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Advanced Machine Intelligence and Society

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Introduction

For about a hundred years, research scientists in medicine and psychology have been testing, defining, and theorizing about the nature of human intelligence.[2] Philosophers have speculated on the nature of the mind and its relationship to the human body for thousands of years. Research into the linkages between electronic devices and biological systems is a twentieth-century innovation, although speculation as to whether machines might be capable of thinking occurred earlier.[3] By 1980, popular magazines frequently featured smart machines or machines that think.[4]

I was fortunate to be one of eighteen American educators involved in a 1980 feasibility study jointly sponsored by the National Aeronautics and Space Administration (NASA) and the American Society for Engineering Education (ASEE).[5] We joined with fifteen scientists and engineers from the various NASA research centers and a number of scientists from American industry at the University of Santa Clara in California. The objectives were (1) to identify what progress might be feasible in computer technology toward reaching "machine intelligence" by 2000, (2) then to select and define a set of space missions that would exploit that level of machine intelligence, and finally, (3) to reconsider current NASA space missions programming in light of the study results. We were assisted in our study through interactions with representatives from Stanford University, SRI International of Menlo Park, California, and the Jet Propulsion Laboratory in Pasadena, California.[6]

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[1] This article, which has been updated for 2021, was first published as a book chapter in *The Systems Approach to Societal Problems*, ed. Stephen E. Stephanou (Malibu, CA: Daniel Spencer, 1982), 203-28.

[2] See J. P. Guilford, *The Nature of Human Intelligence* (New York: McGraw-Hill, 1967); John L. Phillips, Jr., *The Origins of Intellect: Piaget's Theory,* 2nd ed. (San Francisco: W. H. Freeman, 1975) for a tracing of this research.

[3] Pamela McCorduck, *Machines Who Think: A Personal Inquiry into the History and Prospects of Artificial Intelligence* (San Francisco: W. H. Freeman, 1979), Part I.

[4] A good example was *Newsweek*, of June 30, 1980 which featured an article on machines that think titled "And Man Created the Chip" (50-56).

[5] The breakdown of the group by disciplines was Astronomy-1, Business/Management-2, Computer Science-2, Engineering-1, Geology-2, the Humanities-2, Mathematics-3, Physics-4, and Psychology-1.

[6] The co-directors of the study, Professor Timothy J. Healy of the University of Santa Clara and James E. Long of the Jet Propulsion Laboratory, completed the Technical Summary in September 1980. This report is available at ntrs.nasa.gov/api/citations/19830007077/downloads/19830007077.pdf. For a summary of the study with an orientation toward the Republic of Korea, see Robert M. Krone, "Advanced Machine Intelligence: NASA Research and Korean Implications," *Korea Observer* (the Academy of Korean Studies) 12, no. 1 (Spring 1981): 3-29. Permission to use portions of this article for this discussion was kindly granted by the Academy of Korean Studies. See also Robert A. Freitag, Timothy J. Healy, and James E.

My discussion of advanced machine intelligence and its relationship to society uses the concept of machine intelligence formulated by this NASA feasibility study as a foundation.[7] It is not claimed that this is the only possible description of advanced machine intelligence—only that it is one that received a considerable amount of intellectual effort from a multidisciplinary group of scholars. Furthermore, universal consensus as to the precise definition and description of a machine intelligence that will exist in the future is not as important as the consensus that some form of such intelligence will be achieved. Nor are the conclusions and recommendations derived from the assumption that advanced machine intelligence will emerge highly sensitive to our accuracy as to its timing. Whether science and technology achieve the goal in the middle or the long term, it is useful to begin impact analysis now. For perhaps the most important independent variable influencing the outcomes of this phenomenon will be the quality of human management of the development of machine intelligence. There are dangers as well as opportunities inherent in the computer and information revolution the world has now begun. The specter of an autonomous technology sweeping humans toward undesirable futures should not be dismissed as trivial in the euphoria surrounding our rapidly rising capabilities.[8]

Advanced Machine Intelligence

Carl Sagan, in his brilliant work on human intelligence, *The Dragons of Eden,* predicted that "The next major structural development in human intelligence is likely to be a partnership between intelligent humans and intelligent machines."[9] No universally accepted definition of machine intelligence exists, and probably none will exist for the foreseeable future due to the state of scientific knowledge of human intelligence. The term "advanced machine intelligence" was selected by the 1980 NASA Study Group[10] to

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Long, "Advanced Automation for Space Missions," *Proceedings of the Seventh International Joint Conference on Artificial Intelligence,* Vancouver, BC, Canada, August 24-28, 1981, Vol. 2, 803-08.

[7] Neither this formulation nor any reference to advanced machine intelligence necessarily reflects the official position of NASA.

[8] For a development of this theme see Langdon Winner, *Autonomous Technology: Technics-Out-of-Control as a Theme in Political Thought* (Cambridge, MA: MIT Press, 1977).

[9] Carl Sagan, *The Dragons of Eden: Speculations on the Evolution of Human Intelligence* (New York: Ballantine Books, 1977), 236.

[10] The responsibility for producing a working definition of machine intelligence fell to the space exploration team of the study group. This was no easy task, as definitions are very sensitive to a particular scholars' worldviews and scientific expertise and interests. The entire team worked with this problem over a matter of weeks. The team members were Barbara Bernabe, Institute for Cognitive Studies, Rutgers University; Elizabeth Brackman, Department of Astronomy, University of Massachusetts at Amherst; Professor Jerry Gravander, Humanities Department, Clarkson College of Technology, Potsdam, New York; Professor Joel D. Isaacson, Department of Mathematics, Statistics and Computer Sciences, Southern Illinois University; Dr. Robert Krone, University of Southern California, team leader; Timothy Seaman, student in the Department of Electrical Engineering and Computer Science, University of Santa Clara; Dr. James

differentiate our views of future capabilities from the set of research directions now comprising the artificial intelligence field,[11] but the interdisciplinary nature of the subject makes agreement across the sciences impossible. Even within the NASA/ASEE Study Group, there were differing views concerning fundamental definitions as well as future directions. However, the working definition of advanced machine intelligence for the context of autonomous scientific investigation of extraterrestrial objects goes beyond Alan Turing's initial questions of "Can machines think?"[12] to the more operational ones of "Can machines observe environments?" "Can machines formulate new hypotheses about these environments and its observations?" "Can a total system be controlled, managed, and even adapted in light of the conclusions drawn from these new hypotheses?" and, finally, "Can machines do all this without direct intervention from humans?"

Working with these sorts of questions and drawing on the existing knowledge of cognitive psychologists, computer scientists, and philosophers of logic, the working definition of advanced machine intelligence for space sciences purposes was determined to be:

> Advanced machine intelligence is the ability of a machine system to autonomously formulate and to revise the patterns of order required for it to conduct scientific investigations and to survive, as evidenced by continued systemic survival and investigatory behavior despite any environmental challenges it may encounter.

This definition results from a merger of conceptual insights drawn from the American Pragmatists school of philosophy—particularly its development of and explanation for

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Strong, NASA-Goddard Space Flight Center; and Dr. William Wells, Science Applications, Inc., Schaumberg, Illinois. The major credit for the machine intelligence conceptualization, which is highly oversimplified here, should go to Professor Isaacson, Professor Gravander, and Ms. Bernabe.

[11] There is no generally agreed definition of artificial intelligence either, but perhaps the best source for views of the meaning, composition, and directions of artificial intelligence in 1982 is the *Proceedings of the First Annual National Conference on Artificial Intelligence*, Stanford University, August 18-21, 1980, sponsored by the American Association for Artificial Intelligence. This conference met during our NASA/ASEE study period and provided a valuable insight into ongoing research in artificial intelligence for our study group participants. The Table of Contents of the proceedings volume gives interested readers a capsule view of the main concerns of artificial intelligence at the time. Its major divisions are: Vision; Program Synthesis; Theorem Proving; Mathematical and Theoretical Foundations; Problem Solving; Knowledge Representation; Knowledge Acquisition; Specialized Systems; Applications; and Natural Language.

[12] Alan M. Turing, "Computing Machinery and Intelligence," *Mind* 54, no. 236 (1950): 433-60. The American weekly, *Newsweek*, also featured an article on the impact of the semiconductor chip and "smart computers" using the cover title "Machines That Think," *Newsweek*, June 30, 1980, 50-56.

intelligence;[13] the three basic patterns of logical inference necessary for hypothesis formation—analytic, inductive, and abductive;[14] the literature of psychology having to do with perception, pattern recognition, genetic epistemology, and human knowledge structuring;[15] and the work of scientists and scholars in computer science research."[16] Also very important are the works on the importance models play in thought and in the evolution of science."[17]

The primary criterion of a definition of advanced machine intelligence is that it encompasses purposes, components, and standards for its application to the real world. Autonomous machines must be able to survive and work in environments of uncertainty, complexity, and novelty. Furthermore, they must be able to create patterns of order from that environment upon which behavior can be based to achieve the system goals of survival and productive work and—even—growth. Human intelligence has accomplished this for human beings. The achievement of growth and adaptation assumes a logical capacity and memory that can sort out the successful from the unsuccessful investigations and experiments and capitalize on the successful ones. The standards for evaluation for the possession of and degree of advanced machine intelligence will focus on observations of the ability of the system to self-correct unsuccessful behavior, to achieve goals, and to grow through the collection and utilization of knowledge. This assumes the capability to invent revised or entirely new knowledge classification schemes (theories, models, formulas, algorithms, taxonomies, categorizations) from its observations, as well as utilizing existing ones. Intelligence capable of creating new knowledge must be able to apply three known logical inference patterns of human intelligence: analytic logic, inductive logic, and abductive logic.

Analytic inference in logic (also termed deductive logic) is needed to process raw data and to identify, describe, predict, and explain events and processes in terms of existing knowledge classifications and structures. Its origin was with Aristotle. Analytic

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[13] In lieu of voluminous references in Notes 12, 13, and 14, I simply provide the relevant names of authors from the American Pragmatist school of philosophy; William H. Davis, John Dewey, K. T. Fann, George Herbert Mead, David L. Miller, Charles Sanders Pierce, and H. S. Thayer.

[14] See the works of Charles Sanders Pierce, Arthur Burks, K. T. Fann, Harry G. Frankfurt, Peter Alexander, Rom Harré, Carl G. Henpel, Karl Popper, John O. Wisdom, L. J. Cohen, I. J. Good, Mary Horton, Keith Lehrer, Nicholas Rescher, Wesley Salmon, and Brian Skyrms.

[15] The works of G. Sperling, U. Neisser, I. Rock, R. Klatsky, and Jean Piaget are relevant here.

[16] To avoid excessive referencing, let me just cite here the Pulitzer Prize-winning book, *Gödel, Escher, Bach: An Eternal Golden Braid,* by the Indiana University computer scientist Douglas R. Hofstadter (New York: Basic Books, 1979), which not only covers much of the literature and knowledge bases of advanced machine intelligence, but also addresses the basic question of the machine-human symbiosis problem and concludes that computer hardware and software may one day produce machines with qualities similar to will, intuition, and consciousness, and the "beautiful many-voiced fugue of the human mind" (719).

[17] Particularly important here are the following works of Thomas S. Kuhn: *The Structure of Scientific Revolutions*, 2nd ed. (Chicago: University of Chicago Press, 1970) and *The Essential Tension: Selected Studies in Scientific Tradition and Change* (Chicago; University of Chicago Press, 1977).

inference moves from the general (model, principle, law, theory, or concept) to specific segment(s) of reality and then back to general and more universal statements.[18] Raw data is viewed through the lenses of a classification scheme, processed using quantitative or symbolic languages, then descriptions, identifications, predictions, and explanations are made about the real-world segment that produced the raw data. Systems theory and general systems theory have produced the concept of *system*, which provides the generalized model that all open systems are composed of inputs, structure, process, outputs, and boundaries, which separate it from its environment. Analytic logic leads us to view new raw data in terms of that model to expand the model's domain of applicability to identify, describe, predict, and explain observed events. As long as the model works, our scope of relevant knowledge increases.

Inductive inference in logic moves from the specific raw data to the general in the presumed absence of preconceived classification schemes. Sir Francis Bacon (1560-1626) is the father of inductive logic, which became the knowledge root for the behavioral sciences.[19] The real world is observed, measured, and counted first, and then generalization or abstraction occurs. Karl Deutsch has called this the bread-and-butter method of science and essential to knowledge growth. We can observe the raw data of world population growth statistics and then attempt to abstract and generalize from that data. The analytic and inductive schools of logical inference have spawned the facts-versus-values debate of the positivists and the philosophers.

Abductive inference in logic combines both analytic and inductive logic and is considered to be the logic of discovery and invention.[20] In abductive logic, a theoretical

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[18] See Peter Alexander, A *Preface to the Logic of Science* (London: Sheed and Ward, 1963); Rom Harré, *An Introduction to the Logic of the Sciences* (London: Macmillan, 1960); Carl G. Hempel, *Aspects of Scientific Explanation* (New York: Free Press, 1965) and *Philosophy of Natural Sciences* (Englewood Cliffs, NJ: Prentice-Hall, 1966); Karl Popper, *Conjectures and Refutations* (London: Routledge and Kegan Paul, 1965); John O. Wisdom, *Foundations of Inference in Natural Science* (London: Methuen, 1952).

[19] See L. J. Cohen, *The Implications of Induction* (London: Methuen, 1970); I. J. Good, "Rationality, Evidence, and Induction in Scientific Inference," in *Machine Intelligence*, ed. E. Elcock and D. Ivliehil (New York: Halstead Press, 1977), 171-74; Mary Horton, "In Defense of Francis Bacon: A Criticism of the Critics of the Inductive Method," *Studies in the History and Philosophy of Science* 4 (1973): 241-78; Wesley C. Salmon, *The Foundations of Scientific Inference* (Pittsburgh: Pittsburgh University Press, 1967); Brian Skyrms, *Choice and Chance: An Introduction to Inductive Logic* (Belmont, CA: Dickenson Press, 1966).

[20] See William H. Davis, *Peirce's Epistemology* (The Hague: Martinus Nijhoff, 1972); John Dewey, *Logic: The Theory of Inquiry* (New York: Henry Holt and Co., 1938); K. T. Fann, *Peirce's Theory of Abduction* (The Hague: Martinus Nijhoff, 1970); Norwood Russell Hanson, *Patterns of Discovery: An Inquiry into the Conceptual Foundations of Science* (Cambridge: Cambridge University Press, 1958); Kuhn, *Structure of Scientific Revolutions* and *Essential Tension*; Imre Lakatos, *The Changing Logic of Scientific Discovery* (Cambridge: Cambridge University Press, 1970); David L. Miller, *George Herbert Mead: Self, Language, and the World* (Austin: University of Texas Press, 1973); Charles Sanders Peirce, *Collected Papers, Volumes 1-6*, ed. Charles Hartshorne and Paul Weiss (Cambridge, MA: Belknap Press, 1960) and his *Collected Papers, Volumes 7-8*, ed. Arthur W. Burks (Cambridge, MA: Belknap Press, 1966); Stephen Toulmin, *The Philosophy of Science* (New York: Harper and Row, 1960).

or conceptual structure, theory, model, law or classification is taken as a premise. Predictions are made on the basis of the theoretical structure, and data is collected, observed, and manipulated within that structure or paradigm of knowledge. If events that are not predicted by the theoretical structure occur, the classification scheme itself is modified or replaced to allow for the inclusion of all data now available. The Hegelian dialectic logic of thesis, antithesis, and synthesis (or original tendency, opposing tendency, and their unification in a new movement) is abductive logic. For machines to function autonomously or semi-autonomously in uncertain, complex, and novel environments, they must have an intelligence capable of accomplishing abductive logic.

To summarize this introduction to a concept of advanced machine intelligence, see Figure 1 and Table 1 for relationships in machine intelligence. I reserve further reference to the 1980 NASN/ASEE study until later, when I discuss the implications for society of the application of advanced machine intelligence to space exploration and exploitation. However, it represents the beginnings of scientific inquiry into the subject. Although the concept of advanced machine was at the time of writing—1982—largely theoretical, inventions have emerged from the US Patent Office to the effect that electronic signal-processing that is similar to human intelligence logic patterns. In a 1981 patent,[21] Dr. Joel D. Isaacson described his invention of an "Autonomic String-Manipulation System" involving the implementation of dialectical (or Hegelian) logic through autonomic processing. Such processing is said to achieve the transformation of environmental inputs to information structures that mimic DNA organization for the storage, retrieval, and recognition of patterns, including visual images. This invention could move the concept of advanced machine intelligence toward technological reality.

[21] Joel D. Isaacson, US Patent No. 4,286,330, August 25, 1981, "Autonomic String-Manipulation System."

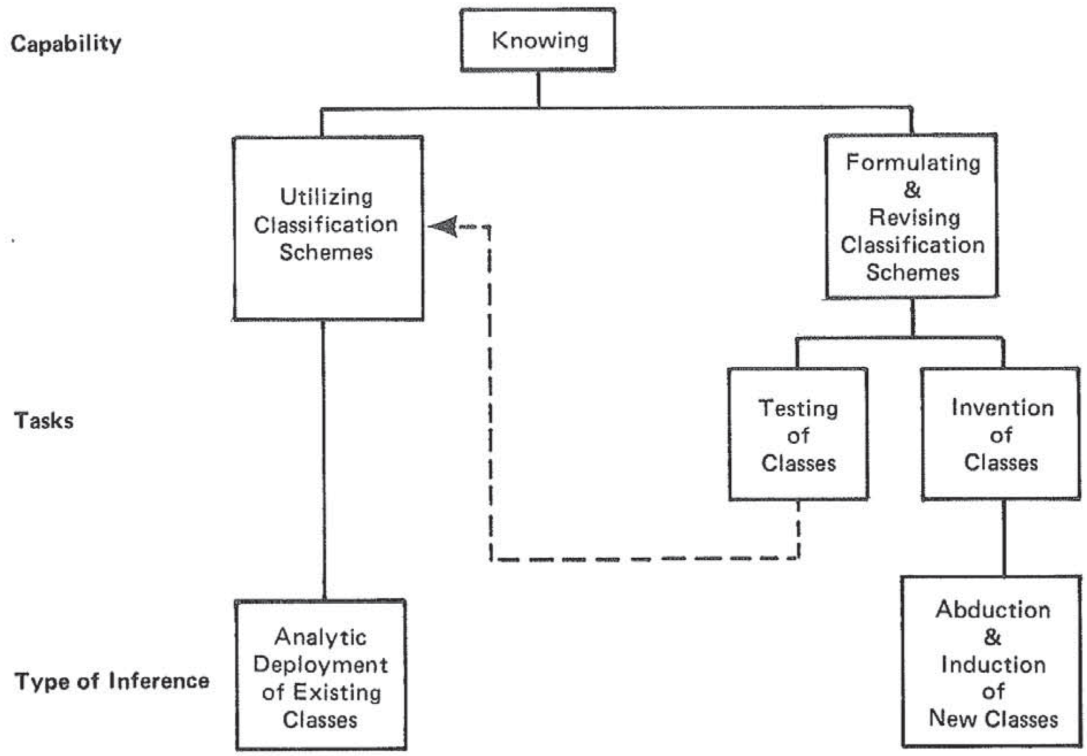

Figure 1: Systems Graph for Machine Intelligence[22]

Table 1: Components of Advanced Machine Intelligence[23]

- Learning—capacity to form universals associated with information patterns present in the environment. Learning subsumes a certain level of hypothesis formation and confirmation in that new universals may be formed "on probation" (i.e., as hypotheses) and then adopted permanently only as the result of "confirmation" such as through "reinforcement" or "rehearsal."
- Memory—capacity to maintain such universals indefinitely, particularly through some recirculating or replicating process.
- Recognition—capacity to identify, or classify, information patterns present in the environment on the basis of preestablished universals.
- Machine intelligence—a highly integrated mix that includes all the above, preferably in a single function or process, and in an autonomic mode of processing.

[22] Source: *Advanced Automation for Space Missions,* Final Report of the 1980 NASA/ASEE Summer Study on the Feasibility of Using Machine Intelligence in Space Applications, University of Santa Clara, California. Major credit for this concept belongs to Professor Jerry Gravander, Clarkson College of Technology.
[23] Source: *Advanced Automation for Space Missions*. Major credit for the development of this concept belongs to Professor Joel D. Isaacson, Southern Illinois University.

Systems Theory and Advanced Machine Intelligence

Human intelligence has given people the capacity to theorize about their environment and themselves. The ability to construct theory and models using symbolic language and thought provides the major distinction between humans and other life forms. Animals learn only from their own experience and through inherited instincts. Humans can learn from the experience of others as well as their own and even transcend experience through intellectual processes of storing, manipulating, and recalling symbols and abstractions of reality for application to discrete problems and events.[24] The achievement of advanced machine intelligence capable of analytic, inductive, and abductive logic and using the immense memory capacity of ultrafast computers and very large scale integrated circuits may well exceed current human intelligence capabilities in many ways. A human-machine mix combining the superior capabilities of each into a synergistic advanced human intelligence is also conceivable.

What does the emergence of systems theory and the systems approach over the past several decades signal for the relationship of advanced machine intelligence and society? The systems approach has gained such momentum in recent years that one cannot avoid systems in today's living. This is true throughout the world and in public and private enterprises at all levels. To validate this, all one needs to do is observe the almost ubiquitous use of the word system. We are in the midst of the systems paradigm —to use the concept popularized by Thomas S. Kuhn in his modem classic explanation of how scientific knowledge evolves and progresses.[25]

According to Kuhn, scientific knowledge grows within normal science through the aggregation of information consistent with a theory or through replacement of one theory with a successor theory. He describes the process whereby normal science develops a paradigm, or universally recognized and accepted body of knowledge. This paradigm, for a time, provides solutions to problems for a community of scholars and practitioners. Over time, research and practice within this paradigm begins to reveal anomalous facts unaccounted for in the theory. This stimulates new scientific discoveries creating a crisis of credibility in the paradigm. A new theory emerges that precipitates a scientific revolution, or a non-accumulative developmental episode in which an older paradigm is replaced in whole or in part by an incomplete new one—often with traumatic and long-range impacts on science, on scientists, and on society. There is ample historical evidence in the physical and social sciences to validate this theory, although anomalies and exceptions exist.

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[24] Portions of this section appear in slightly different form in Robert M. Krone, *Systems Analysis and Policy Sciences: Theory and Practice* (New York: John Wiley & Sons, 1980), Chapter 2, "Theory and Models" and Chapter 3, "Systems Concepts."

[25] Kuhn, *Structure of Scientific Revolutions*. The theory it presents has itself reached the status of a scientific paradigm.

In the 1979 review of systems research characteristics, accomplishments, and current developments accomplished for the Society for General Systems Research by Roger E. Cavallo,[26] the "major accomplishments which can reasonably be attributed to the systems movement and/or perspective" were listed as

- A new conceptual language, a new methodology, a new modeling approach showing that analysis is not the only rational way to deal with problems.
- Introduction of rigorous methods into an holistic approach.
- A growing holistic/ecological *weltanschauung,*
- Counterpoise to the tendency toward specialization.
- Better planning for environmental protection, energy use, health care, and city planning.
- Multiple ways of thinking, multiple views of the world.
- Increased awareness of methodological problems generated by increasingly complex problems.
- Increased interdisciplinary contacts.

My own abstraction of useful concepts flowing from systems theory and the systems approach is as follows:[27]

(a) Systems are characterized by wholeness, organized complexity; interdependence; reciprocal dependence (an action within a system causes other actions); dynamics (systems grow, alter, decay, and die over time and through interventions); components of inputs, people, structure, process, outputs and boundaries; interchanges with the environment; equifinality (the concept of multiple paths to reach a goal); Gestalt phenomenon; health and/or pathologies.

(b) Systems have functions of system maintenance, policymaking, planning, goal setting, memory, control, learning, feedback, cross feeds, purpose, and unifying force.

(c) The systems approach provides understanding and comparisons within and between systems; encourages simultaneous research into different parts of the system: leads to awareness of the hierarchical nature of living and natural systems; creates knowledge; helps you to recognize what you do not know; asks different (and often better) questions than alternative approaches to problem solving; forces consideration of coordination, control, level of analysis, and implementation, as well as goals and problem solution; stimulates innovation; suggests a means-ends investigation; becomes

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[26] Roger E. Cavallo, ed., "Systems Research Movement: Characteristics, Accomplishment, and Current Developments," Society for General Systems Research, *General Systems Bulletin* special issue 9, no. 3 (1979): 40.

[27] Krone, *Systems Analysis and Policy Sciences*, i.4.

a variable in the system product quality; and is intellectually challenging and increasingly relevant.

(d) The significance of systems management: with the emergence of large complex human systems such as governments (all levels), multinational corporations, huge transportation and communication systems, and networks of information systems. The importance of systems management and systems managers has increased proportionately. Ten reasons why this has occurred are:[28]

- The world needs more and better systems managers … demand is rising faster than supply for
    - Managers with technology knowledge plus people skills.
    - Managers with a mix of public and private awareness and experience capable of achieving effective service and profitability goals.
    - Managers who can use both quantitative and qualitative methods and tools.
    - Managers with cross-cultural abilities,
- The systems approach contains the most powerful set of intellectual concepts of the twentieth century.
- Quality requirements of decision-making are increasing, and decision-makers are likely to resolve more issues.
- Public and private systems need improvement, redesign, and/or innovation to survive in rapidly changing environments.
- Impacts of systems failure are increasing and systems analysis—the macro tool of the systems manager—can often turn failure into success.
- Science + technology + management + people = problem solving.
- The constantly changing technology being applied to specific purpose systems, which dominate the marketplace today.
- Ideas move faster than things or people (about 1.3 million times as fast).
- Systems managers are emerging as the most fundamental independent variable for impact on the quality and stability in human systems.

[28] These reasons are presented in a slightly different form in my contribution to L. Troncale, ed., *A General Survey of Systems Methodology: Proceedings of the Twenty-Sixth Annual Meeting of the Society for General Systems Research with the American Association for the Advancement of Science, Washington, DC, January 5-9, 1982* (Louisville, KY: Society for General Systems Research, 1982), 854-55.

- The sensitivity of systems management toward the three most characteristic phenomena of our age: uncertainty, complexity, and novelty.

It is worth noting that the systems bed of roses is also strewn with potential pitfalls when it comes to applications. Pitfalls exist in all efforts to translate theory to practice and only serve as reminders that both ideas and their implementation must be validated for the specific purpose selected. Consider the following pitfalls and dilemmas of the systems approach which, if neglected, can lead to gross conceptual errors.[29]

(e) The pitfalls of the systems of the systems approach include interchanging the abstracted system with reality … subsystem sensitivity to system assumptions ("What's good for the marketing department is good for the company") … the problem of individual benefits versus system benefits (the "Who is the client?" problem, where improving the system may mean firing people) … the requirement but inability to study more than one part of the system adequately due to complexity (a dilemma since the systems approach is the most useful one available for handling complexity) … the part selected for analysis may not be the most important one (poor prioritizing due to the quandary of "I have defined the system; now where do I start?") … neglecting history … relying on historical metaphors … shortage of competent analysts … knowledge is adequate for only a superficial analysis … bias toward rational thinking … excess analysis … using the systems approach in non-applicable situations:

> When [the] aim is to force a rapid change through shock … for destructively negative goals … for systems where [the] leadership aim is power recruitment, coalition maintenance, or political consensus … when social-political ideology, faith, and/or family loyalty—not reason—are the prime movers … for pure scientific research … for the arts.

What paradigm is likely to replace the systems paradigm of today? None can be positively identified, but advanced machine intelligence is bound to play a role in its emergence. Elsewhere I have provided one illustrative alternative future for the elements of a new paradigm to replace the current systems approach within systems analysis and systems management. I call it "Reality 21."[30] Under the Reality 21 (meaning the twenty-first century) paradigm, our analytical capability would have progressed to the point where we would not have to theorize and conceptualize systems approaches to simulate reality. Our capability for empirical knowledge collection, reproduction, aggregation, and manipulation would offer us a real-time view of reality. Whatever segment of physical, transportation, communications, meteorological, energy, or agricultural life in the world

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[29] See Krone, *Systems Analysis and Policy Sciences*, 15.
[30] Krone, *Systems Analysis and Policy Sciences*, 13.

policymakers or scientists were interested in analyzing would be available on command. The medium of reproduction might be three-dimensional laser-generated hologram images superimposed with desired data capable of sensitivity analysis in any dimension. With another command, instant outcome arrays for a spectrum of normative probabilistically accurate world states would emerge for the future—each being the dependent variable resulting from allocations of designated independent variables of material and intellectual resources. Furthermore, there would be a capability for rapid Delphi surveying of every world citizen and organizational entity to obtain values analyses concerning which future states were preferred, with what intensity, and in what manner those individuals and organizations were prepared to contribute to achieve the preferred future states.

Alas, or fortunately, depending upon one's feelings of how the political and social world might look under those conditions—Reality 21 was not a reality in 1982. I leave that concept for the future. The systems approach remains the best idea currently available. Reality 21, however, is not a completely facetious offering. The concept itself does not predetermine answers to the centralization versus decentralization and freedom versus order issues so well stated by E. F. Schumacher in his 1973 book *Small is Beautiful*.[31]

Perhaps the most pervasive and significant linkage between systems concepts and advanced machine intelligence is that the manipulation of information couched in symbolic form is the life blood of both. Systems concepts provide the guidelines for the heuristic search for new knowledge. Advanced machine intelligence will be the engine for accelerating the rate of growth of knowledge. The growth of science, technology, and knowledge—with a corollary link to power for those who best understand and utilize that growth—should be the major byproduct of the achievement of advanced machine intelligence.

In 1978, Wilfred A. Kraegel extrapolated the rate of knowledge growth of the previous thirty years—doubling every ten years—to the next hundred years and concluded that "our knowledge available today will be only 3% of that available in the year 2079."[32] Depending on how fast the development of advanced machine intelligence takes place, that estimate could be very conservative. Rather than knowledge growth reaching thirty-three times in 2079 what it was in 1978, it could well reach 10^3 or even 10^8 times what it was then. Even the most creative imaginations of today could not begin to describe a society possessing that level of knowledge accurately. As the purpose of this chapter is to stimulate thinking in that direction, the reader is encouraged to forecast his or her own societal impacts to add to those few I have hypothesized in the following section. One way to approach the conceptualization

[31] E. F. Schumacher, *Small is Beautiful: Economics as if People Mattered* (New York: Harper and Row, 1973).

[32] Wilfred A. Kraegel, "Futurizing a City: A Proposal for Milwaukee's Coming Transformation," *World Future Society Bulletin* (May-June 1978): 7.

of that endeavor would be to juxtapose the accomplishments, characteristics, and functions of the systems approach and systems management listed above with the capabilities of advanced machine intelligence described.

Societal Impacts and Advanced Machine Intelligence

Given the state of the concept of advanced machine intelligence in the 1980s—taking shape—any predictions of future impacts would be highly speculative. Then why bother? The best answer to that question can be found in the axiom of Dr. Paul Cone, educator, entrepreneur, and businessman: "If there is a vacuum and you care, then act." Since advanced machine intelligence has not yet achieved its future form and impact, it is similar to any unborn child. We care very much whether the child grows up to be an Einstein or a Frankenstein. Therefore, the more intellectual effort we can expend now to identify sets of possible alternative futures, the higher probability society has to forge the growth of advanced machine intelligence to create future realities our children and grandchildren and their children will find satisfying. Our task then, is similar to the description by Norbert Wiener—made seventy years ago—about the contribution of Willard Gibbs to physics. In Wiener's classic book, *The Human Use of Human Beings,* he said: "Gibbs' innovation was to consider not one world, but all the worlds which are possible answers to a limited set of questions concerning our environment."[33] Gibbs and Wiener were talking about the birth of probability and statistics to replace the Newtonian causative and deterministic world of the seventeenth to nineteenth centuries. We are talking about the birth of advanced machine intelligence, which in the twenty-first century will replace or modify many of our current orientations, values, and lifestyles.

In the following subsections, there are a few vignettes of possible societal impacts from the achievement of advanced machine intelligence. They are only illustrative. The reader will be as qualified as I to expand on those suggested, to conceive new alternative impacts, and to speculate on their dimensions. The list should grow as a checklist for use in the identification of preferred futures and in the avoiding of counterproductive or self-destructive futures. Such a checklist will be important to policymaking centers, to public and private organizations, and to world citizens everywhere as a policy sciences tool.

(a) Implications for Survival

Society's most overriding need is to insure human survival. Jonas Salk, American biologist and humanist, has hypothesized that humanity is now in a transition period between what he labeled Epic A—where the predominant paradigm has been Darwinian evolution or survival of the fittest—to Epic B where the predominant paradigm will be

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[33] Norbert Wiener, *The Human Use of Human Beings: Cybernetics and Society* (New York: Houghton Mifflin, 1950).

survival of the wisest.[34] In Epic B, knowledge acquisition and use, imagination, and intellect will supplant many of the traditional physical, military, and economic power levers or be the prerequisites to the further development of new classes of social drivers. Knowledge, and the ability to use it wisely in the policymaking process, are, therefore, linked to survival of humanity. Failure to transit adequately from Epic A to Epic B, according to Salk, will prevent human survival. Now, we have no assurances that advanced machine intelligence will equate to advanced wisdom in the application of knowledge to future societal problems. Ultrafast computers that think may produce information overloads for humans or allow poor choices to be made with much higher speed and frequency than they are today. Social experimentation in the past, as a result of new technology or new sociopolitical ideas, has been spasmodic, occurring in isolated parts of the globe, and relatively slowly. That process has allowed the trial-and-error method of human decision-making to create a healing response to a pathological direction. The Third Reich of Germany was terribly devastating to a large number of people, but society eventually reacted. Disease, epidemics, and natural disasters of the past have never ceased to affect global society. Pockets of pollution have appeared, but so far, they do not seem totally irreversible. Advanced machine intelligence might have the capability to influence the entire world's population in a relatively short time in comparison to previous technological revolutions. Our task will be to link the progress in machine intelligence to a better understanding of human intelligence and to channel them both with wisdom to the human use of human beings.[35]

(b) Implications for Industry

The most obvious first industrial impact of advanced machine intelligence was in the microelectronic technology, microcomputer, and computer-linked businesses such as software manufacturers, and microelectronic devices, which have exploded over the years. However, the electronic industry was just the beginning of the impact on national and international industries. Robot manufacturing also increased substantially. Robots have replaced humans in many hazardous occupations, such as coal mining, undersea work, and space construction, as well as for repetitive and boring production-type jobs. Robots have vision, touch, and hearing senses as well as other senses that are beyond human capacity, such as infrared, sonar, ultraviolet, and radiation sensing. Offices, stores, schools, homes, cars, boats, and aircraft are all being studied by industry for increasingly sophisticated microelectronic technology applications. Businesses are now dependent upon the computer for inventory control, budgeting, payrolls, transactions, and accounting. Education-oriented computer applications are proliferating. Entire new industries will be required to design, produce, market, and maintain microelectronics products. One fascinating potential of the electronics and robotics development is that

[34] Jonas Salk, *The Survival of the Wisest* (New York: Harper and Row 1973).
[35] Wiener, *Human Use of Human Beings*.

future applications may be less and less constrained by economics, thus leaving only the constraint of human imagination as a barrier to further applications.

(c) Implications for Communications and Transportation

Our society today measures distances in comparison to the speed of the automobile or the airplane. The use of microcomputers and advanced machine intelligence is allowing an increasing portion of human interaction to occur at the speed of light —just as the July 29, 1981 wedding of Prince Charles and Princess Diana in London was transmitted by satellite to seven million people around the earth. A significant difference in the future is an increasing capability for interactive processes rather than a passive one-way communication, as in the past.

(d) Implications for Science

Science is the segment of human effort dedicated to the increase and use of validatable physical and social knowledge. Advanced machine intelligence will increase knowledge of and knowledge availability for the physical and social worlds, as well as providing more powerful tools for the validation of that knowledge by scientists.

(e) Implications for Education

Imagine having the holdings of the Library of Congress at your fingertips through your home, school, or office portable terminal and random-access video discs. Then imagine that advanced machine intelligence could help you formulate research hypotheses, models, theories, concepts, and mathematical algorithms to accomplish analysis and synthesis of that information. What impacts would that have for education, for educational systems, for teachers, and for the philosophy of education for all ages in society? Then imagine a machine capability of translating languages and expand this notion world-wide.

(f) Implications for the Transformation of Humans

Humans are conceived, born, grow, learn, age, deteriorate, and die. Science fiction provides us a rich source of human-machine symbiosis, which changes the historic patterns of that process. Surely every portion of the lifecycle could be influenced by advanced machine intelligence, and some have already been changed by twentieth-century science and technology. Traditionally, doors have progressively closed for the aged from the end of their culturally defined societal work period until death. Now, biological, medical, and health sciences are extending life, replacing organs and body functions, and curing more and more human pathologies. Already microcomputers offer the senior citizen and the handicapped a multitude of new open doors to life and the world.

The possibility of human immortality—or drastically extended life—is approaching feasibility, or, at least, is receiving serious consideration. A society that conquers death will have so many social, religious, industrial, economic, philosophical, legal, psychological, agricultural, demographic, and ecosphere impacts that we can assume that advanced machine intelligence would be a prerequisite to societal functioning under those conditions. Even at today's lifespan, the achievement of advanced machine intelligence may change individual self-perception and human psychological stability. Issues of freedom and control for the individual, human-machine symbiosis, dehumanization or depersonalization threats, possible pathologies resulting from increasingly rapid change requirements for humans, or the erosion of human will or work ethic when machines can replace the traditional work habits and functions of people are important for parallel research with machine intelligence development.

The expansion of human intelligence through vastly increased access to knowledge and even the extension of human knowledge outward through space and inward to the mind may transform the human self-image. The behavioral sciences should be active in monitoring, understanding, predicting, and/or controlling such transformations. Finally, there are limits to the capability of rational analysis to be the sole mode for relating human aspirations toward complex and fuzzy futures. Advanced machine intelligence will help humans to expand their capabilities for rational analysis, but the extrarational characteristics of humans—such as judgment, intuition, creativity, faith, love, joy, sorrow, hate, charisma, fear, loyalty, will, and perception—and the cultural environments from which they develop are critical variables that have through history balanced what is rationally known with what is tacitly known.[36] At this point in time, it is even difficult to speculate about the role machines will play with regard to the extrarational variables of human existence, while asserting that there must be such a role.

(g) Implications for Politics

The machine intelligence revolution may exceed any previous development in history in its impact on politics. For better or worse, politicians and governments will have an ever-increasing ability to observe, document, survey, analyze, control, store information, communicate in real time, and compare individuals, groups, cities, states, and nations. This has the potential for a profound impact on political systems at the local, state, national, and international levels. Microcomputers have already reached center stage in international power politics. According to Jean-Jacques Servan-Schreiber, French President François Mitterrand proposed to President Ronald Reagan at the Ottawa Summit Conference in July 1981

> a new, nonviolent crusade by the high-technology civilizations (America, Europe and Japan) and the oil-exporting nations. Its aim would be to reorder the developed world's investment priorities so as to bring to the 3

[36] To understand the concept of tacit knowledge—or the knowledge people gain from living as opposed to the explicit knowledge people gain from learning—one must absorb the theory of personal knowledge of Michael Polanyi, which he developed between 1946 and 1966. See his *Science, Faith and Society* (Chicago: University of Chicago Press, 1946); *Personal Knowledge* (Chicago: University of Chicago Press, 1958); *The Study of Man* (Chicago: University of Chicago Press, 1958); and *The Tacit Dimension* (New York: Doubleday & Co., 1966).

> billion men and women of the Southern Hemisphere an art which now is at the base of all sciences, the one that was born only a few years ago, and whose offspring are now exponential: The art of microcomputers.[37]

With ten million unemployed in Europe and thirty million unemployed in the industrial nations, the French saw microcomputers as a new means to create wealth. Mitterrand's Minister in Charge of Decentralization, Gaston Defferre, explained the policy this way:

> Decentralization will allow France to develop a microcomputer industry, which can be distributed all over the country, and which will create many long-lasting jobs in enterprises of the future. In this way, we will be able to accommodate a shift change in the distribution of the capital of knowledge and therefore, of creativity, among the social classes and individuals within our society. This new vision, allowed by computer science, is going to lead to a transformation of the distribution of economic and political power.[38]

The increasing complexity of political issues requires more sophisticated means for bringing the results of good analysis to the public as well as to the relevant decision-makers.

Increasing the policy contribution capacity of employees, managers, decision-makers, and politicians should be a high-priority goal for any democratic nation. Democratic theory assumes rational choices by an informed electorate. Improved modalities for bringing information and analysis to a wider range of people and groups, to schoolrooms and board rooms, and to government agencies at all levels, are needed. Successful politicians of the future could use advanced machine intelligence to analyze issues and to inform themselves as well as their constituencies. Individual citizen views on issues could be collected very rapidly and thoroughly, thus making the democratic process meaningful to many who now feel isolated by the political system. Leaders not concerned with establishing or sustaining democratic political systems may find advanced machine intelligence a powerful tool for amassing power and controlling knowledge, although the nature and trends of microcomputer technology are likely to make knowledge repression and control more difficult in the future.

(h) Military Systems and Advanced Machine Intelligence

The impacts of advanced machine intelligence on the policy, planning, acquisition, control, maintenance, deployment, and employment of national or international military

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[37] Jean-Jacques Servan-Schreiber, "The Day America Wakes Up: A Challenge from the New Pioneers," *Los Angeles Times,* July 12,1981, Part IV, 3.

[38] Servan-Schreiber, "The Day America Wakes Up," 5.

forces and weapons systems for war-fighting or deterrence purposes will be as significant as on any other segment of society, and they may occur sooner due to the high priorities placed on national security. Those tasked with national security responsibilities must do the brainstorming on potential impacts; however, some of the issues to which advanced machine intelligence might be applied are the formulation of national strategy (i.e., those concepts justifying the use of force), allocation of national resources to civil-military systems, internal military system resources allocation, weapons systems acquisition, personnel training, research and development, military alliances and overseas military deployments, threat perception and analysis—to include intentions as well as capabilities, military-in-society issues, leadership and management, and recruitment and retention.[39]

(i) Impacts on Human Needs and Natural Resources

Human population growth, the pollution output of that population, and the natural resources and food available from Earth to fill the needs of that population were out of balance in 1982, and they were projected to become much more so by 2000 without radical and rapid action. The *Global 2000 Report to the President of the US,* issued July 24, 1980 concluded:

> If present trends continue, the world in 2000 will be more crowded, more polluted, less stable ecologically, and more vulnerable to disruption than the world we live in now.... Despite greater material output, the world's people will be poorer in many ways than they are today.... For hundreds of millions of the desperately poor, the outlook for food and other necessities ... will be worse.... Life for most people on earth will be more precarious than it is now.

America's most famous technological optimist, Herman Kahn, took the opposite view:

> Are we running out of energy? The answer is absolutely no. No way. Are we running out of resources? Absolutely not. No way. Are we running out of the ability to feed people from a technological and economic point of view? Absolutely not. No way. Can we retain clean air and clear water and a reasonable aesthetic landscape? Absolutely.... The overall prospects for the world are basically optimistic except for two things: One is the

[39] See also, Robert M. Krone, "Policy Sciences and Civil-Military Systems," *Journal of Political and Military Sociology* 3 (Spring 1975): 71-84.

> possibility of nuclear war and the other is the possibility of misunderstood technology.[40]

I spent a week with Herman Kahn at his Hudson Institute at Croton-on-Hudson, New York (sometimes called Herman-on-Hudson), and he was asked how he could be so emphatically optimistic. His answer was: "Well, I'm not really that optimistic. But when uncertainty exists and I have a choice between pessimism and optimism, I will always take optimism. Pessimism is sick. Both can be self-fulfilling prophecies."[41]

This article was originally written to serve as a text in the Master of Science in Systems Management Degree Program provided by the University of Southern California. One axiom of systems management is that the quality of management may be the most important independent variable influencing the outcome of the enterprise. Whether projections of 2000 are accurate depends to a great extent on how well we humans manage ourselves, our science, our technology, and our resources. Advanced machine intelligence is an emerging resource that has great potential for being an important factor in that development. When in doubt, choose optimism, and then manage well to achieve a self-fulfilling prophecy.

(j) Impacts on Religion, Philosophy, and Faith

What role does faith have to play in the achievement of advanced machine intelligence? Machine intelligence is a scientific creation of humans developed to this point with a combination of faith in human abilities to do so. R. Buckminster Fuller's work, *Critical Path,* contains his guidelines to an "all-win" world.[42] To Bucky, God is the intelligent designer and when humans discover eternal laws they are:

> discovering the intellectually designed scenario Universe, whose designing required the a-priori external existence of an intellectual integrity of eternally self-regenerative Universe … an eternal, omnicomprehensive, infinitely and exquisitely concerned intellectual integrity that we may call God, though knowing that in whatever way we humans refer to this

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[40] Herman Kahn, "A World Turning Point—And a Better Prospect for the Future," and "Things are Going Rather Well: A State-of-the-World Message," *The Futurist* 9, no. 6 (December 1975): 284-92.

[41] The pessimist-optimist debate concerning growth and the future reached heated controversy after the publication of Dennis L. Meadows et al., *The Limits to Growth,* 2nd ed. (New York: Universe Books, 1974), which stimulated a much-increased level of research into the problems of world population growth, pollution, industrial production, food production, and natural resources. The first "Limits to Growth" conference occurred in 1975. In 1977, the conference was titled "Alternatives to Growth," and by 1979, it had changed to "The Management of Sustainable Growth," reflecting the influence that the Kahn "expanding pie metaphor" for world resources had made on the Meadows "fixed pie metaphor." Variations of the debate continue today.

[42] Barbara Marx Hubbard, "Critical Path to an All-Win World: Buck Fuller Designs the New Age," *The Futurist* 15, no. 3 (June 1981): 31-41.

> integrity, it will always be an inadequate expression of its cosmic omniscience and omnipotence.

To Buckminster Fuller, the world was designed for success, and humans should assist in this process—individually and collectively. Albert Einstein said: "The cosmic religious experience is the strongest and noblest mainspring of scientific research…. That deeply emotional conviction of the presence of a superior reasoning power, which is revealed in the incomprehensible universe, forms my idea of God."[43]

Is there a natural universal law of information structure and process that, when discovered, will explain human intelligence and also be discernable by machines capable of autonomic modes of processing that information? Assuming that is the case, will it make God any less omniscient in relationship to humans? I doubt it. Having faith helps both to define our humanity and to lead humans to scientific discovery. However, it remains to be seen what impact advanced machine intelligence will have on the belief systems of individual religions.

(k) Impacts on Space

Since the concept of advanced machine intelligence presented here had its genesis in the 1980 NASA/ASEE feasibility study previously introduced, and since four research teams devoted a total of ten thousand person hours to that study, the space applications envisioned therein may have the highest scientific credibility of the societal implications outlined in this chapter. The four missions selected by the study group teams to illustrate the potential for advanced automation and machine intelligence were: (1) a fully automated earth resources and environment monitor, (2) a machine intelligence-directed deep space exploration spaceship, (3) an orbiting space factory using non-terrestrial materials, and (4) a factory on Earth's Moon which would have a capability for self-replication plus product manufacturing.[44]

It might be useful here, however, to question whether the whole idea of space exploration, utilization, and industrialization for human purposes is not too long range, too far out, too expensive, too much like science fiction, and too uncertain to occupy our attention when there are the many immediate and urgent problems on Earth of starvation, disease, energy shortages, economic inflation, unemployment, increasing crime rates, international and internal terrorism, some 195 sovereign nations with conflicting needs that too often lead to war, the proliferation of massively destructive weapons, and an increasing gap between those with plenty and those with nothing to sustain human dignity or survival? It is necessary to respond to the question of "Why space?" just as it is necessary to respond to the question of "Why advanced machine intelligence?"

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[43] Lincoln Barnett, *The Universe of Dr. Einstein,* rev. ed. (New York: Bantam Books, 1968), 108-09.

[44] For further details, see note 6.

My answer to the "Why space?" question is that some 3.5 billion years ago on Earth something organized the set of carbon-based molecules of Earth's oceans and atmosphere into living systems, which were then able to make copies of themselves and adapt through biological evolution into all the living creatures of the Earth. That something may have been an electrical charge or some as yet undiscovered natural law or organization of information.

Perhaps the most important thing humans can do—if there is such a thing as human destiny—is to discover the answer to questions of our origin. Were living things merely an accident at this one celestial body among trillions? We somehow intuitively know that this complex process of life was not an accident and that life also exists elsewhere.[45] There are theological and philosophical as well as scientific issues here, for if that original spark of life came from an intelligent or divine guidance, then we can assume some greater purpose to life than mutual antagonism and annihilation or to render our Earth habitat unsuitable for the continuance and improvement of life. If we began and evolved simply by accident, natural selection, and survival of the fittest, we will also become extinct by accident if we have no capacity to understand or deal with the processes that created us and increased our numbers.

An understanding of our origin and evolution will help us to influence our biological future as well as to prevent irreversible damage to Earth's ecosphere. if we learn to move freely about our Earth, Moon, and planetary system, should we assume that there are limits beyond which people should not go? According to Gerald O'Neill, we are on the verge of human "breakout into space,"[46] with routine trips into space for 200 million people a year. We are, in the late twentieth Century, opening up the vistas, the challenges, and the opportunities of space—the apparently limitless frontier that may only be matched by another seemingly equal frontier—the human brain and mind. We have now made primitive probes into each of those intricately woven mazes. We assume that there are fundamental linkages between the two—for as Carl Sagan says, "We are star stuff."[47]

Are there fundamental laws of the universe that organize chemical molecules into living systems? Titan, the largest moon in our planetary system, or one of the planets, may hold the answer. The Solar System, itself, seems to have condensed from charged

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[45] Already a considerable amount of research has been done on the search for life elsewhere in the universe. The best summary of that search, and its rationale, can be found in Phillip Morrison, John Billingham, and John Wolfe, eds., *The Search for Extraterrestrial Intelligence (SETI)* (Washington, DC: NASA Scientific and Technical Information Office, 1977).

[46] Gerald K. O'Neill and William T. Bryant, "Breakout into Space," in *Through the '80s: Thinking Globally, Acting Locally*, ed. Frank Feather (Washington, DC: World Future Society, 1980); *2081: A Hopeful View of the Human Future* (New York: Simon & Schuster, 1981).

[47] Carl Sagan, *Cosmos* (New York: Random House, 1980).

atoms, energetic molecules, and electromagnetic forces of some primeval nebula with the capacity to evolve into a staggering diversity in its galaxies, suns, and planets.

We hypothesize that carbon-based chemical living systems are not the only ones that can make copies of themselves. What are the implications of a discovery that there may be life forms or machine form or some other life-machine symbiosis other than ours capable of reproduction? Finding the answers will lead directly to knowledge concerning the roots of what is human and what is machine, who and where we are, and where we are going. We also assume that a better understanding of those complex issues will lead us directly to solutions to problems we face on Earth today—solutions that will determine the quality of life for generations to come.

As yet, we have failed to explore for the benefit of humankind the limits of the universe. Continued scientific efforts to do so hold the promise of quantum leaps in the availability of resources, of knowledge, and even of wisdom to apply to the near- and long-term problems of humans wherever they may be or go.

Policy Sciences and Advanced Machine Intelligence

Policy science is a complex set of policy-oriented disciplines and efforts that has grown from an original idea by Harold Lasswell in 1951.[48] its main goal is the application of knowledge and creativity to better policymaking throughout public or private systems.[49] All the knowledge we possess, the knowledge we need, and the knowledge that may become available to us can be conceptualized into the following three categories:

1. Environmental knowledge. Knowledge about the understanding, control, and direction of the environment. This knowledge falls predominantly into the domain of the physical and natural science.
2. Human knowledge. Knowledge about the understanding, control, and direction of individuals, groups, and society. This knowledge falls predominantly into the domain of social, behavioral, and life science.
3. Control knowledge. Knowledge about the use of, and further development of, knowledge within the first two categories.

Although we are not sure of the precise impacts of advanced machine intelligence on society, we can rank it with the splitting of the atom and the discovery that genetic information resides in the double helix of deoxyribonucleic acid (DNA) for potential impact. Therefore, policy-making systems, policymakers, the policy sciences, and policy

[48] Harold D. Lasswell, “The Policy Orientation,” in *Policy Sciences*, ed. Daniel Lerner and Harold D. Lasswell (Stanford, CA: Stanford University Press, 1951), Chapter 1. This seminal article is considered the beginning of the policy sciences as a new discipline.

[49] For an expanded discussion on the policy sciences, see Krone, *Systems Analysis and Policy Sciences* and the works of Yehezkel Dror, whom I consider the world’s leading policy sciences scholar.

scientists should devote a great deal of time in the future to questions surrounding the use of, and the further development of, advanced machine intelligence.

One of the most important components of the policy sciences is values analysis. Values are things or principles preferred by an individual, group, organization, nation, or any social entity. They are what humans want and feel to be the reason for existence. Values regulate the political process and the managerial process and lie at the heart of resource allocations. They are the lenses and filters through which the world is viewed. Of all the analytical tasks of systems analysis values, analysis may be the most difficult and most important.

Policymakers in the very near future will make decisions about the use of and further development of advanced machine intelligence. Those policymakers have personal value sets formed at roughly twenty years of age and modified somewhat by their experiences since then. Advanced machine intelligence will impact society some decades from now. What will the values of people be then? We do not know. Perhaps the best we can do is to identify sets of possible values and consider those sets in the policymaking process so that advanced machine intelligence progress does not take directions that would be in violation of the most probable emerging values of future society. In any case, the utility of advanced machine intelligence cannot be adequately assessed without an attempt at values analysis.

This leads to the last thought of this article, but certainly not the last one on advanced machine intelligence. My optimistic bias has presented more utopias than dystopias to be wrought from the achievement of advanced machine intelligence. It will take more than optimism to avoid an autonomous technology, out of control and following its own course, independent of human direction, as postulated by Langdon Winner in 1977.[50] Systems theory leads us to the idea that we must consider the total set of positive and negative effects on society. There are bound to be social costs as well as benefits to advanced machine intelligence. The French decentralization plan to stimulate new industry through microcomputer technology may very well increase personal freedoms for French citizens, but the possibility of shock to French values and culture are real. Einstein's last public act was to join with Bertrand Russell to advocate a ban on the development of nuclear weapons. It was too late. Advanced machine intelligence may be the force that pushes the Third Wave movements described by Alvin Toffler into the reality of a new civilization.[51] Is that what we want? Is that what our grandchildren will want?

When Edward Feigenbaum and Julian Feldman drew up the first collection of articles on artificial intelligence in 1963, they did not include a paper on social implications of the intelligent machines "for reasons of sharp focus."[52] The *Proceedings of The First*

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[50] Winner, *Autonomous Technology*.

[51] Alvin Toffler, *The Third Wave* (New York: William Morrow and Co., 1980).

[52] Edward A. Feigenbaum and Julian Feldman, *Computers and Thought* (New York: McGraw-Hill, 1963), vi.

Annual National Conference on Artificial Intelligence at Stanford University in August 1980 did not include a paper on social implications.[53] Social implications were not study objectives of NASA for the 1980 feasibility study on which the concept of advanced machine intelligence presented herein is based. In the 1,116 pages of the two volumes of papers presented at the Seventh International Joint Conference on Artificial Intelligence at Vancouver in 1981, there is not one paper on or reference to social and psychological implications."[54] It is time that the social and psychological implications of artificial intelligence and advanced machine intelligence be thoroughly scrutinized through the lenses of systems theory, policy sciences theory, and Norbert Wiener's counsel to ensure the human use of human beings.[55]

Questions and Topics for Discussion

Speculation on societal impacts of the achievement of advanced machine intelligence raises more questions than it answers. The following ones are just a beginning. Add your own to the list.

1. The advanced machine intelligence definition in this article is oriented toward the space sciences. What definition would you formulate for your professional interests? From the viewpoint of systems management?
2. Superimpose the characteristics, accomplishments, and current developments of systems research and systems management as summarized by Robert Krone and Roger E. Cavallo over the definition and potentials of advanced machine intelligence described here. What new insights and impacts does that stimulate that are not mentioned in this chapter?
3. If you had a personal computer today capable of performing intelligent functions, what types of problems would you give it?
4. If systems analysis is the macro tool of the systems manager, speculate on the changes to systems analysis that might result from the achievement of an advanced machine intelligence. What are your reactions to the "Reality 21" concept?
5. Can you imagine what the increase of knowledge to 10^3 times what it is today would mean in your area of expertise? How about 10^8 times?
6. Why would some advocate the suppression of knowledge leading toward the achievement of advanced machine intelligence?

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[53] *Proceedings of The First Annual National Conference on Artificial Intelligence*.

[54] *Proceedings of the Seventh International Joint Conference on Artificial Intelligence (LICA1- 81),* Vancouver, BC, Canada, August 24-28, 1981, 2 vols. (Menlo Park, CA: American Association for Artificial Intelligence, 1981).

[55] Wiener, *Human Use of Human Beings*.

7. Values are things or principles that are preferred. Forecast your own set of values that will prevail in American society in 2050, then see how advanced machine intelligence might contribute to, be destructive of, or be neutral to that set of values.
8. What is the significance of the Isaacson invention of an electronic signal processing device that incorporates dialectical logic? What applications can you envision?
9. Three characteristics of our age are uncertainty, complexity, and novelty. In what specific ways might advanced machine intelligence help us to understand, analyze, and predict in a world described by those characteristics? In what ways might human systems be improved through its application?
10. Using Thomas S. Kuhn's explanation for how scientific knowledge evolves, try to conceptualize a scientific paradigm in which advanced machine intelligence plays a prominent role. What would be the major components of that paradigm?
11. Until the twentieth century, humankind generally placed its future in the hands of omniscient and supernatural entities—such as the gods or fate. If advanced machine intelligence allows an increasing percentage of human affairs and natural phenomenon to be understood, controlled, and manipulated by humans, what societal and psychological problems do you see emerging?

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Editors' Notes: When this book chapter was published in 1982, human intelligence had been under serious research for one hundred years, Alan Turing had predicted machine intelligence in 1950, and Carl Sagan had speculated in 1977 that the next development in intelligence would be a partnership between human and machine intelligence; personal computers were just being developed; machine intelligence theory existed and NASA had begun formal research; and a patent on the identification of a discovered cosmos natural intelligence process, by Dr. Joel Isaacson, titled "Autonomic String Manipulation System," had just been published in 1981. All these events pin down the early 1980s as a turning point in the understanding and applications of the human intelligence phenomena. ***Bob Krone and Gordon Arthur*.**