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Editorial

To Whom Are We Speaking?

It is rare that a Managing Editor gets the chance to give voice publicly in an editorial. With the kind permission of our always kindly Editor, Milton Katz, I have been given that chance. I would like, therefore, to take the opportunity to speak of some of my concerns both as Managing Editor of the ASC Cybernetics FORUM and as Vice President of the ASC for Publications.

My relationship with the ASC began as a direct outgrowth of the development of the new FORUM. Thus I have watched (and helped guide) its growth. In the somewhat more than a year since the first issue of the new format came out, the FORUM has published a wide range of topics. During this time, we have also received a number of articles which we deemed too technical for inclusion in a non-technical publication like the FORUM. It is appropriate to review the purposes of the FORUM so that future contributors are clear as to its role and reason for being.

When it was decided to upgrade the FORUM from a “newsletter” to a magazine, it was looked upon as an opportunity for the ASC to provide a window on (and to) the world for cybernetics. Like most windows, it was intended to provide two-way access. The inhabitants of the “house of cybernetics” were to have a view of the outside world, and at the same time the outside world was to have a non-technical look at what cybernetics is, what it does, and how it can be used to deal with the complex problems of a complex society. These were—and still are—the goals of the ASC Cybernetics FORUM. In my opinion, however, we have not yet attained these goals—and for reasons that go right to the basic question of whether or not there should be a FORUM or an ASC.

As an (I hope) intelligent layman who is concerned—both philosophically and in terms of my work—with the problems of society, I consider myself to be a member of the prime audience for a publication like the FORUM. Yet, quite frankly, as I read through many of the articles we have so far published I am struck by their insularity and “ivory tower” orientation. I imply no criticism of those authors—their work is the scientific underpinning of cybernetic practice. Rather I would criticize those who call (or consider) themselves cyberneticists, who are members of the ASC, or readers of its publications, and who fail to participate in either its affairs or its publications. I suspect that it is these latter people whose work and writings could most profoundly effect changes in the organization and structure of society—changes that might help us solve (or even comprehend) some of the problems that face the world today.

With all due respect to our academic colleagues, insofar as a discipline called cybernetics exists in this country, it is unknown to those who most need what it can provide, i.e., a means of understanding the nature and operation of the complex system we call society, and a method for coping with its complexities. If we fail to make ourselves known—both as a discipline and an organization—to those political, economic, cultural and social leaders whose activities affect all of our lives and futures, we will have failed to justify our existence. We must learn, as have the industries of the world, that to build the better mouse-trap implies building an equally good marketing program.

One means of bringing cybernetics and the ASC to the attention of these “movers and shakers” is through a publication like the ASC Cybernetics FORUM. To accomplish this, however, we must do more than meet and talk with each other once a year. Rather, we must write and communicate—intelligibly, and as an ASC—on technical subjects for non-technical readers. We must sell, if you will, the concept of cybernetics to the laity whom we would help and whose help we need. We must take an active role as cyberneticists in the activities of other organizations as well. We must, in short, be news and make news.

If we continue to let only a few concerned, motivated people carry the burden of writing all of the articles, organizing all of the meetings, and managing and supporting all of the ASC’s activities, the answer to the question that heads this editorial will be, “ourselves.” We will have ceased to exist—whether we admit it or not.

—Jack Lass
Herbert W. Robinson, who was elected President of the American Society for Cybernetics for the year 1975, has resigned effective 15 August 1975. His resignation has been accepted with great regret.

Gary D. Bearden, a Director and for the past three years Chairman of the Membership Committee, has been appointed Acting President for the remainder of the current year.

New elections will be held in time for 1976, and a list of candidates for officers and directors should reach our members in October. We urge you to respond to it promptly. Any suggestions from the membership will be appreciated.

In the meantime, let us give our Acting President all possible assistance.

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Gary D. Bearden, Director, Bureau of Manpower Information Systems, U.S. Civil Service Commission. Formerly Assistant Bureau Director, Bureau of Data Processing, Social Security Administration; Director, Washington Data Processing Center, U.S. Department of Agriculture. Served as consultant, speaker and instructor and successfully installed project management systems in several organizations. Former ASC Vice President (Administrative).

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Israel Feldman (Administrative), Deputy Director, Management Data and Evaluation Division, U.S. Department of Housing and Urban Development. Formerly President of Wiley Systems, Inc.; Director of MITRE Corporation.—B.S. in electrical engineering, Technion Israel Institute of Technology. M.S. in industrial management, Massachusetts Institute of Technology.

Louise G. Becker (Educational), Analyst in Information Sciences, Congressional Research Service, Library of Congress. For the past nine years has served as a consultant and researcher to Congress on information technology policy and related matters, has contributed to a number of Congressional documents and most recently has examined some of the problems associated with privacy and security information and record keeping systems.—Graduate of Brooklyn College, New York.

Jack Lass (Publications), Information Specialist with Aspen Systems Corporation (Government Systems Division) Managing Editor, National Health Planning Information Center and Managing Editor of the ASC Cybernetics Forum. Formerly Managing Editor of the Journal of the American Society for Information Science. For the past eight years, a publication consultant to many firms and organizations in the Washington, DC area. Special fields: neurology, psychiatry, social welfare, education, systems analysis and computer science.
TREASURER:

David D. Bergan, Professor of Business Law and Tax, Catholic University, Washington, DC. Consultant in computer application and legal research, Mead Data Central, Washington, DC. Formerly with Peat, Marwick, Mitchell & Co., Washington, DC, and with Sauter Laboratories, Nutley, NJ. B.S., Boston College, Chestnut Hill, MA; J.D., Georgetown University Law Center, Washington, DC.

SECRETARY (by appointment)

Gertrude B. Herrmann, for the past five years actively engaged in work for ASC. Formerly consultant on foreign trade and statistician, The Aluminum Association; executive secretary and market researcher, Transamerican Management Co., Inc., New York City. During World War II, economist at the Office of Strategic Services. Scientific assistant to the Undersecretary of Trade and Commerce of Prussia, Berlin; did editorial work for cultural and historical publications in Hamburg, Germany and Vienna, Austria. Wrote a report on Academic Exchange in Europe for the League of Nations; also did extensive translating of medical and technical material into English from German, French and Italian sources. --Doctor of philosophy (cum laude), Heidelberg University, Germany.

NEW DIRECTORS—1975

Roy Herrmann, Chairman of the Board of Directors, President of Center of Cybernetic and Interdisciplinary Research, Inc., and of Institute for Socio-Economic Studies, Ltd., Washington, DC. Formerly professor of management sciences and operations research, The George Washington University; professor of naval science, U.S. Naval Academy, Annapolis, MD; chairman, College on Logistics, a Subdivision of The Institute of Management Sciences. B.S., College Francais, Berlin; Doctor of political science and economics, University of Rostock, Germany. ASC President, 1972, 1973, 1974.

Melvin S. Day, Director, National Library of Medicine, National Institutes of Health. Formerly Head, Office of Science Information Service, NSF; Deputy Assistant Administrator for Technology Utilization, NASA; Director, Scientific and Technical Information and Educational Programs, NASA Headquarters; Director, Division of Technical Information, A.E.C.; Chief, Technical Information Extension, A.E.C., Oak Ridge, TN; U.S. Army Corps of Engineers (Manhattan Project); chemist, Metal Hydrides, Inc., Beverly, MA. B.S., Bates College, Lewiston, ME; graduate work in industrial management, University of Tennessee.

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Laurence B. Heilprin, Director-at-Large. Professor of Information Science, University of Maryland. Formerly staff physicist for the Ford Foundation’s Council on Library Resources; worked for MIT in operations research for the Navy; physicist at the National Bureau of Standards directing the Control Testing Laboratory for quality control of radio proximity fuzes and research teams on electronic ordnance. Bachelor’s degree in economics and business administration, University of Pennsylvania; Doctor’s degree in physics, Harvard University. Associate Editor of the ASC Cybernetics Forum.
Philosophical Precursors of Cybernetics

Pascal, or Method

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Pascal: A Paradox

It may seem paradoxical that Blaise Pascal (1623-1662), scientist and mathematician, writer and apologist, should figure at the head of a series on philosophical "precursors" of cybernetics, for it is doubtful on the one hand that he would have accepted the title of "philosopher," and on the other hand the most "systematic" exposition of his thought, his Pensées is doubtless the least systematic of works. These 923 "thoughts" appear to us as though their author had sought to create from the outset that same elliptically suggestive fragmentation which a long course of history has bestowed upon the sayings of Heraclitus the Obscure. Pascal intended his Pensées as an eloquent defense of the Christian religion, yet already in the fourth of them, he announces that "true eloquence makes light of eloquence, true morality makes light of morality," and then concludes briskly, noting that "to make light of philosophy is to be a true philosopher." But it is precisely as an apologist for that very special Christianity proposed by the Jansenists of Port-Royal that Pascal shows himself as our first contemporary in science and thought.

To be sure, he has other—and seemingly much more direct—claims on our consideration: he was the first to design and construct a machine that performed the four basic operations of arithmetic (or at least the first whose plans and models have survived); he was an early explorer of the binomial theorem and (at the age of 16!) the author of an important work on conic sections; he worked with Fermat on the theory of probability, and Leibniz tells us that he obtained his own notion of the "characteristic triangle"—and thus the germ of his calculus—from Pascal's treatise on the sine of the quarter-circle; he replicated Toricelli's experiment with the column of mercury—and through all this, found time to take a leading part in the philosophical and religious disputes of the day. In the last year of his life he organized the world's first omnibus service, in Paris, just as he was arguing, in his Pensées, that the true Christian had no interests of this world. And, truly paradoxically, it is in his reflections on his "other world" that we find a train of thought that closely parallels our own. Let us see how this is so.

Pascal's Wager

Pascal is the author of that argument for faith which is known as the Wager. It is simple enough. We can have no knowledge, Pascal says, concerning whether or not God exists. And just because of that we have a choice. We may act as if He did exist or we may act as if He did not. Our knowledge of what could be the case here and our ignorance of what is the case combine to produce four outcomes: 1) He does not exist and we act as if He did not—we have nothing to lose; 2) He does not exist and we act as if He did exist—again, we have nothing to lose; 3) He does exist and we act as if He did not—we stand to lose everything; 4) He does exist and we act as if He did—and we have everything to gain. Therefore, the rational man will wager that God exists, for by this wager he has nothing to lose and everything to gain.
“The eternal silence of these infinite spaces casts me into dread.” The Wager is not an argument for the existence of God. Indeed, it rests on the assumption that no such proof is possible. It is not an ontological argument but a methodological reflection. Here Pascal is a forerunner of Kant, who systematically sought to transform all the “transcendental” questions of the traditional metaphysics into methodological principles, and from there it is not far to the Wittgenstein for whom nothing could be said at all about such questions and to the Vienna Circle which sought to end the discussion altogether. But even in its most radically logicistic form, this line of development is a working out of the ethical consequences of Pascal’s “hidden god”; the old identity between ethics and objectivity remains unchallenged and knowledge itself unproblematical. Just this is challenged by Pascal and it is just here that the structure of his theological reflections converges with our most modern methodological thought.

Epistemological Consequences

The epistemological consequences of the Wager are more radical than the theological ones. If we can have no knowledge concerning whether or not God exists, then, since if He were to exist He would be the ground of all being including the knowledge of Him, all our knowledge becomes subject to the conditions of the Wager. But for Pascal, this necessary lack of a secure foundation for knowledge does not render science into an idle game lent support by its usefulness; rather it is itself the basis of science. “Our science,” he says, “resembles a sphere that grows without interruption. To the same extent as its circumference increases, its points of tangency with the unknown increases as well.” Karl Popper could have said that. Elsewhere he says that “whenever a proposition is beyond our comprehension, we ought to suspend our judgment and not on that account deny it, but apply ourselves to the investigation of that which opposes it. Then, if we find the latter manifestly false, we may boldly affirm the truth of the former, incomprehensible as it may be to ourselves.”

Heinz Von Foerster once suggested that noise may serve to bring order out of disorder. This, roughly, is the value of our considering our philosophical precursors: the disorder of their thought may order and illuminate the disorder of our own. So we will not be too quick to claim that our precursors are, just because they preceded us, our inferiors. Cybernetics rests on a bold wager: the wager that precisely those aspects of reality that long seemed most elusive and even irrational can be caught in the conjectural net of a science of general systems. Hidden like his God among the artful ruins of his thoughts, Pascal is our first contemporary in this conjecture.

With this issue we inaugurate a new department of the ASC Cybernetics Forum—“Philosophical Precursors of Cybernetics.” As the name implies, this department will concern itself with cybernetics origins in the thoughts of many men. The series will be edited and (mostly) written by Richard Howe, a frequent contributor to the ASC Cybernetics Forum.

(This is the second part of a two part article)

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In countries with socialistic enterprises, such as those in the U.S.S.R., the manager of every factory gets his particular plan from a central agency which makes plans for the whole country. The plan specifies the amount of goods to be produced. This stifles the initiative of people at all levels of the economy. Rigid central planning and the absence of incentives and competition are responsible for the relatively low productivity of socialistic enterprises and for the low quality of their industrial goods. These factors make it difficult for socialistic enterprises to compete with capitalistic ones on international markets.

Let us summarize. Three billion years of development within the global system has produced ever greater negentropy. This trend was first demonstrated by the emergence of the single cell. As a result of evolution the level of biological negentropy was raised to that of simple organisms, reptiles, mammals and, finally, man. With the emergence of *homo sapiens* the negentropy of the central nervous system reached the level at which a conscious awareness of the external and internal world was possible. Social negentropy began to increase, thus providing conditions for greater human creativity. The result of this creativity, in the form of social and technological negentropy, formed the new material and cultural habitat of people—our civilization. We will call the development towards a greater negentropy upward development. The Law of Upward Development can be expressed in the following form:

The amount of social and technological negentropy on our planet is increasing.

This would be a rather trivial statement were upward development the only development occurring on our planet.

The Law of Downward Development

One of the basic laws of physics is the Second Law of Thermodynamics. According to this law the amount of negentropy in a system is decreasing by itself. The Law is probabilistic and allows for local deviations from this trend, *i.e.*, for an increase of negentropy in a given system. However, the greater the increase in negentropy, the less probable it is and, in the long run, the net effect is still a decrease in negentropy of the given system. This is the law of nature and all processes involving matter and energy must obey it. However, the Second Law of Thermodynamics does not distinguish between the artistic negentropy contained in the statue of Venus de Milo and the chemical negentropy of an equivalent piece of marble from which it is made. In the event of destruction of a masterpiece painting only the loss of negentropy of paint and canvas are covered by this law. To us, the most important negentropy, that of the painting, goes unnoticed. The same is true of biological, technological and social negentropy. This requires an expansion of the Second Law of Thermodynamics to encompass the loss of all kinds of negentropy produced by man, including man himself. By analogy with upward development we will call this trend downward development.

Correspondingly, the Law of Downward Development can be stated in the following form:

All forms of present biological, social and technological negentropy decrease with time. Every process resulting in these negentropies is accompanied by a decrease of negentropy in all four spheres of the global system. The Second Law of Thermodynamics is a special case of this Law; it expresses the decrease of negentropy in all irreversible material and energetic processes, but ignores the loss of the man-created negentropy caused by the same processes.

The Law of Downward Development is our most important and merciless enemy. In accordance with this Law every human being is constantly losing the negentropy of his central nervous system which results in his forgetting some previous knowledge. Brain cells
are constantly dying without being replaced. When a person dies all his negentropy which is capable of creating more negentropy is lost. Social organizations lose their negentropy and are replaced by new ones. Everything born is destined to die, everything created by the human genius will be destroyed by time or by people, directly or indirectly as a consequence of their technological activity. The Acropolis and the Roman ruins are witnesses to, and examples of, the destruction of the marvels of human creativity.

One of the important consequences of this Law is the loss of geospherical negentropy of non-renewable resources and that of ecological negentropy needed to sustain life. Therefore we have to exercise strict control over the processes leading to fuel depletion, pollution, overheating or overcooling of our planet, and to the possible loss of the ozone layer protecting us from ultraviolet radiation.

The effect of the Law of Downward Development on the technological negentropy existing in industrialized countries should not be underestimated. The pure maintenance of the negentropy in these countries requires almost a total renewal of their share of the technosphere within a certain period of time. For example, in the United States the maintenance of the hundreds of thousands of miles of railroads and highways requires a great deal of repairs and periodic replacement of rails. After a certain number of years of work every machine must be replaced by a new one. Every one of the hundred million automobiles on the road will find its way to the junkyard after a maximum of 15 or 20 years of service and will be replaced by a new one.

To maintain the existing level of living, all existing television and radio sets, household appliances, etc. have to be replaced after a relatively short period of time. Some of the materials of which they are made can be recycled but others are subject to chemical transformation such as rusting and cannot be recovered. Such materials as most clothing, paper and old furniture are dumped after their relatively short service. During his lifetime a member of an advanced industrialized society buys and junks several cars, television sets, several sets of furniture, dishwashers, washing machines, bicycles, heaters, builds and repairs a house, uses tons of paper, thousands of pieces of clothing, etc., and sometimes an intentionally built-in obsolescence reduces the lifetime of products.

The Law of Steady State

The limited resources of our planet and their constant loss to the Law of Downward Development require mankind to be economical in its activities. The greatest economy can be achieved by a proper application of this law. Although the law is a law of nature, so that the loss of negentropy accompanies every process, the amount of loss depends on the mode of operation of a particular system. In the case of open systems—to which biological and social systems belong—the loss of negentropy is at a minimum if the systems operate in their steady state, i.e., under homeokinetic (biological systems) or sociokinetic (social systems) conditions. This is the meaning of the Law of Steady State. Any system which deviates from this condition—as is the case with a person with a high fever, or a society in a state of war, famine, epidemic, etc.—suffers a substantially higher loss of negentropy.

The most economic mode of operation of mankind requires that the global system reach its steady state. The further the global system or any of its parts are from this state, the more wasteful is its mode of operation, i.e., the more negentropy is lost in corresponding processes. The Law of Steady State corresponds not only to the application of the Second Law of Thermodynamics to the processes in open energetic and material systems, but includes also the biological and social processes which are not reducible to pure material and energetic ones as it was shown above.

An organism which forms an open system with its environment has a built-in mechanism to return to its homeokinetic condition. This is the key to its survival since only under such conditions can it operate with a minimum of waste. If an organism grows slowly, then the process of growth can be considered as a sequence of homeokinetic states so that the amount of waste is still at a minimum.

Sociospherical systems do not return to their sociokinetic condition automatically as do biological systems. Some consciously introduced controls are required to keep such systems as close to their steady state as possible. The process of growth of a sociotechnological system is usually conducted by a positive feedback development which tends to move the system away from its sociokinesis. Only if the growth is controlled in such a way as to proceed in small steps can the system avoid any significant deviation from its steady state. The control of a society to assure its sociokinetic condition requires the introduction of normative laws. This is usually done in the process of competition of various social forces. They may act as promoters or suppressors of a given social parameter affecting it in a way determined by the relative strength of power groups. In a democratic society the normative laws may express a compromise between these groups.

The Law of Development

The Laws of Upward and Downward Development and the Law of Steady State are concerned with the change of the same basic parameter—the negentropy of a system. By expressing the processes in the global system in terms of negentropy instead of entropy we
reversed the stress from the material and energetic processes governed by the Second Law of Thermodynamics to those in the sociosphere expressed by the Laws of Upward and Downward Development. Every increase of negentropy of one kind is accompanied by a decrease of negentropy of another kind. Every person produces a certain amount of various negentropies during his lifetime, consumes a certain amount of negentropy of different kinds, and is exposed to some finite amount of non-consumable negentropies.

It is interesting to note that the negentropy of masterpieces created by the great painters, sculptors, writers and philosophers has not shown a growth throughout history. Indeed, Homer, Praxiteles, Sophocles and Plato made contributions to the negentropy of the world civilization which equal or exceed those of our best contemporary writers, sculptors, playwrights and philosophers. Judging from this, human capabilities have not changed during the last few thousand years. It may also show that certain social and economic conditions are required to unlock individual creativity. The “Dark Ages” with their stifling religious controls did not provide these conditions while the Renaissance did, enriching us with Dante, Leonardo da Vinci, Copernicus and Shakespeare. The epochs of our civilization can be characterized by the amounts of the particular type of negentropy produced within each. Our epoch is distinguished by the production of an especially great amount of informational and technological negentropy.

The amount of negentropy lost in the process of production of new negentropy, and as an effect of time, depends on the degree of deviation of the system from its steady state. This is another criterion for judging the past and present epochs of our civilization—their deviation from sociokinesis in the process of development. The increase in negentropy which results from an application of the cybernetic method in the bio- and sociosphere, and in the process of creation of the technosphere, is always accompanied by a decrease in negentropy of these spheres and especially of the geosphere. The net decrease in negentropy will be smallest when the global system operates in its steady state.

Let us consider two examples of the struggle between the trend toward an increase in negentropy in a cybernetically controlled process and the counter trend toward a decrease of negentropy which accompanies such a process.

The process of building a factory is a controlled one conducted according to the cybernetic method as it is directed toward an increase in negentropy. Building materials and the machinery for the factory contain more negentropy than the sand, clay, ores and other materials used for their production. However, clearing an area of trees and plants destroys their negentropy, while the use of workers, machinery, raw materials and fuel causes decreases of their respective negentropies. Indeed, the burning of fuel decreases its negentropy; octane molecules of gasoline have more negentropy than the molecules of water, carbon dioxide and the toxic products of combustion. Their discharge causes pollution which decreases the ecological negentropy.

The farmer increases the negentropy of his crops by adding negentropy to the soil, in the form of fertilizers, and by using machinery to harvest the crops. At the same time, some negentropy is lost due to such factors as depreciation of machinery, the burning of fuel to operate it, the use of fertilizers, pollution caused by fertilizers washed into rivers, a restructuring of the soil, and finally, a loss of the farmer’s own negentropy in the process of farming.

The maintenance and increase of the negentropy of a human being requires the negentropy of food, goods, and services as well as all forms of social negentropy, particularly those providing education and training. During his working life man creates a certain amount of negentropy used by his fellow men. Therefore every processed negentropy of socio-technological systems contains a part of human negentropy.

Since cybernetically controlled processes are conducted only in the bio- and sociosphere, the struggle between upward and downward development takes place only there, while in the geosphere the direction of development is only downward toward a lower negentropy as required by the Second Law of Thermodynamics. In the biosphere the Law of Development is demonstrated by the fact that every day a certain fraction of cells in an organism dies out and is replaced by new ones. The exact nature of the laws of control governing the behavior of biospherical systems is still unknown.

The major activity of the sociosphere is the building of the technosphere to provide people with food, goods, services and jobs, as well as to insure further development of the civilization. The negentropy of the sociosphere is contained in its economic structure, government, social organizations, organization for production and dissemination of knowledge, etc. The Law of Downward Development acts on the sociosphere in much the same way as it acts on the biosphere, by constantly forcing the replacement of men in the organizations of a society and by changing the organizations themselves.

The technosphere occupies a special place in the global system. It does not increase its negentropy by itself. If man as a member of the sociosphere should disappear, the technosphere would not be distinguishable from the geosphere and there would be a constant decrease in its negentropy in accordance with the Second Law of Thermodynamics. An increase in negen-
entropy of the technosphere or just keeping it at the same level requires that the sociosphere constantly pump negentropy from itself, the geos- and biosphere, as well as from the technosphere. Indeed, the Law of Downward Development demands a high price for our technological activities. While the sociosphere builds the technosphere, the technosphere in turn makes a tremendous impact on the sociosphere increasing its negentropy. Ecological cycles allow us to maintain a steady state in the biosphere for a long time. However, the technological activities of a society disturb them causing a deviation of the biosphere and its habitat, the geosphere, from their steady states.

Functional Complexity as the Fundamental Parameter of Socio-Technological System

The finite resources on our planet and the delicate ecological equilibrium on which our existence depends set a limit to the total amount of negentropy potentially available to us. As was shown above, this limit is not fixed but depends on the closeness of the global system to its steady state. In a steady state system the use of scarce resources is minimized and the ecological equilibrium is not displaced to any significant degree. In order to reach its steady state, the global system has to overcome two major obstacles: the fragmentation of the sociosphere and the uncontrolled increase in population, especially in less developed countries. Obviously, the rate of depletion of planetary resources depends on the number of people using them and on the standard of living in every society represented by the rate of their production and consumption of negentropy.

Since the global system has not reached this state, we should concentrate on particular socio-technological systems such as individual countries, studying their conditions in the light of the Law of Development. It follows from the preceding analysis that the amount of processed negentropy of such a system is not a sufficient characteristic of the processes taking place there. One should also know the types of negentropies produced in the system, the conditions under which it is done in terms of the degree to which the system deviates from its steady-state condition, as well as the way in which the produced negentropy is consumed or used. We will call the concept which incorporates all this information about a given socio-technological system its functional complexity. The adjective "functional" implies greater stress on processes in the system than on its structure. The kind and amount of processed negentropy produced per unit time is a quantitative characteristic of the productivity of the system.

Correspondingly, we will call the ratio between the net negentropy increase in a unit product manufactured in a given process, and the time required for it, the differential coefficient of productivity of the system. The net increase in negentropy is the difference between the negentropy of the final product and the sum of negentropies of all input products: raw materials, fuel, the negentropy lost by amortization of the structural negentropy of the plant, as well as the negentropy of waste accompanying the process which is discharged into air and water and causes pollution. The additional negentropy required to clean the polluted environment should also be treated as input negentropy.

Time in the coefficient of productivity expresses implicitly the human negentropy spent by the personnel. The less time a given crew spends on manufacturing a unit product, the more units they manufacture and the less negentropy (food, goods, services, education and training as calculated per unit product) is consumed by them in the process. The product obtained by multiplying the coefficient of productivity by the time spent on manufacturing is the net increase in processed negentropy. Adding together these expressions for everything produced in a given socio-technological system, we will get the total increase of negentropy per year. And adding together every kind of negentropy produced in each country we will get their values for the global system.

The total amount of negentropy produced in a given system (country, global system) is an important but not sufficient characteristic of the system's use of scarce resources. One must also take into consideration the amount of time this negentropy is used before being discarded or recycled. The quantitative expression of the process of consumption of the processed negentropy is given by the differential coefficient of consumption defined as the rate at which negentropy of a product is decreased. In other words this coefficient is the fraction of the total negentropy of a product used per unit time. The longer the lifetime of a product the smaller is the coefficient of consumption. Multiplying the differential coefficient of consumption (in which time is expressed in years) by one year we find the amount of negentropy of the product used during one year. Adding together such terms for all products used in a country or in the global system we find the amount of negentropy consumed in these systems.

In a truly competitive society the price of a given product on the international market would serve as the measure of the amount of negentropy of that product. However, the actual relationship requires more extensive study which should take into consideration the relative scarcity of a particular resource, the degree of pollution caused by its production, etc. As one can see, functional complexity is a composite parameter requiring several indicators for its full characterization. Mathematically speaking it is a multi-dimensional vector the components of which are the parameters of the functional complexity. The coefficients just intro-
duced are applicable primarily to technological negentropy, which is only one of the basic types of negentropy characterizing the functional complexity of a socio-technological system.

We should be aware that the four basic types of negentropies—sociospherical, technospherical, biospherical and geospherical—are different in nature and therefore cannot be simply added algebraically. The enormous differences in the complexities of the systems they characterize make them qualitatively different and not reducible to each other. However, we can compare the functional complexity of two countries as well as the amount of change in a particular negentropy within any country during a given time interval. This can be done by a formula similar to one suggested by von Förster who utilized the Shannon expression for equivocation, however: we give their formula a different interpretation. The level of uniformity \( \mu \) is defined in the following way:

\[
\mu = \frac{N_m \cdot N}{N_m}
\]

where \( N_m \) is the maximum possible amount of negentropy of a given kind within a given system and \( N \) is the actual negentropy in a system to be compared with the first one. Let us apply this formula to two extreme cases. In a country where only one ideology is permitted, any two citizens could be interchanged with respect to their ideology without changing the ideological setup of the society. Thus the ideological negentropy of the society is zero \((N=0)\) which corresponds to \( \mu = 1 \). If, in a given school, no two students are exposed to exactly the same set of subjects, then \( N = N_m \) and \( \mu = 0 \). This corresponds to maximum negentropy produced by the school. In accordance with this criterion of two school systems, the one which offers the greater variety of curricula has higher functional complexity, assuming that the quality of courses in both systems is the same and that the variety of subjects for each student fits the variety of students' learning characteristics.

The rate of production of social negentropy as an expression of the creativity of a society can be measured by the rate of scientific publications, by the rate of creation of new pieces of art, literary works, musical compositions, sculptures, and by the number of students graduating each year from various institutions of learning. The quality of publications, of pieces of art, of the education of students, etc. is more difficult to measure, although the development of new fields of science, creation of new literary styles, new varieties in musical and other art forms, and greater variety of professions for which students are prepared can also serve as a measure of the increase of functional complexity of the corresponding subsystems.

With respect to the structural negentropy within which these processed negentropies are produced, the functional complexity can be measured, for example, by the increased capacity of research facilities of colleges, universities and other research organizations. The increased rate of production, dissemination and utilization of information creates greater variety and correspondingly less uniformity in a society. The greater the variety of the subsystems, the easier it is to create additional varieties and the greater is the number of functionally complex subsystems which can be made from them. In other words, the process of production and utilization of information is a positive feedback process and one which should be stimulated.

There is, however, a limit to this process which is determined by the productivity of a given society. The higher its productivity the more scientists and artists it can support. When we speak of a variety we mean a constructive variety, i.e., that which is potentially suitable for creation of new, functionally complex subsystems in a society. To the class of non-constructive varieties which do not have this property belong the fragments of Christian churches which were intended to be one church. The variety of poverty in the country, that of violence shown in movies or on television, or of mediocre films are also examples of non-constructive varieties. Indeed such films rarely increase the ethical or aesthetic negentropy of the person watching them.

The increase in the variety of the members of a given society can be measured by their exposure to the information flow, including the number of papers read per person, the number of hours of television, the number of telephone conversations per person, etc. That raises again, however, the problem of the quality of available information and, again, we can use, in many cases, the principle of variety as an indirect expression of quality. If all newspapers were to have identical interpretations of events, if all networks were to have similar programs such as the same kind of game show on every channel, then their negentropic content would be low.

Deviation from the steady state of the global system can be measured by the change of ecological negentropy such as the increased percentage of carbon dioxide in the atmosphere, the changes in the amount of atmospheric dust in the composition of the ozone level, and by the increase in the chance of nuclear or conventional war. For a country, the deviation from its steady state can be measured by an increase of pollutants of every kind in the geosphere, by the rate of depletion of non-renewable resources, by the rate of population growth, by the increase in internal and external politico-economic tensions, and often by its positive feedback developments. In general, such developments should be viewed with suspicion since they may lead the system away from its steady state. However, some positive feedback developments may result in increased productivity and improved technology which would allow the system to support more scien-
tists, innovative educators, writers and artists. The increase in the corresponding negentropies may create additional positive feedback development, further increasing the productivity and negentropy of the society.

There is, however, always a danger that the additional negentropy would be channeled into excessive consumption or that it would be used to increase military negentropy, which is designed to effectively destroy all types of negentropy, and this would lead the global system further away from its steady state. To maximize the functional complexity of the global system one needs to unify the biosphere into one socio-technological system in which the parts would functionally supplement each other. Only such a unified system can be brought into a steady state and can assure the survival of mankind for the longest possible time.

In summation, we can define the functional complexity of a given socio-technological system as a composite concept expressing changes in four basic types of negentropy as measured by coefficients of production and consumption, changes of certain social parameters, particularly in the variety of the members of the society. In addition, functional complexity is characterized by the rate of production, dissemination, and utilization of information and by a deviation of the system and its subsystems from their steady states.

Complexology as the Science of Functional Complexity

The Law of Development into which the Laws of Upward and Downward Development and the Law of Steady State were incorporated represents the foundation of the new science for which I propose the name Complexology. Complexology studies the change of functional complexity in the socio-technological subsystems of the global system and in the global system as a whole. It is the only truly integrative science which considers all aspects of human existence as interdependent processes. In a broader sense of the word, its object of study is the basic property of man—his creativity—as manifested in the various kinds of negentropies he produces. These include artistic, scientific and technological negentropies. The smallness of our planet and its limited resources compel us to be economical in our operations so that the delicate living conditions of our planet will not be violated and its human population will be provided with the necessary food, goods and services. This requires that every socio-technological system operates at its steady state.

This does not mean that the systems must stop their development. On the contrary, if we would maintain the population at the same or even a reduced level, we still could continue to increase all kinds of negentropies including technological ones, but only through the use of more effective operations corresponding to those under steady state conditions.

Since functional complexity can be increased or maintained at the same level only by the application of the cybernetic method, this method is the basic method of Complexology. The goals necessary for the application of the cybernetic method, as well as the agents acting in a controlled system which result in positive or negative feedback development, can be attained through Complexology since only the study of the whole system with all its interactions can provide this information. A device, a person or an organization applying this method should, however, know how to operate its particular system, which requires that they must know the repertory of decisions needed to change the actual value of the parameter into the goal value as well as the way in which the decisions can be effectively executed.

Let us analyze some common properties of large, complex systems dealt with in Complexology. According to the Law of Development the increase in functional complexity is an inherent property of the bio- and sociosphere. It does not mean, however, that in all events taking place in the global system the negentropy of the socio-, bio- and technosphere is always increasing. Negentropy is a probabilistic quantity determined by the three laws governing its creation and destruction. Therefore a local and temporary decrease in the amount of negentropy in a complex system is a probable event. Such probabilistic events as war, revolution and famine decrease the net amount of negentropy in the societies where they occur. Decay of civilizations and the corresponding loss of their negentropy has taken place throughout our recorded history. A fast increase in the destructive power of weapons and in the scope of technological activity makes negentropy destruction possible on a global scale.

An exponential growth of the functional complexity of socio-technological systems in industrialized societies demonstrates the positive feedback mechanism: the larger the functional complexity of the system, the faster it can grow. This also explains why it is so difficult to increase the functional complexity of undeveloped countries which do not have any industrial basis.

The existence of complex systems has both advantages and disadvantages. The more complex a system is the greater will be the number of various parts and interactions between them, and correspondingly the more modes of operation the system will have at its disposal. These added contingencies allow the system, in the case of an emergency, to change its normal mode of operation to meet the emergency. Here are several examples in which this type of variety proves advantageous.

A ruptured oxygen tank on the service module of the Apollo 13 made its major engine inoperable. The astronauts changed their plans and moved to the attached lunar module with its intact engine. This
allowed them to return to earth safely.

The difference in the functional complexity between the U.S. and Bangladesh explains the fact that while many thousands of people perished in Bangladesh as the result of a flood caused by a tidal wave followed by heavy rains, the devastating flood in the eastern United States in 1972 caused by unusually heavy rains associated with a hurricane took only relatively few victims. There was no weather service in Bangladesh which could provide advance warning, no transportation for rapid evacuation, no means of communication to relay the needs of people in the flood area and no money available to organize a relief operation. In the United States all these economic and technological means were at hand and all the corresponding organizations changed their regular mode of operation to meet the emergency created by the flood.

Let us consider also one hypothetical example.

Assume that a fatal illness caused by an unknown virus against which all existing vaccines proved to be ineffective started to spread in the United States. There are hundreds of bacteriological laboratories in hospitals, pharmaceutical firms and universities in the U.S., performing their routine functions. In the case of such an emergency they could be mobilized to work primarily on finding a vaccine against the virus. Without the existing functional complexity of bacteriological institutions such problems could not be solved in a reasonable time and a great number of people could perish. These examples show that the degree of complexity of systems is a determining factor in their survival.

However, this great number of possible modes of operation also requires more controls to suppress all modes of operation except the desired one in which the system operates best. It creates the danger of a gap between the fast growth of complex systems and the slower growth of necessary controls. Major social perturbations such as wars, revolutions, etc. can be traced to this discrepancy. The fast growing complexity of the socio-technological systems without the corresponding growth of controls resulted in a great number of undesirable negative feedback developments creating situations fraught with grave consequences for our civilization. We have already mentioned some of those developments in the form of population growth, pollution, depletion of natural resources and the nuclear race.

Technological activity and its effect on warming and cooling of the planet and on the composition of the ozone layer protecting us against ultraviolet radiation form further dangerous positive feedback developments. Every such development is caused by the absence of the controls needed to change it into a negative feedback development towards the establishment of steady state. Such uncontrolled positive feedback developments would inevitably lead to catastrophe on a planetary scale.

Thus according to Complexology, the general illness of our epoch can be diagnosed as:

\textit{an increasing gap between the fast-growing complexity of socio-technological systems and the slower rate of introduction of controls needed for their proper functioning.}

It should be realized that just to maintain the existing level of functional complexity of a social system requires a great deal of control since the insufficiently controlled system has a tendency to degenerate toward a simpler state by losing some degree of its organization. The growing complexity of socio-technological systems has not been accompanied by introduction of the additional controls needed to protect the society against the side effects of technological activity and to bring the international relations in line with global destructive capabilities of nuclear weapons. These relations continue to be regulated by old fashioned rules incompatible with the existing level of socio-technological complexity. How can a country justify an "internal affair" preparation for a nuclear war which would not only kill many millions of people but which might also destroy the protective ozone layer and cause the annihilation of most life on the planet. No country can consider the killing of millions of its citizens as its internal affair—it is as much the problem of mankind as a whole as is the prevention of starvation. We still adhere to the same old ideas and try the same old methods as though no qualitative changes have taken place during the last quarter of a century to threaten the very survival of our civilization. Expensive piecemeal solutions are preferred to the fundamental ones which, to be successful, require the acceptance of this diagnosis of our general illness followed by a commitment to cure it and to prevent it from recurring in a different form.

The gaps between the fast-growing complexity of systems and the slower growth of the controls needed for their efficient functioning should be considered not as various illnesses of our society but rather as various expressions of the same general illness. This illness also shows itself in the form of the following gaps:

1. The exponentially growing body of knowledge vs. essentially unchanged forms of the teaching-learning process by which knowledge is transmitted to the next generation;

2. The planetary scale of problems in fragmented societies and their use of narrow national approaches to these problems;

3. The growing wealth of the industrialized countries vs. the much slower economic growth of the agricultural countries;

4. The economic interdependencies of all societies vs. uneven distribution of resources leading to monopolies in certain commodities;

5. The growing destructiveness of weapons without adequate control over their use.
There is a long list of such gaps and the list is getting longer as the societies continue to ignore their general illness. There seems to be no other way to cure it but to impose additional controls directed toward elimination of the existing gaps and preventing new ones from occurring. In doing so, the society should be very careful not to introduce excessive controls which may lead to the elimination of freedoms and to restriction of human creativity. Too much control is as dangerous as a lack of it.

I do not accept the hypothesis that every civilization must perish at a certain time and nothing can be done to prevent it. It seems that the introduction of proper controls at proper time might have saved many civilizations. The actual suicide of the old Russian civilization in 1917 offers a strong support to this statement. Indeed the attempts of the Russian Czar to cope with the complexity of the 20th century, by using the controls of the 19th century invited catastrophe.

What should be done to cure our general illness? First of all we should know the direction in which the society should head in order to survive; then we can design the minimum number of controls which assures this direction by preventing any undesirable positive feedback development leading the society further from its steady state. These are the basic practical problems of Complexology. Complexology concerns itself with two ultimate mutually dependent problems:

1. To specify the conditions under which every person can develop in accordance with his genetic potential to his full intellectual, emotional and spiritual capabilities, and to design methods to achieve these conditions; and

2. To design a society into which every person could be fit in such a way as to minimize his avoidable anxieties while maximizing his contribution to the well-being of the members of the society and to show how such a society can be realized.

These problems can only be solved within a society in a steady state. A steady state society must be a part of a unified integrated world society since only such a system can achieve maximized functional complexity compatible with planetary resources and ecological conditions. The planning of a strategy that would lead to the unification of mankind is the most important intermediate problem of Complexology.

Only the most basic ideas of Complexology have been presented here. It is clear that they require further research particularly in respect to the ways in which the various negentropies and their differential coefficients can be evaluated.

Let us make a comparison of Complexology with Cybernetics and General Systems Theory. While GST is interested in general properties of various systems and Cybernetics is concerned with control properties common to such systems, Complexology deals with the specifics of systems. In particular, Complexology attempts to study the agents within a system which determine the changes in its negentropic content, since without knowledge of the specifics an efficient functioning of the system would be difficult or impossible.

The subject matter of Complexology is the process of production, maintenance and use of various negentropies within a certain structure, a basic tenet being that every process and its corresponding structures are treated in their unity. In addition, a consideration is made of the overall effect of a process on all spheres of the global system instead of just on isolated or local changes in a given system. Control is an important concept in Complexology as the foundation for the cybernetic method, the only means of increase or maintenance of negentropy.

Of course, all the findings of Cybernetics and GST will be utilized in Complexology to the full extent. However, Complexology may prove to be a more universal science since it is concerned with the fundamental property of human beings—their creativity as expressed in the amount and kind of negentropy they produce.

References

Update

Trentowski’s Use of the Word Cybernetyki in 1843

(An update on the history of the word cybernetics.)

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Background

In discussing the origins of the word cybernetics Wiener (The Human Use of Human Beings: Cybernetics and Society, P. 15. New York: Doubleday Anchor Books, 1954) made the elliptical statement, “kubernety nor steersman. . . had been introduced in another context by a Polish scientist . . . (in) the earlier part of the nineteenth century.” As a part of my study of the history of cybernetics (ASC Cybernetics Forum. VII(2): 14-15. Summer 1975), I have sought to discover who this Polish scientist was and believe the answer to be Bronislaw Ferdynand Trentowski.

Trentowski

Trentowski was born January 21, 1808 in Opole, Poland and died on June 16, 1869 in Freiburg (Germany). He studied at the universities of Warsaw, Heidelberg and Paris and from 1838 to 1847 lectured at the University of Freiburg (probably the German Freiburg im Breisgau, Baden — and not the Swiss Fribourg). He was a philosopher, educator, publicist and ardent nationalist at a time when the Polish people had no country of their own but were divided among Prussia, Russia and Austria. While he was inspired by Hegel and other German philosophers he sought to establish a Polish national philosophy and to enhance the Polish reputation by developing a universal system of human knowledge. He believed that education for the masses and an improvement in social conditions were essential to the establishment of an independent Polish nation. Starting in 1840 he wrote all of his work only in Polish for patriotic reasons.

While he was still a lecturer at Freiburg in 1843 Trentowski published a book in Polish at Poznan which he titled “Stosunek filozofii do cybernetyki, czyli sztuki rządzenia narodem.” An English rendering of this title is, “The Relation of Philosophy to Cybernetics, or The Arts of Governing People.”

1843 was the same year that the second edition of Ampère’s famous work appeared, “Essai sur La Philosophie des Sciences, ou Exposition Analytique d’une Classification Naturelle de Toutes Les Connaissances Humaines.” The first edition appeared in 1834 shortly before the time Trentowski was studying in Paris. It is interesting, thus, to speculate that Ampère inspired Trentowski to write his own book on cybernetics. The similarity between Ampère’s phrase “natural classification of all human knowledge” and Trentowski’s “universal system of human knowledge” suggests such an influence.

Acknowledgments

I am greatly indebted to Dr. Panos D. Bardis of the University of Toledo for introducing me to Dr. Bronislaw Kuchowicz of the University of Warsaw. It was Dr. Kuchowicz who identified Trentowski and kindly provided the biographical material given above. My colleague, Dr. Roland A. Laroche, has also been helpful in this study of the origins of the word “cybernetics.”
Introduction

In the summer of 1975, Dr. Roy Herrmann, then President of the American Society for Cybernetics, suggested that I prepare some personal notes on cybernetic developments for publication in the ASC Cybernetics Forum. Inasmuch as I had been instrumental in calling and chairing the first discussion meeting that led eventually to establishment of the ASC, and inasmuch as I served as Chairman of the working group whose activities culminated in inaugural and founding steps, it is appropriate that I respond affirmatively to Dr. Herrmann’s suggestion.

I am taking the opportunity to describe some of the motivational conditions that existed 12 to 15 years ago, to restate some of the goals and justifications as set forth at that earlier time for a cybernetics society, and to relate what I consider to have been some of the best thoughts then with what has happened, and what seems about to happen, in the information sciences. This account will be somewhat personal, and the reasons for this will become more obvious as we go along. Various others were involved in the organizational steps, of course, and I shall mention some of them. If they or anyone else were to write personal notes concerning the same period and subject matter, many of the same facts would be mentioned and then the individual’s personal involvements described. Such is the pattern used here. A memoir’s statement, it may be said, affords one of the best opportunities for sequential listing of thoughts and insights that in time appear to have gained significance.

In his letter Dr. Herrmann called attention to Warren McCulloch’s autobiographical statement, “Recollections of the Sources of Cybernetics,” published posthumously in the Summer 1974 FORUM. This reminder seemed to suggest a format and a departure point for me—an approach I was glad to adopt. Dr. McCulloch vividly drew attention to the fact that one can find in the writings of scientists, mathematicians and philosophical analysts clear evidence of thinking about communication and control processes long before principles and rules had been formulated. Among other interesting things, Dr. McCulloch included this comment: “...the sphere belongs to the pure mathematician, the ball to the physicist, the engineer and the biologist.” With respect to cybernetics, my comments will pertain mostly to the ball—to the fundamental more than the abstract.

Early Impressions of Information Science

In the late 1950’s and early 1960’s, I was in the Division of Biology and Medicine of what was then the Atomic Energy Commission. The purpose of this Division was to process contract proposals for radiobiologic research, assuring that requests were in accord with authorizing legislation, that they were scientifically reasonable and that the proposed investigations were feasible. This same work led on to approval and the provision of funds. About 1960, I was assigned the task of handling the proposals having to do with the effects of high energy radiations on nervous system functions, including brain functions. Although I had up to that time had considerable laboratory experience with other radiobiologic effects, such as sterility, augmented embryologic development, redirected tissue maturation, cancer induction, cataract formation, life shortening and the lessening of genetic vigor of populations, I had not had such experience with nervous systems functions and operations.

As it happens, my AEC activities coincided with the period of rapid emergence of computers—devices that had their development in a specific way only about a dozen years previous to the mid- and late 1950’s. I was intrigued by the expressions being used by information scientists: “automated control,” “artificial memory” and “machine intellect,” to mention only some. For an experimental biologist who had worked mainly with cause and effect relationships asking only about “what” and “how,” such expressions were somewhat
surprising—and, I may say, intriguing. It seemed to me though that something special was going on in scientific thought in connection with both beyond the development of fast calculators, but I could not at the time put my finger on it.

In the late 1950's, it will be remembered, much was being said by information people about systems—particularly the managed operations of complex systems. As I read, listened and reflected on the ideas of systems, I became impressed with the significance of "goal." I agreed with what was being said—namely, that systems made very little sense except in terms of goal or purpose; meaning, of course, targets, levels, directions, specific states, and the like.

But goal and purpose? This just had to be heresy! My background of development made it clear that no self-respecting scientist would speak of such. By training and commitment, he spoke only of what he could observe, measure and calculate, leaving goal and purpose to other disciplines—mainly theology. Yet, here they were. People in the information sciences field spoke freely and with ease about goal and purpose. I was both puzzled and impressed.

Reading took me back to Norbert Wiener's definition of cybernetics—"communication and control in the animal and the machine," and to his book The Human Use of Human Beings, 1956. My copy of the latter is much marked and there are various questions and notations written in. Although by devious pathways, my reading led inevitably to the 1943 Philosophy of Science paper by Arturo Rosenblueth, Norbert Wiener and Julian Bigelow, "Behavior, Purpose and Teleology." There it was, plain as day. Somebody in science had spoken forthrightly about purpose—without equivocation and fairly recently. Look at the title! Reference to objectivity and goal as inherent in both nature's and man's operational processes could not have been more direct. In this case, it was a neurologist (of all people)—a biologist, as it were—dealing with communication and control in animals and being goaded by mathematicians to draw the obvious conclusions. But, I thought, could these people be serious and are they for real? Could they have been aware of the heresy they were perpetrating? Had they stopped to think of the bewilderment and consternation they were striking in the minds of those with Lamarckian ideas who had been beaten down because of lack of evidence of purposeful evolution? Despite my resonance with the new ideas, my suspicion of the first writers on purpose continued. It persisted as inner thoughts for awhile, irrespective of how ridiculous it soon was to seem.

With further consideration, it became clear to me that in the 1940's (during World War II, of course) Rosenblueth had sensed what I was confronted with and sensing in a different way in the 1960 period—namely, that the behavior of organisms directed toward the achievement of ends beneficial to survival is not only inherent, but also purposive, and that the magnificent coordination in organisms is accomplished by information processing done in specific ways. Rosenblueth spoke of input and output, but indicated that "input does not energize the output directly," thus allowing for a processor in between. Most significantly, he stated that, "if we decide to take a glass containing water to our mouth, we do not command certain muscles to contract to a certain degree and in a certain sequence; we merely trip the purpose and the reaction follows automatically." I thought of how I use tools—how my attention is fixed on the tip of the scalpel, the probe, the pipette, the pencil, the screwdriver, the shaping tool or whatever—that is, at the point where the action is causing goal and objective to change continuously as there is awareness of the consequences of the step just previous is known. Clearly, moment-to-moment goal determination is paramount in the processes of organism behavior and I found myself asking whether it is not just as fundamental in social and economic behavior and in the operation of adaptive machine processes. A question for me in 1960 was coming to be, "How is it that ionizing radiations affect goal determination in complex adaptive processes?"

There were also other papers that had a direct bearing: in Mathematical Biophysics, 1943, by McCulloch and Pitts, "A Logical Calculus"; in a chapter of a Princeton University Press book of 1947, by John von Neumann and Oskar Morgenstern, The Theory of Games and Economic Behavior; in Mathematical Biophysics, 1947, by Pitts and McCulloch, "How we Know Universals"; in a John Wiley book, 1948, by Norbert Wiener, Cybernetics—or Control and Communication in the Animal and the Machine; in a University of Illinois Press book, 1949, by Claude Shannon and Warren Weaver, The Mathematical Theory of Communication; and in the Proceedings of the IRE, 1959, by Lettvin, Maturana, and McCulloch, "What the Frog's Eye Tells the Frog's Brain." There are, of course, many other publications that have made significant contributions to the emergence of cybernetics and the science of information use, but the ones mentioned stand out in my mind as special and they influenced me a great deal in the 1960 period.

investigating the Sources of Cybernetics

Reading carried me back still farther. Like Warren McCulloch, I wanted to know more about the sources of cybernetics. I wanted to know what it was, if we could identify it, that caused people with such divergent backgrounds to be talking at the same time in the 1940's about communication and control and about purposive behavior. Reading and personal contacts revealed the saga of the Josiah Macy Foundation conferences held at the Princeton Inn, 1942-46. Memories of just how many meetings were held and how they
feedback can be employed to achieve various designated directions, levels, equilibria, etc. This—remember—was still in vacuum tube days, before transistors, but radio circuits were already advanced and television was in sight. More elaborate ideas for electronic machine control began to develop; and, for me, it is noteworthy and significant that various of the authors I have cited above were in attendance at the Macy Foundation meetings.

It seemed necessary, even by 1960, to accept that to a very large degree because of considerations given to circular causal and feedback systems, computer technology had leaped at the world. So rich and so rewarding had been the returns that few were continuing to think about goal and purpose as such and especially in biologic and social systems; yet it was from consideration of these features in particular that cybernetic and computer developments got much of their impetus for starting. In the 1960's, Bionics was a kind of spin-off from computer science, the purpose of which was to study living processes as a means of learning more about how to develop more elaborate and more functional hardware systems. Few seemed to be thinking of the benefits that would arise from reversing the approach and using the magnificent computer systems as models for understanding better the operational behavior of biologic systems. Much was being done about neural chemistry and physiology generally and about behavior from the physiologist's point of view, but little about the nature of consciousness, intuition, reasoning and intellect as such.

In my quest to find out more about the sources of cybernetics, I thought about thermostats and thermoregulated devices and remembered that such had been used successfully for control purposes since long before use of the term cybernetics. I thought of the turning ball governor used so effectively to control the speed of steam engine flywheels since well back in the 19th century. I thought also of the regenerative feedback electronic circuit that had such great influence on radio development, and of the fact that the first description of this circuit in professional literature was by Howard Armstrong in the Electrical Journal, 1921. I had read Lawrence Lessing's book, Howard Armstrong—Man of High Fidelity, and gained some impression of the thinking that seemed to be responsible for the electronic feedback circuit with its amplifying features to appear when it did; and, on the basis of this alone, it seemed to me strange that cybernetics as a discipline and the significance of purpose in operative systems had not emerged at least a decade earlier. Later I met Lessing and he gave me a copy of Armstrong's schematic drawing of the 1921 feedback circuit showing how a simple coil in the plate circuit of a vacuum tube can insert a small portion of the output as further input in the filament circuit and thereby achieve still larger output. Because of the vast significance this simple drawing has had in engineering developments and as a model for understanding much of what happens in living systems, I thrill every time I look at it.

Something More than Simple Feedback

In 1960 I was beginning to realize not only that knowledge of cybernetic principles was fairly old, but also—as things were developing—that information processing in living systems consisted of considerably more than circular causal feedback neuronal networks. The reservation stemmed from observations earlier in the laboratory on free living cells, on sperm and ova, on embryos before neuronal elements had formed, and on plants where nervous systems in the usual sense do not exist. In the protozoan, Paramecium, there are cilia on the surface of this single-cell form that beat in unison to propel the organism along in its watery medium. Under the microscope, one can see a Paramecium swim into an immovable object, reverse the ciliary beat and move back a bit, and then turn right or left in a meaningful or beneficial kind of way. Information was received and processed and behavioral action was taken that was favorable to the organism. Clearly the basic attributes of an adaptive system were manifest and this without the aid of nerves or neurons.

Consider also Volvox swimming in a watery medium. Volvox is just visible to the unaided eye and it consists of a hollow sphere of cells, each with a flagellum. The flagella beat in a coordinated fashion, causing the organism to roll and move effectively in the medium. Again the coordinative function is achieved without nerves or neurons.

Consider two tissue cells that lie together in the germinal cell layer of the skin, the lining of the alimentary tract, or in the seminiferous tubules of the testis. One cell will mature to form surface skin, surface gland cells of the gut, or spermatozoa, as the case may be, while the other stays behind to proliferate more
germ cells. Each got the message of what it was to do—and without direct contact with nerves or nerve cells. Clearly it is necessary, in the case of organisms, to take into account information processing and control without nervous systems in many instances and without direct nerve or neuron contact in other instances.

During the period around 1960, I thought a great deal about systems and behavior of many types—the situation in machines as well as in organisms with and without nervous systems. I thought of input and output, of sensors and expressors, and of processors and brain. Where nervous systems existed, I came to see information as the commodity of nervous system function in the same way that blood is the commodity of the vascular system, and hormones the commodity of the endocrine system. I came to look upon information processing as an attribute of systems generally—that is, of devices or entities that respond to stimuli. I came to look upon the simple reflex (input-processor-output-goal) as a model for information processing, at least of certain generalized types. In some respects, I was retracing the thought experiences of many others.

But, I also came to look upon brain as a specialized subsystem, which was a view rather different from that presented in various textbooks of neurology and physiology where brain is treated as the main departure point for mental processes. I made note of the fact that information processing, as such, can go on in non-living (machines) as well as in living entities, thus making it unnecessary to accept that mentation is associated only with living things. More importantly, or so it seemed to me, I made note of the idea that information processing, as such, can go on in non-living (machines) as well as in living entities, thus making it unnecessary to accept that mentation is associated only with living things. More importantly, or so it seemed to me, I made note of the idea that information processing must be a feature of all cells—and possibly also crystals and molecules. In particular it caused me to look more at the nature of information itself, and not just the symbols, vehicles and machinery by means of which it is expressed or manipulated.

“Information Per Se”

In order to organize the evolving thoughts about information as a phenomenology, I prepared a paper which was published in Nature, 14: September 1963, under the title “Information per se,” pointing out what seemed to be the special aspects of information as a motivational force. The style employed was rather different from any I had used previously for scientific papers, the effort being to use self-evident truths and obvious deductions. I was surprised at how far it was possible to go. Some of the first paragraphs have a bearing on the development being described here:

Receipt and use of information is a feature in all living systems.

The information used by living systems is of three types: inherited, acquired and generated. Inherited information is that brought into organisms at the moment of conception; acquired is that brought in continuously during life by means of the sensory shield; and generated is that formed inside the system by interaction.

The means by which acquired information is received and developed varies widely among species.

Systems in organisms for processing acquired information have undergone evolutionary change comparable with that which has occurred in systems having to do with other functions.

Along with ability to detect and transduce stimuli, and along with ability to transmit information-laden impulses, has come an increased ability to comprehend, to understand and to know, also an increased ability to imagine, feel, evaluate and make judgments. Acquisition of the more specialized information processing capabilities, and of the greater emotional capacities, have coincided with elaboration of the cerebral cortex.

In the human species, that is, the species considered to have the most advanced cerebral cortex, the ability to develop and utilize information greatly transcends that of other species. The human mind—the means by which we think—can be regarded as the most highly elaborated product of evolution.

Information is an entity apart from the means by which it is processed, the symbols by which it is represented, or the responses made to it. Messages contain intelligence (dispositional, organized, usable and available information), but as such do not themselves constitute intelligence.

Information can be transmitted and stored by means of impulses and symbols, but it exerts an influence only after removal from the encoded message and interaction with other information, as can happen in a cell, a brain or a computer.

Information can be regarded as existing in pieces or concepts, but probably not as units. Information, as such, is not amenable to quantification in a manner comparable with that which applies to entities having force, mass and charge.

In the last analysis, information consists of data, especially unrelated facts and statistics. With
organization of data, intelligence is created and with further organization of organized data, intelligence is developed and advanced.

Intelligence, like life, is a manifestation of sustained interaction. Each is associated with matter and fully dependent on it. Each, nevertheless, occupies a place apart from and beyond matter. Remove intelligence or life, or both, and the residue of constituent elements remains unchanged.

Life and intelligence are dispositional manifestations. Each consists of information processing carried along by energy systems utilized as vehicles. Life as we tend to define it, is dependent on wet (protoplasmic) systems, whereas intelligence can exist and build in either wet or dry (hardware) systems.

The Ideas of George Sakalosky and Others

At the AEC, I became acquainted with George Sakalosky, a person with a background in physical and biological chemistry. George Sakalosky’s ideas filled a gap in my thinking much more than I realized at the time. He was attempting to understand the operation of complex molecules in nature’s grand scheme, particularly those in biological systems. He pointed out that valence and bonding concepts of molecular function tended to represent little more than fixed conditions, and chemical equations little more than change of one compound into another. What was needed, he stressed, was a picturing of the dynamic and continuous operations in nature’s ongoing system. George was evolving for himself some views about molecular operation in terms of proton numbers and symmetry in atoms and molecules. Using deoxyribonucleic acid (DNA) as a prototype molecule, with precisely the same atoms considered by the valence chemistry approaches, a lattice was constructed that permitted visualization of the kinds of features in molecules such as seem required for the information processing that so obviously takes place there. So far as information transport is concerned, George thought of energy (electrons) and information as synonymous. He spoke of pi-electron switches or throttles with capability to regulate and direct energy flow in conjugated molecular systems, of memory based on conditions of electron spin, of decision-making based in part on thermoelectric semiconduction capable of long range transmission of electronic perturbations within the system, and emotionality in terms of effective nuclear charge which in turn modulates the behavior of pi-electron fields.

These ideas were a satisfaction for they seemed to be getting toward an explanation of how information processing is done at all levels in organisms. I spent many lunch periods with George getting to understand his ideas. Although we did not know it then, a number of noteworthy papers on organic semiconductors were just appearing or were about to appear. In particular, I am thinking of the paper by M. Sugita, “Feedback Mechanism of Chemical Systems from the Viewpoint of Information Technology,” in The Progress of Theoretical Physics, 1961, and the Chapter by D. D. Eley, “Semiconductivity in Biological Molecules,” in Horizons in Biochemistry, edited by Kasha and Pullman, Academic Press, 1962, both of which provide references to related work.

The Need for a Cybernetic Society

Another person with whom I became acquainted at the AEC was Walter Munster. Walter had an interest in, and a concern about, information science as I had. He agreed that some kind of society was needed, even at this late period, because of the vast divergence and the vast potential of this new field. We both felt that benefit would come to the field, and to human society generally if efforts were made by those concerned to manage the developments in as responsible a manner as possible. Walter and I also spent many lunch periods together, among various other things, to get our heads as straight as we could, a glossary of cybernetic terms was prepared. Some of the terms, together with the definitions we accepted for them at the time, indicate where our thinking was and how our thoughts were running:

- **System:** A means for accomplishing a task.
- **Reflex:** A simple cause-and-effect stimulus-response process.
- **Brain (or ganglion):** An accumulation of cells or other entities used especially for information processing.
- **Information:** Unorganized facts and data.
- **Intelligence:** Organized facts and data.
- **Intellect:** The power of knowing.
- **Intuition:** Direct perception of truth.
- **Perception:** Comprehension by means of the senses or mind.
- **Mind:** The means by which we think, including memory and logic.
- **Mentation:** Information processing or thought; the business of mind.
- **Reason:** Explanation and justification of any act, fact, situation or condition.
- **Soul:** The essence of a being, including any attributes philosophy, values, principles acting to shape ethical and moral standards.
- **Epistemology:** The science of the grounds for knowledge, especially with respect to limits and validity.
- **Existential:** The state or fact of being, including the subjective.
- **Ethology:** The science of behavior, including personality and ego development and involving interdisciplinary approaches.
- **Fleuristics:** Discovery through exploration; organization and control plus direction.
- **Homeostasis:** The tendency toward steady state.
Will: Power coupled with choice.
Free will: Unhampered and uncoerced choice.
Freedom: Unconstrained by fate, necessity or coercion.
Happiness: A pleasurable feeling state involving satisfaction, confidence and relaxation.

Walter Munster and I talked with others of our colleagues in the AEC and with people in other Government agencies and in various institutions in the Washington area. We found concurrence in the idea that a cybernetic society might well be desirable and we took the initiative in calling a meeting to see what could be done. The first of many Soirees Cybernetiques was held at the Brookings Institution headquarters in Washington on February 11, 1964. Most of the Soirees that took place during the year that followed were held in my home. The February 11 meeting was attended by 20 people and they represented interest areas such as law, medicine, biology, business management, psychology, data processing, bionics, communication, etc. Walter Munster and I were prepared. Among other things, we had a resolution that contained direct wording:

Be it resolved that an association of cybernetics be formed with objectives as follows:
1. To stimulate and encourage clear and broad-gauge thinking with respect to cybernetic matters.
2. To disseminate views and opinions by means of a professional journal and by promotional work generally.
3. To serve as a focal point for formulation and implementation of constructive plans.

This was so much boiler plate, but arguments favoring the resolution were more interesting: (1) “Indications are that cybernetic and mind science developments will have an impact on human society as great and probably much greater than the Industrial Revolution”; and (2) “With intelligent utilization of cybernetic potential, whole new realms of advancement may be expected to open up before us, whereas with simple opportunistic application it could greatly disrupt, if not actually destroy civilization.” In the discussion, interestingly, one thought was that a cybernetics institute for research and teaching should be formed parallel to an organized society or association, and sponsored by one or more universities.

Attention was directed to the emerging role and the probable impact of cybernetics (then defined more inclusively as “communication and control in organisms—plants as well as animals—in society and in machines”) as a science and a discipline. Stress was laid on the view that those in the information sciences fields owed it to themselves and to the general public to assume a positive role with respect to developments. Soon there was concurrence in the idea that action steps should be taken. A working committee was formed and plans for other meetings drawn.

The founding of ASC

In time the working committee was transformed into the first Board of Directors, and the membership war was as follows: Robert Livingston (neurophysiologist, NIH), Douglas Knight (IBM administrator), Donald Michael (sociologist), William Moore (Washington attorney), Jack Ford (CIA strategist), Walter Munster (nuclear engineer, AEC), and myself (experimental radiobiologist, AEC), Chairman. In time a Charter and By-Laws were hammered out.

An early draft for a Charter contained the following preamble statements:

In the predawn of Century 21, Man's greatest challenge is that of how Man will himself deal intellectually with his own intellectual achievements. There is need for a new enlightenment— one enabling Man to live with his discoveries and creations, and one assuring comprehension and application of these for the enrichment of human life.

Because of availability of knowledge making possible the control of disease, development of resources, increase of productivity, elimination of drudgery, management of populations, improvement of heredity and establishment of ethical standards, the Human Species could have for itself almost any standard and level of living it would choose to specify. Moreover, because of the rapid emergence of information science and automation, completely unimagined realms of pursuit, advancement and exploration lie just ahead. It is evident nevertheless that without prudent choice of direction, Human Progress will not only be checked, the whole of Civilization will be plunged into the abyss of annihilation. Without positive orientation, the fine line between advancement and deterioration—between advancement and destruction—grows narrower.

The above words were lifted almost directly from my “Information per se” paper. In retrospect, it is clear that my thoughts at the time were influenced by fears of the success of science as well as the prospects of untold advances. I had lived through the post-World War II period and had functioned as leader of the Oak Ridge Engineers and Scientists group (the so-called Atomic Scientists at Oak Ridge) which had expressed such great concern about the uses to which atomic energy would be put. As Co-leader of the first Atomic Bomb Casualty Commission to Hiroshima and Nagasaki in 1946, I had witnessed firsthand what can happen to whole populations of people when the might of science is brought to bear. One of my strongest reasons for wishing a Society for Cybernetics was to see concerned people in the information science field doing what they can in an organized way to prevent the irrational and diabolic application of the achievements of science.
Strengthening the Nuclear Nonproliferation Treaty

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Editor's Note

Here is an article which lays out a vital set of issues with profound consequences for the world. Professor Kobe's approach is rational and discursive, exposing as he goes, pervasive problems of goal definition, regulation and control, deviation sensing and feedback and still other concepts readily recognizable as cybernetic in nature.

Kobe's pleas for studies, analyses, figures-of-merit and other grist for the regulation mill seem a pointed challenge to cyberneticists. Where is cybernetics now that we need it? Is it up to the task? Here, certainly, is an opportunity to find out. Who will take up the challenge?

Introduction

It is 1984. Twenty-five countries have nuclear weapons and their means of delivery. A series of nuclear explosions devastate the ten largest U.S. cities in one day. Against whom should the U.S. retaliate?

Such a scenario points out poignantly one of the dangers inherent in the proliferation of nuclear weapons. The concept of deterrence of nuclear war through selective retaliation would be inoperative in such a world, and a country could use nuclear weapons to initiate a war to destroy its enemies if it felt that it would escape a retaliatory attack. In addition, the danger of nuclear war by accident, miscalculation or insanity would be increased. The theft of nuclear weapons by terrorists and criminals could lead to nuclear extortion and senseless destruction.

Recognition that the proliferation of nuclear weapons would be a destabilizing factor in the world and would increase the chances of nuclear war lead to the signing of the Treaty on the Non-proliferation of Nuclear Weapons (NPT) in 1968. The NPT entered into force in 1970, a quarter of a century after the first atomic bombs were dropped, when it was ratified by the U.S., the U.S.S.R., Great Britain and over 40 other governments. Its purpose was to reduce the chance of nuclear war by preventing the horizontal spread of nuclear weapons to countries other than the five nuclear weapon countries, which are presently the permanent members of the U.N. Security Council. At the same time, the treaty calls on the nuclear weapon countries to end the "vertical proliferation" of nuclear weapons, i.e., their increasing technological sophistication, testing, manufacturing and stockpiling, with the ultimate goal of their elimination from national arsenals under effective international control.

Because of the recent energy crisis, more countries want to develop nuclear energy for power production. A country with a highly developed peaceful nuclear technology will find it easier to exercise its option to make nuclear explosives for: 1) peaceful purposes, such as excavation and mining; 2) purposes of national prestige and status; and 3) an increased feeling of security. While these reasons are to a large extent illusory, they seemed to be sufficient for India, which exploded a nuclear "device" a little over a year ago. It now appears that during the next few years Argentina, Brazil, Egypt, Israel, South Korea, Libya, Pakistan, South Africa, Spain and Taiwan may follow the Indian example. Of these countries, Egypt, South Korea and Libya have signed the NPT, but not ratified it. Only Taiwan has ratified the NPT, but according to Article X any party may withdraw after a three-month notice if it feels that "extraordinary events... have jeopardized the supreme interests of its country." A review of the background for this situation and the present status of the nuclear proliferation problem has been given by Epstein in Scientific American (232(4): 18, April 1975).

This year, five years after the NPT first went into force, a conference was held in Geneva under the terms of the treaty to review its operation and to assure that its purposes are being realized. Of the 96 parties to the treaty, only 58 attended, along with
seven signatories who have not yet ratified, and seven non-signatories as observers. The lack of attention which such a potentially significant conference received is indicative of the weakness of the treaty.

Peaceful Nuclear Explosions

Article V of the NPT calls on the nuclear-weapon countries party to the treaty to share the benefits of nuclear explosions for peaceful purposes with the non-nuclear-weapon countries. In 1968 when the NPT was first signed there was considerable optimism regarding the peaceful uses of nuclear explosions for such things as excavation of harbors and canals, and the development of natural resources. Excavation with nuclear explosives has been used in the U.S.S.R., but the U.S. has not considered such use feasible.

Studies of the most promising uses of peaceful nuclear explosions (PNE's) which are: 1) the preparation of oil shale for in situ retorting; 2) stimulation of the flow of natural gas in rock formations of low porosity; and 3) creation of storage caverns for gas and oil have recently been made by two groups in the U.S. Without taking political questions into account, the conclusion was that conventional methods are generally superior, although a general consensus among the governmental agencies involved (ERDA and ACDA) was not reached.

A recent proposal for PNE's suggests that energy from fusion bombs can be harnessed by exploding them in large cavities in salt domes which are partly filled with water. The water would be converted into high temperature steam when an H-bomb was exploded in the cavity. The heat from the steam can be recovered by passing it through heat exchangers and fissionable isotopes of uranium and plutonium which were bred in the explosion can also be recovered. For 2000 megawatts of power it is estimated that two 50 kiloton bombs per day would be required. Whether or not the proposal is economically feasible will depend on the stability of the cavity in the salt dome, the cost of H-bombs and other technical questions.

As long as there are novel proposals for PNE's, there is further motivation for a country to develop its own indigenous nuclear explosive capability in order to be independent of the nuclear-weapon countries. Some countries maintain that the nuclear-weapon countries have not or will not share their full knowledge of the peaceful applications of nuclear explosions with the rest of the world in order that they may retain their nuclear superiority. Ostensibly, the Indian nuclear test is part of a program to study the peaceful uses of nuclear explosives, and to keep abreast of the technology. Even the U.S. and the U.S.S.R. recognize the use of nuclear explosions for peaceful purposes, and specifically exempt them from their so-called threshold test ban agreement of 1974. Since a nuclear explosive which is used for peaceful purposes can also be used for military purposes, the testing of nuclear explosives for peaceful purposes provides a convenient cover for the development of nuclear weapons.

A thorough study of PNE's should be made by an international group of experts in various disciplines. They should critically evaluate the results of all tests carried out thus far for peaceful purposes, as well as all new proposals for PNE's, to see if any of the proposed peaceful uses of PNE's would be superior to conventional methods from the standpoint of cost, effectiveness, safety, health and environmental impact. If it turns out that in virtually all situations conventional methods are superior to nuclear explosives, the testing and use of nuclear explosives for peaceful purposes should be banned. If, on the other hand, there are any possible peaceful uses, then they should be carried out under an international authority. Since the negotiation of a complete and universal test ban would be a big first step in ending the arms race, PNE's should be banned if their advantages over conventional methods are not overwhelming.

The Arms Race

To eliminate the vertical proliferation of nuclear weapons, Article VI of the NPT calls on each party:

- to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a treaty on general and complete disarmament under strict and effective international control.

Although the language of Article VI is weak, its spirit and intent is clear, especially in the context of the Preamble. The extent to which the nuclear-weapon countries have met their obligations under Article VI has been discussed recently by Epstein and some recommendations have been made. There is general dissatisfaction among the non-nuclear-weapon countries regarding progress toward ending vertical proliferation, since they feel that the nuclear-weapon countries are not living up to their obligations under the NPT.

The so-called threshold nuclear test ban treaty, signed by the U.S. and the U.S.S.R. on July 3, 1974, is viewed by many as a step backward. It permits unrestricted underground testing until March 31, 1976. After that time tests of up to 150 kilotons will be permitted, which exceeds in size most of the tests conducted in recent years, and testing for "peaceful purposes" is exempted. Since tests of 12 kilotons or less can be distinguished from earthquakes, 150 kilotons can hardly be called a "threshold." It is also possible to test larger weapons at less than their full yield, so the agreement does not in practice limit development of nuclear weapons. A comprehensive agreement on the banning of all underground tests, as
called for many times during the last decade by the U.N. General Assembly, would greatly reduce the technological spiral of increasingly sophisticated nuclear weapons. The fear of a "technological breakthrough" would continue to give impetus to weapons research, but without testing there would be no certainty that a new idea would work in practice. If such a test ban were negotiated between the U.S., U.S.S.R. and Great Britain there would be pressure on France, China and India to agree also.

The intention to pursue strategic arms limitation talks (SALT) was announced by the U.S. and the U.S.S.R. upon the signing of the NPT on July 1, 1968, but they did not begin until November 1969. These talks have not dealt with nuclear disarmament per se, however, or even ending the nuclear arms race, but rather have sought the elusive goal of increased stability through an institutionalization of the arms race.

In a review of negotiations since World War II, L. J. Carter in articles in Science, points out how opportunities for the complete prohibition of all anti-ballistic missile (ABM) systems and multiple independently-targetable re-entry vehicles (MIRV) were lost. The principles established at Vladivostok in November 1974 may lead to an agreement for SALT II, but permit the U.S. and the U.S.S.R. to have even more weapons than they now have. The purpose of this surprising agreement is to reach a base level from which future arms reductions could presumably be made. However, some critics think that the new base level will only be a level to which additional new types of armaments will be added. Critics call for a phasing out of all ICBM's, containing submarine launched ballistic missiles (SLBM) and bombers for deterrence, since the ICBM's could be destroyed by a first strike. They also call for a gradual reduction of missile and bomb tests. It is easy to understand how the non-nuclear-weapon countries would accuse the U.S. and the U.S.S.R. of not negotiating "in good faith," but that alone should not be a sufficient reason for their withdrawal from the NPT.

Peaceful Uses and Safeguards

The energy crisis has increased the interest in nuclear fission reactors as a means of alleviating the shortage of petroleum and other fossil fuels. More countries will find nuclear power reactors economically competitive with fossil fuels. They also want to be relatively independent of other countries in their energy production. Under Article IV of the NPT each country party to the treaty has an "inalienable right to develop research, production and use of nuclear energy for peaceful purposes without discrimination..." This also permits countries party to the NPT to cooperate with other countries, whether or not parties to the NPT, to develop nuclear energy for peaceful purposes.

However, under Article III, the non-nuclear-weapon countries party to the NPT agree to accept safeguards, under the supervision of the International Atomic Energy Agency (IAEA), to prevent diversion of nuclear material for weapons from all peaceful nuclear activities, Nuclear-weapon countries are exempt from this article, which is one of the basic asymmetries in the treaty.

It was under Article IV that the Nixon Administration announced in June 1974 that it had offered to sell 600 megawatt nuclear reactors to both Egypt and Israel. Egypt, a signatory to the NPT, is not likely to ratify it until Israel has. Although strict safeguards were to be attached in the sales agreement, they would apply only to the nuclear reactors sold. A country party to the NPT, however, has to accept IAEA safeguards on all of its nuclear programs. Thus, the United States in agreeing to sell these reactors, capable of producing plutonium from which weapons could be fabricated, has undermined the NPT by showing that countries not party to the NPT can obtain all the advantages of Article IV without the safeguards and controls imposed by Article III on all nuclear facilities.

To strengthen the treaty, Adlai Stevenson III proposes that the U.S. should not sell nuclear reactors and technology to any country unless it agrees to accept the IAEA safeguards on all its nuclear facilities. Other nuclear technology exporting countries should be encouraged to adopt the same policy.

A recent deal between West Germany and Brazil emphasizes problems connected with Article IV. West Germany, a party to the NPT, has agreed to sell Brazil, which is not a party, a $4 billion package involving all aspects of the nuclear fuel cycle. The package includes, in addition to nuclear fuel reprocessing facilities from which plutonium can be recovered, uranium enrichment facilities based on the jet nozzle principle. The deal is perfectly legal under the NPT and IAEA safeguards are required. However, with the experience gained from these operations, Brazil will soon be able to make its own uranium enrichment plants which will not have to be under IAEA safeguards. Brazil, with vast natural resources, has affirmed the right of a country to test nuclear explosives for peaceful purposes.

The right to use nuclear explosives for peaceful purposes has also been affirmed by Argentina, which has not signed the NPT either. It has recently been reported (Newsweek, July 7, 1975, p. 27) that without IAEA knowledge, 50 kilograms of plutonium waste was removed from an Argentine reactor. This incident emphasizes the need to strengthen the IAEA safeguards and to increase its inspection team from the present 67 inspectors. Only ten days after the Indian nuclear explosion on May 18, 1974, Argentina and India entered into an agreement to share nuclear technology for peaceful purposes. Argentina and Brazil have long had a rivalry and the first one to test nuclear explosives would have an inside track for South American
hegemony.

South Africa, a country with large deposits of uranium ore, is developing a uranium enrichment plant based on the jet nozzle principle. Not a party to the NPT and faced with neighbors perceived to be hostile, it has a motive for building nuclear weapons. Since it will presumably sell its enriched uranium to other countries for reactors, a nuclear explosion "for peaceful purposes" would dramatically publicize the quality and potential of its product, as well as giving a warning to its neighbors. A number of countries in Black Africa have not signed the NPT either, and faced with a nuclear-armed South Africa, would also feel the need to acquire nuclear weapons.

From a complete nuclear power program, which includes fuel reprocessing and uranium enrichment, the nuclear explosive option can be developed relatively easily. In order to reduce the chance that this option would be utilized, it has been suggested that Regional Nuclear Centers be established under IAEA supervision in various parts of the world to process and enrich nuclear fuel. The reduced cost of such an arrangement would be an incentive for some countries to accept something less than complete nuclear autonomy, but in this day of rampant nationalism it would appeal only to those countries which would not otherwise be able to afford nuclear energy. Additional inducements, technological, economic and political should be used, however, to increase motivation for all the countries in a region to join in regional nuclear fuel processing. These centers should be under international control. They can take steps to insure that the fabrication of nuclear weapons from the reprocessed uranium and plutonium would be as difficult as possible. Thus, theft of the fissionable material by terrorist and criminal groups after processing would be discouraged.

The nuclear-weapon countries will undoubtedly be the first to have a large number of nuclear reactors for commercial power. Krieger has pointed out that these reactors are, in effect, "Trojan horses" because of their vulnerability to attack or sabotage by a hostile country or terrorists, with subsequent release of large amounts of radioactivity. Although an attack or sabotage would be extremely serious in terms of loss of life and property contamination, it should be no worse in most cases than the worst possible accident involving a core meltdown and a subsequent loss of containment. For a 1000 megawatt light-water reactor, it has been estimated that on the average 169 deaths would follow immediately, while perhaps another 15,000 cancer deaths and 3000-20,000 genetic defects would follow from such an accident. These figures are sobering, and would call for increased security and safety of nuclear reactors, and their underground construction.

It would be ironic indeed if nuclear reactors, heralded to bring the peaceful benefits of nuclear energy to mankind, were to become the "doomsday machines" of the future. Unless a moratorium on nuclear reactor construction is declared, as Krieger suggests, all the countries in the world will soon be vulnerable to this kind of radiological warfare. An admission of this problem may hopefully cause more cooperation between the nuclear and non-nuclear weapon countries.

Transfer and Manufacture of Nuclear Weapons

The nuclear-weapon countries, defined by the NPT to be countries with nuclear weapons prior to 1967, are forbidden by Article I to transfer nuclear weapons to any non-nuclear-weapon country, or to aid them in developing nuclear weapons. On the other hand, in Article II the non-nuclear-weapon countries are forbidden to receive nuclear weapons from the nuclear countries, or to manufacture nuclear weapons. These two articles reflect further the basic asymmetry in the treaty between the nuclear and non-nuclear weapon countries.

In fact it was soon realized that non-nuclear-weapon countries could be liable to nuclear extortion or attack by countries with nuclear weapons, and that a security assurance was required to supplement the NPT. To this end the U.N. Security Council in 1968 adopted Resolution No. 255 which says that in case of nuclear aggression or its threat, the U.N. Security Council would act in accordance with the U.N. Charter. In addition, it says that the Security Council welcomes the intention of certain nuclear-weapon countries to go to the aid, in accordance with the U.N. Charter, of any non-nuclear-weapon country party to the NPT which is the victim of nuclear aggression or its threat. The resolution has been criticized for doing little more than reaffirming the U.N. Charter. The U.S., for example, has been reluctant to give neutral countries the same protection that she gives to her staunchest allies. Thus, some unaligned country, like India, may well feel that only if it has its own nuclear weapons will it be safe from nuclear extortion, blackmail or aggression.

If all the nuclear-weapon countries would pledge never to use or threaten to use nuclear weapons first and to go to the aid of any non-nuclear-weapon country which is a victim of nuclear extortion, blackmail or aggression, the non-nuclear-weapon countries would feel more secure. The Soviet Union and China have already made unilateral declarations of renunciation of the first use of nuclear weapons. The U.S. has maintained the right to the first use of nuclear weapons in order to deter a Soviet attack on Western Europe. To this end, even tactical nuclear weapons have been developed and deployed for possible use in Europe. Since the NATO forces have fewer men and conventional weapons than the Warsaw Pact countries, nuclear weapons have been used to restore the balance. Although there are good political and military reasons for keeping the nuclear option open for Europe, the
overall effects of denuclearization of international relations should lead to a less dangerous, and presumably more stable and peaceful world in the future. The stability of Europe or any other part of the world should not depend on the possible use of nuclear weapons, with their disastrous consequences. Further negotiations on controlled troop reductions and nuclear withdrawal in Europe should be pursued.

A sincere effort should be made to remove the basic asymmetry in the NPT between the nuclear and non-nuclear-weapon countries, with the eventual aim of treating all countries on an equal footing. To this end the proposal by the U.S. to place all non-military nuclear installations in the nuclear-weapon countries under the supervision of the IAEA should be pursued. A ban on the use of all fissionable materials for military purposes should be negotiated. Together with a freeze on nuclear armament levels and a ban on all nuclear explosive testing, the incentives for another country to develop nuclear weapons would be reduced. Eventually negotiations for the destruction of stockpiles of nuclear weapons could be carried out. In 1971 the Convention on the Prohibition of the Development, Production, and Stockpiling of Bacteriological [Biological] and Toxic Weapons and on their Destruction was signed. Hopefully nuclear weapons will be added to this treaty in the not too distant future.

Conclusions and Recommendations

This paper has been concerned with the principal articles of the NPT, some of their weaknesses, and some proposals for strengthening them. The conclusion and recommendations of this paper are similar to the ones made by the Divonne (France) Conference held in 1974 under the auspices of the Arms Control Association and the Carnegie Endowment for International Peace which were recently published.

The main recommendations of the present paper are as follows:

1. A study of the peaceful uses of nuclear explosives should be made. If there are advantages of using nuclear explosives over conventional methods, they should be carried out under an international authority.
2. A ban on the testing of all nuclear weapons should be negotiated. Testing for peaceful purposes, if necessary, should be carried out under an international authority.
3. The nuclear-weapon countries should do more to negotiate arms control agreements aimed at making the world stable and safe.
4. The nuclear-weapon countries should adopt a policy not to be the first to use nuclear weapons. They should agree to give assistance to any country which is a victim of nuclear extortion, blackmail, or aggression.
5. When a country not a party to the NPT buys nuclear technology, safeguards under IAEA control should apply to all of its nuclear facilities.
6. Safeguards should be strengthened to prevent diversion or theft of fissionable materials.
7. Regional fuel reprocessing plants under international control should be encouraged to prevent any country from having all aspects of the nuclear fuel cycle under its own control.
8. The nuclear-weapon countries should cooperate in removing the asymmetry in the treaty and put themselves under the same kind of controls that the non-nuclear-weapon countries have.

These recommendations—if adopted—and others, could strengthen considerably the NPT so that it could gradually become an instrument for the promotion of peaceful nuclear technology and for the abandonment of weapons development by all nations. The alternative is nuclear anarchy.
Much of what is said about multinational corporations draws from a well of emotion which reflects fear and mistrust of agencies apparently operating free of world system constraints. Paul Kainen proposes a less gloomy and more functional way of regarding multinationals and their relation with the world.

—The Editor

Introduction

There is a fundamental duality in nature, which is the archetype of mathematical duality, imbuing many phenomena with two quite different interpretations. For example, in biology we now regard species interaction as symbiotic-cooperative rather than aggressive-competitive. That is, we no longer view the world as an arena in which species battle for survival with natural selection turning thumbs up or down. Instead, the world is seen as a stage on which species dance ecologically together in creative synthesis. The pertinent data base is essentially unchanged despite recent advances in microbiology and genetics. It is our interpretation of the information—and this is a critical distinction—which has been altered.

Similar examples occur in physics (wave vs. particle interpretation of light). Even in history there has been a radical change in perception achieved by viewing history as an aggregation of small private lives rather than a panorama of vast impersonal forces.

In fact, cybernetics itself could be seen as a similar type of reversal. Instead of saying that intelligence creates system (an essentially Aristotelian framework), the cyberneticist looks at intelligence as the artifact of the system.

Duality and the Corporations

What has all this to do with multinational enterprise? The connection, while indirect, is significant and that is what I would like to explore in this article. My objective here is not to present new information or new economic insights but merely to indicate how this philosophical notion of duality, together with the system-theoretic idea of feedback mechanism, can suggest a changed conception of the role of the giant companies.

Duality can be applied directly to the multinational corporations by trying to regard even their least appealing aspects in a positive light. Some of these abuses have recently become headlines—huge slush funds, enormous bribes for foreign politicians, illegal political contributions at home—and possibly worse infractions lurk beneath the surface. The larger companies resemble in wealth, influence and power sovereign nations of no mean stature. Indeed, they are so powerful that they can often control the actions of governments.

But is this the unadulterated evil it may seem? All the evidence indicates that the giant companies operate solely from considerations of profit. They seek a climate of stability and international cooperation, low tariffs and world peace, in which to maximize their gains.

These goals, we repeat, are not altruistic but are calculated simply to increase profit. Thus, working from the axiom that only the bottom line counts, we can predict with reasonable accuracy the behavior of such cartels. Nations, on the other hand, are almost totally unpredictable, operating as they do on the basis of many conflicting motives.
Multinationals as a Deterrent to War

It can be argued that multinational corporations exploit underdeveloped countries for their cheap labor and raw materials. But by the same token the corporations need a friendly reception from the host country which can therefore obtain humanitarian concessions by economic means.

It can also be argued that the global companies owe no loyalty to individual states, carrying, like freighters, the flag of convenience. However, this too, is really an advantage. If Japan went to war with Brazil (God forbid!), would the giant Japanese corporations gloat over the smoking ruins of the plants in Sao Paolo? Thus, the very existence of the international corporations is a deterrent to war.

Feedback Mechanisms

Perhaps the best way to look at things is from the perspective of systems theory. The multinationals function as a feedback mechanism linking various components of the world economic system, transmitting technology and echoing economic climates. Weather in the Ukraine affects the cost of bread in the United States; an Italian invention facilitates the production of German steel.

The human body could not get along very well if its parts were autonomous and the various biological subsystems operated independently of one another. The circulatory network, among others, provides a feedback service. White blood corpuscles are manufactured and rushed to the scene of a mild infection since the blood would ultimately carry even a far-off infection in the big toe right back to the most vital organs.

Conclusion

If the multinational corporations function as a feedback mechanism in the best sense and if their profits are made directly dependent on the world’s social and political health, then they will bind together the nations of the planet into a single organism which is concerned with the well-being of each of its parts. For if a creature dies, does its blood survive?
Book Review

One of Many Faces of Cybernetics

V. G. Drozin
Bucknell University
Lewisburg, PA 17837


The face of cybernetics offered in this book is the one preferred by engineers and applied mathematicians. After five introductory chapters in which the concepts of movement, input, output, transformation, models analogue and mathematical, black box, dynamic system, phase space, stability, cycles, signals, coding, information and memory are introduced, ten chapters are devoted to control. They have the following headings: Control, Automatic Control, Optimal Control, Automata, The Computer, Adaptation, Games, Learning, Large Systems and Operational Control. The next three chapters deal primarily with psychological and biological aspects of cybernetics: The Brain, Organized Systems and Man and Machine—but also from the point of view of an engineer. In the last chapter the author expresses his views about future prospects of cybernetics. At the end of a chapter a few problems with solutions are offered as exercises.

The mathematical level of the book does not go beyond algebra but almost every chapter contains formulae. Numerous illustrations help the reader comprehend the text. At the end of the book a list of recommended readings for every chapter guides the reader's interest in further study. This book was first published in the U.S.S.R. in 1967; 40,000 copies were printed. The translator and the editor have produced a readable book. Although the editor eliminated irrelevant ideological references in the text he left this kind of reference in the list of recommended literature, and instead of original titles of some English works he left the reference to their Russian translation which is of little help to the English-speaking reader. I would recommend this book not only to engineers, but also to everyone interested in cybernetics who can go through the algebra of the presented formulae. It will help the reader get acquainted with some aspects of the cybernetic control theory and its various applications.
Conference Calendar

20-22 October 1975

26-30 October 1975
THIRTY-EIGHTH ASIS ANNUAL CONFERENCE, Sheraton-Boston Hotel, Boston, MA. Theme: Information Revolution. The meeting will examine the effects of the emergence of new computer network, communication and reprographic technologies as well as the accelerated growth of the research literature. Contact: Skip McAfee, Jr., ASIS, 1155 Sixteenth Street, N.W., Washington, DC 20036, (202) 659-3644.

22-23 November 1975
SPECIAL WEEK-END SYMPOSIUM on "Biofeedback, Meditation, and Self-Regulatory Therapies," co-sponsored by Albert Einstein College of Medicine and the Institute for the Study of Human Knowledge. Roosevelt Hotel, New York City. Contact: Mel Roman, Department of Psychiatry, Albert Einstein College of Medicine, 1165 Morris Park Avenue, Bronx, NY 10461.

17-19 November 1975
NATIONAL ORSA/TIMS JOINT MEETING on "OR/MS and Logistics," MGM Grand Hotel, Las Vegas, NV 89109.

3-5 December 1975

27-30 December 1975
EIGHTY-EIGHTH ANNUAL MEETING of the American Economic Association, Dallas Statler Hilton, Dallas, TX. Includes joint sessions with Allied Social Science Associations, such as American Finance Association, Association for Social Economics, Industrial Relations Research Association, Econometric Society, Association for Comparative Economic Studies, etc.

29-31 March 1976

20-23 April 1976
THIRD EUROPEAN MEETING ON CYBERNETICS AND SYSTEMS, Austrian Society for Cybernetic Studies, at the University of Vienna (Main Building), Vienna, Austria. Papers (accompanied by abstracts) should be mailed so as to be received no later than 1 December 1975. Address of the Organizing Committee: Schottengasse 3, A-1010 Vienna 1, Austria.

12-15 May 1976
23rd INTERNATIONAL TECHNICAL COMMUNICATIONS CONFERENCE of the Society for Technical Communication on "Communications '76—Meeting the Challenge of Economic Reality." Statler Hilton Hotel, Washington, DC.

16-20 June 1976
INTERNATIONAL FEDERATION OF AUTOMATIC CONTROL (IFAC) Symposium on "Large Scale Systems Theory and Application," Udine, Italy. Special attention will be given to the application of the theoretical tools and techniques for solving practical problems arising in: industrial process control; information processing; bioengineering; economic systems, environmental dynamics and control; agricultural systems; power systems; systems for management and administration. Contact: G. Guardabassi, Istituto di Elettronica, Politecnico di Milano, Piazza Leonardo da Vinci 32, 20122 Milan, Italy.
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Dr. Drozin is Professor of Physics at Bucknell University in Lewisburg, PA. He holds a Physics diploma from the University of Göttingen, Germany and a Ph.D. from Columbia University, New York. Dr. Drozin's present research interest is the application of cybernetics to social problems and to automation of the teaching-learning process, particularly the correlation between biopotentials of a learner and his degree of concentration.

PAUL S. HENSHAW
Dr. Paul Henshaw received his doctoral degree from the University of Wisconsin in 1930. He has enjoyed a diverse and productive career in biophysics, medicine and human behavior. His list of publications includes 75 articles and a number of books, ranging over such fields as radiation effects, fertility, birth control and mental health. Dr. Henshaw is now Visiting Scholar associated with the Isotopes Geochemistry Laboratory, Department of Geosciences, University of Arizona, Tucson.

RICHARD H. HOWE
Richard Herbert Howe obtained his degree from the University of Illinois in 1971. Since that time he has worked as a freelance writer, editor, and translator here, in Germany and in Canada. He has been associated with the Biological Computer Laboratory, Department of Electrical Engineering, University of Illinois, Urbana, since 1969.

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Dr. Harold K. Hughes returned to college teaching (physics and mathematics) in 1974 after a career in business administration and five years as Vice-president for Academic Affairs at State University of New York College at Potsdam. He holds 18 patents, is the author of numerous publications and has served the ASC in several capacities since 1967.

PAUL G. KAINEN
Dr. Paul Kainen is Associate Professor of Mathematics at Case Western Reserve University in Cleveland, Ohio. He has taught at the Wharton School of the University of Pennsylvania and has been a consultant on several corporate research projects. He has written numerous technical articles and is co-author with Thomas Saaty of a new book on the Four Color Problem.

DONALD H. KOBE
Donald H. Kobe is a Professor of Physics at North Texas State University. He received his Ph.D. in Physics from the University of Minnesota in 1961 and was a Visiting Assistant Professor at Ohio State University for two years. During the 1963-64 academic year, he was a Fulbright Lecturer in Taiwan.

From 1964 to 1966 he was a Visiting Scientist in the Quantum Chemistry Group at the University of
Uppsala in Sweden, and from 1966 to 1967 he did research at the University of Copenhagen. Before coming to North Texas State University in 1968, he was a Visiting Assistant Professor at Northeastern University in Boston for one year. His interest in peace research began in 1959 with an investigation of a mathematical model of "catalytic war", a situation which could occur if nuclear weapons were possessed by many countries.

Call for Papers

The 1976 National Computer Conference will be held in New York 7-10 June 1976. Papers are needed in every area of Computer Science, Data Handling, EPD Applications, and Information Processing. Hither-to unpublished papers (six copies of the manuscripts) are to be submitted to the Program Chairman, Dr. Stanley Winkler, IBM, 18100 Frederick Pike, Gaithersburg, MD 20760. Deadline: 5 January 1976.
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The ASC CYBERNETICS FORUM is designed to provide not only cyberneticists, but also intelligent laymen, with an insight into cybernetics and its applicability to a wide variety of scientific, social and economic problems. Contributions should be lively, graphic and to the point. Tedious listings of tabular material should be avoided.

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Types of Manuscripts: Three types of contributions are considered for publication: full-length articles, brief communications of 1,000 words or less, and letters to the editor. Letters and brief communications can generally be published sooner than full-length manuscripts. Books, monographs and reports are accepted for critical review. Two copies should be addressed to the Editor.

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