

# Design Science and The World Game

an introduction

by michael ben-eli

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## INTRODUCTION

Michael Ben-Eli is an Architect and a Cybernetician. He has been involved with Design Science projects for the last ten years and has served as an active advisor to Earth Metabolic Design. The directors and staff of Earth Metabolic Design feel that "Design Science and the World Game" is a lucid explanation, from a cybernetic perspective, of the role of design science in society. The paper represents the author's vision of the World Game which we feel represents a major step forward in this new field. It does not necessarily represent the exact perspective of Earth Metabolic Design. We wish to express our appreciation to both Michael and to the Design Science Institute, under whose auspices the paper was originally prepared, for permission to reprint the material.

Howard Brown  
1975

## PREFACE

This paper was written to provide a broad introduction to Fuller's concepts of Design Science and the World Game. It is published by Earth M.D. specifically for the benefit of students who may wish to gain preliminary acquaintance with these topics.

The subject matter is organized in two sections. The first outlines a conceptual background, a systems overview, which will help in introducing the substance of the World Game concept and its inherent global approach. The second, reviews some of Fuller's key ideas regarding Design Science and their relation to the World Game. The World Game concept, its scope and bearing on the notion of planetary planning are defined, and the embodiment of the concept in a working facility is sketched in outlines along with the logic of its operational essentials.

The material presented here is adapted from "Steps to World Game", a document developed for the Design Science Institute. It is reprinted by kind permission of the institute's directors. Throughout, the content leans heavily on Dr. Fuller's work and all the quotations in section II are taken from his writings. (Specific references are not given.)

M.B.E.

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"The World Game is a scientific means for exploring expeditious ways of employing the world's resources so efficiently and omniconsiderately as to be able to provide a higher standard of living for all of humanity - higher than has theretofore been experienced by any humans - and on a continually sustainable basis for all generations to come, while enabling all of humanity to enjoy the whole planet Earth without any individual profiting at the expense of another and without interference with one another, while also rediverting the valuable chemistries known as pollution to effective uses elsewhere, and conserving the wild resources and antiquities."

R. Buckminster Fuller

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# I. TOWARD AN INTEGRATED WORLD INFRASTRUCTURE

## OF LIFE SUPPORT SYSTEM

### 1. Organisms and their environment

There is a way by which we can view an organism and its environment as two systems coupled to each other. This view sees the environment as a vast complex of events in which local organisms are distinguishable as distinct patterns of semi-autonomous, self-stabilizing behavior.

The differentiation between the two is not always clear-cut. In many cases, there will be a considerable overlap and a certain degree of ambiguity as to the exact boundaries of the individual system. This conceptual distinction will be helpful, however, in developing the thoughts that follow.

In a dynamic environment conditions change continually. In order to survive, an organism will have to adapt continuously in order to maintain certain values of critical stabilities. These facts, of an environmental change which impinges on the organism and the latter's ability to maintain its stability and integrity, are the essence of the coupling between such systems and their environment. It is manifest in the way they interact with and affect one another.

The dynamics of this interaction and its typical feedback characteristics are, in broad terms, the common features of systems that evolve. And from this point of view, evolution in a given

environment can be regarded as the synergetic totality of such continuous and progressive adaptations. The whole notion of evolution and the implied ability to learn bears, of course, a profound significance to the problem of survival.

Adaptation, or response to change, can be of two basically different types. It can be internal, in other words a change within the organism; or external, whereby the organism modifies its environment. In the first case we talk about internal re-organization; physiological, or basically of a genetic or internal-structural type. In the second we refer to organization of some features in the environment directed to ensure elimination of unfavorable conditions, or initiation and reinforcement of conditions favorable to general well-being and survival.

In this respect, of particular interest are those systems, or organisms, which are capable of 'learning from experience,' and which can, over time, augment and refine their externalized functions.

As a rule, the potential survival efficiency of a system will increase many times if it does not have to depend exclusively on internal processes for adaptation, but can instead externalize its metabolic functions and modify and reorganize its environment in preferred ways.

In order to maintain its integrity it will not only evolve procedures, selected through experience and survival, for automatic

regulation of its internal functions, but will increase the efficiency and range of such functions by organizing segments of its environment in selective patterns which amplify its potential capability to maintain critical stabilities in the face of external disturbances.

This capability, of amplifying performance of internal functions by a hook-up to an organized hierarchy of externalized functions, is fundamental to the evolution of biological species on earth. It is manifest, for example, in the case of a bird building a simple nest, or humans building a complex city.

Accordingly, we can make a powerful distinction between general systems, by the extent of their ability to selectively modify an environment. This ability, we shall find, will tend to increase as life forms become more complex and heterogeneous. In our known part of the universe, humans seem to display this kind of ability in a most dramatic way, because of their capacity to externalize and magnify organic corporeal functions through the use of technology and because of their organized capability to anticipate environmental changes, always rearranging and rechanneling energy events, and reorganizing informational structures in order to progressively increase their survival advantage.

In principle, much of the vast range of technologies developed and used by Man can be viewed as such externalized processes employed by society in order to preserve its comprehensive economic integrity and increase its survival potential. Indeed,

some major aspects of history can be interpreted in terms of the dynamics and evolution of 'externalized' technologies as employed at different times by different peoples.

The reference here is not to specific artifacts associated with a technology, but to the broad totality of organized capability associated with different periods in history and referred to in terms such as a hunter's economy, agrarian economy, or industrial economy. The historical progression implied relates intimately to a most important evolutionary function of society, which is that of continuously organizing its externalized metabolic functions in a way best adapted to the circumstances and knowledge of a time.

This function, viewed against the background of the present century, calls for world society to study the feasibility and nature of an integrated global infrastructure of life support system, designed to guarantee the unconditional availability, and regenerative maintenance, of progressively higher standards of living for all mankind.

## 2. Vital functions of survival

Essential for the effective survival of the class of systems we have been talking about is the ability to continuously build a comprehensive image of their environment. This is a kind of mapping process which determines what features of the world system can recognize and integrate into a meaningful whole.

Thus, at one end of its behavioral cycle, we can talk about its tuning capability. According to specific cases, this implies a simpler or more complex set of scanning devices; namely, what we normally refer to as sensory receptors. The function of such a sensory system is that of detecting relevant changes in the environment and relaying information about such changes to the next essential function, that of evaluation and control.

In the control system coded information arriving from the sensory mechanism, and portraying myriad aspects of the environment, is continuously integrated into a dynamic world picture. Furthermore, this information is evaluated against past experience and against the success pattern of past actions in terms of survival.

The evaluation capability is the background against which, or the foundation upon which, decisions are made in a reaction to incoming new information. Once a decision is reached, it will be translated into an action directed to the relevant part of the world.

The system, therefore, has to be able to mobilize some mechanism

which can act to implement its decisions. We find that instructions from the control function will be transmitted to a system of 'affectors', levers of some kind, such as muscles or a complex of machines. These must be capable of acting effectively, in a purposive way and under the comprehensive supervision of the control function, when reacting to environmental challenges.

In general, then, the successful survival of an organism in a given environment will depend on the existence, effectiveness, and evolutionary potential of these primary vital functions: namely, its sensory mechanism, its control, or regulating function, and the leverage it can mobilize for action. All of which successful operation can be tremendously augmented by the ability to communicate with other systems of its kind. It is specifically this communications capability which inevitably results in the formation of 'social' aggregates and in the 'division of labor' among individual systems.

### 3. The analogy to man and society

The primary vital functions discussed above, the logic of their differentiated tasks, and their integrated operational structure, is quite general to the behavior of purposive systems. They can be clearly identified as operative in mechanisms directed to maintaining stability of internal processes, as well as in those related to processes which extend from an organism to include parts of its environment, in the overall network of its externalized metabolic functioning.

The broad analogy with biological organisms, possessing features like sensory organs, a nervous system and muscular apparatus, all of different degrees of complexity and efficiency is clear. On the appropriate level of abstraction, the analogy will hold in the case of more complex entities as well. These may range from small groups of humans organized for a specific task to whole societies and their externalized life support functions. In this sense, of fundamental significance is the way in which a society is organized to get its information about the world, how it constructs its 'world-picture', what are the overall goals it adopts, what decision-making procedures it employs, and finally, what mechanisms it can mobilize to achieve its goals and ensure its evolutionary stability.

An additional concept, which bears directly on the analogy to man and society, has to do with the fact that the evolutionary horizon of any system is determined to a great extent by its

inherent potential variety. The higher the variety embodied in its structure, the more the unpredictable conditions to which it will be able to adapt. Hence, the greater its overall dynamic stability.

It is this concept of a system's potential variety which puts the whole notion of externalizing vital functions into its appropriate evolutionary focus. By externalizing and extending its internal functions, an organism can increase its potential variety way beyond the level dependent on its genetic endowment alone.

Both as an individual and in the context of his social reality, Man displays such a uniquely high potential variety. This is clearly demonstrated, as noted earlier, by his dramatic ability to externalize metabolic functions, selectively modify his environment, and continuously integrate new features of his expanding world. The limits to this broad potential variety are extended, furthermore, by the fact that, in the context of his society and culture, Man was able to integrate individual personal experiences into coherent systems of knowledge. Thus, by 'externalizing' individual experiences into a symbolic domain, in which he operates chiefly through the use of language and the creation, manipulation and communication of symbols and abstract thoughts, Man has been able to introduce a real sense of continuity into his history and to gain a considerable freedom from the constraints of his physical temporality.

All these factors combine to produce a uniquely effective

evolutionary strategy, which is comprehensive rather than specialized in nature. Man is not frozen into a pattern but is able to learn and express his learning in the way he organizes his world.

The point is that in the case of Man, all the primary vital functions have evolved from specialized, internal, direct, organic functions into general systems of externalized advantage-yielding devices, to which Man can hook up at will. These have increased the range of his sensorial tunability, have augmented his capacity to analyze, integrate and evaluate large volumes of rapidly accumulating information, have refined and magnified his communications performance, and have given him a growing lever advantage.

At present, such externalized functions range from electronic microscopes to radio-telescopes and sensitive 'spy' satellites, to systems of fast electronic computing machines and remote control devices, to high speed means of locomotion and powerful communication systems, and finally, to increasingly efficient energy conversion systems and the vast complex of industrial production.

#### 4. Historical interpretation

Man's general ability to externalize vital functions, and particularly his comprehensive tool-making skills, have introduced an important qualitative dimension to the dynamics inherent in his feedback interaction with the world.

The introduction of such tools, whether physical artifacts or abstract organizational institutions, have tended to continuously increase the boundaries of the universe accessible to Man with the result that new problems have become manifest and further development followed. This has given a quality of continuous expansion to the history of Man as a tool-maker, and to the overall interactive process of Man, his tools and his environment. Thus, by and large, Man has found himself in the need to organize his activities in environments which have become increasingly large and more complex; in other words, in which he had to integrate a constantly growing number of variables. To such changes in the scope of his world, Man had continuously to adapt with a new awareness, new consciousness, new organizations and new tools.

At intervals of various lengths such changes have accumulated until their synergetic interaction reached a critical level in which reality obtained an essentially novel qualitative meaning. At such times a new integration of human affairs came about, with its associated broader vision and spontaneous behavioral adaptations.

From this viewpoint, a fundamental feature of the world today has

to do with the fact that society has been slow to adapt to new options created by the rapid acceleration of growth in scientific knowledge and technological capabilities. As have major similar cumulative breakthroughs in the past, these have virtually changed the world, creating new realities which indicate a looming need for a broad new qualitative reorganization in human affairs.

The meaning of the overall change can be summed up in two broad statements. One relates to the fact that, in the context of the present industrially based society, the minimum system which must be considered as the arena for mankind's existence and successful survival is the whole Earth, with all its interlocking ecological patterns, interdependent actions of human beings, and all its inherent constraints and potentials.

The second has to do with another fact, which constitutes indeed a fundamental historical change; that for the first time the inhabitants of this planet possess the comprehensive technological means to ensure an adequate standard of living for all.

Mankind can now assume the goal of organizing its external metabolic system in a way which will ensure an environment of abundance, and which will encourage the increase of freedom and potential self-realization of all its individual members. This, however, will require a complete shift from the fragmented, com-

petitive, locally biased and oftentimes lethal strategies employed at present by sub-groups of humanity, to an integrated effort of development and world co-operation, on a new basis and of an unprecedented scope.

## 5. Towards an integrated world infrastructure of life support system

In order to achieve the goal of bringing about a comprehensive world system of regenerative life support, frameworks of existing external metabolic functions will have to be redesigned and enlarged in scope and potential, so as to accommodate their broader new task.

Reflecting the fundamental logic of a planetary economy, such a world-embracing system will consolidate the fragmented parts of man's externalized functions as they now exist, and will combine them into a mutually self-augmenting whole. It will consist of a hierarchy of mechanisms whose component elements will follow the operationally integrated characteristics of vital organic functioning. On the whole, these will monitor the relevant global conditions and relay critical information to a world network of processors, with the aid of which the overall performance of the technico-industrial complex will be mobilized for the progressive advantage of a world society.

The technology required for the assembly of such a world infrastructure of life support and its cybernated regulation is to a great extent already in existence. A space-technology based, complex, and highly sensitive 'sensory' system, developed by warring nations to spy on each other, is now operative. It could serve equally well in monitoring the earth and its biosphere, providing a comprehensive knowledge about the location and relative concentration of all the Earth's natural resources. It could

monitor the distribution of minerals and conditions of world crops, as well as major ecological trendings, overall weather patterns, and many other, relevant aspects of the world.

Though still only partial in its function, the recently launched Earth Resources Technology Satellite is a notable example of such a capability which could provide most of the critical information essential for the competent management of a world economy.

The dramatic evolution of computing machines and the associated communications and display technologies will make the integration of such information, on a global scale, fast, efficient and effective. Guided by principles observed in the regulation dynamics of complex mechanisms like the brain, such computing and communications technologies could be organized into a world network of decentralized man-machine decision functions. By possessing the requisite variety essential for their task, these could constitute the backbone of a world-wide 'nervous system,' which would tremendously amplify man's effectiveness in managing his externalized life sustaining production and distribution systems.

With regard to these production and distribution functions, with all their related technology, knowhow and hardware, they will continue to evolve and will be augmented with new and more efficient tools and methods. To function effectively in the support of world society, they will have to switch from an exclusive, local, short-term profit-making orientation, to a more comprehensive accounting system, based on the objective fundamentals of

industrial technology, and adjusted to the reality of finite resources and their regenerative economic management, within the context of the Earth's ecology. They will have to hook up in a total world effort, concerted, automated and self-improving.

The detailed rationalization and final realization, link-up and smooth operation of such a world-wide external metabolic infrastructure is a major evolutionary task. It is absolutely essential for the creative survival of man and for the future well-being of society. Such total integration alone could lay a sound foundation for world stability and a real condition of peace. Its ultimate successful implementation should strive to ensure a comprehensive life support system, as a framework for a world economy, designed to enrich human life and preserve the earth's ecology with all its natural and historical beauty.

## II. DESIGN SCIENCE AND THE WORLD GAME

### 1. Man's external metabolics and design science

Against the broad framework of ideas sketched in the previous section, Fuller's key concepts regarding design science and World Game can be clearly understood. The general approach addresses itself to the overall system of external metabolics, its nature, actual performance and potentials. Specifically, the external metabolic system is seen as a comprehensive infrastructure of life support. It has evolved in order to augment, directly and indirectly, Man's internal organic functioning and in so doing, has increased his survival efficiency and has continuously released new expressions of his creative self-realization.

The embodiment of the external metabolics is the technology available at a given time, from simple tools to world around networks of machines and complexes of various man made artifacts. By and large, it has evolved continuously throughout known history and its fundamental characteristics, organization and structure, have been associated with major economic eras in the history of civilization.

The overall performance of the external metabolic system is generally associated with the notion of a standard of living; thus the essence of viewing such performance, in retrospective, as well as with respect to present capability, is in how many human lives can the total system support, at what standard of living,

and for how long.

A major transformation in the nature, structure and potential of the external metabolic system has occurred relatively recently, with the transition from an agrarian to an industrially based economy. This transition is manifest, for example, in the switch to, and increasing employment of, inanimate rather than animate sources of energy. It is also manifest in the augmentation of primary economic dependency on livestock and vegetation with the whole range of newly discovered chemical elements and their complex synergetic compounds, most of which were unknown to man only two centuries ago. Fundamental to this transformation is the fact that it has brought about a profound switch in orientation from economic dependency on local farming and its unstable yearly cycles to a global system of industrialization based on regenerative and unperishable resources the distribution of which is inherently world-wide.

The evolutionary move from one type of economy to the other, still incomplete in many parts of the world, has been followed by a tremendous increase of efficiency in general life support capabilities, with the result that a higher standard of living was made available, almost overnight, for many more humans than ever before.

Most significantly, since the early decade of the present century, this increase of performance efficiency was not so much the result of finding new resources as it was the result of learning how better to use those already available. In this respect, two

facts are of great significance: first, the material prime movers of the industrial economy are the unperishable chemical elements which can be recycled after the termination of every use; and second, with every recycling, increase in technological know-how can bring about new and far greater performance advantage per unit of invested resource. For example:

"Of all the copper mined in the History of man, only about 14 percent has gone out of circulation, the rest gets melted up and employed over and over again. And every time we use it . . . we continuously up the performance."

The possibility of such growing performance efficiencies with each cycle of use is absolutely fundamental to Fuller's interpretation of the potentials inherent in existing world resources and their employment by a scientifically guided world industry. The associated growing advantage is always a result of the ability to increase previous performances, while using less resources and investing less effort in a process of "progressively doing more with less." This process explains the capacity to provide a higher standard of living for a growing population in spite of diminishing reserves of unmined resources. It, above all else, is responsible for the fact that:

"Between 1900 and today . . . while the world's population has approximately doubled, we have at the same time also gone from less than 1 percent of humanity to 40 per-

cent of all humanity enjoying a higher standard of living than was known to or was dreamed of by any monarch before the twentieth century."

A dramatic demonstration of doing more with less, and obtaining a far greater performance with only a fraction of the amount of resource previously used, is furnished, for instance, by the fact that at present:

"One communication satellite weighing a quarter of a ton is outperforming the trans-oceanic communication capability of 175,000 tons of copper cable."

Similar examples abound in all areas of high technology.

The increase of performance efficiency in the overall area of resources utilization is associated with conscious design. It is in this context that Fuller speaks of "design science," the application of which can be directed to rearranging the environment in preferred ways and to continuously upgrading the performance of the total external metabolic system for growing human advantage. Thus, the broad task of design science is to explore and develop ways:

"To employ the principles of nature to do so much more for ever more people, with ever less investment in ounces of materials, kilowatts of energy and seconds of time per each unit of realized, desirable functional performance."

Such desired performance relates specifically to:

"Man-favoring rearrangement of the environment which could be conducive to humanity's spontaneous self-realization of its higher potentials."

Observing the fact that at present only 40% of humanity enjoys the services of advanced technological capabilities, Fuller's lifelong study of trends in industrialization, the evolution of technology, and the potentials inherent in existing resources, lead him to conclude that:

"It is technically and economically feasible to take care of all humanity without any one prospering at the expense of another."

This could be brought about by the integrated rational management of an entire world embracing external metabolic system, the operating capabilities of which will be based on continuous recycled flows of all the regenerative chemical elements and a complete switch to the use of nondepletable "income" energy sources. Its overall performance will be progressively amplified with each increase in human technical competence and know-how.

This implies a world economy of abundance and a non-conventional definition of wealth which will require the adoption of a universal economic accounting system free from the constraints of assumed scarcity and: "Consistent with the cosmic economics of an eternally regenerative physical universal system."

Bringing about such conditions of economic abundance, and broadening the availability of these conditions to a growing number

of humans, will depend essentially on the ability to raise the overall performance efficiencies of technology, which at present are extremely low. In this context the stress on design inputs rather than on political management is a fundamental premise of Fuller's thought. Thus:

"Nothing politics per se can do can make the resources adequate to support all of humanity. Adequacy can only be attained by competent design which advances the overall efficiency of humanity's technology from its present 5%."

Accordingly, the comprehensive function of design science is to make the world's available resources serve all rather than only part of humanity:

"We must redesign the use of the world's total resources in such a manner as to make those now engaged exclusively in the service of only 44% of humanity adequate to the effective servicing of 100% of humanity at a higher standard of living than ever before."

It is in this sense that Fuller speaks about a "design revolution" and about "making the world work."

## 2. Design science - function and priorities

It is in the overall context of "World design initiative," and with respect to the realization of an operative world external metabolic system capable of supporting all mankind, that the concept of design science can be seen in its intended scope.

On this scale, Fuller regards design science as more than the application of engineering and technology to the design of single artifacts, but also the:

"total responsibility and capability for development, production and distribution . . . of not just a product, but a total service system on a world wide basis."

Thus it must be viewed with respect to the overall design, development, organization and management of the total technico-industrial capability on a global scale. It is consciously directed towards the total human environment, its "arrangement" and "rearrangement" in preferred ways favorable to comprehensive interaccommodating human goals and sensitive to the orderly ecological processes of the planet.

Approaching the formulation of design science strategies and their application to world development, Fuller has proposed, as an overall guiding outline, a logical hierarchy of priorities. These range from concerns with world literacy re world problems to a review of prime resources and the overall industrial system, including the evolution of general tool complexes, networks of world service industries and final 'end' products.

The five key items in the hierarchy are intended as five successive logical phases in a comprehensive plan directed to the ultimate realization of an external metabolic system operative on a world-wide basis. Quoting from Fuller's "World Design Science Decade" document no. 2 (1964), those phases are:

"Phase 1. World Literacy re World Problems

World Industrio-Economic Literacy and its design science solution by dramatic educational tools for realization of the world's resources inventory of human trends and needs, by world's people. Together with dramatic indications of potential solutions by design science upping of the overall performance of world resources to serve 100% instead of the present 44% of humanity.

"Phase 2. Prime Movers and Prime Metals

Review and analysis of world energy resources-- differentiation between 'income' and 'capital' energies--design of more efficient energy utilization. Analysis of circulation and scrap recycling of prime metals. Redesign towards comprehensive and more efficient use and reuse 'assemblies' with higher extraction of performance per unit of all invested prime metals in use.

"Phase 3. Tool Evolution

Differentiation and evolution of machine tools--

the integration of these tools into the industrial complex; reviews and analysis of generalized and specialized tools--automated processes and control systems, i.e., total buildings, being assembled by computer within optimum environmental control, air delivered ready to use in one helilift.

"Phase 4. The Service Industries

Analysis of world network of service industries, i.e., telephone, airways, communications services, hoteling, universities. General extension of dynamic network operating principles into formerly 'static' areas of environment control both internal and external. Frequency modulated--world planning three shift, 24-hour use of facilities, i.e., most industrial facilities as yet operating under obsolete agricultural dawn to dusk, single frequency usage. Trans-sonic 1800 mph air travel transcends day-night and seasonal characteristics. Men literally jump out of night into day and out of winter into summer in minutes. Thus, local patterns of facilities employment trending swiftly into 24-hour succession of users, i.e., electrically lit telephone booths by roadside.

"Phase 5. The Evolving Contact Products

Usually phrased as 'end' products--there are in effect no end products but only the contact instruments of industrialization's human ecology services which are the plug-in or latch-on terminals of service industries, e.g., the telephone, transportation and other communication units, the motel (bathroom and bed)--and eventually the world around environ control service unit."

Phase One of the five successive phases relates to the function of education and communication and puts an emphasis on the need for a well informed world society with an open access to objective and comprehensive information about its evolutionary dilemmas and alternatives. The other four phases are directed specifically to the functions, structure and performance of the external metabolic system and to the identification of ways to increase its total operating effectiveness.

Though they interact, overlap and affect one another greatly, the five phases offer natural, distinct priorities in addressing the dynamic processes inherent in the continuous evolution of Man's external metabolics.

### 3. Design science and the World Game

As emphasized earlier, the very essence of the evolving industrial economy is manifest in its tendency to integrate operations on a world-around basis. Unlike the geographically specialized and locally self-sufficient agrarian life support, it can only be understood with respect to the whole Earth and as an integrated whole system.

The fact that the prime resources of the industrially based economy are unevenly distributed around the planet means that even some of the simpler operations of present technology may require the assembly and integration of myriad resources, organized in a continuous world-embracing network of production, distribution, and use.

The prime resources, whether energy, matter, or information, can be viewed as generalized items brought together temporarily in order to satisfy specific local needs. Material and information resource components may be combined to yield specified performance advantage only to be differentiated, redistributed and reintegrated later again. The whole process follows a succession of regenerative cycles geared to a hierarchy of typical gestation rates which are related to given tasks and their respective technologies.

In spite of the essentially integrative qualities inherent in the overall industrial technology, and in spite of its all-inclusive life support potentials, powerful imposition of exclusive interests

have kept it operating along specialized competing lines. The point is not a matter of ideology. It bears upon the very essence of the process itself. Selfish, short-sighted and locally biased strategies tend in effect to cripple the promise inherent in technological development. They prevent it from providing a truly universal life support and create a serious threat to the structure of the environment, the integrity of which they blindly ignore.

Thus, it is because of its very nature that the total synergetic potential of the industrially based external metabolic system will be realized only when it is approached as a logical whole and when all its operational components are integrated and organized to reinforce and augment one another.

In this connection the global character of the technico-industrial system, the world wide scope of its operations, and the fact that its general impact cannot be localized or dealt with successfully in isolation, imply the need for developing a new comprehensive approach to overall "planetary planning." The urgent need for such an integrative planning tool is becoming all the more clear as major crises, such as those related to world food and energy supplies, reflect the persistent failure of local traditional methods to deal with problems of global concern.

It is with respect to the development of such a facility for "planetary planning," and particularly with regard to its function of guiding the positive and stable operation of Man's evolu-

ing technologies, that Fuller's World Game concept can be best understood.

Thus, while design science deals specifically with the development of comprehensive artifacts and with general design inputs intent on upgrading the performance of available resources, the World Game is conceived as the appropriately related "planetary planning" tool.

As a general planning tool, and an instrument for design science, World Game would incorporate a comprehensive inventory of total world resources as well as inclusive information about human trends and needs. It would provide dynamic means for relating proposed design science strategies, testing their effect on the overall performance of Man's external metabolic system, and selecting alternatives most universally effective for the ultimate realization of total human life support.

Offering the means for creative exploration and search for ever more effective ways of employing the world's resources, it would help expand general awareness about world problems and their possible positive solutions. Above all, it may encourage the spontaneous formation of a better-informed judgment and lead to sounder and clearer decisions in the process of peaceful world development.

#### 4. World Game - concept and facility

The basic and most fundamental idea behind World Game can be emphasized as it is contrasted with existing war games, in which world powers, assuming the inevitability of resource inadequacy and ultimate confrontations, engage in simulated testing of various military strategies and in assessing the options available for mobilization of war technology.

In contradistinction, Fuller has envisioned the World Game as an organized effort of co-operative exploration for ever more effective ways of employing technology and directing its application specifically for the support and enrichment of human life. In this respect, the foremost function of the World Game is that of isolating specific means and defining overall strategies which would render "all humanity a total economic and physical success at the earliest possible moment."

The concept of "playing" the World Game relates accordingly to the continuous formulation and testing of such strategies, and the notion of "winning" rounds in the game is associated with the successful demonstration of new workable options yielding a higher advantage than was assumed possible before. As one such round demonstrates the potential capability to sustain all humanity at a desired regenerative standard of living, another would follow by showing how this could be achieved even in a shorter period of time, and so forth.

To carry out these explorations Fuller has proposed the actual development of a World Game facility, utilizing a computerized version of his World Resources Inventory co-ordinated with a dramatic visual display and hooked for instant access to interactive remote control capabilities.

"Players" would thus be given an opportunity to test out their theories on "how to make the world work." They would interact with the comprehensive logistical information of the Earth's total physical and human resources and input proposed developmental strategies. While the Game evolves, they would be able to observe the effects of various moves and their relative measures of success as relevant visual indications are relayed on to an electronically controlled, illumined surface of an accurate flat projection of the Earth.

In its totality, the concept implies the dynamic integration of three basic functions. The first will consist of advanced surveillance and transmission technology. It will trace the location and flow of the world's resources, monitor the operation of Man's external metabolic system, and generate the critical information essential for regulating its performance.

The second will carry out the function of analyzing and evaluating the general conditions of the external metabolic system and its immediate ecological context. It will incorporate powerful computing capabilities for organizing the incoming data for handling all relevant inventories. It will continuously update in-

formation, identify and project trends of special significance and allow for simulated testing of newly formulated strategies and design science inputs.

The third and final function will fulfill an important educating role. By utilizing special audio-visual display systems and communication techniques, it will make humanity's evolutionary predicaments and its positive options popularly understood and generally known. It may thus help develop Man's collective awareness and encourage world-wide creative participation in shaping future social and economic trendings.

While these three functions are clearly identified as basic elements essential for the successful operation of the total facility, the latter could be best conceived of as a general information network linking up all parts of the world and providing special 'points' for local accessibility. Metaphorically it may be viewed as forming an integrated nervous system which will ultimately coordinate all operations of humanity's external metabolic system.

## 5. World game - framework of operational logic

As a working "planetary planning" tool the core of a World Game facility can be conceived of as a comprehensive computerized information system, augmented with special visual displays and provided with dynamic interactive access capabilities for inquiry and experimentation.

In spite of the complexity of the overall subject matter, the approach and its associated operational logic is basically simple. The essence of the methodology relates to a dynamic representation of performance patterns and utilization efficiencies, of the world's total available resources as they flow through the external metabolic system and all its relevant sub-components.

Sets of measurable quantities relating to expressions of various available "standards of living" and describable on a world-per-capita basis indicate the actual outputs attained by the whole external metabolic system. They provide a measure of specific "payoffs" generated by the system's relative operational efficiency and reveal its overall capacity as a general life support.

The explicit purpose of the "game" is to demonstrate how workable design inputs directed at upgrading performance efficiencies of resource utilization will raise the level of existing outputs and provide higher "payoffs" for more humans.

Such proposed design strategies must, however, take into account consciously self-imposed constraints having to do with preserv-

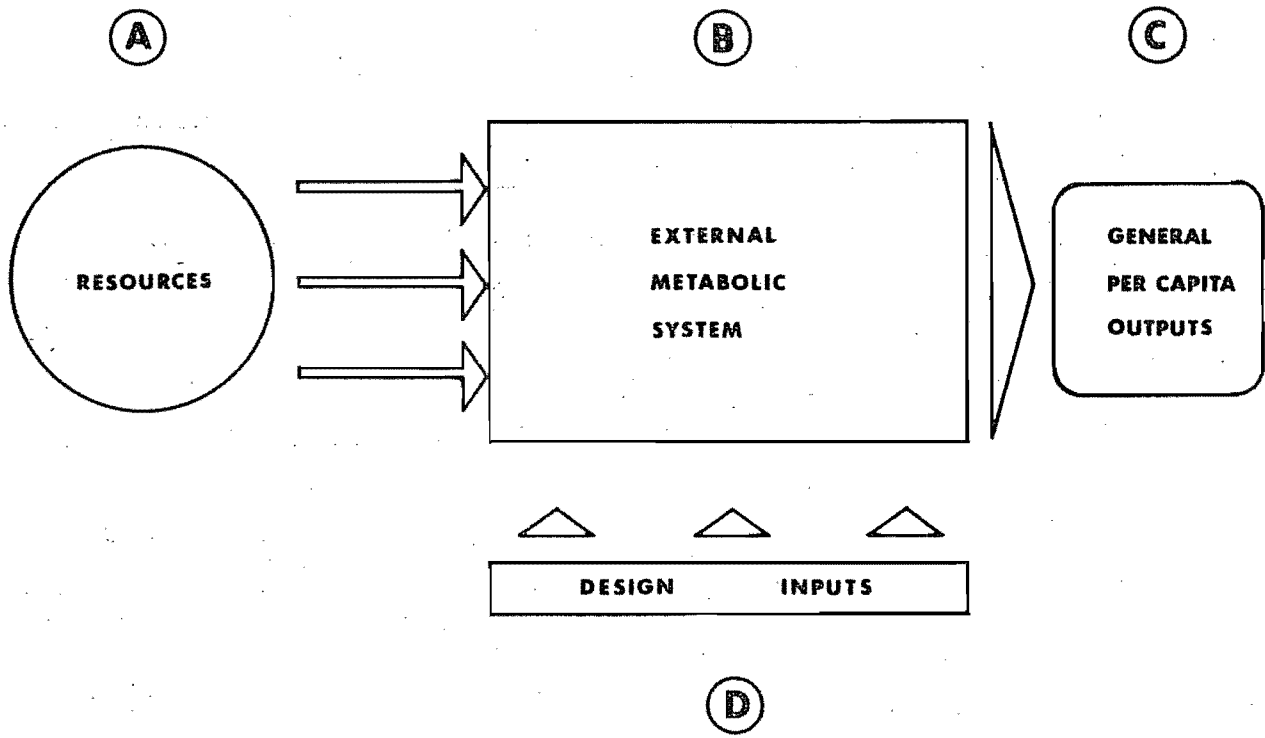
ing the integrity of the natural environment and foresaking negative impositions on other humans.

The general idea is conveyed by diagram 1., where the function of design strategies (D) is to upgrade the performance of the external metabolic system (B), so as to yield, with finite resources (A), a higher output (C).

Diagram 2. represents the process on a finer level of resolution. Although it attempts to capture the essence of an essentially dynamic activity by using only simplified static symbols, it provides a helpful conceptual framework for reviewing the general dynamics and operational logic of the system.

Resource inputs (A), to the external metabolic system (B), consist of three major types: an input of material resources representing the 92 regenerative chemical elements (a1); an input of energy sources (a2); and an input of technical knowhow (a3). In combination, these "feed" the different subcomponents of the system and "fuel" its operations.

The external metabolic system itself can be represented by a general network of production functions (b1), and by various service functions (b2). The former represents the total industrial production function and is resolvable into the hierarchy of major typical industries described by the design science list of priorities quoted earlier. Beginning with industries involved with the production, refinement and conversion of the prime material and energy resources, it follows through industries which produce



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DIAGRAM 1. WORLD GAME: FRAMEWORK OF OPERATIONAL LOGIC

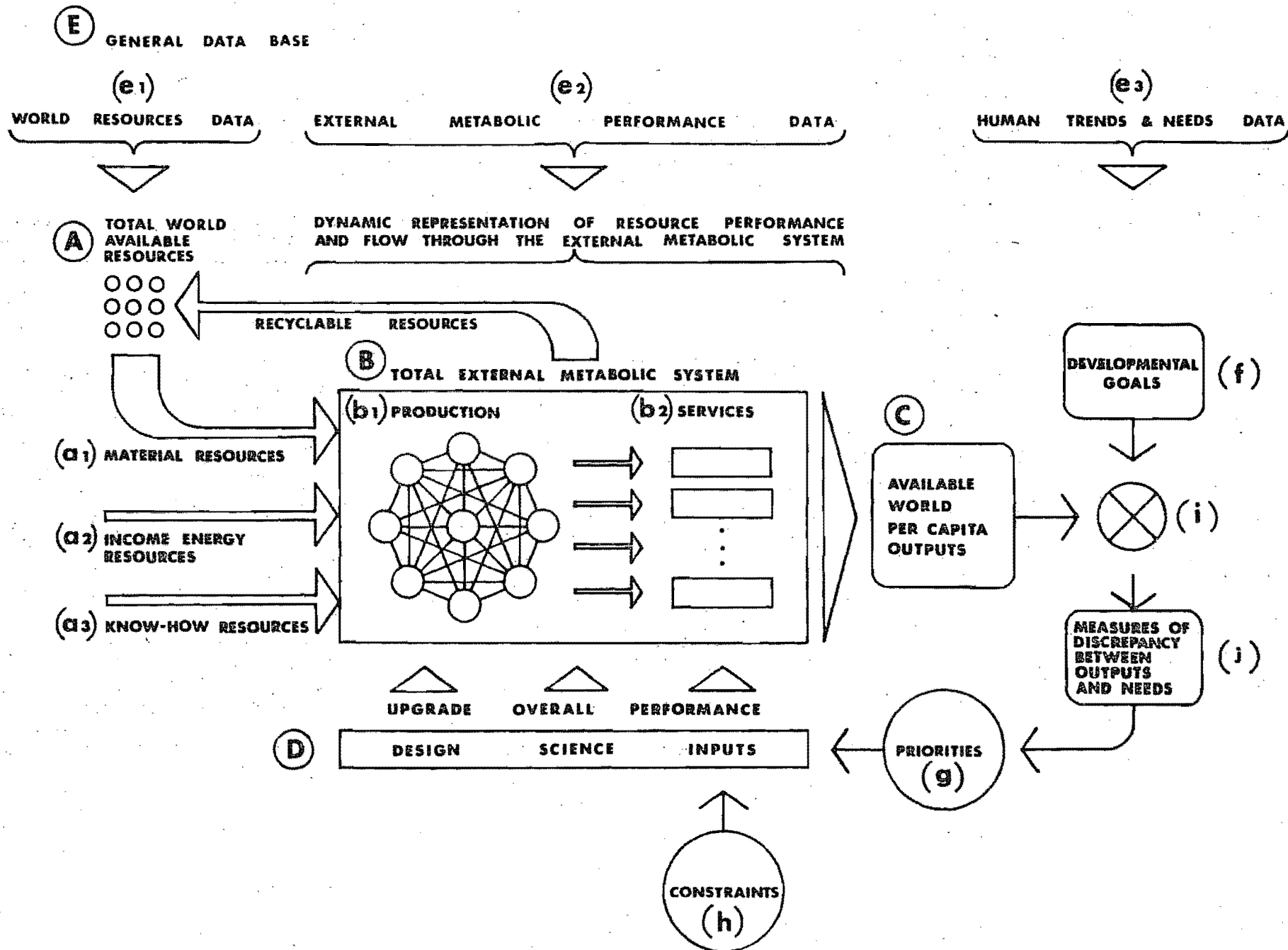


DIAGRAM 2. WORLD GAME: FRAMEWORK OF OPERATIONAL LOGIC

complex machine tools, to service industries, and finally, to those producing specialized end products.

The total production output supports a range of service functions associated with nutrition, shelter, health, education, transportation, communication, recreation and so forth.

Indications of availability of such services, on what standard and for what percentage of the total human population, provides a description of the overall performance of existing technology as it relates to total actual outputs (C).

Design Science inputs (D), are directed at the working capacity of the external metabolic system with strategies developed to raise its overall efficiency. Such inputs may operate by upgrading a specific localized performance, such as increasing utilization efficiency of a given resource as it enters a new recirculation phase, introducing a better machine, a new and more efficient alloy, or a more effective organizational procedure. They may, on the other hand, introduce a totally novel strategy aimed at raising overall performance efficiency by changing the very structure of the existing operating system. A typical example would be developing a strategy for a complete switch from dependency on fossil fuels to exclusive use of income energy sources.

General developmental goals, (f), generated by reviewing a typical distribution of needs, and expressed by a projected desire to provide a certain standard for so many humans by a certain date,

is compared (i) with the indications of actual per-capita outputs. Resulting measurable discrepancies (j) provide the rationale for design priorities (g).

As mentioned earlier, strategies aiming for the goal of increasing the operative performance efficiency of the existing life support system adopt as voluntary constraints (h), the necessity to preserve the Earth's ecology as well as the integrity of other humans.

In order to operate effectively, the World Game system depends on a comprehensive data base (E), containing all relevant information about the world's total available resources (e1), about the structure and performance characteristics of the external metabolic system (e2), and about relevant human trends and needs (e3). It will include such items as the whereabouts, unique characteristics and available quantities of the chemical elements, types, potentials and distribution of energy sources, operational performances of specific technologies, rates at which typical recycling resources are coming around, availability of distribution and quality of know-how and technical expertise, type and distribution of human life support needs, and so forth.

Special provisions would make it possible to switch typical resolution levels, such as from Industry treated as a general item to a specific type of industry and further down to an isolated process in that industry. Resource flows and patterns of use could be studied with respect to each case. Thus, the dynamic

flow representation of the external metabolic system will organize the data inventories into different levels of aggregation relevant for different inquiries and experimental design inputs.

In general, the design process can proceed in two directions. One would test the effect of a new technology on the performance of the whole system and identify the resulting increase in pay-offs. The other would project a desired future goal, such as being able to sustain the total world's population at a given level of per-capita service capability and proceed by seeking to define and try out available means of attaining its goal by input of different possible strategies and their respective execution priorities. In this respect, it can also identify areas where new technological development is required and define critical parameters for needed developmental actions.

The process can continue in real time, as developing strategies are able to demonstrate the opening of new creative options for ever more humans. The point is not in trying to impose a value or a life style, but in identifying clearly the objective operational capacity of total available technology and the critical trends associated with patterns of its evolution.

As the system develops, its central dynamic resource flow representation may be hooked up to specific peripheral simulation capabilities which would refine its capacity to test the effect of proposed strategies on particular parts of the external metabolic system as well as on relevant ecological processes. For

example, when a new technology is being introduced and is tested for its effect on a selected criteria of general "pay-off" outputs, its known side effects could also be tested for their possible effect on relevant processes of the Earth's ecology.

As the informational content of the system grows and its operational procedures are refined and diversified, and as it hooks up with other centers of information and computing resources, it will become an increasingly effective tool for comprehensive world resources management and planetary planning. By providing an unambiguous representation of humanity's external metabolic system, its actual performance and potential capacity, it would offer powerful assistance in approaching the world's future economic and social development. It would help identify potential problem areas, their associated trends and possible impact, and may tremendously accelerate the process of formulating clear definitions for possible corrective measures, the critical choices which would have to be made and the critical path of creative actions which would lead to preferred states of affairs.