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The Bridge To Humanity's Future:

A System Dynamics Perspective on the Environmental Crisis and its Resolution

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Human life on Earth is threatened by the growth of world human consumption which quadruples every 35 years. Major environmental imbalances may soon severely deplete our planetary life-support system. However, the world economy is designed to create and depend on consumption growth. If this growth were to stop, major economic, social, and military crises could result. We call this tragic dilemma the Ecocosm Paradox. Powerful human instincts drive the positive feedback-loop processes that generate consumption growth. This growth involves many human, technological, and natural environmental variables whose separate study has given rise to specialized intellectual disciplines. However, in order to address our current dilemma, these variables must be analyzed together as a single, complex process. A new method of analysis, synthesis, and implementation based on a new transdisciplinary field, "Ecocosm Dynamics," is herein proposed for this analysis.

Keywords:system dynamics,worldsystem,environment,growth,Ecocosm,technology,sustainability

INTRODUCTION

In recent times (recorded history) humans have come to believe that they and their societies are separate from and superior to the natural Earth with its land, sea, and air communities of plants, animals, insects, and microorganisms. Humans took what they wanted from the natural storehouse without regard for the consequences. As long as the human population was small and technology was primitive, the natural world was able to support this intervention. However, in the last 50 to 100 years, scientists have discovered that the massive human recovery and disposal of Earth's resources is having a profound effect, not only on the ability of the planet to support life, but even on the weather, geology, and the composition of the atmosphere. The human presence that once was negligible, is now significant. Therefore, in this paper "Ecocosm" refers to the combined, continuously interacting system of humans, human artifacts, and human societies; plant and animal communities on land, in the sea, and in the air; nonrenewable materials; the atmosphere; and electromagnetic fields. These function on and about the tectonic surface plates of a molten fluid sphere 8,000 miles in diameter that is bombarded by thermonuclear radiation as it revolves on its axis and around a minor star in the frigid, near-vacuum conditions of galactic space.

The Ecocosm's human presence (annual consumption) has grown to an unmanageable size because humans are driven by genetic instincts that induce positive feedback loop controlled reproduction and consumption. But like-motivated "lower" animals do not decimate the environment as we do because they have other instincts that direct them to establish territories on

which reproducing units (pairs, small groups, or herds) live and support themselves. If a territorial group over-stresses the resources on its territory, the group does not survive and the territorial resources recover because the animals use only renewable resources (air, plants, water, other animals) (Ardrey, 1966). Humans are territorial also, but our large brain has developed technology. Technology makes possible the exploitation of nonrenewable resources and separates people from the land by producing and distributing higher quality essential products that are easier to obtain than from the territory. Breaking the bond to the land and achieving the mass production of long-lasting products from nonrenewable materials has enabled humans to sustain their positive feedback reproduction and consumption processes far beyond the limits that would have kept them environmentally sustainable.

In a natural community, positive loop reproduction/consumption is desirable because, if a local catastrophe destroys animal inhabitants, the exponential growth that the positive loops generate restores the community to full capacity in a short time (Gutierrez, Fey, 1980). When all of the local territories are reoccupied, population growth stops automatically. Consumption growth also stops automatically because only existing organic products are gathered from the territory to be consumed. Since modern humans are not bound to territories and since technology creates an endless array of new products, human population and consumption growth have no perceptible limits, automatic or consciously imposed.

Humanity has taken hundreds of thousands of years to perfect a socio-economic system (civilization) that is designed to create and to be critically dependent upon the rapid exponential growth of world human consumption without regard for its environmental consequences. Since no variable can grow indefinitely on a finite planet, this growing human system must be replaced by a stable one or the life support system of the planet may cease to function. However, the system cannot be changed without the breakdown of securities markets and the production/distribution system of goods and services, social chaos, and war. This dilemma, which we call the Ecocosm Paradox, is the climactic condition of the first phase of human civilization, Expansion; and guarantees that the second phase of human civilization, that we shall soon experience, will be Disintegration. The civilization that finally works so well that it makes many prosperous is destroying its own life support system. At the least, the socio-economic system will disintegrate or be voluntarily dismantled with at best substantial, but controlled, destruction of life and property. At the worst, both the environment and the socio-economic system will disintegrate.

Therefore, humanity is faced with a choice between allowing the growth to continue until the life support system collapses, thereby forcing the socio-economic system to collapse and threatening the survival of the species; or designing a sustainable socio-economic system that will limit consumption growth, and then transforming the growing system into the sustainable one by restructuring its functions and attitudes. Unfortunately, humanity does not really believe the environment will stop supporting life, does not know how to design and implement a sustainable socio-economic system, and does not want to give up a system that is making so many people rich, whether it destroys the environment or not.

A third option is to let the system grow and also to design the sustainable system and its implementation plan. When the environmental collapse becomes clearly inevitable, the implementation can be done then. There are two problems with this strategy. Firstly, the greater

consumption and population grow to be, the more the environment will be damaged, the worse the transition destruction will be, and the lower the eventual sustainable carrying capacity will be. Secondly, by the time the environmental collapse becomes clearly inevitable, it will be too late to stop it, and the implementation will fail.

This paper describes the Ecocosm Paradox, the devastating speed of the consumption expansion, the characteristics of the socio-economic system that cause the growth, the dependence of the world economy and a peaceful international society on continued growth, a method for designing a sustainable Ecocosm that is capable of adapting its structure to changing conditions, and an implementation process to transfer the socio-economic controls from the existing growing system to the adaptive-sustainable system. The method specifies the creation of a research group that will develop a new intellectual discipline. This discipline will be used to design the adaptive-sustainable Ecocosm and its implementation plan. Both the system design and the implementation plan will be very difficult to create for a system as large, complex, and out-of-control as the current Ecocosm. Any implementation plan will be extremely difficult to carry out in the real human world.

THE ECOCOSM PARADOX

Understanding Earth's environmental crises begins with the concept that world human consumption is the crucial variable. The primary connection between the natural environment and the human presence is consumption. It is the algebraic product of world human population and average annual per capita human consumption. Human consumption is the forced flow that draws resources from the environment and turns those resources into waste. When people cut down the trees of a forest or take iron ore from a strip mine, they are doing it either directly or indirectly to provide products for humans to consume. Even before consumers discard used products, the recovery process destroys environmental infrastructure and discards resources. Product manufacturing also wastes resources. This description does not include the details of the recovery, manufacturing, and consumption activities, nor the degradation and recycling of some of the waste back to usable resources. However, since there is a large net annual decrease in available resources in the environment and a large net annual increase in the volume of waste; the concept represents the net effect of human living on the environment.

The Data

UN data for world human population (U.N. Population Division, 1994) are plotted, Figure 1 left, on a linear vertical scale. The same data are plotted, right, on a logarithmic scale. The exponential shape on the logarithmic scale depicts an exponential function whose doubling time is getting shorter (here called a "hyper-exponential"). Human population is now about six billion. An additional billion people is being added every 10 years. Figure 2 shows data for human population's annual growth percentage (U.N. Population Division, 1994) the growth coefficient for the population exponential. This exponential abruptly changed its slope around 1900 C.E. As annual growth percentage has increased, population doubling time has fallen in the last 500 years from 650 years to its present doubling time of 34 years. The abrupt upward shift in slope of the population growth rate at the end of the nineteenth century was caused by a rapid decline in deaths per year per thousand in the early twentieth century. Births per year began to fall later.

The Figure 3 left graph shows time histories (Cipolla, 1974) for birth and death rates per thousand people in less-developed countries. The right graph has recent data for whole world birth and death rates (U.S. Bureau of the Census, 1974,83,91,94,96). The acceleration of population growth was caused by technology-driven health advances that reduced the death rate. The world human birth rate is still more than twice the death rate; and major new health breakthroughs appear imminent. Strong population growth is not over.

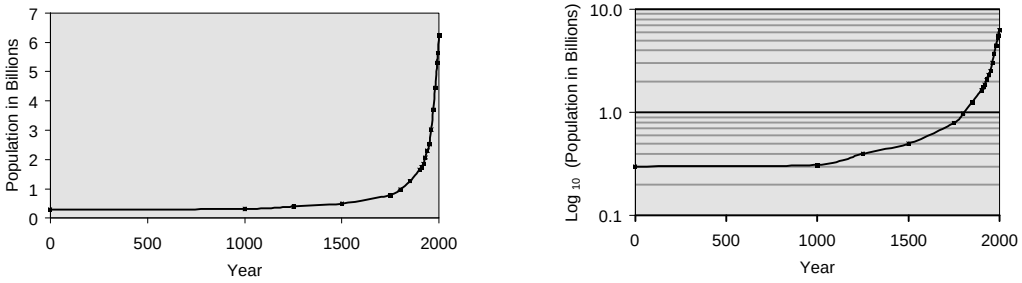


Figure 1. World population growth—a hyper-exponential

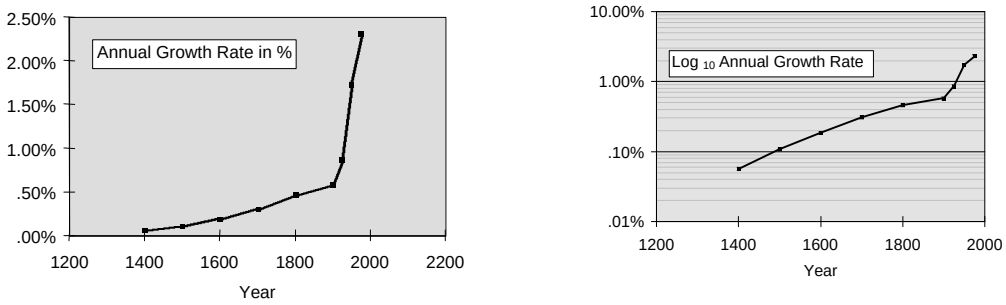


Figure 2. Annual growth percentages for population

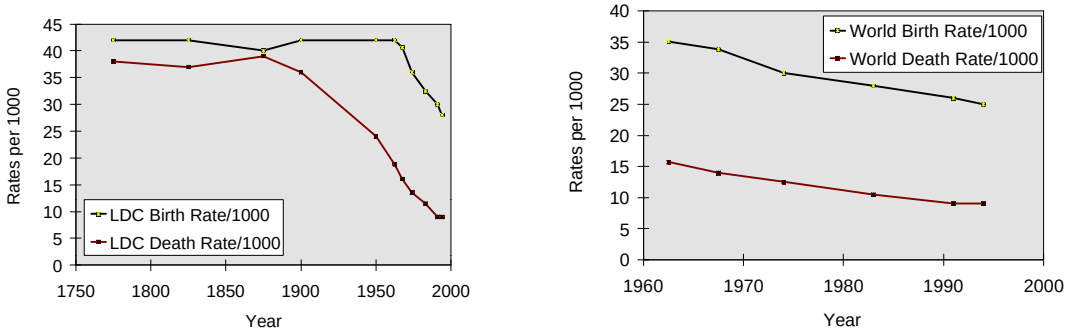


Figure 3. Birth and death rates for developing countries and the world

Time histories for total world energy consumption and average per capita energy consumption from 1650 to present (Cohen, 1995) are shown on both a linear and logarithmic scale (Figure 4). Since total energy use is the product of hyper-exponential population and per capita energy use, world energy consumption is growing at a rate that is here defined as a "compound hyper-exponential rate." This is especially sobering in light of Boyden and Dovers' observation (Boyden, Dovers, Shirlow, 1992) that 74% of the world's total energy is consumed by 23% of the world's human population which resides in developed countries. They characterize extrasomatic energy consumed by humans as technometabolism, energy used beyond human metabolic energy; and measure this energy in human energy equivalents (HEEs), each of which is equivalent to 10 megajoules per day. The average daily per capita energy use is 6 human energy equivalents

(HEEs) in developing countries, 56 HEEs in developed countries, and 100 HEEs in the United States (Boyden, Dovers, 1992). As the 77% of the human population in developing countries increases its standard of living, the exponentials in Figures 4 & 5 will expand dramatically.

Data for world human consumption; whether measured in resource utilization units, an "index," or a standard currency; are very difficult to estimate. Consumption includes many incommensurate products and services with different environmental impacts. Governments estimate consumption in monetary terms often measured in local currencies with variable exchange rates. UN data (Parent, 1984) in Figure 5, which show the growth of the world GDP per capita index on a logarithmic scale, probably underestimate consumption's impact on the environment. Most resources are recovered in less-developed countries where much consumption goes unreported and where resource prices are absurdly low and local currencies are undervalued. This linear time history on the log scale from 1950 to 1980 indicates that per capita consumption is exponential. Population is doubling every 35 years and per capita consumption doubles in about 30 years in this figure. Thus, their product, world consumption, quadruples in 30 to 35 years. Therefore, stopping population growth will not stop consumption growth. If current population growth and per capita consumption growth continue, world human consumption will increase by a factor of 16 during the 70-year lifetime of an average person. Since even today's consumption clearly is unsustainable, such growth will devastate the environment.

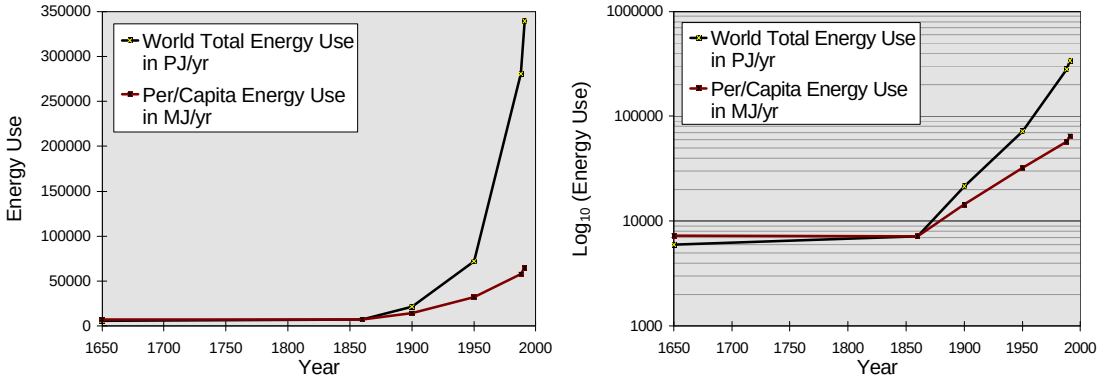


Figure 4. Total world energy use and per capita energy use from 1650 to present

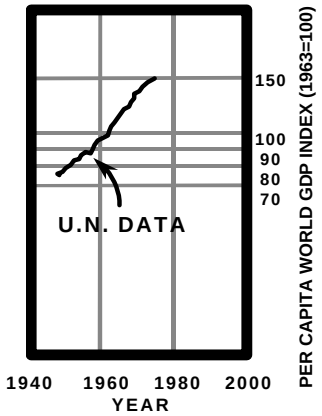


Figure 5. World GDP per capita on a logarithmic scale (adapted from Parent, ©1984)

Feedback Structures That Cause The Exponential Time Patterns

World consumption is the product of human population and average annual human per capita consumption (Figure 6). Each has its own set of positive feedback loop reinforcements that cause its growth. Population growth is driven by the instinctive human reproduction positive loop and the biotechnology positive loop that progressively extends life expectancy. Per capita consumption growth is created by the positive technology loops reinforced by positive world economics and government action loops (Figure 6). These loops (details below) are highly aggregated; so the variables include all related activities worldwide. Environmental collapse, resource exhaustion, and toxic pollution constraints on consumption are the negative loops that may finally stop the growth.

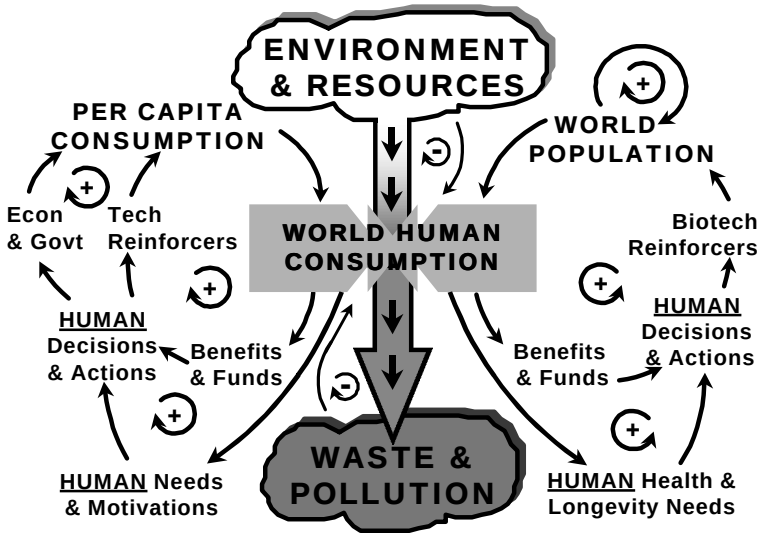


Figure 6. The causal-loop diagram for the Earth's environmental crisis

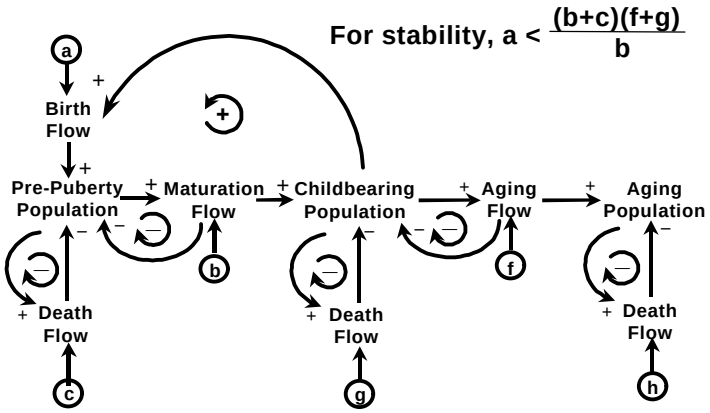
World Human Population Feedback Structure

In Figure 7, the causal-loop diagram for human reproduction, births per year provides the inflow to the population of pre-puberty humans. Humans flow out of this population as they die or as they reach sexual maturity. The maturation flow decreases the pre-puberty population and increases the childbearing population. The magnitude of the maturation flow is set by the pre-puberty population and the time to reach maturity. Childbearing-age people flow from that state as they die or as they age. The aging flow is the inflow to aging population. The birth flow is created by the childbearing population and average human reproductive fertility. Death flows are created by the indicated population and the probability per year of such people dying.

In this causal-loop diagram for population, an arrow represents the causal influence of the arrowend variable on the arrowhead variable. The arrows, when followed from end to head, end to head, et cetera, until the first arrow is revisited, form a feedback loop. The algebraic sign of a causal arrow is plus if the effect variable at the head changes in the same direction as a change in the cause variable at the end. Thus, effect increases, after cause increases; and decreases, after cause decreases. When the arrow sign is minus, the effect variable changes in the direction opposite to the cause direction. After cause goes up, effect goes down. After cause goes down, effect goes up. The algebraic sign of a loop is the algebraic product of the signs of the loop's

arrows. Positive loops reinforce trends. Negative loops resist or reverse changes. If a variable in a negative loop increases, the action of the loop, later in time, is to resist the increase and cause it to decrease. In any human system there will be many loops. The time pattern produced by an individual loop may be modified by other loops to which it is connected. Growth created by a positive loop may be stopped by a negative loop that limits it.

Figure 7. Causal loop diagram for world population (first order approximation)



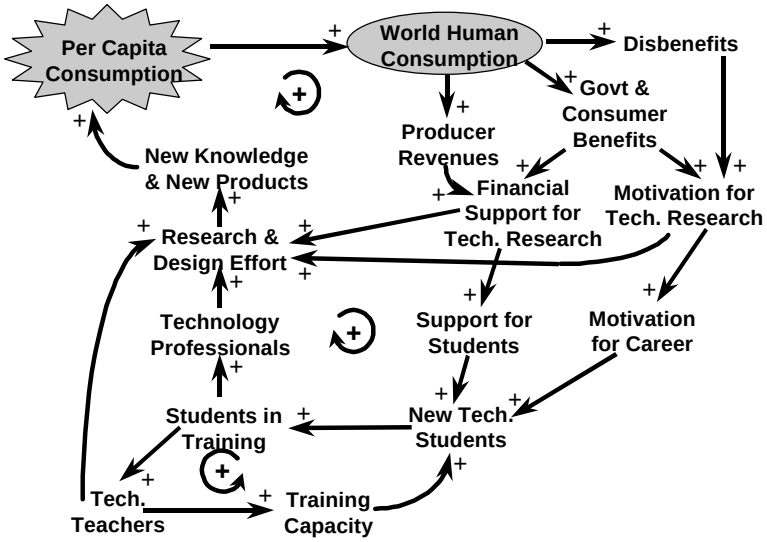
This population system has one positive and five negative loops. Differential equations were written and then solved to show that the positive loop will cause growth, if the reproductive fertility factor, a, is larger than the function shown of inverse delay times in the pre-puberty and childbearing states and death probabilities in the two populations (Fey, Lam, 1998). Today, human fertility produces new humans faster than deaths and shifts to the non-reproductive state can remove people from the childbearing population that energizes the positive loop. This reproduction loop is the first positive loop that drives consumption growth (Figure 6, top right). In this analysis, birth and death probabilities are assumed to be constant; but in most countries, both birth and death probabilities are falling (Figure 3). Death rates are falling because public health measures and medical technology are extending human lifespan. Funds and benefits from medical consumption motivate biotechnologists to do more research to find new medical products that will lower the death probabilities even further. This biotechnology loop is the second positive loop (Figure 6, right center) that drives the population exponential. It makes population's exponential growth hyper.

Technology's Feedback Structure

Technology's effect on per capita consumption is even more dramatic. Virtually all of the products humans consume are conceived and produced by technology. Today, most technological advances result from organized research by highly-trained people working for governments or private organizations. In the upper part of the technology causal-loop diagram (Figure 8), research and design effort leads to new knowledge and new products. These motivate higher per capita consumption which increases world human consumption. Increased consumption of technologically based products results in benefits to consumers, governments, and producers. It also leads to individual and social disbenefits (e.g., environmental destruction). The benefits and, paradoxically, also the ***disbenefits*** both motivate more research because technology

creates useful products *and* solves problems. This is the primary positive technology loop. Since technologically-trained people are required to do the research and design, the lower part of the diagram shows one loop that motivates people to obtain the education needed for a career in technological research or design. A second lower loop controls the creation of the teachers who set the annual capacity for training scientists and engineers. Technology is a positive feedback process in which theories and products that have resulted from scientific research produce both benefits and disbenefits which motivate more research and more trained people to do more research. This process produces hyper-exponential growth in the breadth and speed of introduction of new technology which provides new products and processes that induce us to consume more (Figure 6, left center).

Figure 8. Technology Causal Loops

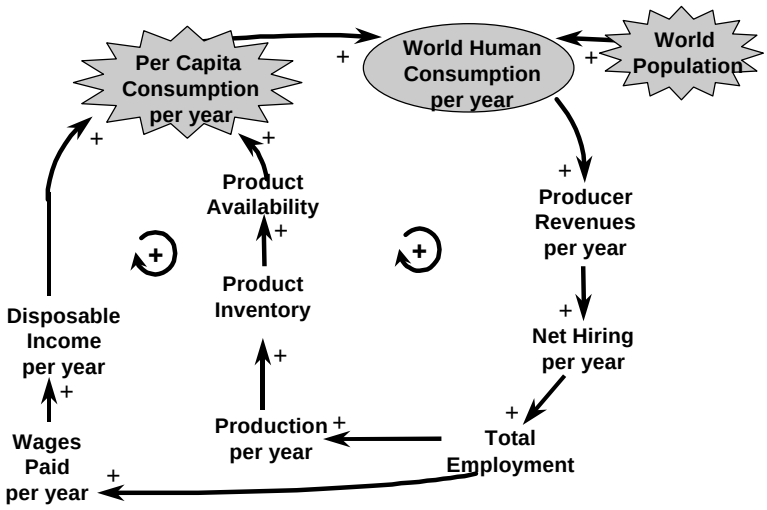


Economic And Government Feedback Structures

The interaction of human attitudes/instincts and technology that drives per capita consumption growth is reinforced by economics and governments. There are two sides to economic life, production and consumption (Figure 9). Producers make from environmental raw materials the products that consumers consume. Producers receive money from consumers to pay for these products. From this money, the producers pay the employees who make production possible. After the employees receive their wages, they change into consumers and use the income to pay for the products they want to consume. Thus, everyone is both a producer and a consumer with a built-in positive loop that drives them to produce, so they can consume. The point of consumption is the closure point for all major economic loops. It ties together the producer and consumer roles of each person and focuses all the attitudes and actions of both producers and consumers to reinforce consumption. Consumption also relates the intangible financial aspects to the tangible physical aspects of the economy. To increase consumption (Figure 10), producers design and produce desirable technologically-based products, market them, advertise them, invest in production capacity, hire workers, and provide credit to customers. To increase their ability and desire to consume, consumers work and invest to obtain income. They borrow; perceive advertising that makes them desire more; and use and then discard their purchases when they are

used or better new products appear. Positive feedback loops reinforce all of these actions and, thereby, reinforce consumption.

Figure 9. Production and Consumption Causal Loops



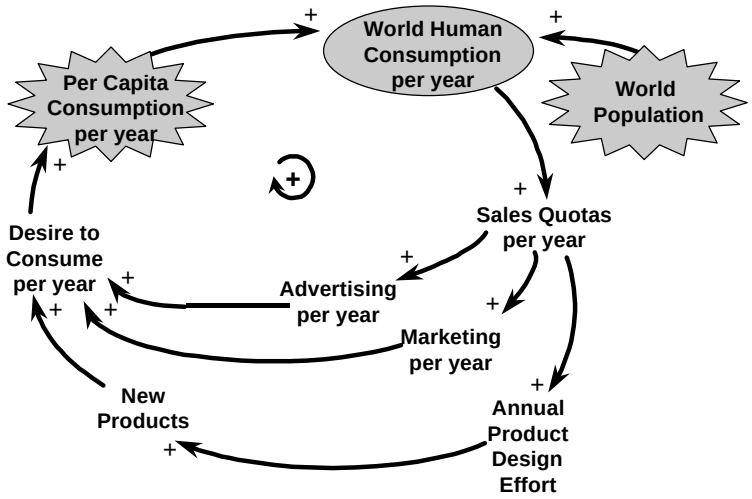


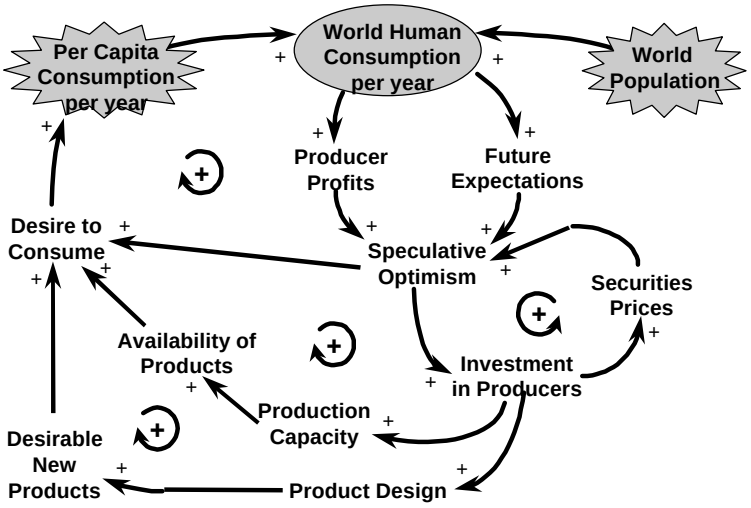
Figure 10. Marketing Causal Loops

The speculative operations of the securities markets are regulated by positive investment loops (Figure 11) in which consumption growth motivates price increases for securities. This attracts speculative funds from investors to finance producer operations that reinforce consumption. If consumption growth were to stop permanently and speculators believed that it would not restart, stock and bond prices would collapse.

Governments also engage in positive feedback loop behaviors (Figure 12) to reinforce consumption growth. The primary source of government revenues is taxes on income, sales, capital gains, value added, and real estate. Therefore, governments must and do encourage consumption growth to insure the growth of their revenues. They do this through their own

consumption, the creation of money and credit, generous depletion allowances, and deductions for the costs of the activities that stimulate consumption. To encourage consumption growth, commercial banks also create money through credit expansion that creates demand deposits. Nearly all of the loops in Figures 9-12 reinforce consumption (Figure 6, top left). It is the operation through time of the positive technology loops reinforced by positive economic, financial and government loops that drives the exponential growth of per capita consumption.

Figure 11. Investment and Speculation Causal Loops



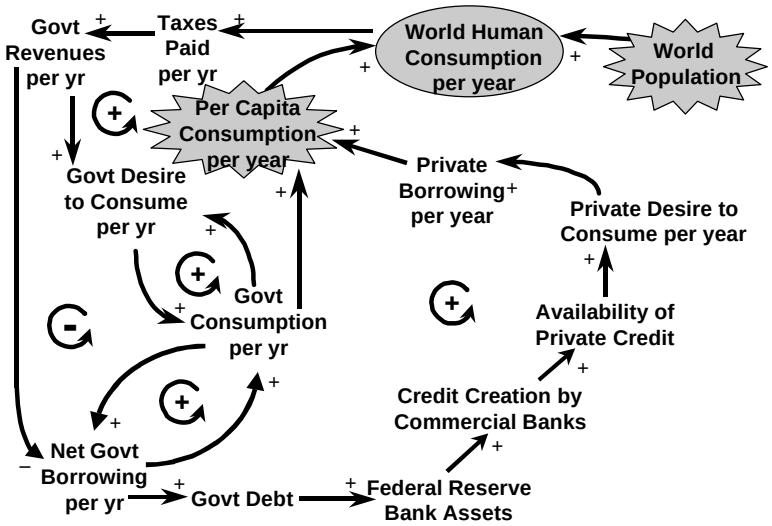


Figure 12. Government and Borrowing Causal Loops

Intractability Of The Current Human Dilemma

The Figure 6 diagram shows our hypothesis for the causes of the world environmental crises. Causal-loop diagrams in Figures 7-12 show the details of the aggregated loops in Figure 6. Notice that technology is the fundamental positive loop facilitator for the instinctive human drives to consume and to reproduce. Only the population self-loop arises from pure, unaided instinct;

and that would be limited by territoriality without technology. Since the beginning of serious technology (~ 500,000 years ago, when the spear was invented (Ochoa, Corey, 1995) and transformed humans from a prey to a predator species), a set of positive feedback loop processes have operated to cause world human population and average annual human per capita consumption to grow exponentially. At first the growth rates were very, very slow and erratic. With the invention of writing (~10,000 years ago), the growth rates increased substantially. The development of various mathematical methods contributed more rate increases; and the development in World War II of the problem-focused, highly-trained, multidisciplinary research group has accelerated consumption growth to a point where it now overwhelms all economic cycles and resource constraints. Throughout this long development, human consumption has grown with a compound hyper-exponential pattern; but it has only been in the last 75 years that the magnitude of annual world consumption has exceeded the regeneration capacity of the Earth's life support system. Today, we have unsustainable annual consumption, so either all growth must stop soon or some kind of major catastrophe will occur within the lifetimes of today's children.

To summarize, our hypothesis states that, for the survival of all life on planet Earth, the critical variable is world human consumption, which is now growing at a rate that *quadruples* consumption every 35 years. Intellectually this is difficult to believe; emotionally, it is inconceivable. Most people do not realize that a seemingly small 4% per year increase in a variable causes the variable to quadruple in 35 years, but it does. The growth is driven by a set of interlocking positive feedback loops (Figures 6-12 show some of the positive loops; others are not presented here). No one loop is important. What is important is that the human instincts to reproduce and to consume are being enormously amplified by technology (economics and politics are applied technology) through a host of positive feedback loops that cause this compound hyper-exponential growth of consumption. The natural planetary life support system cannot absorb this accelerating destruction and continue to function effectively. Since the lifestyles of almost all persons, all business enterprises, and all governments are organized around goals and activities that depend on, create, and demand consumption growth, it is unlikely that even one positive loop can be stopped, much less, all of them.

The tragic paradox revealed by the Ecocosm's dilemma is: if, somehow, growth could be stopped to save the environment; societies would become unstable, the world economy and securities markets would collapse, and wars would follow. Therefore, the prospect for humanity is continued explosive growth until some kind of catastrophe devastatingly ends the growth; and, perhaps, humanity itself.

A METHOD TO FIND A SOLUTION TO THE ECOCOSM PARADOX

Worldwide, humanity has organized itself into billions of socio-economic units (families, firms, nation states) and structures that regulate their operations and relationships (laws, trade arrangements, currency and security exchanges, transportation and communications networks, money and debt creators and regulators). All of these depend on and reinforce the consumption growth that is overwhelming the Earth's life support system to create the environmental crisis. No currently proposed solution to the environmental crisis directly faces the reality that the Earth is finite and eventually world human consumption growth must not only stop, but that consumption must be reduced to a long-term sustainable annual amount. This requirement can

only be achieved by a restructuring of the socio-economic units and the ways that they are interrelated and supported, so they are not dependent on expansion and do not create it. The current piecemeal focus on efficiencies of use, conservation, and recycling may delay the eventual environmental collapse, but unless the growth stops and a sustainable condition is established worldwide, the deterioration will continue.

The natural process of positive loop reproduction, breeding-units bonded to territories large enough in size to support them yet small enough for them to defend, and consumption only of the organic resources obtained from the territorial area, serves to maximize the species populations in an area; to minimize the time for repopulation after a local disaster; to automatically limit species populations to the carrying capacity of each local environment, thereby preventing environmental degradation; and to avoid animal-caused global crises. This natural arrangement only persists because it is genetically "wired" into the minds of the animals; it is wired in because it has worked. People tend to think of hereditary characteristics in terms of physical attributes. We can tell the difference between a human and an elephant because they look different. However, everything any animal does is controlled by its mind. Behavioral characteristics such as pair bonding, territoriality, and aggression are also inherited, though some local details of carrying out these imperatives are learned. Like physical attributes, mental characteristics must be wired in because animals that do not have highly appropriate behaviors do not survive and reproduce in their environmental niches, no matter how advantageous their physical attributes may be. Human development and use of technology has destroyed the human bond to the land and its organic resources. So human consumption growth can only be limited by catastrophes arising from Earth's environmental inability to sustain world human recovery of resources and its inability to absorb discarded waste. This shift from automatic local environmental preservation to world level lack of preservation permits world human consumption to greatly overshoot sustainable consumption, to drain world resources so eventual sustainable consumption is considerably reduced, and to force environmental crises that affect the whole Earth and threaten the entire human species.

A method of analysis, synthesis, and implementation is needed to discover a realizable modified human system structure in interaction with a modified natural life support system on Earth that will achieve a long-term, stable, balanced Ecocosm. This implies the need for a new socio-economic paradigm for human life, particularly consumption, that is in harmony with human instincts, desires, and capabilities; plant and animal community functions; and planetary dimensions and resources; that will automatically and quickly limit human consumption, without unacceptable laws or force, to the gradually changing planetary carrying capacity as technology progresses and as resources are exhausted. The new system structure paradigm must be achievable with "tolerable" damage to human life and lifestyle. Minimizing the damage during transition from the present over-extended, out-of-control state to the intended stable sustainable system operation is operationally unrealistic. A "painless" transition is impossible. Even today, people are starving and dying in wars. Unfortunately, living systems are extremely complex, internally self-organizing, irregularly precise, and subject to externally-imposed noise with frequencies that so closely overlap signal frequencies that separation of signal and noise is statistically unreliable. In addition, humans are not passive and precisely responsive to forces as electrons are. Thus, the success of science in manipulating the physical world is not easily and directly transferable to the living world, and there is no known algorithmic way to synthesize the

improved system. Therefore, the method proposed here must be and is a science-aided, creative art; not the mathematically derivable, rigorously testable, and experimentally reproducible science that most scientists would demand.

The method must perform its analysis, produce its new Ecocosm paradigm, and begin its implementation with the cooperation of an unknown fraction of human individuals and groups (required for success) before a catalytic event occurs to initiate the collapse of either the environment and/or the world economy. If any of the recommendations be wrong, a catastrophe rather than an improvement may occur. There may be no second chance because changes will have been made that cannot be reversed. Science has produced such toxic materials, powerful forces, and destructive weapons that immense planetary damage can arise from small errors in the planned interventions or from the evil intent of a few influential criminals or war lords. Thus, the method's task is extremely difficult; the time available to do it is unknowable, but short; the margin for error is tiny; and the likelihood of a second chance is small. This is not a task that anyone would want to undertake unless humanity's survival depended on it. The authors believe that it does.

Tasks The Method Must Perform

The method will have to perform four related tasks to produce recommendations for system modifications with detailed implementation specifications to resolve the dilemmas of the Ecocosm Paradox. The first must be done first. The last three must be done simultaneously because they interact. A fifth, very difficult, task must be performed by the entire human community. This is the actual implementation of the system modifications into the operating Ecocosm in an accurate and expeditious manner.

Task I: Observe the system (Ecocosm), gather data to determine the problem, and identify the existing primary feedback loops that are creating the compound hyper-exponential time pattern of world human consumption. Data are presented above to show the general nature of the problem. The feedback loops as described above are incomplete, untested, and, in some cases perhaps, incorrect. The complete Task I analysis must isolate the critical aggregate variable, world human consumption; demonstrate its nonlinear (multiplicative) dependence on world human population and per capita average annual human consumption; and identify the important positive loops that drive population and per capita consumption. It is necessary to determine all of the major positive loops in order to know what processes must be limited. If 30 unlimited positive loops exist and limits are established for 25, the remaining 5 will continue to force exponential growth. In addition, the method must anticipate positive loops that will be created to perpetuate growth, when the existing positive loops are restrained. Task I identifies the problem and the structure of the system that creates it.

Task II: Identify (through a creative synthesis) at least one alternative Ecocosm system structure that, when implemented and operating successfully, will reasonably satisfy the needs of the living participants in the Ecocosm and will automatically limit world human consumption to a perpetually sustainable annual amount. Sustainable consumption, technology, human "requirements," and available resources are all mutually influential and all change through time as the dependencies dictate. If more than one alternative is identified, the best one should be selected for implementation. The improved human society and environmental community must be

desirable enough to both humans and necessary life forms that it will persist in perpetuity and be flexible and resilient enough to adjust successfully to the vicissitudes of the life and conditions of the Ecocosm. Tasks II, III, and IV, which consider changes for humanity and "nature," constitute an engineering design for a realizable, adaptive-sustainable Ecocosm. Human intervention in "nature" is now so pervasive that the design of nature also is required to preserve enough non-human life to support human life.

Task III: Anticipate the Ecocosm structures and time histories that may arise under different types of disintegration of the existing Ecocosm. The existing world socio-economic system as it now interacts with the existing environmental life support system cannot survive much longer. At some point an environmental catastrophe and/or a collapse of the world economy will occur to stop the unsustainable growth. When it does, the existing structure of interacting positive loops will break down. It will be important to know a) what different kinds of collapse are possible, b) what will be the effects on humans and the environment of the different types of disintegration, and c) how the process of disintegration can be controlled to keep the damage to a tolerable level and to lead to the introduction of the improved system of Task II, if one can be found. The answers to these questions must be found before the disintegration to avoid the difficult problem of controlling billions of people in panic and conflict.

Task IV: Develop one or more processes designed to modify the existing Ecocosm of Task I to become the improved Ecocosm of Task II before any collapse anticipated in Task III occurs to create unmanageable chaos and wars. Such a process must specify what changes are to be made by whom, when and how each is to be made, how the accuracy of the modifications is to be measured, what kinds of things can go wrong, what should be done to correct them, what preparations and training are required before the changes commence, and how groups that are more disadvantaged by the changes than others should be compensated. This transition process will require some form of controlled disintegration which, in the realm of human attitude change, is called "unfreezing." Once unfrozen, the system will have to be "restructured" into the format of the Task II recommendations. Then the new structure will have to be "refrozen." Such a change process is difficult enough for a person. It will be much more difficult for the billions of persons and the innumerable life forms in the Ecocosm. Since the time patterns during the transition period will be unlike either the previous expansion exponentials or the future small-amplitude oscillations with slow trends, a model of the process and a dynamic analysis will be required for the transition period. It will be important to have some idea of how bad conditions will get before they will get better and how long it will be before the improved conditions begin.

Both the analysis of and the actual management of the change process will be particularly difficult to do because a) no such analysis or management has ever been done before for the Ecocosm, so there is no experienced help available (it is like doing the first organ transplant, only much more complicated, with much more at stake, and with little time to do smaller scale controlled experiments to see what might happen), b) the transition period, the time between the beginning of system modifications and the beginning of the improved time pattern, will probably be measured in hundreds of years; so many generations of people may have to live through difficult times and their responses to this depravation will be difficult to anticipate, c) the long transition will mean the leaders of the change process will change before the improved performance is achieved; later leaders may not have the same understanding of, confidence in, and commitment to

the changes that the originators had, d) unplanned structure changes will be created by various groups to protect themselves from the effects of the transition or to advance their own self-interests in times of societal trauma; these will be difficult to anticipate for the analysis and difficult to counteract when they occur, e) planned modifications may be incorrectly introduced or accomplished at the wrong times; such errors are difficult to anticipate for the analysis and can have a major effect on the transition dynamics, and f) the improved system may not work as originally anticipated in Task II after the transition period; in fact, the transition period may never end, so somehow it may have to be decided when to start the design process again.

This design procedure with its models, forecasts, assumptions, simulations, poor data, and transition analysis (that even experienced design engineers may never have undertaken), may seem to be a long, difficult, unreliable exercise that is unnecessary. However, consider what is happening now. Human population is increasing by about one billion people every ten years. There were not even one billion people on Earth until about 1850. The rainforests, Earth's reserves of oil and many other materials, thousands of species of plants and animals, glaciers worldwide, all primitive human cultures, potable water, nontoxic air, and quiet places are disappearing at a prodigious rate. Some people are complaining about these things and others are recommending, without reliable analysis, things to do: such as write on both sides of the paper, buy biodegradable products, carpool to get to work, design products to use less materials, separate your garbage into different kinds of waste, stop producing aerosol products, et cetera.

To illustrate how unreliable such unjustified recommendations can be, suppose many people start to write on both sides of their paper; so they buy less writing paper. The paper companies will have to do something to maintain their sales growth rates on which they have come to depend. They might create new products and/or do more advertising to do this. In order to make up the loss in writing paper sales and to cover the extra costs of product design and advertising, the companies may have to sell more physical tons of paper than they would have had to sell to reach their growth goals, if people had written on one side only. Or they might lower their writing paper prices to induce less conscientious conservationists to buy the paper they need to sell. The resulting reduced profit on the writing paper with the same volume of paper sold, may force the companies to create the same new products and/or to do the same extra advertising to sell other paper products. So, again, the total annual volume of paper sold may counter-intuitively increase, instead of logically decreasing, when people "conserve" paper. The reason is that the producers and the producers' workers (who get paid from the revenues from paper sales and who are consumers when they go home), are committed to growth and will do whatever they need to do to keep the growth going. Until this growth mindset is addressed directly and corrected or limited in realistic ways, the environment and the humans who depend on it are both doomed.

Some argue that the world economy is moving away from industrial products toward information and services which do not involve consumption of tangible products; so physical consumption will decline. However, to perform most services and to provide most information, tangible products or materials are consumed. When you buy an airline ticket for transportation, you are not just buying "intangible" motion from city A to city B. You are paying for part of an airplane and airport, aviation fuel, office furnishings and utilities, paper and computers, buildings to house the airplanes, executives, and secretaries, food for yourself and the flight crew, et cetera. Little substantive analysis has been done for many recommendations because they are "logical," so

everyone assumes they will work. However, feedback analyses of such recommendations may demonstrate that such solutions will not stop or even slow down the consumption exponential. In fact, some may even increase its slope because the savings from these activities may force greater compensating consumption of similar things.

Human feedback system analysis is extremely difficult and counter-intuitive. The whole closed-loop system must be analyzed to understand what will happen. All existing feedback models of the world system are inadequate in some respect(s). No one is studying the environmental crisis in the ways suggested in this paper. There are few social scientists who use feedback principles in their analyses at all. Physical scientists often do not understand the characteristics of human systems that destroy the effectiveness of normal "scientific" methods. Legislatures that pass environmental laws do not do meaningful analyses and, therefore, do not know what the implementability or the real, long-term effects of their laws will be. The survival of humanity is at stake, yet many are recommending solutions, without proper analyses; solutions that sound plausible on the surface, but that may not work in the real world. Since the Ecocosm is so complex and the dilemmas of the Ecocosm Paradox are so intractable, the authors cannot at this time recommend any solutions. Our purpose is to clarify the nature, causes, and severity of the problems; to expose superficially logical solutions; to warn against reliance on future corrective actions by abstractions such as "technology," government "policies," the "effectiveness" of the global economy, "free markets," "prices," et cetera; and to specify the characteristics of a method to use to design an adaptive-sustainable Ecocosm and to implement the recommendations.

Task V: The Assignment For The Human Community

The specifications for system modifications and implementation procedures should be provided by those who perform Tasks I through IV. The actual implementation of the modifications as specified in the implementation procedures will require the active participation of many people and organizations guided by people from and trained by the design group. Implementation must be a worldwide, cooperative, coordinated, committed effort. Ancient and recent antagonisms, jealousies, prejudices, hatreds, self-interests, grudges, greed, fears, injustices, intolerances, and political alliances must be set aside by a sizable majority of individuals and groups. As Desmond Tutu preached to South Africans during and after apartheid, "there is no future without forgiveness" (Tutu, 1999).

Actually, to accomplish its four tasks, the design group will have to employ people of many races, creeds, faiths, ages, nationalities, social classes, intellectual disciplines, artistic sensibilities, languages, and skills in a research effort where all must understand the whole concept and what the others are doing, so they can contribute their share to the successful completion of the unified work. Historical conflicts, personal experiences, and present xenophobic instinct will have to be resolved by the group itself before it will be able to accomplish tasks that by all precedents of effort and intellectual conceptualization seem impossible. This internal process will be an invaluable preparation for the design and leadership of the implementation process.

THE BRIDGE TO HUMANITY'S FUTURE

Designing the adaptive-sustainable Ecocosm and the implementation process necessary to bring it into reality is the most important and the most difficult task ever undertaken in the history of

humanity. It requires an effective method that must be created and applied quickly under stress conditions, before the escalating expansion of environmental destruction precipitates a catastrophe. But its tasks must be done skillfully or it will neither avert the disaster nor create the desired result. In order for the method to complete the four specified tasks of sustainable Ecocosm design, three unique, nonexistent entities must be created. These are a) a new discipline, b) a design organization to create the new discipline and to perform the design tasks, and c) the design project itself. A new discipline is required because no existing discipline has the perspective, the real world data, the experience, and the principles and capabilities necessary to perform all four tasks properly. Many disciplines contain some necessary parts, but the narrowly focused perspectives of these fields omit critical relationships to other fields and to this problem that are imperative. Therefore, the new field will have to coordinate, integrate and adapt other fields as well as to create necessary concepts and relationships that are not found elsewhere.

The New Discipline: Ecocosm Dynamics

Before human ingenuity and accumulated technological expertise massively restructured Earth's natural life support system, there were two fairly separable parts of the Ecocosm: humanity, with its people, artifacts and social organization; and nature, with its physical Earth and the terrestrial and marine ecosystems of living communities of interacting plants, animals, invertebrates and microorganisms. Both parts were organized into complex feedback control systems which were internally-motivated and self-organized with behavior patterns governed by mental genetics and learning; and influenced by both internally-generated and externally-imposed random forces. Now, humanity has so thoroughly destroyed or intervened in the natural part of the Ecocosm that there is only one giant, constantly-changing, globally-interacting process. This process is controlled by human decisions which are motivated by uninformed self-interest and pursued with little awareness of their consequences for the Ecocosm at large or often even for their own short-term self-interests. The result of this quest for maximum, immediate self-gratification is the dilemma of the Ecocosm Paradox.

In order to understand and modify the Ecocosm, the designers must be able to conceptualize and analyze the Ecocosm as an entire, living, noisy, feedback control system. While human decisions control the major forces, some nonhuman living communities will have to flourish to provide human life support. The conceptualization and analysis must include all aspects of human and living nonhuman behaviors as they interact on a global scale to preserve the life support system and the living participants. Disciplines that study humans or their systems include economics, political science, psychology, anthropology, social psychology, philosophy, medicine, law, management, the arts, education, mathematics, science, engineering, history, sociology, military science, ethnology, archaeology, biology, and theology. Disciplines that study nonhuman life forms include botany, zoology, entomology, ecology, and paleontology. Disciplines that study the planet include meteorology, geology, geography, volcanology, and seismology. None of these disciplines was created to study the whole Earth system with all of its forms of interaction, and especially not in the pathological state of the current environmental and social crisis. Many fields have poorly developed quantitative measures and relationships. Some have little awareness of dynamic behavior and its feedback structure origins. Each focuses on a specific, manageable, clearly related set of variables whose properties are isolated from the complexity and

incommensurate units of the others. Each is complex enough that years of study are needed to become skilled in the theory and practical use of the field's principles.

Understanding the Ecocosm will require knowledge from all of these disciplines, but seldom in a form the field can provide. Therefore, a new, holistic, statistical-feedback-control-oriented discipline is required that combines the essential knowledge of all of these fields in such a form that the contents of and the relationships between the fields can be applied to the study of the Ecocosm as it is now and as it will become in the future. Such a discipline will involve a) a collection of quantitative data and qualitative information (pictures, stories, descriptions, videos, ...) about the history and nature of the variables related to the field, b) a body of theories of relationships between the variables that cause the observed behavior, c) mathematics appropriate to quantitatively represent and test the theories and to design new relationships for the system's variables, d) "instruments" (computers, computer software, cameras, microphones, notebooks, questionnaires, timers, ...) to measure the variables and to evaluate the theories and designs, e) research and design methods that will facilitate all aspects of analysis, design, and implementation in the field, f) media (books, records, pictures, videos, maps, curricula, ...) that accumulate, record, and retain the data, theories, research and teaching methods, mathematics, mistakes, history, and problems from the discipline's point-of-view, and g) an accessible storage facility (media center) for the media and artifacts of the discipline. Much of this has already been developed in more specific fields, so the creators of Ecocosm Dynamics will have to bring the available information together in one place or reference where it can be obtained from media centers or the Internet. Such a synthesis will be a major undertaking; but it must be done, and done quickly.

It is suggested that the field be called Ecocosm Dynamics. "Ecocosm" is compounded from the Greek words "*oikos*" and "*kosmos*." *Oikos* means house, household, habitat, or environment. Its English combining form is "eco," as in ecology. *Kosmos* is an orderly harmonious systematic universe; also, a complex orderly self-inclusive system. Its combining form is "cosm," as in microcosm. Ecocosm, then, is the whole, orderly, home planetary system of humanity. Dynamics refers to the analysis and control of patterns of change through time of critical variables, in this case the variables of the Ecocosm.

Ecocosm Dynamics must be a discipline that supports the study of the effects when variables from the various disciplines interact. A great deal of learning about many fields and how to adapt their principles to Ecocosm problems will be required. In addition, new methods and procedures for analysis, synthesis, and implementation will be necessary. For example, a new philosophy of modeling is required. An Ecocosm model is not a representation of the Ecocosm. It is a representation of one analyst's perception of only the dominant aspects of the Ecocosm for the purposes of synthesizing a solution to one or more Ecocosm problems. If the analyst or the perception or the problem changes, the model must change also. Simulations of the model are not performed to analyze the Ecocosm. They are performed to change or verify the analyst's perception of the Ecocosm so it becomes "reasonably" aligned with the real dominant aspects of the Ecocosm.

It must be done this way because there are no synthesis algorithms for so large and complex a living system as the Ecocosm. Therefore, the concept for an improved system structure to solve the Ecocosm Paradox must come from an unconscious act of creation by the analyst's mind

supported by all the study, preparation, and modeling. In order for the analyst's mind to perform this extraordinarily difficult creation correctly, the mind must be provided with a fairly accurate perception of the subject system and the principles relating to its effective operation as a whole. Thus, Ecocosm Dynamics principles and the model(s) are tools to inform and to stimulate the analyst's mind; so it will produce a useful recommendation. The model is not a meaningful, independent artifact that others can use as if it really represented reality. That is why two analysts both studying the same system and problem usually will not produce the same models or the same recommendations unless the system and problem are trivially simple. Since there may be many ways to improve the system's performance, both recommendations may be helpful. If there are multiple measures of value for the solution (low cost of development, quick implementation, low transition adversity, large long-term benefit, low maintenance), it may be difficult to select the best recommendation. Due to the complexity of the system; the nonlinear, incommensurate nature of the measures of value for an objective function; and the lack of an optimization algorithm; not only is an optimum unattainable, but a given solution cannot be tested for optimality.

The Design Organization: Ecocosm Research Group

A group of people is needed to create the Ecocosm Dynamics discipline and to perform the four analysis/design tasks described. All of the Ecocosm Research Group members must understand the Ecocosm's characteristics and the modified disciplines. All will contribute to discipline development and system design. Each will produce his/her own model(s) and design recommendation(s). Then the group will attempt to evaluate the recommendations and present the best or the best few to the wider community to consider. This should not be a contest to see who is the smartest analyst; but a part of the group strategy to produce a solution to the Ecocosm Paradox that will save humanity and the planet. Therefore, recommendations that seem promising, if any, should be presented to the world anonymously, as the group's proposal(s).

In order to study the major statistical feedback control aspects of the whole Ecocosm, the members must be willing and able to learn about the whole Ecocosm, learn about each others' disciplines, share their insights and analysis with all the others, and keep open, honest minds. It must be a team (not a collection of self-interested experts) that is totally committed to solving the problem properly (not to becoming wealthy, powerful, famous, or winning prestigious prizes). It is likely that doing this analysis correctly and honestly will earn for the group the animosity of almost everyone. The team will be trying to discover a planetary system that will stop consumption growth and establish what might be called dynamic stability. Since almost everyone is committed to growth and hopes to become rich because of it, no one will want to hear about reducing growth. Everyone wants to hear that efficiency, recycling, and conservation will save the environment without sacrificing growth. When the virility of 4% per year growth is understood; and the real, practical limits of the efficiency and recycling "solutions" are determined, the necessity for growth reduction will become impossible to ignore. Once the research work begins, it will soon become clear to the team just how enormously difficult its two assignments really are to do properly with reasonable assurance of success in the short time available.

If the team overcomes these obstacles and produces promising recommendations, it is unlikely that world leaders will accept them and authorize implementation. That is because the

recommendations will be counter-intuitive (they will not make sense to people who do not understand the complex feedback analysis) and they will forecast detrimental effects during the transition period that few will be willing to accept. If the team is fortunate enough to receive approval, the adversity during transition will appear intolerable to most everyone; and the team will be blamed for it. If the Ecocosm design is successful, it will be successful only long after the group members are dead. To create the new discipline, to do the Ecocosm analysis, to modify the existing planetary system, and to wait for the transition time pattern to lead into the eventual stable pattern probably will take at least one hundred years. Only very unusual people are willing to undertake such a difficult task knowing that their only reward will be antagonism and that they will never know whether they were successful. It will not be easy to find and retain members of the Ecocosm Research Group.

Finding financial support for the group and its tasks will be extraordinarily difficult. The group's growth-limiting objective and its rejection of simple technological, economic, government, and general conservation recommendations will make it unpopular. Universities, private foundations, corporations, and government research funding agencies worldwide will be reluctant to support such work. Even if such organizations were willing to provide support, the group should not accept it from them. These organizations have an interest in maintaining consumption growth and in advancing their own solutions. It would be difficult for the group to remain objective, truthful, and independent and to retain and protect its research directions and results, if it were financially dependent on such sources. Too much is at stake for humanity to allow growth-dependent, special interest groups to control the Ecocosm design research. The products of the research (books, papers, videos, lesson plans, et cetera) will no doubt be unpopular also; especially as the established disciplines, the news media, and government authorities will probably denigrate such unconventional work. Therefore, sales of such items will not support the group; though, along with small contributions by individuals, some of the expenses might be paid. There is so much at stake for so many growth-dependent people and organizations both during the final stages of the expansion and in the trade-offs and distribution of losses arising from the adversities of the transition period, that there will be great pressure on any independent research group that seeks to influence these outcomes. History tells us that those who hold power will not give it up for the good of posterity or for the good of other, less influential, people and life forms.

The Ecocosm Design Project: Operation Rainbow Bridge

The creation of the new discipline, the development of the research group with its interaction/mutual support skills, and the design of the adaptive-sustainable Ecocosm and its implementation plan, are all part of a group research method to produce an effective solution to this extremely difficult problem in a relatively short time. Since these three activities are mutually dependent, they must progress simultaneously, with the lines of demarcation between them being left unclear. As the Ecocosm is a unified whole in which all major factors affect each other, and must be studied together; so the group research method is a unified whole in which all major factors affect each other, and must be managed together. Since solving the Ecocosm Paradox is the objective, it should be named and be given the highest priority. We call it Operation Rainbow Bridge.

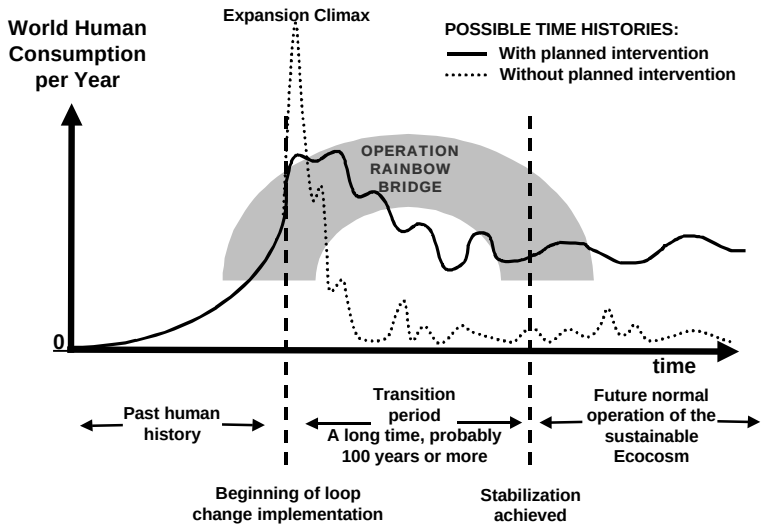


Figure 13. Possible Transition Time Patterns

As human consumption grows beyond its sustainable annual amount at a faster and faster pace, humanity will move higher and higher on the precipice overlooking the valley of disintegration (Figure 13). The successful development and application of the method with its research group, new discipline, and design of the sustainable Ecocosm (including implementation, maintenance, and evaluation procedures) can be symbolized by a bridge over the valley from the unsustainable peak of consumption to a lower sustainable consumption plateau. If an effective design is implemented properly and in time, the Ecocosm will avoid the environmental and social catastrophes that would force the critical variables into a rapid decline into the bottom of the valley. The design's transition time patterns of life and property (consumption) will also decline; but not as far, nor as fast, with less destruction, and with a faster recovery. Thus, a well-constructed bridge (design and implementation method) will save many lives and prevent much devastation.

The symbolism of the rainbow is included to reflect the beneficial properties of the rainbow in the traditions of many cultures. In the *Tanach* (Hebrew Bible), a sacred text of Judaism, Christianity, and Islam, the rainbow is used as the sign of God's covenant with Noah that humanity will never again be annihilated by a great flood. Maintenance of the adaptive-sustainable Ecocosm design will insure that Earth's life support system will never again be threatened. In the black South Africans' resistance to apartheid, one important symbol that sustained them and prepared them for a peaceful transfer of power from oppressive white rule to black leadership with shared influence was the concept of the multiracial "Rainbow People of God" (Tutu, 1996). Now, people of all colors are working together to create a new, free South Africa. In the adaptive-sustainable Ecocosm, a similar sharing of resources and influence among all of Earth's diverse people will be required. In ancient China, a wondrous bridge design called the rainbow bridge, was used to construct shallow-arched bridges supported only at their two ends with unobstructed spans of 60 to 80 feet. The arch was high enough for boats to pass under it and low enough for easy crossing over the bridge on foot or by cart. These rainbow bridges were constructed of interwoven wooden beams in a unique design, not fully understood even today, that gave the bridges great

strength and flexibility; yet they were fast and inexpensive to build. Since there were many narrow waterways in China, the ability to build such bridges was an important factor in facilitating communications and transportation and in unifying such a large country. Maintaining communication and solidarity of purpose will be critically important during the design and implementation process. Hopefully, the result of that process will reduce destructive forms of competition and unify the people of the Ecocosm in their resolve to avoid future threats to their life support system.

THE GREAT TRANSITION

Perhaps the most difficult aspect of the Ecocosm Paradox solution will be the design and execution of the transition to the sustainable Ecocosm design. In order to stop the consumption exponential and obtain long-term stable consumption, certain changes will have to be made in some aspects of humanity's mindset and of the Ecocosm's feedback structure. Task II of the design effort must determine what these changes should be. In order to obtain improved performance in the real Ecocosm, these changes must actually be made in the operating structure. When efforts to change mindset and loop structure begin, transient patterns (time patterns that are different from old system patterns and different from eventual improved system patterns) will be initiated that will persist for a time, but eventually will disappear. Usually, such transients do not disappear until after the changes in structure are fully implemented; sometimes long after. These transient patterns dominate during the transition time period, between the beginning of structure changes and the clear beginning of improved patterns. Changes that actually come to be implemented are seldom exactly the same as the changes proposed. In addition, there may be unplanned structure changes created by system participants who are trying to cope with the system's dynamic crises, and other structure changes created by those who are trying to evade, circumvent or take advantage of the proposed system changes.

Such transients and unplanned structure changes can cause serious implementation problems. If a system's ordinary feedback loops are producing unstable time patterns (e.g., growing exponential time functions whose values are approaching the system's environmental limits), many different structure-change efforts are likely to become active. The result may be chaotic, violent, conflicting, unpredictable, counter-intuitive, and/or uncontrollable time patterns that complicate and lengthen the transition period. In some such cases, the problem may never be resolved.

To evaluate all the effects of the imperfections and complex dynamics associated with the modification process is very difficult. Forecasts of a) the time patterns during the transition period followed by the patterns when the imperfectly changed new system is functioning normally, and b) the future patterns of the existing system without modification, should be compared to be sure that the proposed changes really will eventually result in improved patterns that are better than the patterns of the unmodified system would be. If the transition patterns followed by the improved patterns are better than the unmodified system's future patterns, the proposed changes should be implemented in the real system. If the improved patterns will not be a great improvement or the transition hardships are not worth the improved patterns' benefits, the changes should not be made. Since the transition period may be very long, the benefits of the improved time patterns may not be experienced by anyone who is living when the loop changes begin.

For simple systems, the transition analysis is performed using a model of the entire process of change as perceived by the analyst, including the original model structure (augmented by existing loops that will become important when the implementation begins) and the changes to the structure, planned and anticipated unplanned, introduced into the simulation, in the sequence, at the times, and with the magnitudes expected. Then this model is simulated to forecast the time histories of the critical system variables over the entire transition period and into the sustainable operation period that follows it. Since noise may be an important factor, many simulations may be necessary for each set of conditions simulated. Since there may be many possible combinations of the characteristics of the changes, the design of the schedule of simulations is an extensive and difficult design-of-experiments problem. For a complex system, like the Ecocosm, the quantitative transition model may be too complex to construct or the design of the simulation schedule may be beyond the scope of current statistical design-of-experiments theory.

Ecocosm Dynamics may be forced to develop entirely new methods to analyze transition dynamics for the Ecocosm. Since so many things can go wrong, since transition dynamics are so complex and counter-intuitive, and since the Ecocosm must go through and survive the transition period to reach sustainability where the life support system is no longer threatened; a reliable transition analysis is imperative. The details of the transition analysis process are beyond the scope of this paper; but it is absolutely essential that it be done correctly because critical choices, of what sustainable Ecocosm design to implement and of what the timing and sequence of the planned changes should be, will be determined by the transition analysis. Today's Ecocosm patient is in critical condition, its illness is progressing rapidly; and the forces of destruction are powerful. The surgery has never been done or even considered before, and the patient will die if effective corrective surgery is not performed soon, for the margin for error is small. If the patient dies, the surgeons die with it and so does humanity, so there probably will be no second chance and no reason for one. Therefore, the surgeons must do all the homework, theoretical development, and small-scale experimentation possible to prepare for this major, life-threatening operation on the Ecocosm that must be successful, the first time.

Humanity's Higher Group Consciousness

The entire preceding description sounds like abstract engineering talk about a physical system, such as an amplifier circuit or an airplane. But, of course, it is about a gigantic living system composed of living beings (humans and nonhumans). The beings are organized into groups, communities, and worldwide networks, each with perceptions, attitudes, feelings, instincts, behavior patterns, self-organized structures, decision processes, energy sources, and consciousness. The personal and group awarenesses of these characteristics are different for each type of being and also for different individuals and groups within any one type of being. Each type of being is in dynamic interaction at all levels of aggregation with all the other types to form a planetary life support system. Thus, the structural changes arising from Ecocosm design recommendations, when and if they are obtained, may involve changes in behavior for many types of beings, not just humans.

At this time it is not clear what the sustainable Ecocosm design and the implementation procedure recommendations should be. It is not even clear whether existing analytical methods are capable of producing them. This paper suggests that a) all current recommendations lack reasonable

demonstration that they will resolve the Ecocosm Paradox, b) there are easily demonstrated major flaws in almost all existing proposals, c) proposals without easily demonstrated flaws are efficiency improvements that cannot solve the problem, but may or may not postpone the catastrophe, and d) current analytical methods and disciplinary knowledge are not capable of producing a design and implementation that can reasonably be demonstrated to be effective based on a review of what such an analysis and demonstration must do.

However, there are some things that can be said. It is the growth of worldwide human consumption beyond a sustainable amount that is destroying the planet's life support system and, thereby, threatens human survival. The process that is causing the consumption growth is the world socio-economic system that humans have created. That system's survival depends on continued consumption growth. Human survival depends on the system's survival. All aspects of the socio-economic system have been created and supported by conscious or unconscious human decisions which preceded the creation and operation of the parts of the system. The decisions arise from the characteristics of and information stored in the minds of the billions of humans who made decisions in the past or who make current decisions. If consumption growth is to stop, the way human decisions are made must be changed. The general structure of the socio-economic system is similar in most parts of the world, though details differ from culture to culture. Therefore, there is what might be called a shared human consciousness. Changing this shared consciousness will be one important part of saving humanity.

Shared human consciousness cannot be changed in the long-term by passing laws or trying to force people to make their decisions differently. Thus, the adaptive-sustainable Ecocosm design must recognize how human decisions are made, starting with the important characteristics of the shared consciousness. The implementation of the Ecocosm design must find a way to change consciousness characteristics, as well as ways to change operating aspects of the feedback structure. This will require creativity and inspired leadership; but it is not clear what attitudes, beliefs, goals, values, and incentives must be changed, nor what the leadership must do to change them. However, there are several aspects of human consciousness that almost certainly must change. These include replacing a) individual and group selfishness with selflessness, b) anger, hate, fear, and vengeance with forgiveness and love, and c) greed and hoarding for the future with sharing. The "higher consciousness" or "sacred way of life" of many spiritual and religious organizations advocates these three attitudes, but they have not been widely practiced. Unfortunately, the twentieth century's phenomenal success of technology and marketing in gratifying people's senses and making many of them rich (despite the most horrendous wars and genocides in human history), is driving human consciousness in the wrong direction. So the sustainable Ecocosm design and implementation will be working against the momentum of the times and the fondest dreams of all but a few. However, there are many people (though not a large percentage of humanity) who recognize the necessity of such changes and are changing their own lives accordingly.

Selflessness

Selfishness is defined as, "to be concerned excessively or exclusively with oneself; seeking or concentrating on one's own advantage, pleasure, or well-being without regard for others." Achieving immediate gratification and accumulating wealth to insure their future gratification, are the objectives of most people today. A recent television documentary called this addiction

"affluenza." Most would deny it, but advertisers know it is true; and reading advertisements carefully, and objectively considering one's own behavior should make it clear. People today are addicted to things, pleasure, and money. And to ease their guilt, the ads make them feel that they "deserve" the good life. People often measure their self-worth in terms of what they have and how fast their incomes are growing. Almost all of the positive loops that drive consumption growth, except in some ways the self-reproduction loop, arise out of self-serving motivations.

Selflessness does not mean renouncing all consumption. It is a lack of *preoccupation* with self-service. It is the difference between eating to live and living to eat. As long as most humans live to consume, instead of consuming to live, the environment has no chance.

Forgiveness

Humans have an instinctive inclination to resolve conflicts with violence (Lorenz, 1966). In the territorial animal mind, control of the territorial land is instinctively established and maintained by force, physical fights between contesting males. However, the violence is controlled. Fights only arise between males who are about equal in size and strength. Smaller, weaker males do not challenge larger, stronger males. When they occur, fights are not lethal, except by accident, even in predator species. The fight ends when the weaker one concedes defeat. The victor does not have to kill him, and he does not. The human species, for reasons yet to be proved, has developed a mental tolerance, if not preference, for lethal violence. Our suspicion is that this arises from the development of weapons. Before the invention of the spear (a handflaked, sharp, pointed rock fastened to a stick), humans appear to have been territorial, vegetarian, prey animals, like chimpanzees, only slower and weaker. Gorillas are territorial vegetarians also, but there are no predators in their territories strong enough to prey on them, except as infants.

Early humans used the spear to kill large animals for food and clothing, to repel predators, and to wage territorial conflicts. In assaults on large animals, humans were forced to hunt in groups to overwhelm the prey. In a territorial spear fight, victory was not based on brute strength; so the loser often did not know he was the loser until a fatal thrust killed him. That first weapon changed forever the human rules for eating, surviving in unfavorable climates, combating predation, and fighting for dominance. As human population grew, living communities got larger, and weapons became more deadly; territorial disputes involved more combatants and became bloodier. Today an atomic bomb can be carried in a small suitcase. Many of the major turning points in human history have been determined by a murder, a battle, or a war: Salamis, Marathon, Arbela, Actium, Jerusalem, Milvian Bridge, Masts, Tours, Hastings, Orleans, Bosworth, Vienna, Lepanto, Armada, Yorktown, Trafalgar, Waterloo, Gettysburg, Marne, Somme, Midway, Stalingrad, Inchon.

Conflict resolution attitudes are going to become more and more important as the consumption explosion continues and competition for resources becomes increasingly intense. When the environmental and/or socio-economic catastrophes occur, the ultimate conflict resolution methods will be employed. Anger, hate, vengeance, and fear are the activating emotions that will motivate the use of violence to resolve major conflicts. Only if those emotions are replaced by forgiveness and love, will humanity survive a catastrophe or the adversities of a transition period.

If the weapons we have today are used in a "cyberwar," no one may survive. In this age, humanity is widely dependent for survival on the fragile infrastructure of electric, gas, water, telephone, television, Internet, and roadway utilities; the police, fire, medical, and sanitation public services; and the worldwide distribution by truck, rail, air, and ship of vital materials and products; all controlled by computers working through communications networks. A war waged against the infrastructure combined with portable, incredibly powerful nuclear, chemical, and biological weapons for strategic and tactical use would be cataclysmic. There will likely be more than two factions all fighting each other at the same time. The front line will be everywhere (Adams, 1998), and the strategy will be the annihilation of everyone else. The developed countries may be most vulnerable because their wealth will attract predation; their freedom, cultural diversity, and access to the Internet will allow enemies to operate in their cities and towns without suspicion; and their advanced weapons will make them the most feared. The recommendation of forgiveness may sound naï ve in the context of millennial hatreds. However, it is not what the authors expect to happen, but what they believe to be essential for survival.

Sharing

When a system structure changes radically, a period of disorganization follows. Lifestyles change; transportation, distribution, and communications are disrupted; production and income decline; assets and savings are lost; fear and local violence increase; and personal and community order, cleanliness and health decline. Order is replaced by disorder, if not by chaos. In such difficult times, sharing is imperative to prevent hoarding and crime, and to preserve as many lives and to utilize effectively as many resources as possible.

Sharing is helpful in unstressed times also. It fosters support, mutual-dependence, and interpersonal interaction. The emotions of both fear and greed are reduced. Consuming and accumulating for an uncertain future also decline. Sharing shifts peoples' attention from things to people. This reduces consumption and increases feelings of well-being.

The Forge Of Adversity

Long ago a high school English teacher said repeatedly, as we studied literary works such as *Silas Marner*, *Macbeth*, and *Moby Dick*, "In times of crisis, we revert to type." Under normal conditions, humans have time to create the appearance they want to convey. They can make themselves up, pretend they are honest and nice, watch their language, and cover up their real feelings and motives. But when the chips are down, the electricity is off, food is almost gone, bombs are exploding, and friends have run away, we find out how our minds really work and what we are really like. Most people do not know, nor do they want to know, what their crisis personality is. Will a person rise to the occasion, remain calm, solve problems, help others, exercise leadership, and effectively combat the detrimental behaviors of others; or will he/she panic, take advantage of others, and save him/herself at all cost?

In the short-run, adversity is a test of what we are; but in the long-run it breaks down our ego strength and helps to shape what we are to become. It forces the unfreezing that must precede significant attitude change. In the case of either an environmental catastrophe or the adversity of the transition period, all of humanity will be in crisis; so everyone will be unfrozen to some extent. The implementation plan will have to use this condition to prepare for the restructuring and

refreezing, so the attitudes that are required for living in a sustainable Ecocosm can be instilled. Since recovery either from the catastrophe or from the implementation may be many generations long, the leadership and training of the restructuring and refreezing will have to be planned carefully in advance and carried out consistently over a long time by different leaders. This may be one of the first things to consider in the design effort because, if the catastrophe occurs before the more orderly and controlled implementation, damage control and observation and regulation of the unfreezing may have to begin with short notice. The adversity of the crisis can and should be used to forge the "higher group consciousness" needed for humanity to survive in the long-run.

The Promised Land: An Adaptive-sustainable Ecocosm

The concept of Ecocosm sustainability seems to imply a preplanned, constant (steady-state) world consumption maintained at the maximum carrying capacity of Earth's environment. However, given the inevitability of continued technological change, change in human attitudes and expectations, and change in the nature of the environmental infrastructure and the resources available to it, such constancy, optimality, and rigidity are neither possible, nor desirable. In fact, the objective of Ecocosm design is not to identify the amount of annual consumption that will be sustainable in the long-term. The objective is to design an Ecocosmwide feedback structure, supported by appropriate human attitudes, that will constantly and automatically (without conscious human measurement, force, or self-control) adjust the human presence (population and per capita consumption) and the non-human environment to do an excellent, but not demonstrably optimum, job of providing for the present living beings and preparing for the support of their progeny indefinitely. Such a process will not and should not produce constant consumption or eliminate all positive loops. The limited positive loop form of control in natural systems is better in many ways than the negative feedback control systems of engineering design that are easier to stabilize. The instinct of reproductive territoriality with the complex of related instincts that support it (dominance, aggression, pair or group bonding, parenting, xenophobia) initiates an automatic, limited-positive-loop feedback control process that consistently provides efficient, effective, adaptive, sustainable, near optimal generation of living communities to fill the available space on Earth. Unfortunately, such instincts seem to be detrimental for a human society that is technologically-sophisticated, self-aware, regulated by conscious decision making, and motivated by short-term self-gratification. It will be quite a challenge to design its successor paradigm in time.

WORLD MODELING USING SYSTEM DYNAMICS

Forrester first modeled the world system using SD (Forrester, 1971). Some of his students refined his model to become the model of *The Limits to Growth* (Meadows, et al, 1972). There followed a long series of extensions and refinements by those authors and others. These are quantitative computer models whose variables grow exponentially until a limit is reached in the early to mid 21st century, whereupon the variables fall to 25%-50% of their peak values within 20 to 50 years. Different initial and parameter values produce minor differences in the time patterns. These models illustrate the principle that no variable can grow exponentially indefinitely without encountering some major limit that will stop the growth and initiate a collapse. Then, the solution is to stop the growth before the collapse.

Major differences exist between the problem perceptions, loops, solution perspectives, and concept presentations of *Limits* and *Ecocosm*. The qualitative model proposed herein (*Ecocosm*) includes the highly-aggregated, primary positive feedback loops whose mutual reinforcement caused the observed past exponential growth. Many of these are different from and more significantly impact the system than the positive loops in *Limits*. In *Ecocosm*, many possible limiting factors are excluded. These factors are far more numerous, diverse, complex, and difficult to represent than is implied in *Limits*. Collapse dynamics are omitted because a completely different set of loops will control the crash. *Limits'* assumption that the same loops will control both growth and collapse is false. In fact, there are so many possible crash-control loop sets and each is so complicated that a major study is required to identify and analyze them. *Ecocosm* uses a consumption perspective, instead of the production perspective of *Limits*. This is important because it demonstrates that growth is caused by everyone, not just a few important producers. Thus, to stop growth will be much more difficult to do than *Limits* implies. The focus on the environment in *Ecocosm* shows clearly the interaction between the environmental loops and the human system loops that creates humanity's crucial dilemma, the Ecocosm Paradox. *Limits* fails to perceive this dilemma, which is that if growth continues the environment will collapse, and if growth stops the human socioeconomic system will collapse. The paradox shifts the solution perspective from the difficult task of stopping growth to the intractable perplexity of stabilizing and balancing the driving forces of the whole Ecocosm.

Even more important differences separate their analysis, synthesis, and implementation philosophies. *Ecocosm* was formulated to address the difficulties of improved system creation, group consciousness elevation, transition analysis, implementation planning and control, and long term maintenance of the improved system. These must all be overcome successfully, if the paradox is actually to be solved in the real Ecocosm in the long-term. These difficulties, which are not adequately addressed in *Limits*, are presented in considerable detail in this paper and in *Intellectual Roots and Philosophy of System Dynamics* (Fey, 2001); even to the point of formulating the theory of a new kind of feedback, pattern feedback control.

CONCLUSIONS

Massive human intervention in the natural environment has created the environmental crisis with its associated Ecocosm Paradox. The intractability of the dilemma of the Paradox and the speed of the environmental disintegration present humanity with an unprecedented and supreme challenge: Design a realizable system structure for the whole Ecocosm that will stabilize human consumption and maintain an adaptable living life support system for the present living beings and their progeny indefinitely; and do it before the environment or the socio-economic system collapses. This paper presents in considerable detail the nature of the Ecocosm, its problems, and the Paradox; the nature of the solution and its implementation; and a suggested procedure for finding a solution and implementing it. It does not present a solution because the authors have not carried out the procedure. They know how difficult the procedure will be to perform and how counter-intuitive the solution will be, if one can be found. Therefore, the authors are not prepared to guess in the face of such complexity and with such enormous consequences for humanity at stake, despite (or perhaps because of) their considerable experience with this type of analysis.

To the authors' knowledge this is the first description of the entire process required to design and effectively implement a realizable, adaptive-sustainable Ecocosm. There have been many descriptions of models of the world system and recommendations for solutions to the environmental crisis. However, *none* of these have a) resolved or even recognized the existence of the intractable dilemma of the Ecocosm Paradox, b) resolved or even recognized the severity and immediacy of the human crisis created by compound, hyper-exponential growth that is *quadrupling* an already unsustainable world human consumption every 35 years, c) considered the true nature of the complex interactions within and between the human socio-economic system and the environmental life support system that now function as a combined, unified Ecocosm, d) realized the nature and great difficulty of creating the design of an adaptive-sustainable Ecocosm, e) resolved the problem of adverse transient time patterns during the transition period, f) considered the nature and difficulty of designing the implementation plan, and g) considered the nature and problems of implementing the changes in consciousness and structure needed to establish the adaptive-sustainable Ecocosm (there is a great difference between creating the implementation plan and actually performing the implementation successfully according to the plan).

The creators of these models and recommendations appear to have little concept of the real nature and severity of the problems, and little idea of what will be required to solve the problems in the real world. The virtual worlds of television, computers, mathematical abstractions, positive thinking, managed news, psychological advertising, unprecedented economic prosperity, and models of hypotheses that are mistaken to be models of reality, have so decoupled science and humanity from reality that the real nature of life on our small planet is almost totally obscured. As Walter Truett Anderson warned, "The central political problem of our time is not that people in power do the wrong things, or that some people have more power than others, or that there is a lack of clarity and honesty in political dialogue; all of these are real and serious, but they are only dim reflections of a larger problem, which is that we literally do not know what we are doing" (Anderson, 1987). We had better find out what we are doing; and do it in a very short time.

It is ironic that extensive, detailed, scientific design is in progress to begin the colonization of Mars in 2012. At great expense, we are anxious to export to an undefiled, resource-rich planet an unstable, conflicted, warlike human system that is unashamedly destroying its own home planet's life support system to make its leaders wealthy. The Carter Center reports that there are currently 20 to 30 major ongoing wars now in progress worldwide (Carter Center, 2000). Besides these violent local wars, revolts, genocides, and border conflicts, hundreds of American elementary, middle, and high schools maintain a constant, permanent, armed police presence. Only when our civilization of greed and violence cleans up its own species consciousness and its decimated environment will humanity be justified in extending its influence to new, uncorrupted worlds. Technology can transport humans to Mars, but it cannot bring honesty, selflessness, and peace to the colony.

What is presented here is the authors' recommendation for a method to resolve the Ecocosm Paradox. The procedure will be difficult to accomplish. The analysis and synthesis probably will turn out to be impossible to do. If somehow a reasonable adaptive-sustainable Ecocosm design and implementation plan can be created, it is unlikely that world leaders will accept it; and the actual implementation, if ever started, is likely to fail. In good times, humans are often

opportunistic, arrogant, and greedy; in crisis most are cruel, fearful, dishonest, and/or violent. Human history repeatedly demonstrates the inventiveness of physical science and the treachery of politics. Our recommended design procedure is offered as our understanding of the only reasonable chance humanity has to save itself from itself. Virtually all of the prophetic traditions of religions and cultures worldwide, ancient and modern, forecast a catastrophic "end time." In a few, humanity is obliterated; in most a small remnant survives. Now, a catastrophe that could threaten human survival is upon us in the form of the intractable dilemma of the Ecocosm Paradox. How will we respond? How will you respond?

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