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A PROPOSAL FOR A QUASI-COMPLETENESS TEST OF GENERAL SYSTEMS THEORIES USING COMPUTER-CONFERENCING AND COMPUTER DATA BASE SEARCHING COORDINATED WITH A PUBLIC MUSEUM EXHIBIT STRUCTURE

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ABSTRACT

A search for understanding of the instability of human civilizations in 1935 led to the hypothesis that we need engineers with sociological understanding working in industry to watch for clues as to how high technology civilizations break down. Various two and three dimensional charts were developed to visualize the relations between science, technology, and the humanities. Since 1954 with the cooperation of S.G.S.R. it has been possible to make more systematic charts to visualize the components of general systems theory. Now in 1979 a three-level computer data base of general systems knowledge is proposed to facilitate testing of hypotheses and to generate segments of a public museum exhibit. The indexing of the data bases would be keyed to sections of physical, astronomical, and living systems segments of the museum exhibit. Citizens could participate in computer-conferencing on the first level. Scientific society members could use both the first and second levels. Senior science advisors would edit what passes through to the third level to be made available to library computer search terminals.

INTRODUCTION

This paper is a mixture of systems science and autobiographical data for a specific purpose of providing academic sociologists with clues that might not otherwise be available to them. There is a conjecture that there is a sociological uncertainty principle similar to Heisenberg's uncertainty principle in physics. However, it appears that the sociological equivalent of Planck's constant is not a constant, but a parameter that varies with time and between different societies. When one makes observations of social systems, both the organization and the observer may be changed in the process. Therefore, I feel it is important to include enough autobiographical material to provide sociologists clues to use in their research on the sociological uncertainty principle.

I was in high school as the Nazis were coming to power in Europe. I wondered how the leading country of the world in the arts and sciences, namely Germany, could change so quickly into a barbarian society. For a long time I have felt there must be something lacking in our understanding of the relationship between technology and society that permits the highest technology to slip into the hands of the barbarians. I concluded that our country needed to have people who understand the social implications of new technology. To do this we needed to have engineers at the interface between science and technology who had some training in sociology who could analyse the social implications in addition to accomplishing their assigned engineering work. I decided that I would be one of those engineers.

ENGINEERING AND SOCIAL SCIENCE STUDIES

At U.C. Berkeley I majored in electrical engineering, and tried to include some social sciences, but found that in the 1936-1940 era it was not practical to obtain cooperation between the engineering and social science faculties. I found a semi-underground method of

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learning social science in addition to my formal training as an electrical engineer. The churches and student YMCA and YWCA at the borders of the Berkeley Campus had series of seminars on current social and political problems. By attending these off-campus seminars I gradually built up an understanding of the current problems in the social sciences. From these activities I developed a chart to help me keep a perspective of all the specialized fields of human knowledge such as is shown in Figure 1. This chart was useful to me in maintaining a perspective while I was working on the development of RADAR and related weapons systems in the earlier part of World War II (Wood, 1971). I was trying to maintain a "balance" or "wholeness" or "completeness," while putting my principal efforts on development of weapons to defeat the Nazis. I felt that the retreat to barbarism of Germany was not a special case, but a possible development in any highly specialized technological society.

SPECIALIZATION POINTS TO TAKEOVER BY BARBARIANS

The fundamental feature of a high technology society that makes it susceptible to breakdown and takeover by barbarians appeared to be the high level of specialization. If it were possible to develop a perspective of human knowledge that promoted the perception of overlaps between different fields of science, scientists and engineers might have a better chance of developing a sense of social responsibility. As a first step I tried to develop an improved perspective chart to replace Figure 1.

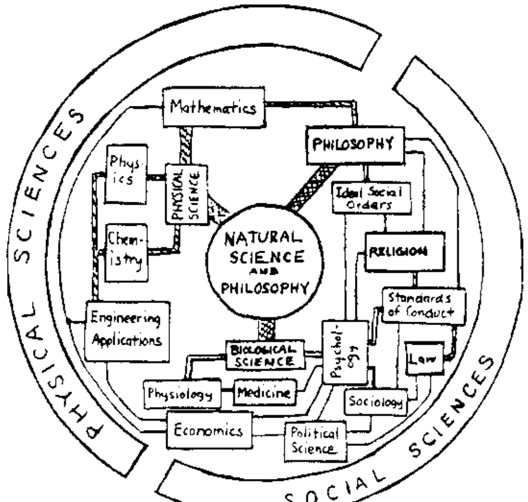

Figure 1. A Preliminary Attempt to Organize a Synthesis of the Specialized Fields of Science to Assist the Engineer in Developing an Interpretation of Science in Terms of Human Needs

I prepared cards for the topics and principal ideas considered by the young people's group at the Arlington Street Church in Boston for 1941-1942. Experimenting with a three-dimensional skyscraper model made from a toy "Erector" set, I found that the cards fitted a near optimum overlap of relationships when arranged to fit into the categories of Figure 2.

INTUITIVE SPIRAL RELATIONSHIP

I found that if the vertical columns of Figure 2 were transposed in certain ways there was an incomplete spiral connection between the topics in the skyscraper structure. Figure 3 illustrates the suggested form to develop the spiral form. Since my data were too vague, I put aside the spiral form. In the meantime I took the skyscraper model and my notes to some professors of sociology at Harvard University. They advised me that I was rediscovering the concepts developed by the early sociologists such as Auguste Comte, Herbert Spencer, and Lester Ward. My off-campus seminars on current sociological problems had not given me an adequate historical background in social science.

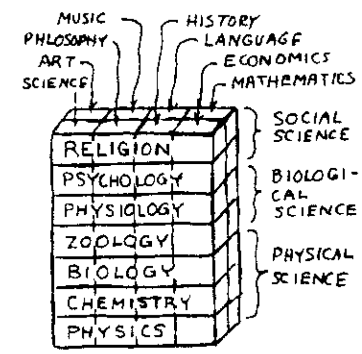

Figure 2. A Three-Dimensional Correlation

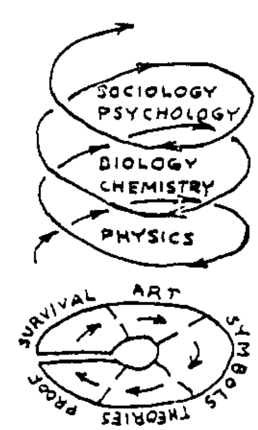

Figure 3. Spiral of Development

BACK TO SOCIOLOGY FUNDAMENTALS AND CIVIL LIBERTIES

It took some time to catch up on the history of sociology. Also, it took a few years of graduate study to obtain a Ph.D. in electrical engineering. In 1953 I took a job with IBM where I was again at the interface between new developments in science and the application of new technologies. I had planned to organize discussions of the social implications of new technology at the First Unitarian Church of San Jose. The McCarthy Era hysteria in the United States swept California along into a state supervision of churches such that religious organizations had to sign loyalty oaths to the government in order to retain their religious tax exemption. It took from 1953 to 1958 for the legal fight in the courts to get a favorable ruling from the U.S. Supreme Court that the California loyalty oath tax on religious organizations was unconstitutional. The court fight took a good deal of my spare time during that period.

SOCIETY FOR GENERAL SYSTEMS RESEARCH

The preliminary organizational meeting of the proposed Society for the Advancement of General Systems Theory in 1954 at the Center for Advanced Study of the Behavioral Sciences, Stanford, inspired me to renew my previous studies of the relationship between different fields of science. Figure 4 illustrates a checking chart for the social implications of computer-communications systems which would establish a universal credit system which could replace money (Wood, 1959).

EXTENSION TO COVER SCIENCES, ABSTRACT PHILOSOPHY, AND HUMANITIES

As I tried to extend this type of chart to other systems I found that the division between "Humanities" and "Science" was not adequate. I concluded that three divisions were more realistic, namely:

Humanities: Intuitive, Poetic, Artistic, etc.;
Abstract Models: Philosophical, Logical, Abstract, etc.;
Sciences: Empirical, Experimental, Verifiable, etc.

A revised three-dimensional chart using the above categories is shown in Figure 5 (Wood, 1964). In this chart there are five levels: physical, chemical, biological, psychological, and social. There are three slices representing three methods: humanities, abstract-philosophical, and empirical-scientific. There are four horizontal classes of activity: basic laws or science, engineering or applied science, education, and decision and action.

Figure 5 illustrates how my own work relates to the more general fields of knowledge and skills. I have noted on the chart on the physical level where my past work fits in, such as Radar, Cybernetics, Information Theory, Telephone Cables, Data Transmission with Error Feedback, Data Transmission Code Standards, and Computer Components and Programming. My original use of this chart was to plot possible spin-offs from the uses of cybernetics and information theory on the physical level to other levels. For example, there are similar negative feedback processes on each level of phenomena, but as we go from physical to social levels there is less and less mathematical precision. Similarly, there are entropy-like properties on each level. At the top level we have a possible correspondence between Albert Schweitzer's principle of "Reverence for Life" and some entropy-like property of a living system. Also, we can find properties of a political system in which an entropy-like measure gives us some understanding of the degree of democracy in the system (Wood, 1963). In the third column we have the property of information-input overload at all levels (Miller, 1960). In the fourth column we have a similar type of code in genetic coding as in what is called comma-free codes in electrical communication theory and in computer programming. On the psychological level there is a loose analogy to coding theory in the fragile equilibrium between "love" and "hate." In ideological coding we have the situation where people omit some facts about reality in order to have a simple concept of the world. This is similar to information compression without being able to precisely reconstruct the original message or picture accurately.

If widespread ideological coding occurs in political systems without being subject to test and verification, we are subject to possible future returns to barbarism, such as occurred in Germany in the 1930's. If we can correlate humanistic principles like "Reverence for Life" with computable entropy-like properties of social systems, we have a better chance of maintaining progress in human civilization with minor cycles of regression. I became impressed by the fulfillment of the predictions in the book Iron Heel by Jack London (1907) in the activities of the Nazis in Germany in 1934.

SPIRAL EVOLUTION IN CHEMISTRY AND SOCIOLOGY

I found an interesting book by Tomkeieff (1954) in which Mendeleev's periodic table of the chemical elements is transformed into a spiral form. This reminded me of the spiral form I described in Figure 3 and the possibility that the curves of social change of Sorokin (1948) might be projections onto a plane of a three-dimensional spiral. In January 1968, Bergson gave a talk to the Bay Area Group of S.G.S.R. at a meeting in San Jose where he described a spiral form of representing biological evolution that seemed to connect with the work of Tomkeieff and Sorokin.

At the S.G.S.R. meeting in Portland in September 1972, Bergson (1972) presented a paper on his spiral representation and Troncale presented a paper on

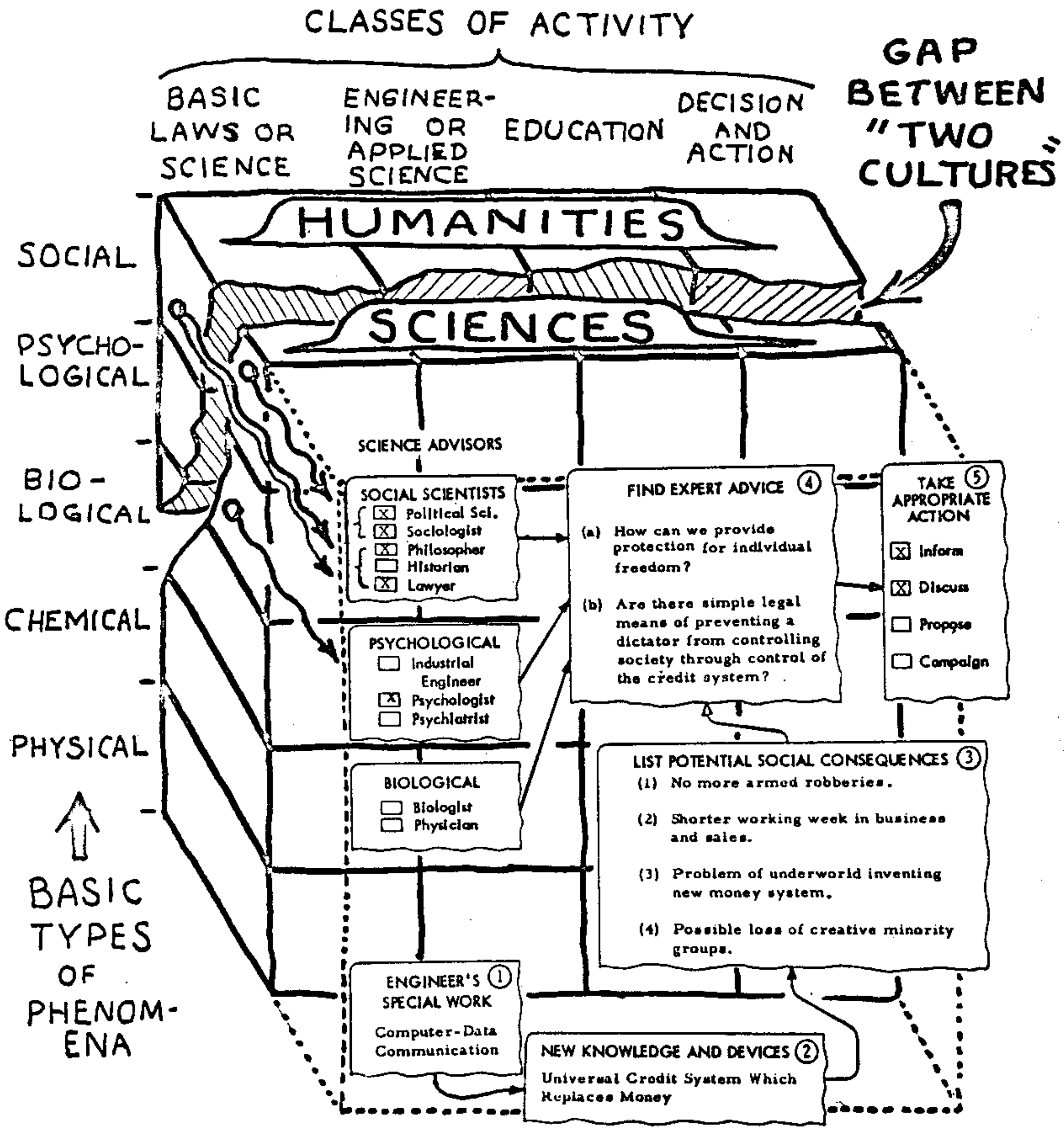

Figure 4. Extension of Three-Dimensional Chart to Visualize the Interaction of the Humanities and Sciences

hierarchies that resulted in spirals on a more universal scale (1972). Although these theories of spiral evolutionary curves are very important in the quality and stability of social systems, the primary purpose of this paper is to discuss the evolution of a quasi-completeness test for general systems theories. I think it is more expedient to direct attention to the particular variation of general systems theory for which we have the most information. I believe that J. G. Miller's Living Systems (1978) of 1102+xli pages and 173 cross-level hypotheses fits this category.

COMPLETENESS THEOREMS IN MATHEMATICS

Now to get back to the fundamentals of a completeness test, in engineering where we use mathematical series in the solution of problems that are defined by differential equations, we can confer with mathematicians

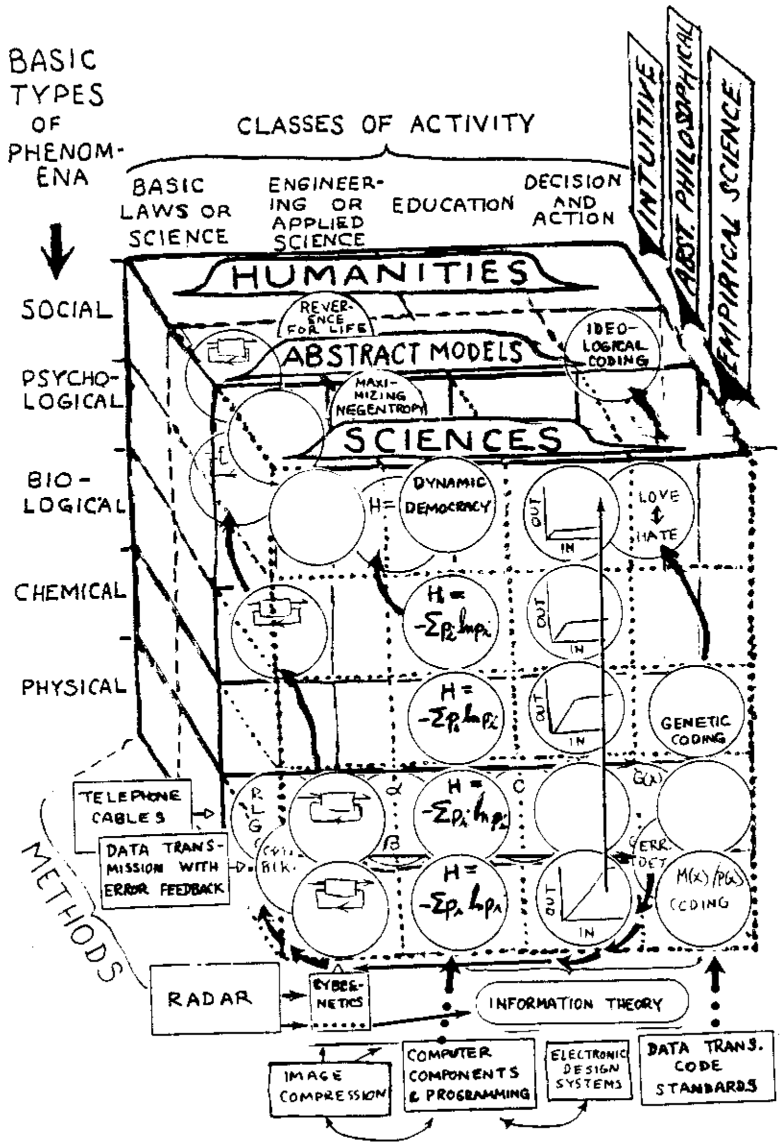

Figure 5. Relationship of my Own Work to the Three-Dimensional Chart of the Humanities, Abstract Models, and the Sciences

who can demonstrate a completeness theorem that tells us that the series we plan to use can represent a solution to our physical problem with any specified limit of error by using enough terms in the series. For example, the sawtooth waveform of Figure 6 has a decreasing error in Figure 7 when we use one, two, three, and four terms in the Fourier series representation.

I have learned from biologists that it is not possible to prove a completeness theorem for a mathematical model of a living system. I propose that we do the next best possible in testing systems hypotheses. I propose that we expand the three-dimensional chart of Figure 5 to use as checklist for making sure that we have feedback from all segments of society. The system must also be visible to the public, such as having exhibits in museums and libraries.

MILLER'S LIVING SYSTEMS

James G. Miller's book Living Systems (1978) is the most comprehensive book published to date applying general systems theory to living systems. Miller and his associates identify 19 subsystems of living systems on seven levels: cell, organ, organism, group, organization, society, and supranational system. He lists

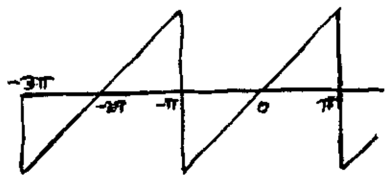

Figure 6. Sawtooth Waveform from Engineering to be Analysed by Fourier Series

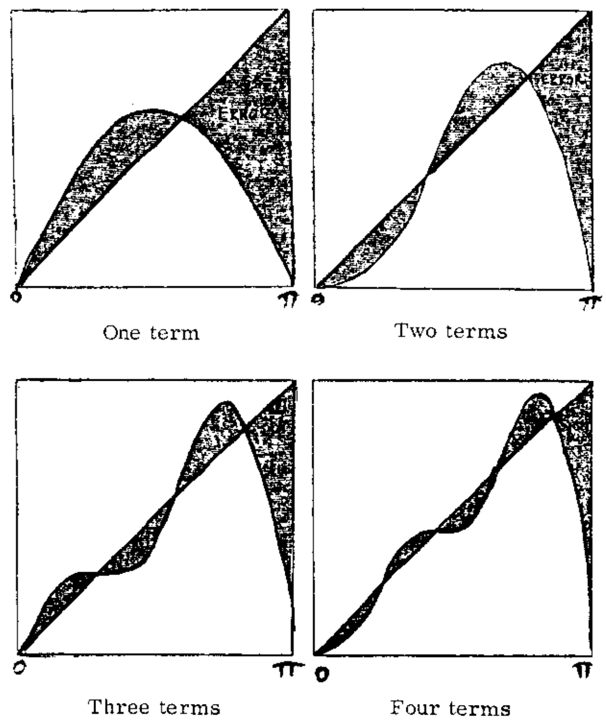

Figure 7. Error of Fourier Series Representation of Sawtooth Wave

173 cross-level hypotheses in language that is easily understood by biologists, communications engineers, and computer scientists. Of the 19 subsystems, two process both energy-matter and information, eight process matter-energy, and nine process information. These are listed in Figure 8.

I shall give some sample checks on the usefulness of Miller's Living Systems: (1) how organ level helps me in a systems analysis of my own health problems, (2) how on the organization level his hypotheses help me understand the problems of the organization (IBM), (3) how on the society level his hypotheses, with some additions, help us to understand problems of energy policy decisions, and (4) how scanning the humanistic-intuitive slice of the quasi-completeness testing chart turns up a

A) Subsystems which process both matter-energy and information:

1. Reproducer
2. Boundary

B) Subsystems which process matter-energy	C) Subsystems which process information
3. Ingestor	11. Input transducer 12. Internal transducer
4. Distributor	13. Channels and Networks
5. Converter	14. Decoder
6. Producer	15. Associator
7. Matter-energy storage	16. Memory 17. Decoder 18. Encoder
8. Extruder } 9. Motor } 10. Supporter	19. Output-transducer

Figure 8. Subsystems of Living Systems (Miller)

gap that needs to be filled in to insure a truly humanistic application of Living Systems.

First we consider that one or more replicates of Figure 8 fit into the front left column of Figure 5, a stack of two on the biological level for cell and organ; a stack of two on the psychological level for organism and group; and a stack of three on the social level for organization and society and supranational.

Earlier this year I had some eye trouble and a heart condition (tachycardia). I decided to do some research of the medical literature myself, and found that with my background of having studied Miller's Living Systems that it was much easier to select the right index terms in Index Medicus and the best computer search terms for a computer search of the Amsterdam, Netherlands, base Excerpta Medica computer files.

LIVING SYSTEMS AND MANAGEMENT SYSTEMS

In IBM for a number of years I have had confusing problems with IBM management. Sometimes I would receive conflicting messages from different lines of management in IBM, and my direct manager avoided the conflict. Following the articles in Behavioral Science upon which much of Living Systems is based helped me understand the nature of the communication problems in large organizations like IBM. In recent time IBM has successfully trained their managers to follow a standard procedure to avoid such conflicts. I have found the hypotheses in section 3.3.7 Decider in Living Systems helpful in understanding the confusion in the chain of command in IBM. Also, I have found some deficiencies in these hypotheses. It appears to me that the hypotheses were developed by social scientists on the outside observing large organizations. It appears that there are some phenomena that are only easily observed by people at lower levels of the management hierarchy.

For example, consider "Hypothesis 3.3.7.2-4: The signature identifying the transmitter is an important determinant of the probability of the receiver complying with it." I have seen policy decisions with the same authoritative signature take one day, one month, and eight years to implement. The one day action involved product production plans and were associated with assignments of matter-energy. The one month action involved hiring policies and was accompanied by the appointment of compliance officers to see that the decision was carried out. The decision taking eight years to implement was skipped over by most managers due to the information input overload conditions described in Miller's Chapter Five (1978) until some employees raised enough objections to force the managers to read the appropriate sections of the manager's manual and management briefings. The higher levels of management have now learned to transmit some energy-matter along with an information message so that the accounting for the money (energy-matter) will provide feedback on how the directive is being carried out. Some of these apparent discrepancies with hypothesis 3.3.7.2-4 can be partially explained by a combination of hypotheses 3.3.7.2-11, 3.3.7.2-13, and 3.3.7.2-16. I think that a corollary to 3.3.7.2-4 needs to be developed to cover these problems more simply. More can be gained by applying Miller's hypotheses 5.2-21 and 5.2-22 to the above problems. It is possible that I have missed seeing relationships of some of the 173 hypotheses to these problems.

RECOMMENDATIONS

The complexity of dealing with Miller's 173 hypotheses and the many other general systems theories listed by Troncale (1977) leads me to believe that we need the three following things to help us make quasi-completeness tests of GST/s:

(1) An open general systems theory computer conferencing network through which people, both professional and hobbyist, can communicate;

(2) A restricted computer conferencing network through which senior advisors elected by various scientific societies can review the work developed by the first network and select that which is sufficiently verifiable for inclusion in a general systems encyclopedic data base; and

(3) A three-dimensional framework upon which computer printouts from item (2) can be mounted in museums for inspection by the general public.

The connections between the above three parts are shown in Figure 9.

By means of the above recommendations, I propose that we become "on-line intellectual communities" in the sense discussed by Kochen (1977), which extended the computer-conferencing reviewed by Turoff (1974) and by Umpleby (1979). The use of the 173 hypotheses from Miller (1978) plus his classification of subsystems and his principal simulation models cited would provide a good start. To this data base we could add the major uncompleted work of the late Professors Dodd (1970) and Lamb (1970). Then we could add Haskell's (1972) and Bergson's (1978) differing spirals of evolution derived from the periodic table. Gordon Pask's systems science exhibit at the Brooklyn Children Museum inspires expansion to a more general concept of museum exhibits.

In 1907 the intellectuals ridiculed Jack London for his novel <u>The Iron Heel</u>, yet the essential features of social breakdown he described did occur by 1934. It is my hope that we can prevent the breakdown described by the novelist Sally M. Gearhart (1979) from coming to pass. We can make some progress by providing a computer terminal to Ritva Kaje, author of "Bringing the Feminine into Forecasting" (1977).

PROPOSED PUBLIC MUSEUM STRUCTURE

My attempts to place sections like Figure 8 in the appropriate cubes in Figure 5 led me to realize that although the 19 subsystems of Figure 8 appear on every level with few exceptions, that something, possibly the processes going on, increase on each higher level. This leads to a new three-dimensional diagram for use in testing the completeness of general systems theories. This new structure is shown in Figure 10.

Although my explorations of this method of a quasi-completeness test have so far been somewhat sketchy, I wish to mention two examples of trying out this type of procedure. One comes from studying the consequences of moving technology assessment procedures from the organization level to the society level. The other comes from trying to push the logical hypotheses over from the empirical slice to the humanistic slice.

SOLAR ELECTRIC EXAMPLE

The example of moving from the organizational level to the societal level relates to solar-electric power. The policy developed by ERDA and continued by DOE of projecting the development of solar semi-conductor cells such that a reasonable price will be obtained in 1985 has been described by Bacon and McWhorter (1975) and by Redfield (1978). The scientists at the Bellagio Conference chaired by Branscomb (1976) issued a concluding report in which the first goal was to "Improve the Process for Generating and Managing the Introduction

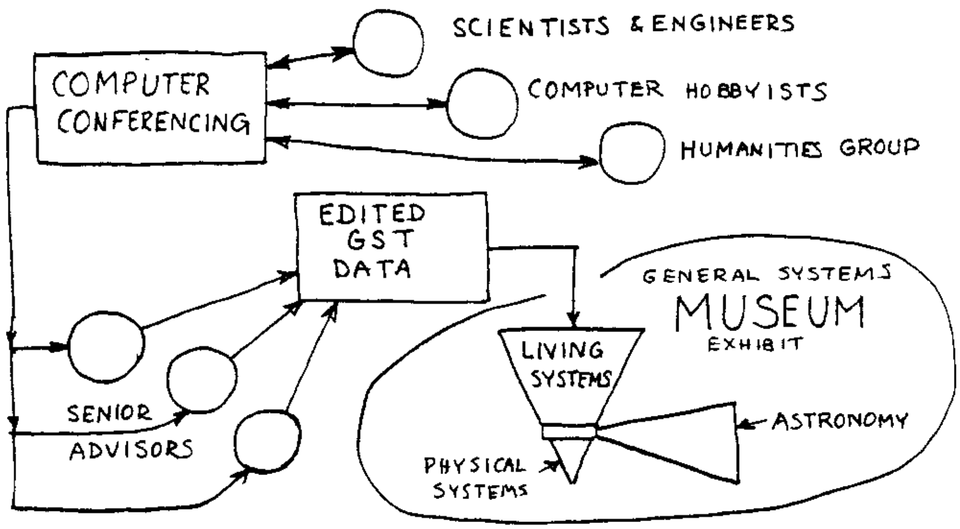

Figure 9. Computer-Based System of Updating Quasi-Completeness Tests of General Systems Theories and Producing Museum Exhibits

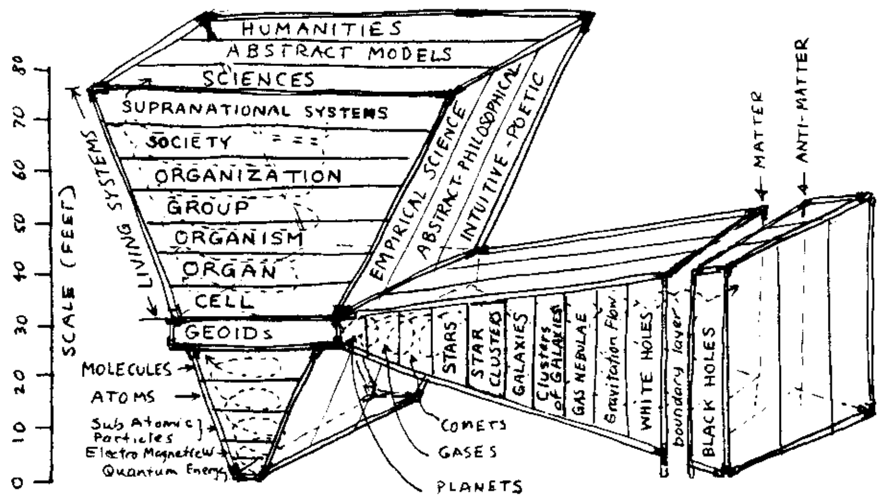

Figure 10. General Plan of General Systems Museum Exhibit

and Evolution of Technology." When I work with a background of using Miller's Living Systems with emphasis shifted through use of my concepts of a quasi-completeness test, I find that the DOE solar policy falls far short of the Bellagio Conference objectives.

The solar cell development projection curves are similar to the solid state circuit projection curves of 1964 upon which IBM based its computer policy development decisions which were correct decisions where one is limited to business and engineering efficiency. In 1964 a few IBM engineers objected strenuously that the decisions were blind to social consequences that many small businesses might fail in the ten years before low-cost microcomputers would be available to them. At that time there was no technical arm of Congress such as the Office of Technology Assessment to which the engineers could appeal.

The pursuit of the DOE solar policy postpones solar-electric generation until inflation has wiped out the independent middle class in the United States, making a generation of retired people dependent solely on social security after their savings are wiped out by inflation (unless they were foresighted enough to put most of their savings in land). There is a technology available now in the multimodule solar thermal electric plant designed by Otto J. M. Smith (1978) and described by Hart (1977) for which the buss-bar cost would be 3.1 cents per KWH in 1976 dollars or 3.6 cents in 1978 collars. Thus I feel that using a general systems approach to problems, provided one adds a quasi-completeness test, can greatly increase our understanding of technology assessment problems. Applying this quasi-completeness test to the Smith solar design indicates there is a land policy problem as to whether the federal government, the State, or public utility companies would own the land and what would the tax policy be.

EXTENSION TO FUZZY SETS

In reexamining von Bertalanffy's General System Theory (1968:246) we find the statement: "The Aristotelian logic, for millenia considered as giving the general and supreme laws of reasoning, actually covers only the extremely small field of subject-predicate relations. The all-or-none concepts of traditional logic fall short of continuity concepts basic for mathematical analysis." In about 1965 Zadeh presented an approach called "Fuzzy Sets" to the Bay Area Systems Group which shows great promise of providing a way of dealing with properties of social systems which do not have precise characteristics. For a summary of the significance of some developments in respect to fuzzy sets, a recent thesis by Hale (1977) reports on an entropy-based investigation of information, non-Newtonian systems theory, and the restoration of the excluded middle. We need to see how computer-conferencing systems can develop a connection between Miller's Living Systems and the recent work with fuzzy sets.

CONCLUSIONS

Although only a few of Miller's 173 hypotheses have been discussed in this paper, I feel that this pilot study indicates that the material in Living Systems would form a good starting base for computer-conferencing and for the living branch of a public museum general systems exhibit. It is important that the computer-conferencing and library data base systems not be restricted to any one computing system. The Lockheed DIALOG (1978) Information Retrieval Service has demonstrated how access can be obtained to 78 different data bases from any computer terminal through different communication networks such as TELENET, TYMNET, Teletype, or dial-up telephone service.

To make computer-conferencing more accessible without relying heavily on government and foundation funding, we need to develop interconnections with computer hobbyist networks. We could assume at a minimum each active member of S.G.S.R. could purchase his own microcomputer or convince his institution to make the equivalent available. Also, provision could be made for off-line members to order tape-cassettes or diskettes of parts of the conferencing and then return units with their comments to a central computer center to be entered into the system.

There are a number of museums across the country interested in including some type of computer service. We could get advice from places like the Exploratorium in San Francisco and the Lawrence Hall of Science in Berkeley on alternative ways to develop the exhibit structures.

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