THE ECOCOSM PARADOX

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Contents:

Glossary:

<u>Ecocosm</u> – humanity's total planetary home system, including human societies and artifacts, plant and animal communities, nonrenewable materials, the atmosphere, and magnetic fields all continuously interacting.

<u>Ecocosm Paradox</u> – a dynamic hypothesis of all the critical global relationships that cause the Earth's environmental crisis, which paradoxically may have no catastrophe-free solutions.

<u>Hyper-exponential</u> – a function that has an exponential shape even when plotted on a logarithmic scale.

<u>Compound hyper-exponential</u> – a function that is the product of an exponential function and a hyper-exponential function.

<u>Stability</u> – a system characteristic distinguished by no continuing exponential growth, exponential collapse, or growing oscillations. The primary concern of this paper is the stabilization of exponential growth.

Sustainability – a world system state that will continue to support human life indefinitely.

Technometabolism – human energy use beyond the basic metabolic energy used by the human body. Technometabolism arises out of the use of technology as basic as fire and as complex as the Internet.

HEE – a unit of measure for technometabolism. Since the approximate amount of energy the human body uses daily is 10 megajoules, this amount is termed a Human Energy Equivalent (HEE), and is used as a unit to measure human energy use beyond this amount.

Summary:

The Ecocosm Paradox identifies critical relationships between our nonliving mineral planetary spacecraft, our human presence, the non-human living biomes that provide life support, and the environmental crisis. The paper discusses the major factors, structures, and feedback loops that constitute the Ecocosm. The Paradox suggests a tragic, species-threatening dilemma for humanity. If world human consumption continues to grow exponentially, even at a reduced growth rate, the resulting environmental destruction may precipitate a major catastrophe in Earth's life support system. Conversely, if consumption growth is stopped to save the environment, the human socio-economic system may experience a securities panic, economic depression, social instability, and world wars with modern super weapons. Although it is not certain what radical new visions and directions are needed to solve the dilemma, it is clear that the current trends can not continue much longer before they cause a catastrophe.

1. Introduction

Exponential growth in world population, energy use, production, technology, pollution, and weapons' destructiveness has focused attention on Earth's environment and ways to insure humanity's long-term survival. This growth is resulting in serious problems such as global warming, resource exhaustion, massive species extinctions, and environmental destruction; these may eventually provoke terrorism and global war. A formula for "sustainability" is needed. Most believe the solution will come from governmental regulatory policies, automatic corrections in the world economic system, and/or the continued growth of technology. Regulatory policies, economic adjustments, and technology are not likely to solve the problems because evolutionary human instincts energize the complex, interdependent, feedback control structures in today's technological world society that produce the unsustainable growth. World human consumption growth is the primary force that drives environmental deterioration; therefore, attaining sustainability is a monumental human behavioral problem. (See *Regional Development, Irrigation Projects and Environment* and see *Ecological Interactions (Kaibab Plateau)*.)

The Ecocosm Paradox is the detailed hypothesis for the whole Earth system that includes closed-loop interactions between the natural mineral/living planetary environment and the technology-based global human presence (Figure 1). It considers the entire dynamic process, historical time histories for the important variables, future prospects for the Earth and humanity, and the characteristics of effective solutions and their implementation strategies that are required to resolve the growth dilemma. *Ecocosm* combines the Greek words "*oikos*" meaning "home" and "*kosmos*" meaning "universe," "form," and "order." Thus, *ecocosm* is humanity's total planetary home system; the closed-loop, unstable, long-term, living and non-living whole-Earth system. A *paradox* arises because the *ecocosm* is inadvertently producing a crisis with multiple environmental problems for which there may be no catastrophe-free solutions. If consumption growth continues, the resulting environmental destruction may precipitate a human species-threatening catastrophe in Earth's life support system. If consumption growth could be stopped to save the environment, economic, social, and military crises would arise. The interaction between nature and the human presence has reached the point where some kind of major catastrophe in the natural environment and/or the human presence appears inevitable. Humans doing seemingly normal, essential things (i.e. reproducing and consuming) are threatening the survival of *Homo sapiens*.

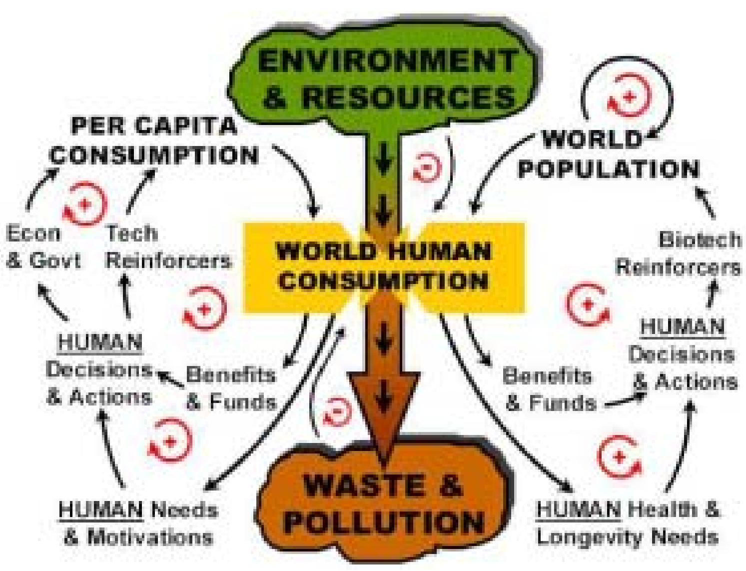

Figure 1. The Ecocosm Paradox

World human consumption is the variable that connects the natural environment and the human presence. The upper cloud in Figure 1 contains the natural environment and the Earth's available resources. In the lower cloud are the discarded waste products of human living. Consumption draws resources from the environment and turns them into waste. When people cut the trees of a forest or remove iron ore from a strip mine, they do it either directly or indirectly to make products for humans to consume. Even before consumers discard used products, the recovery process destroys environmental infrastructure and wastes resources. Product fabrication also wastes resources. Despite degradation and recycling of some waste back to usable resources, there is still a large net annual decrease in available resources at the top and a large net annual increase in the volume of pollution at the bottom, so the figure represents the net effect of human living on the environment.

2. The Power of Compound Hyper-exponential Time Functions

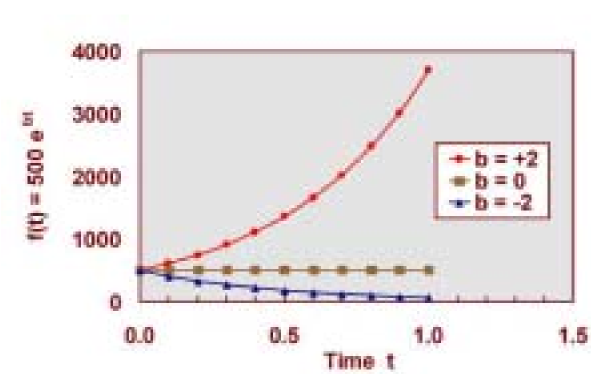

Figure 2a. Exponential time function plotted on a linear scale

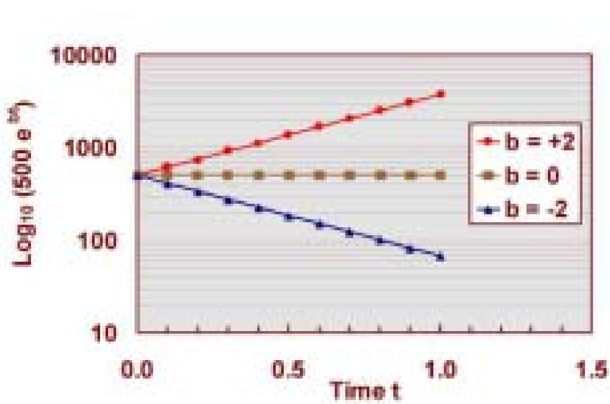

Figure 2b. Exponential time function plotted on a logarithmic scale

The important world human variables are growing exponentially. The exponential time function is given in Equation 1, where K is a constant, e is a number 2.718…, b is a number or a function of time, and t is time.

$$f(t) = K e^{b t} \qquad (1)$$

When b, the exponential growth rate coefficient, is a constant real number, the function has three possible time patterns: for b equals zero, for b less than zero, and for b greater than zero, as shown in Figure 2a. In Figure 2b, with a logarithmic vertical scale, when b is a constant, the function plots as a straight line for all three cases. Table 1 shows the relationship between b, the annual growth rate, and the time to double the function's value. This doubling time is given by (ln 2) divided by b. Very small annual percentage increases double the value in amazingly short times. A two-percent annual increase doubles the value in only 35 years.

Growth Rate	0.1% per yr	0.5% per yr	1.0% per yr	1.5% per yr	2.0% per yr	3.0% per yr	4.5% per yr	7.5% per yr	10.0% per yr
Doubling Time	693.2 years	138.6 years	69.3 years	46.2 years	34.6 years	23.1 years	15.4 years	9.2 years	6.9 years

Table 1. Time to double the value of an exponential time function for some annual % increases

If b increases with time, the function may plot as a geometric progression even on a logarithmic scale. Such "hyper-exponential," growth is overwhelming. Not only is the variable relentlessly doubling, its doubling time is becoming progressively shorter. Hyper-exponential growth is important because, as will be shown, human population growth has been hyper-exponential over the last millenium. Compound hyper-exponential growth is even more devastating. A variable has compound hyper-exponential growth when it is the algebraic product of a hyper-exponential growth variable and an exponential growth variable. A compound hyper-exponential variable (Equation 2) has a growth rate coefficient with a growing time function a(t) part plus a constant part c.

$$f(t) = K e^{[a(t) + c]\, t} \qquad (2)$$

Most world human variables, such as consumption, are compound hyper-exponentials, since they are the product of hyper-exponential population and a per capita factor that is exponential. The rapid growth of population and per capita consumption together causes the environmental crisis.

3. Data Time Histories for Important World Variables

UN data for population are plotted in Figure 3a on a linear vertical scale. The same data are plotted in Figure 3b on a logarithmic scale. The exponential shape on the logarithmic scale indicates a hyper-exponential function. Human population has now surpassed six billion. An additional billion people is being added every thirteen years. Figures 4a (linear scale) and 4b (logarithmic scale) show data for population's annual growth percentage, the "b" coefficient, an exponential that abruptly changed its slope around 1900. As annual growth percentage has increased, the time for population to double has fallen in the last 500 years from 640 years to a present doubling time of 40 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. Births per year began to fall later. Figure 5a shows time histories for birth and death rates per thousand people in less-developed countries. Figure 5b shows recent data for whole world birth and death rates. Technology-driven health advances that reduced the death rate accelerated population growth. Despite recent reductions in population annual growth rate, world birth rate is still more than twice the death rate, and major new health advances appear imminent. Strong population growth has not ended.

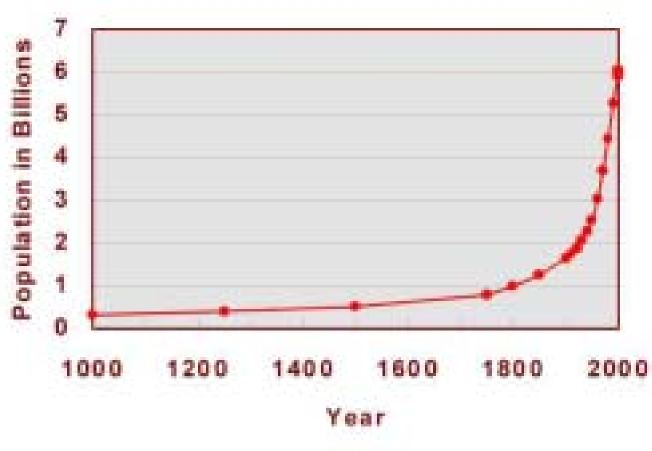

Figure 3a. World population growth on a linear scale

(Source: United Nations Population Division)

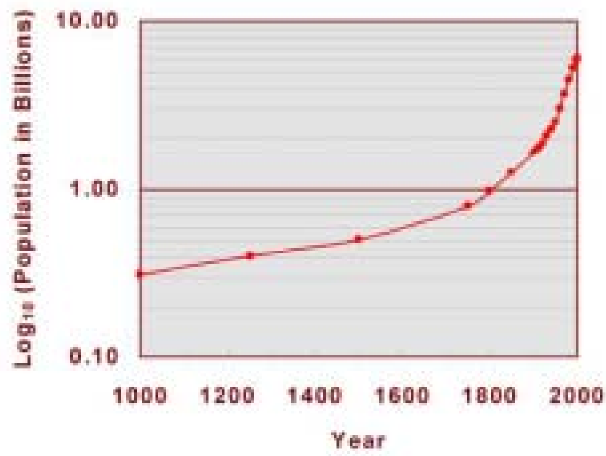

Figure 3b. World population growth on a logarithmic scale

(Source: United Nations Population Division)

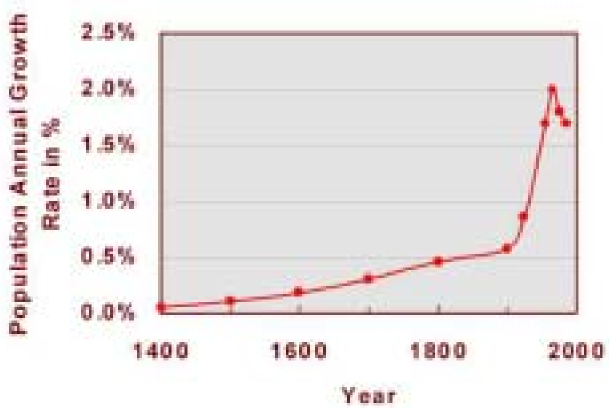

Figure 4a. Annual growth percentages for population (the "b" coefficient) on a linear scale

(Source: M. K. Hubbert)

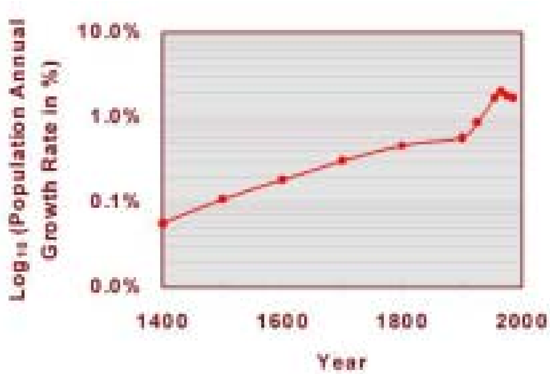

Figure 4b. Annual growth percentages for population (the "b" coefficient) on a logarithmic scale

(Source: M. K. Hubbert)

Figure 5a. Birth and death rates for developing countries

(Sources: C. M. Cipolla; U.S. Bureau of the Census)

Figure 5b. Birth and death rates for the world

(Sources: C. M. Cipolla; U.S. Bureau of the Census)

Data for total world energy use and average per capita energy use from 1860 to present are shown on both linear and logarithmic scales (Figures 6a and 6b). Total energy use, which has more than quadrupled since 1950, is the product of population and per capita energy use. In 1992, 74% of the world's total energy was used by 23% of the world's human population that resides in developed countries. Extrasomatic energy used by humans has been termed "technometabolism," energy used beyond human metabolic energy. Technometabolism can be measured in human energy equivalents (HEEs), each of which is equivalent to 10 megajoules per day. The average daily per capita energy use in 1992 was 6 HEEs in developing countries, 56 HEEs in developed countries, and 100 HEEs in the United States. When the 77% of the human population in developing countries increases its standard of living, the exponentials in Figures 6a, 6b, and 7 will expand dramatically.

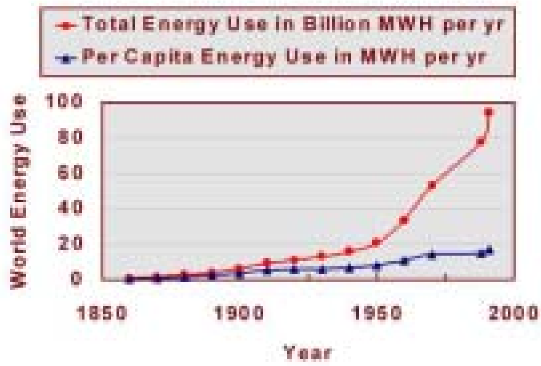

Figure 6a. Total world energy use and per capita energy use from 1860 to present (linear)
(Sources: J. Cohen; C.M. Cipolla; United Nations Population Division)

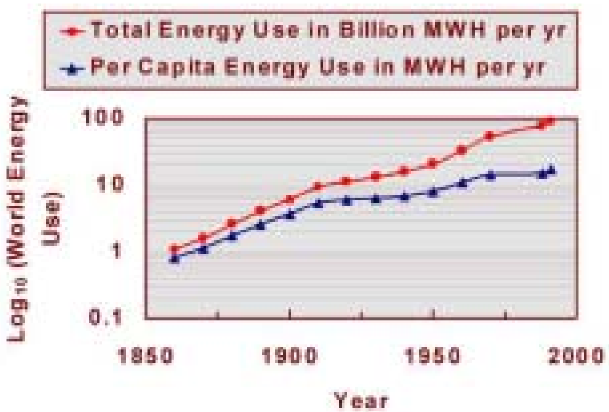

Figure 6b. Total world energy use and per capita energy use from 1860 to present (logarithmic)
(Sources: J. Cohen; C.M. Cipolla; United Nations Population Division)

Data for world human consumption are not very reliable. Consumption, composed of many incommensurate products and services with different environmental impacts, is often estimated in local currencies with variable exchange rates. UN data on a logarithmic scale in Figure 7 show the growth of a world GDP per capita index that may 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 1949 to 1976 indicates that per capita consumption is exponential. With population doubling every 40 years, their algebraic product, world consumption, must then quadruple in about 35 years. Therefore, stopping population growth will not stop consumption growth. If current population growth and per capita consumption growth continue, world consumption will increase by a factor of about 50 during the twenty-first century. Such growth would devastate the environment and clearly is unsustainable.

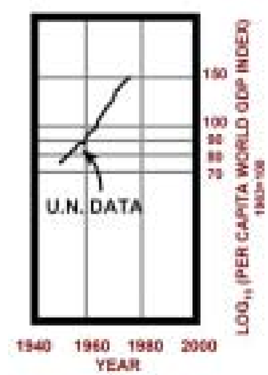

Figure 7. World GDP per capita on a logarithmic scale
(Source: J. Parent)

4. The Instability of the Human System on Earth

Constant-coefficient exponentials are the time-function solutions for linear differential equations. Such equations represent simple feedback system relationships. In all engineering applications, the b growth rate coefficients of the exponentials must be negative; so time functions decline with time. Compound hyper-exponential growth only arises in more complex, nonlinear, human positive feedback systems. Humanity has organized itself into a six-billion-person feedback structure that is producing compound hyper-exponential human time histories. All uncontrolled growth eventually becomes destructive. Stability analysis is used by engineers to be sure that their systems have no growing exponentials. However, in human socio-economic systems, sustained growth is demanded; so almost all human systems are *deliberately* designed to be unstable. If these systems are to obey the engineering design stability constraint, exponential growth must be forbidden. Consumption growth will not end until the world human socio-economic system that creates the growth, is redesigned and changed to be stable.

5. Feedback Structures That Cause the Exponential Time Patterns

World human consumption is the product of human population and average annual human per capita consumption (see Figure 1). Each factor has its own set of positive feedback loop reinforcements that cause its growth. Population's growth is caused by two primary positive loops. These are the instinctive human reproduction loop and the biotechnology loop that extends life expectancy. Per capita consumption's growth is created by positive loops for technology, world economics, and government policy. Environmental collapse, resource exhaustion, and toxic pollution are the negative loops that may finally stop consumption growth. Sections 5.1-5.3 describe these loops, and Figure 1 summarizes their interactions.

5.1 Population Feedback Structure

In Figure 8, 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 the elder population. The birth flow is equal to the product of childbearing population and average human reproductive fertility. Death flows equal the indicated populations times the probabilities per year of such people dying.

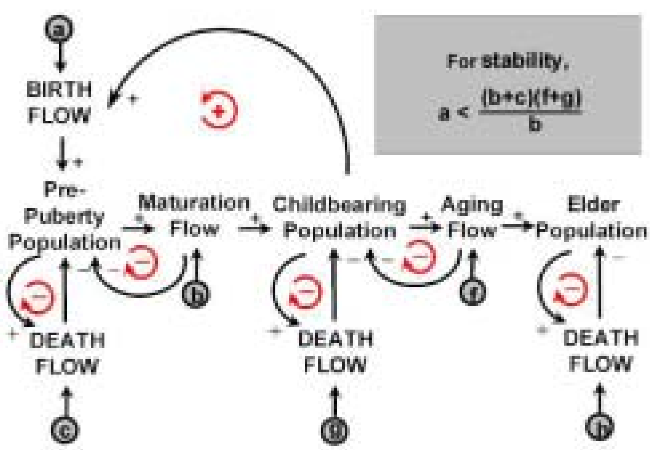

Figure 8. Causal loop diagram for population

In any human system there will be many feedback loops. Positive loops reinforce trends. Negative loops resist trends and reverse changes. 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 influences it. This population system has one positive and five negative loops. The positive loop will cause growth, if the reproductive fertility factor, a, is larger than a function of the delay times in the pre-puberty and childbearing states and death probabilities in the two populations (as shown in Figure 8). Today human fertility produces new humans faster than deaths and shifts to the non-reproductive state can remove people from the childbearing state that energizes the positive loop. This reproduction loop is the first positive loop driving consumption growth (Figure 1, top right).

In Figure 8, fertility and death probabilities are assumed to be constant, but in most countries fertility and death probabilities are falling. Death rates are falling because public health measures and medical technology are extending human life span. 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 1, right center) that drives the population exponential. It causes a hyper-exponential population growth.

Natural animal populations have the same positive instinctive reproduction loop that humans have, but they do not grow exponentially to overrun the Earth. Another instinct called territoriality limits their growth. Males establish territories that they defend against other males of their species. When the strongest males have occupied all the livable territories in an area, no more reproducing units are formed. Weaker, unterritoried males do not mate. Females with no territoried male do not conceive, so the childbearing population in the positive reproduction loop contains only childbearing age animals with territories. Since territories are limited, both the effective childbearing population and consumption are limited. Population growth ends when all the territories are occupied. Humans are instinctively territorial, but technology has broken the human bond to the land. For much less effort and with better quality, technology now provides the things that were formerly obtained from territorial lands with great effort. The human territorial instinct still exists; but it is now expressed in managerial, speculative, and competitive athletic behavior. Since human territoriality has been significantly redirected, human population has been expanding without limit.

5.2 Technology's Feedback Structure

Virtually all products that 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 9), research and design effort leads to new knowledge and new products. These motivate higher per capita consumption that increases total consumption. Increased consumption of technologically based products results in benefits to consumers, governments, and producers. It also leads to individual and social disbenefits. Both the benefits and, paradoxically, the disbenefits motivate more research because technology is used both to design products and to solve problems. This is the primary positive technology loop.

Figure 9. Technology Causal Loops

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 shows 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 result from scientific research produce benefits and disbenefits. These motivate more research and more trained people to do more research. This process continuously develops new technologies that provide new products and processes that induce us to consume more (see Figure 1, left center).

5.3 Economic and Government Loops that Reinforce Consumption Growth

The interaction of human attitudes and technology drives per capita consumption growth, and is reinforced by economics and governments. There are two aspects of economic life, production and consumption (Figure 10). 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 materials suppliers and the employees who make production possible. After the employees receive their wages, they change into consumers and use the income to pay for 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.

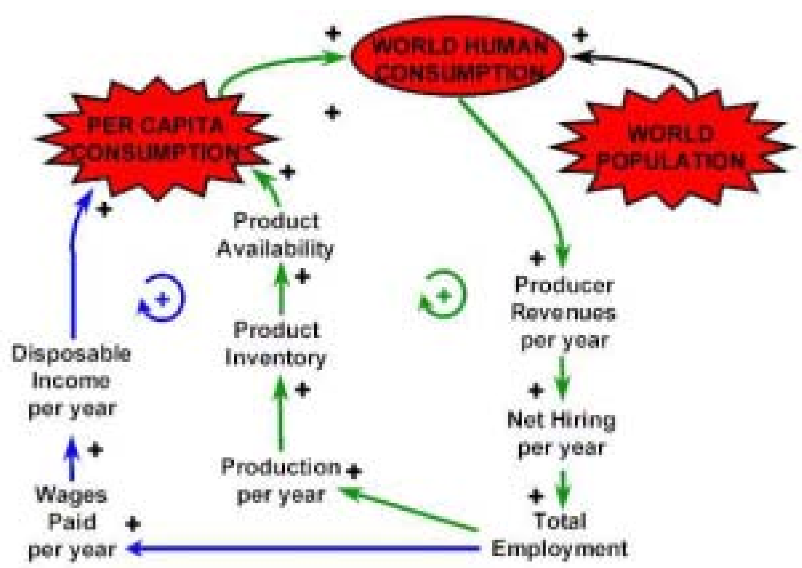

Figure 10. Production and Consumption Causal Loops

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 connects the intangible financial aspects to the tangible physical aspects of the economy. To increase consumption (Figure 11), producers design and manufacture 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 what they have purchased as soon as it is used or a better new product appears. Positive feedback loops reinforce all of these actions and, thereby, reinforce consumption.

Figure 11. Marketing Causal Loops

The speculative operations of the securities markets are regulated by positive investment loops (Figure 12) in which consumption growth motivates price increases for securities. This attracts speculative funds for investments in producer operations that reinforce consumption. Therefore, if consumption growth stopped permanently and speculators became convinced that it would not restart, stock and bond prices would fall rapidly.

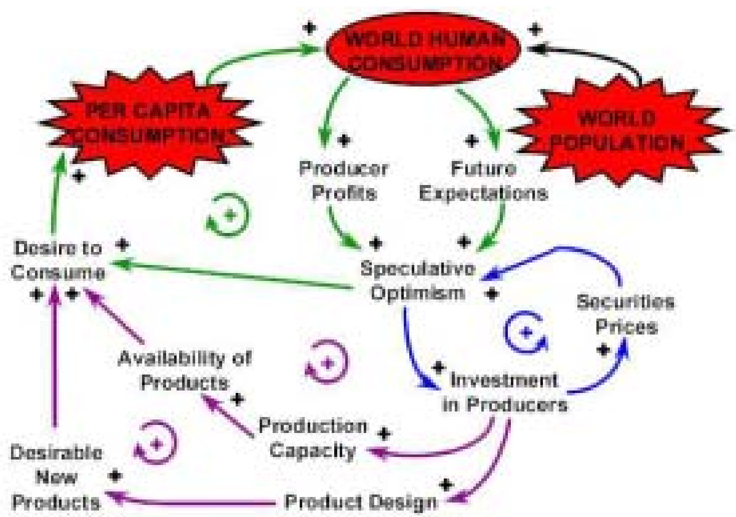

Figure 12. Investment and Speculation Causal Loops

Governments also engage in positive feedback loop behaviors (Figure 13) 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 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 10-13 reinforce consumption (see Figure 1, top left). It is the operation through time of the positive technology loops reinforced by all of these positive economic, financial, and government loops that drives the exponential growth of per capita consumption. The combined force of these interlocking positive loops relentlessly driving consumption upward simply cannot be stopped without seriously harming the world economy. The causal loops for the Earth's crisis, as shown in Figure 1, must be understood if an environmental catastrophe is to be averted without inducing other, equally devastating, economic, social, and/or military calamities.

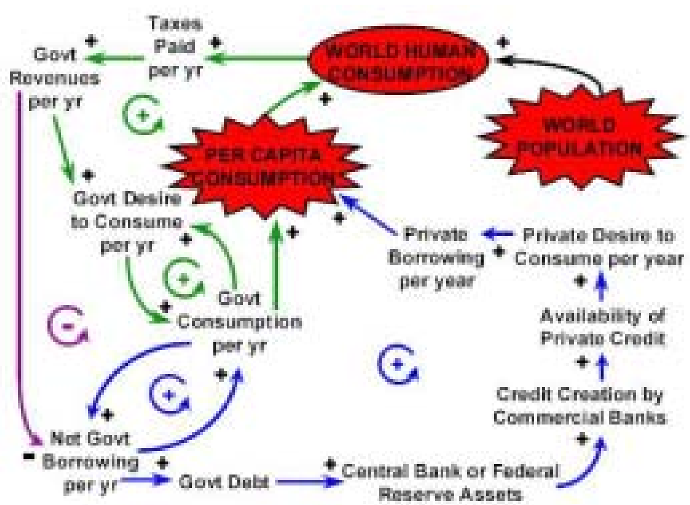

Figure 13. Government and Borrowing Causal Loops

6. The Nature of Sustainability

There is much disagreement and confusion over "sustainability." In general, it means to maintain the Earth and its subsystems in a state that will continue to support life indefinitely. The first widely quoted definition, "development that meets the needs of the present without compromising the ability of future generations to meet their own needs", sums up most sustainability attitudes. This paper's approach to sustainability is empirical. The hyper-exponential growth that exists for all human variables must stop, so the first sustainability criterion must be to stabilize the world system. The world system is too complex, nonlinear, unknowable, and noisy for explicit detailed quantitative stability analysis. Nevertheless, no exponential growth can be allowed, so all positive loops must have limits or have small enough gains to prevent growth. This is the ***stability criterion*** for sustainability.

Perpetual sustainability is not directly addressed by the stability criterion, but consumption growth must end before perpetual sustainability can be considered. Otherwise, all resources will be consumed and sustainability will be a moot issue. Therefore, a second ***sufficiency criterion*** for sustainability should specify that when growth ends, sufficient raw materials and infrastructure must be left in their natural condition in the environment to support future human life forever. This also is too complex for mathematical analysis. Since it is clear that current consumption is not environmentally sustainable; after all growth stops, it will have to be reduced to an annual amount that can be sustained forever from the resources and infrastructure then available.

7. Proposals for Achieving Perpetual Sustainability

After examining the hyper-exponential data time histories for the important system variables and analyzing the positive feedback loops that produce them, an analyst should attempt to synthesize changes in system feedback structure that will create improved time patterns. The changes must appropriately modify the time patterns, and must be successfully introduced into the operating system without inducing changes in parts of the system that are not to be changed. The changes must not create detrimental dynamic patterns during the transition period from old to new structures, and must not cost too much nor take too long. None of the many proposals for solving the environmental crisis adequately addresses the extremely difficult issues of stopping all growth and lowering world consumption to a perpetually sustainable amount.

7.1 Technological Solutions

Proposals intended to end population growth, while helpful, are difficult to implement, are neutralized by medical technology that extends life span, and are inadequate because per capita consumption growth must end also. Proposals based on technological innovation attempt to save the environment by minimizing the flow of resources from the environment to pollution (Figure 1) for a given constant consumption and maximizing the recycling flow back to production and the regenerating flows to the environment. However, consumption will not remain constant because technology will also continue to create new products that will accelerate the growth of per capita consumption; and continue to extend human life expectancy, so population also will continue to grow. Minimizing the resource depletion flow and maximizing the recycling flow may slow the growth of net depletion, but there will still be a continuing net loss in resources and a continuing build-up in pollution which will grow as consumption continues to grow. Eventually, something will precipitate a major catastrophe. The fundamental problem is the growth of per capita consumption and population, that technology facilitates so effectively, not low efficiency in resource utilization or recycling. *The growth that technology facilitates will greatly overwhelm the efficiency improvements it creates.*

Technology is the accumulated knowledge and methods created and used by humanity to provide all of the material things we consume. The term may be misused to imply that there is some single, identifiable, self-disciplined, non-human entity (technology) that creates things, solves problems, and is responsible for the consequences of the human use of technological artifacts. But knowledge and the ways in which artifacts are used arise solely from human thought and action. Therefore, humanity is responsible for all technologically inspired benefits and problems. Unfortunately, "humanity" is not a single, identifiable entity either; so "it" cannot accept this responsibility, nor repent of past crimes, nor correct past errors.

Human beings have not yet had time to acquire an awareness of themselves as mutually-dependent fellow passengers/crew on a small, open, threatened spacecraft whose challenge is the magnitude and destructiveness of their own presence and actions. This threat has arisen only recently because technological advancement, human numbers, and consumption have only approached an Earth-threatening magnitude since World War I. Humans cannot conceive that they, of necessity, all must cooperate as members of Humanity on finite Earth. As militant members of special interest groups on a limited Earth, their allegiances and efforts are directed toward exalting themselves and their small groups at the expense of other individuals and small groups, and, unintentionally, at the expense of the spacecraft.

The human xenophobic instinct (fear and/or hatred of strangers or people who are different in some way) that contributes to this competitive behavior was essential for species survival for hundreds of millions of years. Human aggressiveness, which is coupled to territoriality and xenophobia to resolve conflicts, is also an ancient human instinct that was essential for human survival. Other important instincts are dominance, learning, reproduction, and self/family preservation. However, today, facilitated by the power, products, and social organization of civilization derived from technology; these instincts, through the over-consumption and destructive competition they now engender, soon may destroy our spacecraft's life support system.

Historically, technology has been used primarily to create "desirable" products that satisfy human needs, to invent weapons, to facilitate growth (a desirable end in itself in the past), and to solve problems. However, excessive human demand for the products technology has developed, irresponsible use of weapons, and addiction to the benefits of growth have created the existing human and environmental problems and probably will create much more serious ones in the future. Tragically, technology has been so successful in the past in its dual roles of creator and problem solver that nearly everyone forgets that technology has also created the problems it has had to solve.

The diversity and power of technology's creations and of their problematic side effects are growing so rapidly that soon there may arise a problem that will be too powerful and too complex for technology to solve in time. The concepts we have used for our benefit eventually may be used to destroy us. Thus, technology's proactive role in creating the products, weapons, and growth must end, if technology's reactive role in solving the problems it has created is to succeed. Unfortunately, the emotions that human instincts promote (arrogance, greed, fear, jealousy, selfishness, anger, et cetera) feed on the products, weapons, and growth provided by technology, and force technology's proactive role to expand. Thus, technology's power and success may destroy its human creators, who are still dominated by the ancient instincts and emotions that have become dysfunctional in the modern technological society that now dominates our small spacecraft.

7.2 Economic Solutions

Positive economic loops (Figures 10-13) and technology loops (Figure 9) that reinforce exponential per-capita consumption growth are created by and for the benefit of the people who demand the gratification that the products and growth bring. As long as people and organizations demand and depend on growth, there can be no solution; and an environmental catastrophe is inevitable. Economic theories do not recognize the dominance of these unstable positive loops. They focus instead on presumed equilibrium in the goods and financial markets that will somehow automatically stabilize the world economy and save the environment. The presumed equilibrium is based on unrealistic views of the real behavior of modern consumers, investors, and producers.

Theories about economic forces attribute objectives, information, and optimization strategies to producers and consumers that they do not have. Neither firms nor nations want equilibrium conditions. They deliberately try to avoid equilibrium because they know that growth is more beneficial and achievable. They do not maximize profits at a point in time (they do not know how); instead, they generate as much growth as they can. Neither economic theories nor real economic forces will save the environment.

7.3 Stabilization of Consumption through Price Adjustments

Many believe that world price adjustments will force reallocations of materials usage that will prevent resource exhaustion. However, present pricing mechanisms for resources (local contracts at the source and spot and futures market trading) are holding resource prices at ridiculously low levels that encourage massive utilization. Oil at $12/barrel, copper below $1.00/pound (October 1999), et cetera, are absurdly low from the perspective of prices that must preserve these resources forever. In auction markets and private negotiations, price changes are controlled by the differences between current supply and demand. Since no one is buying now for use 10 years, 100 years, or 10 000 years in the future, the only buying (demand) is for immediate or very short-term use. However, the supply comes from the owners of all the known resources who are typically governments or private interests in developing countries that are economically needy and/or militarily threatened. They must sell whatever resources they have to survive. They cannot afford to hold resources off the market for use in the distant future. Thus, most of the known resources, a large supply, are for sale to buyers for immediate use, a trivial demand.

7.4 Government Policy and Treaty Solutions

Historically, most policies by individual governments, joint activities by government coalitions, and treaties between governments have been short-lived, ineffective, and often destructive in achieving or correcting conditions that are not greatly desirable to the governments. Preserving Earth’s environment and resources does not directly benefit governments. Governments have been exploiting the Earth for millennia. Therefore, government environmental policies will not be vigorously enforced in the face of strong opposition, so they have little chance to solve the environmental crisis.

Government revenues come mainly from taxes on activities that depend on growth and from low interest borrowing that depends on economic prosperity (growth). The political support for governments by the people governed depends on good times (growth); so governments do all they can to encourage growth. Taxing resource use and/or pollution may postpone resource exhaustion and reduce pollution generation; but these policies will also reduce government revenues in the long-term and reduce popular support. Laws passed to force environmentally desirable behaviors often have been ineffective in solving problems because the short-term well-being of governments is more important than the long-term well-being of animals or the preservation of resources. When government policies that protect the environment demonstrably reduce government revenues and popular support, the environmental policies will not be enforced.

One effective thing that governments may do to slow growth is to wage global wars to gain control of the dwindling resources they need. Wars and genocide in the twentieth century alone have killed far more people, destroyed vastly more property, and drained and disabled a much greater portion of the Earth's environment than all of the wars and genocide combined in human history. At present (August, 2000), 20 to 30 local wars, armed border confrontations, and genocides are in progress worldwide; and international terrorism is widespread. This pervasive aggression exists in spite of the United Nations' efforts to establish peace. This has been a century of unprecedented technological advancement, unimaginable human slaughter, devastating environmental destruction, and unparalleled accumulation of wealth by the upper classes. There is so much technological power, unconscionable human greed and cruelty, and enormous vested interests on such a small spacecraft overpopulated with consumption-addicted passengers; it is difficult to believe that there can be a solution that will save the Earth, the people, their lifestyles, their property, and their attitudes intact. If such a solution exists, it must be compatible with the nature of the human mind and the "civilized" technological society that mind has created; and it must effectively modify the feedback loop structure represented in The Ecocosm Paradox of Figure 1 to be environmentally sustainable.

8. Conclusions

Great devastation has been imposed on the Earth's environment, especially in the last century. Since the destruction is continuing and accelerating, many fear that the ability of the Earth to support human life may soon be threatened. Conservation, cleanup, and recycling efforts have begun in some places. Engineers are beginning to consider these issues when they design products and processes. The concept of "sustainability" is being emphasized to focus attention on things that people, businesses, governments, engineers, and scientists can do. Some authorities believe that these actions will insure that Earth's environment will survive to support human life indefinitely; while still providing the resources necessary to meet the needs and desires of humanity today.

World human consumption, the force that is destroying Earth's natural living life-support system, draining Earth's renewable and nonrenewable resources from the environment, and turning them into waste and pollution, is quadrupling every 35 years. Consumption growth is demanded by and created by people, businesses, and governments (everyone) as they use technology to solve past financial problems and to gratify their desires for products and money. Vigorous growth has been institutionalized by the businesses, governments, and central bankers of the world; so it cannot be stopped voluntarily. The viability of the world's socioeconomic system depends on growth. The conceptual model presented herein shows some of the many positive feedback loops in the world socioeconomic system of our global technological society that create and powerfully reinforce consumption growth.

There is increasing evidence that human intervention in the life support system is causing irreversible damage, the full consequences of which are not yet evident. However, this brief review does not contain conceptual models of Earth's natural life support system, with its terrestrial biomes and soils and its marine reefs and deep-water plant and animal communities, nor of the global environmental infrastructure. The infrastructure includes the composition, climate, and weather patterns of the atmosphere; and the creation, decomposition, absorption, motion, and recycling of chemicals (beneficial and toxic), mineral resources, electromagnetic fields, water, land masses, ocean currents, temperatures, and life forms. Also omitted are the critically important closed-loop interactions between the human technological socioeconomic system, the natural living life-support system and the global infrastructure. These models have been omitted because Earth's life support system and infrastructure are very complex feedback systems for which there are no reliable models. The sciences that study these areas are just beginning to produce models, but they are not yet well-established. The research that is presented here will soon be extended to consider the development of these critical models. Without them, no effective strategy can be formulated for solving the Ecocosm Paradox with minimum trauma before a catastrophe destroys the structure of some essential control function.

Nevertheless, despite the lack of a complete ecocosm model, it seems clear that consumption growth cannot be tolerated in the long-term and that a new form of human technological socioeconomic system that does not create nor depend on growing environmental destruction must be conceptualized and implemented. Thus, the Ecocosm Paradox suggests that if consumption growth continues, an environmental catastrophe will eventually occur; and if consumption growth were stopped by an environmental catastrophe or for any other reason, a financial panic would precipitate a world economic depression followed by world wars of such magnitude that the survival of humanity and most other life forms would be jeopardized. Therefore, humanity's tragic dilemmas are these:

- *Continued consumption growth will inevitably lead to an environmental catastrophe.*
- *Everyone is so committed to consumption growth that growth cannot be stopped.*
- *Trying to stop consumption growth will cause economic, social, and military calamities.*
- *Once growth ends, consumption must also be lowered to an unknown perpetually sustainable level.*
- *Such a consumption reduction will precipitate its own conflicts and calamities.*
- *The longer the crisis is delayed, the worse the catastrophe will be and the lower will be humanity's chance of survival.*

No one knows what limit will prove to be the insuperable one that finally will end the exponential growth and initiate the collapse. Nor does anyone know the exact time that it will happen. However, it is certain that consumption cannot continue to quadruple every 35 years much longer before it causes a catastrophe. Perhaps, the Ecocosm Paradox perspective and analysis will motivate and inspire concepts and proposals that will move humanity in radically new directions. Without new directions, one disaster or another may soon endanger the survival of all life on our small, open spacecraft.

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