a Huxley-like *Brave New World,* wherein nature fades and technology propagates the human species.

Designers must acknowledge the value of Todd's Living Machines® to design. Whether a machine, a system, or an amalgamation of both, the Living Machine® charges design thinkers to consider a new machine constitution, a new metaphor. It charges designers to confront error inherent in a classic definition of machines, analyze it, and consolidate the information as knowledge toward the pursuit of new information, which is Barratt's definition of design. Arguably Todd's machines represent a pinnacle in design which aims to merge the natural with the technical world. That merger also represents, in a sense, backwards ideological movement toward the origins of human design, when the environment was mankind's most powerful, and perhaps only, teacher.

On at least one level, human design is currently seeking a pure, ecosystem-based ideological foundation as a means of grappling with twenty-first century ills. Examples include the proliferation of native plant community design, seen in the work of Darrel Morrison at the University of Georgia, or Andropogon Associates in Philadelphia. Ecological designers and energy experts Hunter and Amory Lovins display an ecological foundation for design in their seminal Rocky Mountain Institute (1982 - present). The Institute is living proof that a dwelling can satisfactorily power itself from natural sources in an economically as well as ecologically sound manner. At the core of the Lovins' work is the desire to eliminate waste and to return everything in some form to the earth where it may be reused. Commenting on society's tendency to ignore the realities of resource depletion when considering industrial production, Lovins notes, "This is as if we tried to understand an animal only by its circulatory system, without noticing that it also has a digestive tract that ties it firmly to the environment at both ends" (Cousineau & Zelov, 94).

Human beings are directly tied to the environment at both ends and Lovins' comment emphasizes the importance of maintaining a cycle which respects that connection. Critical to Todd's conception of Living Machines® is a need to progress through a self-regenerative cycle. McDonough calls it a cradle-to-cradle cycle, some people use the phrase sustainability, others refer simply to an aquatic ecosystem for example. Regardless of the chosen terminology, it is clear that, like the natural processes of the earth, the design, in any form, must engage a cycle.

The elimination of waste is a key element in both *The Hannover Principles* and *Todd's Biological Precepts* (see Appendices A & B). Nature eliminates waste by constantly cycling its parts – organisms, food, and waste – throughout the entire system, and then making them available to other systems. There are no junk heaps in nature; everything goes back to the earth, is used by the earth. McDonough's work attempts to satisfy two cycles: one which returns things to the earth and one which returns unusable elements to the industrial process, in another form. Todd's machines cycle wastewater until it is cleansed and returned either to the system or to nature.

These two ecological design strategies offer a valuable lesson to contemporary designers and designers to come, in that inherent to their successful cycling is a successful combination of function and aesthetics. A key design criterion is obviously user satisfaction. All too often user satisfaction is subjective, ambiguous or dangerous. Consider an Army Corps of Engineers solution to streambank erosion, wherein both banks of a creek are straightened for a specified distance and reformed as a concrete channel so that the flow of water will meet little resistance and cause little erosion to the smooth concrete walls. This may solve the problem of bank erosion in the short-term, and only along that one length of streambank. However in the eyes of many observers, the concrete channel effectively de-naturalizes the creek and its adjoining flood plain. The question becomes, "Who is the user, and how does the creek function for each user?" The Army Corps of Engineers may be considered the user, but so may a jogger who appreciates the natural creekside landscape, or a Belted Kingfisher who perches along the banks waiting to swoop down and grab a fish lingering in a pool created by a branch snag.

Design must constantly search for an acceptable union of function and aesthetics. The problem is that function and aesthetics are in constant flux, much like the earth's natural systems. If designers intend to satisfy a user, it may be appropriate to define the earth as the ultimate user of any design. This in mind, the elimination of waste through the incorporation of a cyclical, self-regenerative design may be the most appropriate design solution to any problem.

Such a consideration questions the use of machines, with their algorithmic nature, precision, and standardization, as design models. Part of the dilemma in questioning the validity of using machines as design models lies in ambiguous terminology. What I call a machine, you may not. What John Todd calls a machine, another may call an aquatic system. The word 'machine' may conjure up an image of metal and gears, or of work and grease, which is sufficiently understood by enough people to be considered universal. However, the visual image is not universal, and we must remember that a mental image of a post-industrial age machine has solidified only recently in the history of human thought, and in that short time, it has evolved and may evolve further. For example, until the advent of computer technology, machines tended to be large and obvious. Now they may be microscopic and virtually invisible. The creation of Living Machines® offers another shift in our perception of machines, perhaps the most revolutionary yet – the image of machines as living systems.

For decades science has conceived of organisms as machines. I was reminded of that model while referencing Bertalanffy's *General System Theory* (1969) and most recently, while re-viewing the classic film, *Jaws* (1977), wherein the scientist continually refers to the killer shark as a perfect and perpetual eating machine. "That's all it does," he urges. Are we ready, as human beings, as living systems, to be likened to machines?

Do we want to be considered perfect thinking machines, for example, or perfect money-making machines? We need to understand our reliance upon machines, and how that reliance is, and may be, altered. Todd forces a re-evaluation of our relationship with machines, and subsequently causes us to question again what we like about machines, and further what we could like about machines. Brummett claims that we like machines, in part, because of their ability to do one thing without deviation – their simplicity. This paper has offered several other clever appeals of machines.

Dye-casters, cars, sharks, microchips, aquatic systems – all of these are machines. We think, then, that a designer may access those images when solving a problem. This is not the case. Instead, as shown by our examples, designers are most often armed with one machine perception and that dominant perception influences their design. For example, in the design process, a Paleolithic man may have pictured a bird's nest, Gropius, the steam engine, and John Todd, an aquatic system. Necessarily their designs, although based upon machines, will vary greatly in form and function because of their contrasting definitions of 'machine'. The design process recognizes error and seeks to repair the damage caused by the error. So any refinement in terminology related to machines may act as progenitor to any number of design realms, currently unrealized.

Further, Todd's redefinition of machines as living systems, offers designers a unique and powerful opportunity to use a design model which represents the complexity, unpredictability, and self-corrective potential of natural systems, while also allowing for dependable production. His machines recognize chance and accident, characteristics which are anathema to common industrial machines. Some will say that the attainment and maintenance of dependable natural systems is impossible, or that such a refinement of machines merely harnesses nature for human gain. However, in the wake of their often destructive history, it may be time to redefine what machines do and how they do it. In the words of Albert Einstein: “The world will not evolve past its current state of crisis by using the same thinking that created the situation” (McDonough & Braungart, opening page).

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APPENDIX A

JOHN TODD'S EMERGING PRECEPTS OF BIOLOGICAL DESIGN

1. The Living World is the Matrix for all Design
2. Design Should Follow, not Oppose, the Laws of Nature
3. Biological Equity Must Determine Design
4. Design Must Reflect Bioregionality
5. Projects Should be Based on Renewable Energy Sources
6. Design Should be Sustainable through the Integration of Living Systems
7. Design Should be Co-evolutionary with the Natural World
8. Building and Design Should Help Heal the Planet
9. Design Should Follow a Sacred Ecology

Note: taken from, *From Eco-Cities to Living Machines: Principle of Ecological Design* (1994), by Nancy Jack and John Todd.

APPENDIX B

THE HANNOVER PRINCIPLES

1. **Insist on rights of humanity and nature to co-exist** in a healthy, supportive, diverse and sustainable condition.

2. **Recognize interdependence.** The elements of human design interact with and depend upon the natural world, with broad and diverse implications at every scale. Expand design considerations to recognizing even distant effects.

3. **Respect relationships between spirit and matter.** Consider all aspects of human settlement including community, dwelling, industry and trade in terms of existing and evolving connections between spiritual and material consciousness.

4. **Accept responsibility for the consequences of design** decisions upon human well-being, the viability of natural systems, and their right to co-exist.

5. **Create safe objects of long-term value.** Do not burden future generations with requirements for maintenance of vigilant administration of potential danger due to the careless creation of products, processes or standards.

6. **Eliminate the concept of waste.** Evaluate and optimize the full life-cycle of products and processes, to approach the state of natural systems, in which there is no waste.

7. **Rely on natural energy flows.** Human designs should, like the living world, derive their creative forces from perpetual solar income. Incorporate the energy efficiently and safely for responsible use.

8. **Understand the limitations of design.** No human creation lasts forever and design does not solve all problems. Those who create and plan should practice humility in the face of nature. Treat nature as a model and mentor, not and inconvenience to be evaded or controlled.

9. **Seek constant improvement by the sharing of knowledge.** Encourage direct and open communication between colleagues, patrons, manufacturers and users to link long term sustainable considerations with ethical responsibility, and re-establish the integral relationship between natural processes and human activity.

Note: Taken from the document, *The Hannover Principles: Design for Sustainability* by William McDonough. (see references).