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On Criticisms of World Dynamics

by

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Since the publication of World Dynamics¹ in 1971 ~~and the successor book, Limits to Growth² by Meadows and others in 1972,~~ an often repeated set of criticisms has appeared in reviews and commentaries. These reactions have appeared enough times to justify analysis and comment. → next page

The ~~two books~~ deal with the dynamic interactions between population, capital, natural resources, pollution, and agriculture. ~~They do~~ it does this through the medium of computer models that have been built to capture the essence of assumptions that now seem to underlie political decision-making.

~~Although the debate involves both World Dynamics and Limits to Growth, I will respond only in terms of World Dynamics because some of the comments revolve around specific numerical assumptions that are available in the earlier book. Although the corresponding numerical and quantitative assumptions for Limits to Growth have been available to serious research groups since the spring of 1972, they are not yet at this writing generally available through a commercial publisher. The use of models in decision-making is old and familiar. Human thinking depends on models. One does not have a real city or nation in his head--only assumptions and simplifications that are a model that we use instead of the real system. Nations and the world are now managed entirely on the basis of models. The mental model starts from various assumptions about the parts of a social system, draws conclusions about the future dynamic implications of those assumptions, and goes on to propose modifications of laws and policies that are presumed to lead toward a better future. The computer modeling process on which the two books are based is, in general, the same as the mental modeling process. The differences are in degree rather than in kind. The computer~~

1. Forrester, Jay W., World Dynamics, Wright-Allen Press, 238 Main Street, Cambridge, Mass., U.S.A.

2. Meadows, Donella H., et al, The Limits to Growth, Universe Books, 381 Park Avenue South, New York.

model is more clearly stated and its implications can be determined with more certainty.

The computer model presents its underlying assumptions concretely and explicitly so that they are available for criticism and revision. The assumptions are interrelated in clearly stated ways that divulge the assumed structure for others to analyze. Because the structure has been made unambiguous and the numerical assumptions have been made quantitative, the resulting model (which is a theory of social structure) can be used by a computer to expose the behavioral consequences of the assumptions that have been made.

Why has the public and press given so much attention to these two books? Some have attempted an explanation in terms of publicity efforts by publishers and authors. But World Dynamics was released by a previously unknown publisher with nothing more than the mailing of literature and review copies. Yet within three months it was being discussed in the daily press, business periodicals, and in many special-interest publications. Clearly, the issues touched on deep public concerns.

The ~~resulting~~ controversy has arisen because the computer modeling process exposes internal contradictions that exist in the currently prevalent mental models. The computer models are essentially consistent with present assumptions about major world interactions. The behavior of the models is consistent with the observed rising social, technical, economic, and environmental pressures around the world. But the models come as a shock because they suggest a future that is quite different from the one our mental models have been anticipating. The critics seem to assume that the inconsistency between assumptions and expectations will be resolved by altering the basic assumptions until models behave in accordance with our future hopes. But it has been repeatedly shown that mental models are more reliable in their basic assumptions than in anticipating future behavior that follows from the assumptions.

The reactions to the books seem to rest on nine viewpoints and attitudes that the critics bring to the subject:

1. Assuming that analysis of social systems is premature and hopeless because sufficient information is thought not to exist.

mainly included in W.D. epilogue

2. Seeing the world from a narrow technical and materialistic viewpoint that excludes important social forces.
3. Addressing only limited physical and economic issues while ignoring the successive layers of limits to growth.
4. A sense of impotence toward altering present world attitudes becomes a sense of futility when the future is discussed.
5. Believing capital accumulation is the key to the future in spite of past inability in most cultures to acquire capital faster than population has grown and in spite of the rising forces that will lower the marginal productivity of capital and reduce the social feasibility of more rapid accumulation.
6. Hoping that market forces and prices can solve the problem of shortages.
7. Adopting a narrow disciplinary view so that the degree of aggregation represented in the models is not interpreted correctly.
8. Failing to perceive correctly the implications of aggregation, leading to the belief that technical progress has been omitted from the models.
9. Overlooking the way computer models are changing the rules of debate so that vague and nonspecific complaints are addressed to the clear and specific assumptions that are given in a computer model.
10. *Psychological hemmes etc - main focus - more imp than material limitation*

Taking each of these nine points in turn:

1. Analysis Not Possible. It is commonly stated by academic critics that analysis of social systems as presented in World Dynamics should not yet be undertaken because sufficient information is not available. This is a viewpoint that can be taken only by a critic who is free to stand on the sidelines and wait for certainty. It is a rational viewpoint for the person who need not act and wishes to avoid professional risk. It is, however, an alternative that is not available to the manager, the political leader, or the citizen. We all live now. We all act in the present. What we do or avoid today determines the future. We do not have the option of stopping time while knowledge accumulates. Furthermore, every decision that is made is made on the basis of models. Those models are now the mental models in the heads of citizens, members of parliament, heads of government, and representatives at the United Nations. In general those mental models are less comprehensive than the models that can now be assembled

and put on a computer. They are also less accessible and less specific. In addition they contain internal contradictions between the basic assumptions and the assumed behavior. The critic, by suggesting that formal models should be delayed, implies that he has more confidence in existing mental models than he could ever have in an explicit formal model. He is saying that ignorance is bliss. He would rather depend on a mental model whose assumptions are unknown to him than to depend on the best available model that explicitly states those assumptions. The computer models are now beginning to compete with the mental models in plausibility and influence. The proper rejoinder to an explicit computer model should be to offer equally explicit alternatives and improvements so that our understanding of social systems can rapidly advance.

2. Materialistic Viewpoint. Criticisms have tended to focus only on issues of resources, pollution, and capital. This betrays a narrow materialistic perspective that misses the social, psychological, and political aspects of existence. In fact the consequences of rapid technological change, crowding, pressures on resources, and the need for rising resource flows from the underdeveloped countries to sustain economic growth in the developed countries, all are manifesting themselves in economic stress, genocide, rising crime rates, drug addiction, and an increasing probability of a third world war. The fundamental issue here arises from the way that pressures created by growth redistribute themselves within the social system. If some of the pressures are relieved, growth continues until remaining pressures intensify in other parts of the system.

We know better how to relieve technological pressures than we do economic pressures. In turn, we are more able to deal with economic issues than the social and psychological issues. Therefore, the tendency is to release the technological pressures and allow further growth to shift the stresses into the economic and social realms. Then by partially succeeding in the counteraction of economic pressures, we make the ultimate transition into unresolvable social stresses. In other words, the narrow materialistic view that sees solutions to all problems as achievable through technology will be responsible for intensifying psychological and social disturbance.

3. Layers of Limits. The narrow economic viewpoint tends to see world problems only in terms of resources and capital accumulation. Yet the limits to growth exist in a succession of layers. To the extent that the immediate layer can be relaxed, another layer is encountered. This succession is shown in World Dynamics where, with the particular assumptions that were chosen, the first limit to be encountered arises from resources. Page 73 of World Dynamics, in referring to the resource-limited mode that results in a population peak in 50 years, states,

. . . the figure should be interpreted as one of the possible modes of behavior of the world system. One can argue that exhaustion of natural resources is not the most likely limitation on population growth. Actual stocks of natural resources may be greater than the 250-year supply that has been assumed here. Furthermore, science may make continuing substitutions to delay the impact of resource shortage. If natural resources do not limit population growth and slow the pace of industrialization, however, some other force in the world system will eventually do so.

. . . natural resources may not be the most critical aspect of the world environment. (page 74) . . .

The effect of reducing the demand for natural resources is to take one layer of restraint off the growth forces of the system. (page 75) . . .

. . . [this] teaches a fundamental lesson about complex systems. When one pressure or difficulty is alleviated, the result may be merely to substitute a new problem for the old. Often the new mode is less desirable than the old. In particular, the industrialized societies have come to depend on technology to solve their problems. This succeeded when technology was improving so rapidly that it could exploit geographical space and natural resources faster than the population could increase. But now, as technology reaches the point of diminishing returns and begins to run short on space and resources, the technological "solution" may more and more be only a substitution of one crisis for another. (page 80)

The book then continues to examine pollution as a possible limit, food shortage as another possible limit, and crowding as the ultimate limit. Those who depend only on technology should ask themselves what the next set of limits will be. Will pursuit of technical goals simply lead to more intractable pressures in the economic and social sectors? I believe they will. If so, the arguments presented by the materialistic technologists will in time be recognized as having been a route to greater social disorientation.

4. Futility in the Face of Past Traditions. In effect, some critics plead that we need not address ourselves to the future because we cannot change the present traditions, actions, and value structures of society. This is the voice of resignation and hopelessness. But it arises from misjudging the interest of the public in the longer-term future and the sensitivity of the public to present omens. The public viewpoint has changed markedly in the last ten years toward an increasing concern for environmental issues, an acceptance of the necessity for population limitation, and a recognition that continued dependence on technology alone to solve problems will produce rapidly intensifying stresses in the nontechnical aspects of the world system. I believe the critics' futility is unjustified and that citizens, managers, and political leaders are beginning to recognize deteriorating interactions between technical, economic, and social forces as issues to which they must be increasingly responsive.

5. Confidence in Capital Accumulation. The technical optimism is based on the assumption that massive accumulation of capital can solve all problems. It is often suggested that additional capital investment can increase agricultural output, reduce pollution, and use lower grade resources. This may be true if the capital accumulation can and does occur. But the optimists do not address themselves to the feasibility of such massive capital accumulation. Two developing trends suggest that it will be more difficult than in the past, while, even in the past, capital accumulation has been possible for only that quarter of the world's population that has lived under particularly fortuitous circumstances. As environmental limits are pressed more tightly, the cost of generating capital will increase at the same time that its marginal productivity declines. Furthermore, as population continues to grow while production comes under ever heavier restraint, there will be growing social pressures to divert current production into current consumption. As the pressures for medical programs, old age support, unemployment compensation, and public welfare payments mount, there may be a declining capability for accumulating capital.

6. Rising Prices. Prices have not been included in the variables of the World Dynamics model. Many have seen the absence of prices as a major weakness, and have asserted that price mechanisms would curtail use of scarce goods and thereby prevent their disappearance. But rising prices

imply more effort expended per unit of product. Higher real prices are equivalent to lower productivity and a falling standard of living. It matters very little to the consumer whether he cannot procure goods because they are unavailable or because the price is higher than he can afford. Prices are intervening variables between supply and demand, they are communicators of shortage, and they encourage the use of more abundant alternatives for scarce goods. But prices cannot correct a situation of total demand exceeding total supply such as will exist if population and industrialization extend beyond the limits of the world environment. This viewpoint parallels the U. S. National Academy of Science report of August 1972, Elements of a National Materials Policy, that states, "there was but small support for the view that market forces alone will solve the foreseeable problems."

7. Misinterpretation of Aggregation. An overview of a social system discards fine detail so that broad issues can be more clearly accentuated. When this is done, many of the intermediate relationships in a chain of causality are omitted. A critic who is accustomed to taking a narrow subsystem view may observe the omission of the direct elements of causality without looking beyond them to see if they are adequately represented by a more fundamental set of causes. This failure to judge from the appropriate perspective is illustrated by reactions to the demographic sector of World Dynamics. In the model birth rate depends on the material standard of living, crowding, pollution, and food per capita. But critics suggest alternative effects on birth rate without asking whether or not these might in turn be related to the more fundamental variables already represented in the model. For example, the suggestion is made that social attitudes and institutional factors affect birth rate. Indeed they do but are they not themselves apt to be a reflection of the availability of space, food, material goods, and a satisfactory environment? Social attitudes and institutional factors reflect the self-discipline necessary for man to fit himself into his environment and to the proximity of his fellow man.

As a more specific example, the suggestion has been offered that the decline in French fertility in the nineteenth century might be due to changes in the laws of inheritance, changed social attitudes, and the easier life that fewer children make possible. But one should look back into the

economic and political situation to see why the laws were changed and the social attitudes were altered. And what was it in the changing technology and rising industrialization that made fewer children advantageous? The intervening variables that are suggested will often be but mere reflections of the more fundamental variables dealt with in World Dynamics.

The revived birth rate in the United States after World War II and the more recent decline are often alleged to be contrary to the assumptions in the computer model. But depressed birth rates in the 1930's followed by a rise in the 50's and a fall in the late 60's coincides closely with the varying economic, psychological, and environmental pressures on the population.

8. Technical Change. The erroneous belief that the World Dynamics model takes no account of technical change is also traceable to lack of familiarity with models that take a broad overview. Technical change is represented in the World Dynamics model as part of capital investment. From page 53 we find, "Capital includes buildings, roads, and factories. It also includes education and the results of scientific research, for the latter are not represented elsewhere in the model system and the investment in them decays at about the same rate as for physical capital." Physical capital, education, and technical advancement have very similar dynamic behavior. Each, in a real sense, as it interacts with population, tends to reproduce itself. Physical capital tends to make possible a higher rate of accumulation of physical capital. Knowledge makes it possible to accumulate still more knowledge. Technical accomplishment becomes the foundation for further technical accomplishment. They all, under the proper circumstances, regenerate themselves in a positive feedback loop as in World Dynamics. Dynamically speaking, they are very similar and can be aggregated together as a first approximation. If this had not been done with some success, how otherwise would the behavior of the model, which starts with conditions of the year 1900, by itself generate a trajectory that passes through the conditions of 1970? Certainly the seventy intervening years have been marked by rapid technological change. The several effects could have been separated and represented individually in the model. Doing so would have made details easier to describe, but would have obscured the broad overall structure of world interactions.

9. Changed Rules of Debate. In the past men have debated the merits of mental models and their implications for the future of society. But the underlying assumptions have seldom been made specific and the arguments have been equally vague. But computer models of social structure are explicit, the assumptions have meaning to an ordinary person who has knowledge of corresponding parts of the real system, and any concept that can be expressed in explicit verbal language can be put into computer language. Translation from ordinary language to computer language is simpler than translation between French and English. The grammar is more specific, the constructions are unambiguous. All statements must be made in quantitative form and murky thinking is suppressed.

With a clear and precise statement of assumptions, with an explicit statement about structure, and with an unassailable presentation of the implications of the assumptions as presented in computer output, a new rigor in debate is called for. Contrary assumptions about structures and influences should be presented with equal quantitative clarity. It would then be possible to determine whether or not the alternative suggestions would change the conclusions. But so far most critics are standing outside of the new arena. They throw stones at explicit assumptions that are offered, but do not risk opening themselves to similar inspection. Although far better and more comprehensive models can and will be developed, no one has yet offered an alternative quantitative model that he suggests is better.

The system dynamics methodology illustrated in World Dynamics gives a new basis for drawing together the interactions between technology, politics, economics; law, ethics, and religion.* The interactions between disciplines account for social behavior much more than influences from within any single discipline. System dynamics, by providing a common framework, allows the interconnections to be established. But more than a systems methodology is necessary. Knowledge about the subsystems is required. Time is needed to put each subsystem into a common framework. As the world becomes more congested, the interactions become more significant. If the

*For a discussion of religion in the context of these issues, see my chapter, "Churches at the Transition Between Growth and World Equilibrium" in Toward Global Equilibrium, Dennis L. Meadows, editor, Wright-Allen Press, 238 Main Street, Cambridge, Mass., U.S.A.

changing patterns of social forces are to be understood and controlled, the multiple interactions within society must be better understood. This, I suggest, is the great challenge of the next one or two decades. The task now is not the gathering of more detailed and elementary information. That has been going on for years. We are overwhelmed with bits and pieces of knowledge.

Now is the time to develop concrete theories of how this knowledge is linked together. Computer models are such theories. They show the interrelationships; they allow a derivation of the consequences; they permit a test of the theories against the evidence from reality. Toward achieving this better understanding, I suggest that several major research institutes need to be established. Each should contain men from every significant field of endeavor. All should amalgamate existing knowledge into unified theoretical structures (computer models), so that we can better determine the future implications of what we now know and are now doing. Alternative courses of action could then be evaluated to suggest roads toward the most acceptable of available futures.

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The Fledgling Cheermonger^{1, 2}

by
Jay W. Forrester

*I suggest integrating
portions marked on pp 4, 5, 6
7, and 8 into the format
of an Criticism of W.D.*

A number of writers have recently undertaken to assure the public that no fundamental threat exists from rising population, increasing industrialization, growing pollution, or intensifying social stress. They suggest that the wisdom of man, the foresight of governments, the pursuit of technology, and the infallibility of economic processes will successfully deal with all threats and lead to a future utopia. They have labeled as doomsayers those who point out the hazards implicit in present trends and who suggest that man should alter direction toward a safer and more satisfactory destination.

One such book is The Doomsday Syndrome by John Maddox. (MacMillan, 1972). Perhaps the book is best described by the first sentence of its own preface: "This is not a scholarly work but a complaint." Or for a brief summary one could turn to the author's countryman, Alan Coddington of Queen Mary College, in his paper, "The Cheermongers" (Your Environment, Autumn 1972), where he reviews, before refuting, the essential points made by those who assure us that no problems of the future need be cause for present concern and then continues, "So much for the cheermongering backlash. It is to be found in its purest form in the writings of Anthony Crosland, Professor Wilfred Beckerman, and Jeremy Bray, but traces of it are currently widespread. More recently, John Maddox has made a bid for the status of cheer leader, but his work adds nothing of substance to the existing arguments."

*Corrected in
D-1730* || ~~The cheermonger position as repeated by Maddox seems to rest on~~ one or more of seven attitudes--a focus on the near-term future, the expectation that governments can solve all problems, hope built on the absence of information, unbounded confidence in technology, belief that our economic processes are omniscient, fallacy in argument, and faith in suboptimizing. || Illustrations of all of these are to be found in The Doomsday Syndrome.

Regarding a focus on the short-term future, the author attempts to establish his time horizon as being as distant as anyone's by saying

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2. Submitted for the January 1973 issue of the Cambridge Review, University of Cambridge.

in the preface, "One of the distressing features of the present debate about the environment is the way in which it is supposed to be an argument between far-sighted people with the interests of humanity at heart and others who care not tuppence for the future." But as early as page 2 the time horizon begins to shorten. After mentioning the problems of schooling, housing, Bengal, and Calcutta, the author opts for the present: "The question which the doomsday prophets pose for those who share their compassion for society is whether the energies of the human race should be spent on problems like these which, however difficult, can be solved or whether they should be spent on the avoidance of more distant trouble." An important issue to which Maddox does not address himself is the extent to which solution of the short-run problems will indeed make worse the more distant troubles. And the retreat from the future is complete by page 23 with the worn-out quotation, "In the long run, as Lord Keynes put it, we shall all be dead." In fact, the book does not strike the essential balance between the present and the future. ✕

The author, when it suits his purpose, expresses great confidence that government can rise to any threat that might confront mankind. But in his franker moments he completely contradicts that viewpoint. On page 8 is found a statement of confidence, "The moral, of course, is what it has always been--that governments have a responsibility to ensure that in the process of technical innovation, society reaps mostly benefits. . . . The belief that technology is an all-powerful juggernaut wringing the humanity out of society seems usually to be a cloak for a pessimistic belief in the impotence of social institutions." But even on the next page the confidence falters, "Governments have all too often been unwilling to shoulder their responsibilities. In all advanced societies, governments have wavered on the introduction of jet aircraft without thinking sufficiently about the extra noise that they would cause. They have encouraged industrial development without thinking sufficiently of the unavoidable side effects of industry, pollution chief among them. They have encouraged urbanisation without paying enough attention to city planning." But even this waning confidence in governmental institutions has disappeared one-third of the

way through the book on pages 80 and 81, "The scandal of what has happened to the whales in the southern seas is miserable proof that folly can make its way even in a reasonable world. Since the Second World War, it has been clear that the whaling industry was in danger of fishing itself out of existence. . . . Under pressure from nations anxious to catch as many whales as possible as soon as possible, the commission has consistently set annual quotas which are too large. . . . The result is that the total population of blue whales is probably no more than a few hundreds. . . . The failure of the International Whaling Commission to do the job for which it was set up is a poor augury for the international organisations which are probably already overdue if the stocks of valuable commercial fish. . . are not to be depleted by over-fishing." So, we have the cheer-mongers depending on governmental processes that they already recognize as reacting too little and too late.

The confidence generated by lack of information seems unexplainable except by assuming a head-in-the-sand attitude. On page 6 after mentioning insecticides and concern about unintended weather transformation, the author says, "Fortunately, these chains of events are by no means inescapable. For one thing, the processes which are supposed to lead to disaster are only imperfectly understood." Is imperfect understanding a foundation on which to build complacency? Processes that are imperfectly understood can be more serious than assumed, as well as less serious.

The unbounded confidence in technology and in technologists that some of these authors exhibit is frightening to behold. I speak on this as one whose career from 1939 to 1956 was immersed in the technological frontier. During that period of time it was easy to see the transition of technology from the tradition of the independent, professional engineer to the corporate employee, subservient to financial and political pressures. The trends since have continued to impersonalize the technological process and make it less responsible. On page 95 and speaking of the threat from radioactive wastes, Maddox says, "Worse still, the suggestion that pollution of this kind 'is likely to occur' is strictly a subjective judgment. It implies that something will go wrong with the plans which nuclear engineers are making for the disposal of the waste products from nuclear plants. . . . the message [referring to concern expressed by employees of the Atomic

Energy Commission]. . . is nothing but the message that they lack confidence in the engineers. Is that a sufficient basis for a crusade against nuclear electricity?" Time after time in military equipment, consumer products, and pharmaceutical drugs we have seen defects and disasters because short-range economic pressures and expediencies for early delivery have overridden attempts to achieve good technical design. Today most engineers work within administrative bureaucracies. These bureaucracies, whether corporate or governmental, unavoidably develop a short-term viewpoint that serves the current interests of the people who populate the organizational structures. An engineer who places professional integrity above the pressures to which the organization is responding will be labeled an obstructionist and will be shunted aside, fired, or pressured into leaving. His place will be taken by someone whose strength of character is less or someone whose skill and judgment are not sufficiently well-developed to reveal to him the long-term hazards of his actions. Herein lies the danger. There is indeed a "sufficient basis" that people should "lack confidence in the engineers." Naive belief that all humans are motivated by the long-term good of society, that they know how to implement that motivation, and that they exist in organizations that will permit the implementation are dangerous self-deceptions indeed.

The typical cheerleader's belief in omniscient economic processes is illustrated by a quotation from page 83, "It follows that at some stage in the next century, the petroleum business as it is at present known will come to an end. Either the price of petroleum products such as fuel oil and motor spirit will increase until it is cheaper to use alternatives, or the reserves will be exhausted. On the long view, however, this prospect should not keep people awake at night. For one thing, the petroleum reserves will not come to an abrupt end--instead, there will be a steady increase of price so that economically less valuable uses are eliminated first." This argument has been extended by various writers to include resources, land and food. Rising real prices mean less average output per man-hour of effort and also a falling standard of living. Why so many economists equate rising prices to permanently adequate supplies is hard to understand. Does the man without heat care whether he cannot get fuel because there is a shortage or because he cannot afford to buy the scarce remaining supply?

Another characteristic of much cheer monger writing is the kind of argument that seems persuasive on quick reading, but when more carefully analyzed is found empty. From page 95 we find a typical example. Maddox quotes employees of the Atomic Energy Commission as saying: "'Radioactivity represents one of the worst, maybe the worst of all poisons. . . . One year of operation of a single, large nuclear power plant, generates as much of long-persisting radioactive poisons as one thousand Hiroshima-type atomic bombs. . . . Once any of these radioactive poisons are released to the environment, and this we believe is likely to occur, the pollution of our environment is irreversible. They will be with us for centuries.'" Maddox then goes on to say, "The premise in this argument is true. . . . All existing nuclear power stations produce large quantities of radioactive isotopes. But there is no certainty in the argument that any of these 'radioactive poisons' would permanently pollute the environment, for some of them are exceedingly short-lived." By pointing out correctly that some of the isotopes are short-lived, he tries to establish that there is no threat. He does not address himself to the very long-life isotopes that also exist to which the Atomic Energy Commission authors were addressing themselves and which represent the serious threat.

Those who suggest cheerfully that there need be no concern for the future usually place their confidence in the process of suboptimizing. Suboptimizing means working separately toward each subgoal of a society in the belief that the overall metagoal of the social system will thereby be approached most rapidly. The metagoal is the overall measure that is usually called "quality of life." A society has many subgoals. Each must be partially met, but none will be fully met. The management of a society consists of reallocating resources in accordance with the changing extent to which the various subgoals have been satisfied. Some subgoals can be enhanced through technology. Other subgoals are approached by economic action. Still other subgoals involve altering social and psychological variables.

There is a strong and natural tendency to work toward those subgoals that respond to methods we best understand. An industrial society

is most able to handle technology. But the industrial society is less able to control economic processes. And it is quite ineffective when faced with the need for fundamental psychological and social change. Therefore, because the means are better understood, technical goals get first attention, both in practice and in the hearts of the cheerleaders. With less confidence, secondary effort is devoted to the more uncertain and elusive economic subgoals. Last and not least, faltering and ineffective stabs are made at closing the gap between present conditions and our social and psychological subgoals.

The tendency is almost overwhelming to suboptimize by focusing on the technical subgoals with secondary attention to the economic subgoals. This is a satisfactory procedure as long as efforts to meet one subgoal have no detrimental effect on the likelihood of meeting other subgoals. If there is such independence, an increase in any subgoal makes some contribution to enhancing the metagoal. Suboptimizing is satisfactory under circumstances when subgoals are independent of one another. Suboptimizing is not satisfactory after the social system has reached a condition when efforts to enhance one subgoal actively reduce the chances of meeting other subgoals. I believe that our social systems set here a trap for those who judge the future entirely by the past.

During the exponential growth phase in any social system, there seems to be a high independence between the various subgoals. During growth suboptimizing is satisfactory. A particular subgoal can be pursued without immediate and substantial reduction in the likelihood of meeting other subgoals. During growth the trade-offs exist between points in time. At any particular moment during growth the welfare at that moment can be increased in exchange for a cost that must be paid in the future. The time for paying that cost occurs at the transition region between growth and equilibrium when the growth curve reaches its point of inflection and changes from upward curvature and begins to curve toward equilibrium. This point occurs well before the actual equilibrium condition itself. Today we are in that transition region. We are beginning to pay the price for advantages that mankind reaped in the past. For example, the past increases in food per capita, in public health measures, and in medicine improved health, well-being and security in the past. But those very advantages produced population growth with the accompanying social stresses and threats of today.

But in the transition region and beyond in equilibrium, the nature of subgoal trade-offs changes. No longer can we improve our present lot at the expense of some future time. The trade-offs begin to occur very quickly between the various subgoals in the present. In other words, the condition develops in which improving one aspect of society reduces another. To be more specific, if we continue to work toward technical subgoals and relieve those pressures that technology can relieve, we thereby encourage a continuation of the growth process as recommended by men like Maddox. But the continued growth will make the economic and the social difficulties progressively greater. The very argument to which Maddox addresses himself between the environmentalists and the growthmen is a manifestation of this increasing interrelatedness in subgoals. The economic subgoals are now encroaching upon the environmental subgoals. But even worse, as these two sets of goal seekers attempt to suboptimize, the pressures are thrown into the third realm of social and psychological strain.

We are now at the point where population and industrial growth will be under ever-rising pressures until the growth process is gradually brought to rest. The most fundamental and important question is how we would like to have the pressures distributed. Should there be balanced pressures with some from the technological side, some from economic aspects of existence, some from the social side, and some from self-discipline and self-restraint? Or do we want the pressures concentrated in a single area? If we take off the pressures where we can, and thereby encourage growth to continue, we are active agents in ultimately increasing the stresses in other areas. Men with the Maddox message are essentially saying: remove the economic restraints, allow growth to continue, and maintain the past trends until economic and social pressures sufficiently threaten the society that the latter alone stop growth. We see these social pressures increasing already. I believe we can clearly trace back to growth and to the changes that accompany technology such social disorientations as drug addiction, rising crime rate, aircraft hijackings, genocide, and the increasing threat of a third world war. A third world war is apt to involve conflict over space, natural resources, pollution dissipation rights, and political freedom. All of these pressures are intensified by rising population and by rising industrialization. So the proper question

does not regard the technical feasibility of obtaining more energy and using lower grade resources. Instead the question could better be phrased: assuming that we can solve the technical problems, do we want to? More and more the technical solutions will increase the economic and social pressures. The cheer monger plea is an echo from the past when suboptimizing was a satisfactory way to run society. But the fundamental nature of world society is changing. The siren song of growth now begins to lead down the primrose path to rising social disorder. The interlocked nature of the subgoals is such that the social pressures will rise as high as necessary to counteract the growth-encouraging actions for which the cheer mongers plead. Here lie issues much too serious to be dealt with by a treatment that "is not a scholarly work but a complaint."

Instead, I feel the clash of viewpoints represented by the differing attitudes of the growth economists, the materialistic cheer mongers, the environmentalists, and those that speak for the balanced metagoals of society should receive the most serious attention. The issues are too difficult and deep to be disposed of by quickly written books and brief rejoinders. Nothing less than the best minds of the world working together over the next one or two decades can deliver the insights necessary for modifying our technology, political institutions, legal structures, social organizations, and religions* to make them mutually consistent in support of a decent future.

*For a discussion of religions in the context of these issues, see my chapter "Churches at the Transition Between Growth and World Equilibrium" in Toward Global Equilibrium, Dennis L. Meadows, editor, Wright-Allen Press, Cambridge, Massachusetts, U.S.A., in England from John Wiley.

Jay W. Forrester, Germeshausen Professor, Massachusetts Institute of Technology; inventor of the random-access magnetic core memory used in digital computers; recipient of the Valdemar Poulsen Gold Medal from the Danish Academy of Technical Sciences, 1969; Medal of Honor of the Institute of Electrical and Electronic Engineers, 1972; Benjamin Franklin Fellow of the Royal Society of Arts, 1972; Award for Outstanding Accomplishment by the Systems, Man and Cybernetics Society, 1972; author of Industrial Dynamics, 1961, and Urban Dynamics, 1969, (M.I.T. Press, Cambridge, Massachusetts) and of Principles of Systems, 1968, and World Dynamics, 1971 (both Wright-Allen Press, Cambridge, Massachusetts, in England through John Wiley.)

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cover

On Criticisms of World Dynamics

by

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↑ ↑
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November 13, 1972

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But the models come as a shock because they suggest a future that is quite different from the one our mental models have been anticipating. The critics seem to assume that the inconsistency between assumptions and expectations will be resolved by altering the basic assumptions until models behave in accordance with our future hopes. But it has been repeatedly shown that mental models are more reliable in their basic assumptions than in anticipating future behavior that follows from the assumptions.

The reactions to the books seem to rest on nine viewpoints and attitudes that the critics bring to the subject:

1. Assuming that analysis of social systems is premature and hopeless because sufficient information is thought not to exist.

2. Seeing the world from a narrow technical and materialistic viewpoint that excludes important social forces.
3. Addressing only limited physical and economic issues while ignoring the successive layers of limits to growth.
4. A sense of impotence toward altering present world attitudes becomes a sense of futility when the future is discussed.
5. Believing capital accumulation is the key to the future in spite of past inability in most cultures to acquire capital faster than population has grown and in spite of the rising forces that will lower the marginal productivity of capital and reduce the social feasibility of more rapid accumulation.
6. Hoping that market forces and prices can solve the problem of shortages.
7. Adopting a narrow disciplinary view so that the degree of aggregation represented in the models is not interpreted correctly.
8. Failing to perceive correctly the implications of aggregation, leading to the belief that technical progress has been omitted from the models.
9. Overlooking the way computer models are changing the rules of debate so that vague and nonspecific complaints are addressed to the clear and specific assumptions that are given in a computer model.

Taking each of these nine points in turn:

1. Analysis Not Possible. It is commonly stated by academic critics that analysis of social systems as presented in World Dynamics should not yet be undertaken because sufficient information is not available. This is a viewpoint that can be taken only by a critic who is free to stand on the sidelines and wait for certainty. It is a rational viewpoint for the person who need not act and wishes to avoid professional risk. It is, however, an alternative that is not available to the manager, the political leader, or the citizen. We all live now. We all act in the present. What we do or avoid today determines the future. We do not have the option of stopping time while knowledge accumulates. Furthermore, every decision that is made is made on the basis of models. Those models are now the mental models in the heads of citizens, members of parliament, heads of government, and representatives at the United Nations. In general those mental models are less comprehensive than the models that can now be assembled

and put on a computer. They are also less accessible and less specific. In addition they contain internal contradictions between the basic assumptions and the assumed behavior. The critic, by suggesting that formal models should be delayed, implies that he has more confidence in existing mental models than he could ever have in an explicit formal model. He is saying that ignorance is bliss. He would rather depend on a mental model whose assumptions are unknown to him than to depend on the best available model that explicitly states those assumptions. The computer models are now beginning to compete with the mental models in plausibility and influence. The proper rejoinder to an explicit computer model should be to offer equally explicit alternatives and improvements so that our understanding of social systems can rapidly advance.

2. Materialistic Viewpoint. Criticisms have tended to focus only on issues of resources, pollution, and capital. This betrays a narrow materialistic perspective that misses the social, psychological, and political aspects of existence. In fact the consequences of rapid technological change, crowding, pressures on resources, and the need for rising resource flows from the underdeveloped countries to sustain economic growth in the developed countries, all are manifesting themselves in economic stress, genocide, rising crime rates, drug addiction, and an increasing probability of a third world war. The fundamental issue here arises from the way that pressures created by growth redistribute themselves within the social system. If some of the pressures are relieved, growth continues until remaining pressures intensify in other parts of the system. We know better how to relieve technological pressures than we do economic pressures. In turn, we are more able to deal with economic issues than the social and psychological issues. Therefore, the tendency is to release the technological pressures and allow further growth to shift the stresses into the economic and social realms. Then by partially succeeding in the counteraction of economic pressures, we make the ultimate transition into unresolvable social stresses. In other words, the narrow materialistic view that sees solutions to all problems as achievable through technology will be responsible for intensifying psychological and social disturbance.

3. Layers of Limits. The narrow economic viewpoint tends to see world problems only in terms of resources and capital accumulation. Yet the limits to growth exist in a succession of layers. To the extent that the immediate layer can be relaxed, another layer is encountered. This succession is shown in World Dynamics where, with the particular assumptions that were chosen, the first limit to be encountered arises from resources. Page 73 of World Dynamics, in referring to the resource-limited mode that results in a population peak in 50 years, states,

. . . the figure should be interpreted as one of the possible modes of behavior of the world system. One can argue that exhaustion of natural resources is not the most likely limitation on population growth. Actual stocks of natural resources may be greater than the 250-year supply that has been assumed here. Furthermore, science may make continuing substitutions to delay the impact of resource shortage. If natural resources do not limit population growth and slow the pace of industrialization, however, some other force in the world system will eventually do so.

. . . natural resources may not be the most critical aspect of the world environment. (page 74) . . .

The effect of reducing the demand for natural resources is to take one layer of restraint off the growth forces of the system. (page 75) . . .

. . . [this] teaches a fundamental lesson about complex systems. When one pressure or difficulty is alleviated, the result may be merely to substitute a new problem for the old. Often the new mode is less desirable than the old. In particular, the industrialized societies have come to depend on technology to solve their problems. This succeeded when technology was improving so rapidly that it could exploit geographical space and natural resources faster than the population could increase. But now, as technology reaches the point of diminishing returns and begins to run short on space and resources, the technological "solution" may more and more be only a substitution of one crisis for another. (page 80)

The book then continues to examine pollution as a possible limit, food shortage as another possible limit, and crowding as the ultimate limit. Those who depend only on technology should ask themselves what the next set of limits will be. Will pursuit of technical goals simply lead to more intractable pressures in the economic and social sectors? I believe they will. If so, the arguments presented by the materialistic technologists will in time be recognized as having been a route to greater social disorientation.

4. Futility in the Face of Past Traditions. In effect, some critics plead that we need not address ourselves to the future because we cannot change the present traditions, actions, and value structures of society. This is the voice of resignation and hopelessness. But it arises from misjudging the interest of the public in the longer-term future and the sensitivity of the public to present omens. The public viewpoint has changed markedly in the last ten years toward an increasing concern for environmental issues, an acceptance of the necessity for population limitation, and a recognition that continued dependence on technology alone to solve problems will produce rapidly intensifying stresses in the nontechnical aspects of the world system. I believe the critics' futility is unjustified and that citizens, managers, and political leaders are beginning to recognize deteriorating interactions ^{among} ~~between~~ technical, economic, and social forces as issues to which they must be increasingly responsive.

5. Confidence in Capital Accumulation. The technical optimism is based on the assumption that massive accumulation of capital can solve all problems. It is often suggested that additional capital investment can increase agricultural output, reduce pollution, and use lower grade resources. This may be true if the capital accumulation can and does occur. But the optimists do not address themselves to the feasibility of such massive capital accumulation. Two developing trends suggest that it will be more difficult than in the past, while, even in the past, capital accumulation has been possible for only that quarter of the world's population that has lived under particularly fortuitous circumstances. As environmental limits are pressed more tightly, the cost of generating capital will increase at the same time that its marginal productivity declines. Furthermore, as population continues to grow while production comes under ever heavier restraint, there will be growing social pressures to divert current production into current consumption. As the pressures for medical programs, old age support, unemployment compensation, and public welfare payments mount, there may be a declining capability for accumulating capital.

6. Rising Prices. Prices have not been included in the variables of the World Dynamics model. Many have seen the absence of prices as a major weakness, and have asserted that price mechanisms would curtail use of scarce goods and thereby prevent their disappearance. But rising prices

imply more effort expended per unit of product. Higher real prices are equivalent to lower productivity and a falling standard of living. It matters very little to the consumer whether he cannot procure goods because they are unavailable or because the price is higher than he can afford. Prices are intervening variables between supply and demand, they are communicators of shortage, and they encourage the use of more abundant alternatives for scarce goods. But prices cannot correct a situation of total demand exceeding total supply such as will exist if population and industrialization extend beyond the limits of the world environment. This viewpoint parallels the U. S. National Academy of Science report of August 1972, Elements of a National Materials Policy, that states, "there was but small support for the view that market forces alone will solve the foreseeable problems."

7. Misinterpretation of Aggregation. An overview of a social system discards fine detail so that broad issues can be more clearly accentuated. When this is done, many of the intermediate relationships in a chain of causality are omitted. A critic who is accustomed to taking a narrow subsystem view may observe the omission of the direct elements of causality without looking beyond them to see if they are adequately represented by a more fundamental set of causes. This failure to judge from the appropriate perspective is illustrated by reactions to the demographic sector of World Dynamics. In the model, birth rate depends on the material standard of living, crowding, pollution, and food per capita. But critics suggest alternative effects on birth rate without asking whether or not these might in turn be related to the more fundamental variables already represented in the model. For example, the suggestion is made that social attitudes and institutional factors affect birth rate. Indeed they do but are they not themselves apt to be a reflection of the availability of space, food, material goods, and a satisfactory environment? Social attitudes and institutional factors reflect the self-discipline necessary for man to fit himself into his environment and to the proximity of his fellow man.

As a more specific example, the suggestion has been offered that the decline in French fertility in the nineteenth century might be due to changes in the laws of inheritance, changed social attitudes, and the easier life that fewer children make possible. But one should look back into the

economic and political situation to see why the laws were changed and the social attitudes were altered. And what was it in the changing technology and rising industrialization that made fewer children advantageous? The intervening variables that are suggested will often be but mere reflections of the more fundamental variables dealt with in World Dynamics.

The revived birth rate in the United States after World War II and the more recent decline are often alleged to be contrary to the assumptions in the computer model. But depressed birth rates in the 1930's followed by a rise in the 50's and a fall in the late 60's coincides closely with the varying economic, psychological, and environmental pressures on the population.

8. Technical Change. The erroneous belief that the World Dynamics model takes no account of technical change is also traceable to lack of familiarity with models that take a broad overview. Technical change is represented in the World Dynamics model as part of capital investment. From page 53 we find; "Capital includes buildings, roads, and factories. It also includes education and the results of scientific research, for the latter are not represented elsewhere in the model system and the investment in them decays at about the same rate as for physical capital." Physical capital, education, and technical advancement have very similar dynamic behavior. Each, in a real sense, as it interacts with population, tends to reproduce itself. Physical capital tends to make possible a higher rate of accumulation of physical capital. Knowledge makes it possible to accumulate still more knowledge. Technical accomplishment becomes the foundation for further technical accomplishment. They all, under the proper circumstances, regenerate themselves in a positive feedback loop as in World Dynamics. Dynamically speaking, they are very similar and can be aggregated together as a first approximation. If this had not been done with some success, how otherwise would the behavior of the model, which starts with conditions of the year 1900, by itself generate a trajectory that passes through the conditions of 1970? Certainly the seventy intervening years have been marked by rapid technological change. The several effects could have been separated and represented individually in the model. Doing so would have made details easier to describe, but would have obscured the broad overall structure of world interactions.

9. Changed Rules of Debate. In the past men have debated the merits of mental models and their implications for the future of society. But the underlying assumptions have seldom been made specific and the arguments have been equally vague. But computer models of social structure are explicit, the assumptions have meaning to an ordinary person who has knowledge of corresponding parts of the real system, and any concept that can be expressed in explicit verbal language can be put into computer language. Translation from ordinary language to computer language is simpler than translation between French and English. The grammar is more specific, the constructions are unambiguous. All statements must be made in quantitative form and murky thinking is suppressed.

With a clear and precise statement of assumptions, with an explicit statement about structure, and with an unassailable presentation of the implications of the assumptions as presented in computer output, a new rigor in debate is called for. Contrary assumptions about structures and influences should be presented with equal quantitative clarity. It would then be possible to determine whether or not the alternative suggestions would change the conclusions. But so far most critics are standing outside of the new arena. They throw stones at explicit assumptions that are offered, but do not risk opening themselves to similar inspection. Although far better and more comprehensive models can and will be developed, no one has yet offered an alternative quantitative model that he suggests is better.

The system dynamics methodology illustrated in World Dynamics gives a new basis for drawing together the interactions ^{among} ~~between~~ technology, politics, economics, law, ethics, and religion.* The interactions between disciplines account for social behavior much more than influences from within any single discipline. System dynamics, by providing a common framework, allows the interconnections to be established. But more than a systems methodology is necessary. Knowledge about the subsystems is required. Time is needed to put each subsystem into a common framework. As the world becomes more congested, the interactions become more significant. If the

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changing patterns of social forces are to be understood and controlled, the multiple interactions within society must be better understood. This, I suggest, is the great challenge of the next one or two decades. The task now is not the gathering of more detailed and elementary information. That has been going on for years. We are overwhelmed with bits and pieces of knowledge.

Now is the time to develop concrete theories of how this knowledge is linked together. Computer models are such theories. They show the interrelationships; they allow a derivation of the consequences; they permit a test of the theories against the evidence from reality. Toward achieving this better understanding, I suggest that several major research institutes need to be established. Each should contain men from every significant field of endeavor. All should amalgamate existing knowledge into unified theoretical structures (computer models), so that we can better determine the future implications of what we now know and are now doing. Alternative courses of action could then be evaluated to suggest roads toward the most acceptable of available futures.

Jay W. Forrester, Germeshausen Professor, Massachusetts Institute of Technology; recipient of the Valdemar Poulsen Gold Medal from the Danish Academy of Technical Sciences, 1969; Medal of Honor of the Institute of Electrical and Electronic Engineers, 1972; Benjamin Franklin Fellow of the Royal Society of Arts, 1972; Award for Outstanding Accomplishment by the Systems, Man and Cybernetics Society, 1972; author of Industrial Dynamics, 1961, and Urban Dynamics, 1969, (M.I.T. Press, Cambridge, Massachusetts) and of Principles of Systems, 1968, and World Dynamics, 1971 (both Wright-Allen Press, Cambridge, Massachusetts, in England through John Wiley.)



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Apr. 25 '73

Jay W. Forrester
Germeshausen Professor

ON CRITICISMS OF WORLD DYNAMICS

By

Jay W. Forrester

Since the publication of World Dynamics¹ in 1971 and the successor book Limits to Growth² by Meadows and others in 1972, an often repeated set of criticisms has appeared in reviews and commentaries. Some of these reactions have been frequent enough to justify analysis and comment.

The two books deal with the dynamic interactions between population, capital, natural resources, pollution, and agriculture at the global level. They use the medium of computer models to capture the essence of assumptions that now seem to underlie political decision-making.

Although the debate involves both World Dynamics and Limits to Growth, I will respond only in terms of World Dynamics because some of the comments revolve around specific numerical assumptions that are available in the earlier book.

The use of models in decision-making is old and familiar. Human thinking depends on models. One does not have a real city or nation in

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his head—only assumptions and simplifications that comprise a model of the real system. People have always managed entirely on the basis of models. The mental modeling process starts from various assumptions about the parts of a social system, draws conclusions about the future dynamic implications of those assumptions, and goes on to propose modifications of laws and policies that are presumed to lead toward a better future. The computer modeling process on which the two books are based is similar to the mental modeling process. The differences are in degree rather than kind. The computer model is more clearly stated than are the mental models used in political debate. Also, the implications of a computer model can be determined with more certainty than for a mental model.

The computer model presents its underlying assumptions concretely and explicitly so that they are accessible for criticism and revision. The assumptions are interrelated in clearly stated ways that divulge the assumed structure for others to analyze. Because the structure has been made unambiguous and the numerical assumptions have been made quantitative, the resulting model (which is a theory of social structure) can be used by a computer to expose the behavioral consequences of the assumptions that have been made.

World Dynamics and Limits to Growth have received a remarkable amount of attention from the public and press. The World Dynamics computer model has been rewritten into several computer languages; it is operating on the computers of many corporations and universities. The books have been translated and published into a dozen or more languages.

Before publication, World Dynamics seemed assured of no public notice—the book has 35 pages of equations in the main text, much of the

remainder is computer graphical printout, it was distributed by an unknown publisher, and it deals not with the present but with issues of several decades hence. In spite of these handicaps, within three weeks of publication World Dynamics had been reviewed in the London Observer, June 27, 1971, and that review was reprinted in newspapers around the world. Discussion of the book appeared in diverse publications from Fortune September 1971, to the anti-establishment student press, from The Wall Street Journal September 28, 1971, to the academic journals, and from the Christian Science Monitor August 7, 1971, to Playboy (July 1971). Debate about the book and its conclusions have extended into governments, the issues became a part of one European election campaign, and the controversy has reached the forums of the United Nations.

Why have the public and press given so much attention to these two books? Some have attempted to explain in terms of publicity by publishers and authors. But World Dynamics, which triggered the initial response, was released with nothing more than the mailing of literature and review copies. To the contrary, the widespread reaction seems to arise from two motivations:

1. The public has a strong, latent, but suppressed concern for the long-term future.
2. People are uneasy about the internal contradictions within their mental images and seek clarification and resolution of discrepancy.

The first explanation of interest in World Dynamics lies in the way it connects present conditions with future consequences. In the modern industrial world with its rapid change, time horizons have shortened to a few years. No longer is a society able to dedicate itself to building

a cathedral over a span of 300 years. No longer is one able to visualize what his grandchildren will be doing and how they will be living. The future has shrunk and the relevance of history seems to have dissolved. The focus is on the present. But such a lack of a past and a future is alien to man's tradition. A latent interest in the distant future, even several generations hence, survives. The future reemerges as an issue of significance and debate when a vehicle is offered that allows present knowledge and observations to be projected to their future implications.

The second explanation for the interest in World Dynamics lies in the way the system dynamics methodology resolves the internal contradictions existing in our mental models. Figure 1 represents one way of subdividing the content of our mental images. We have a vast store of local observations about the behavior, pressures, reactions, reasons for decisions, traditions, prejudices, relationships, sources of information, and fears that link the parts of the social system together and that describe how the various parts function. We also have a set of expectations that describe the overall behavior that we believe should follow from the local observations. As a third part of our mental-image structure, we observe the actual behavior of the socio-economic system of which we are a part. Within this image structure are often serious discrepancies between expectations and actual behavior. To maintain the validity of the tie between local observations and expectations, we must explain the discrepancy between expectations and actual social system behavior. The explanation conventionally runs along the lines of insufficient information, missing theory, capricious behavior and random events, or external influences. But the explanations themselves are

without clear logic and evident mechanisms and we are left uneasy. A system dynamics model that can relate local observation to behavior often resolves the discrepancy in a different way. Usually it is shown that the local observations are fully sufficient to explain and to generate the actual social system behavior. The discrepancy lies not between expectations and actual behavior, but instead, between the local observations and expectations. We no longer need to deny half of the world we see; the local observations and the observations about actual behavior become consistent with one another.

With respect to the growth issues in World Dynamics, the expectations that growth would solve all problems were being disappointed. The actual system behavior has shown rising stresses contrary to hopes and promises. By relating structure to consequences, a unity of perception is regained in a world that was becoming increasingly contradictory.

But reactions to the book are far from universally favorable. In fact, they are quite bipolar with strong support and strong opposition. Unfavorable opinions are to be found predominately in the academic press, especially from those trained in economics. The reasons are several. First, the system dynamics methodology is unfamiliar and therefore suspect. Second, the building of models from direct observation and from the content of the current mental models, rather than from time-series data, seems to them treacherous, even though the assumptions are, if anything, less heroic than those involved in deciding what data to use, what statistical methods to employ, what structure to select for inserting the data, and what simplifications to use in fitting a nonlinear world into a linear mold. Third, many of the critical belong to the group that has led the way in establishing the expectations of Figure 1 that now begin to appear inconsistent with the realities. In fact, those who have promoted unrestrained

growth may find themselves overtaken by the fate that befell the atomic physicist after World War II—a sudden reversal of role as seen by the public from the benefactor of mankind to the perpetrator of a Pandora's Box of evils that can no longer be contained.

The critics often seem to assume that the inconsistency between the implications of World Dynamics and their prior belief in growth would be resolved by finding errors or omissions in the model structure. Although the existing models have never been advanced as more than temporary,

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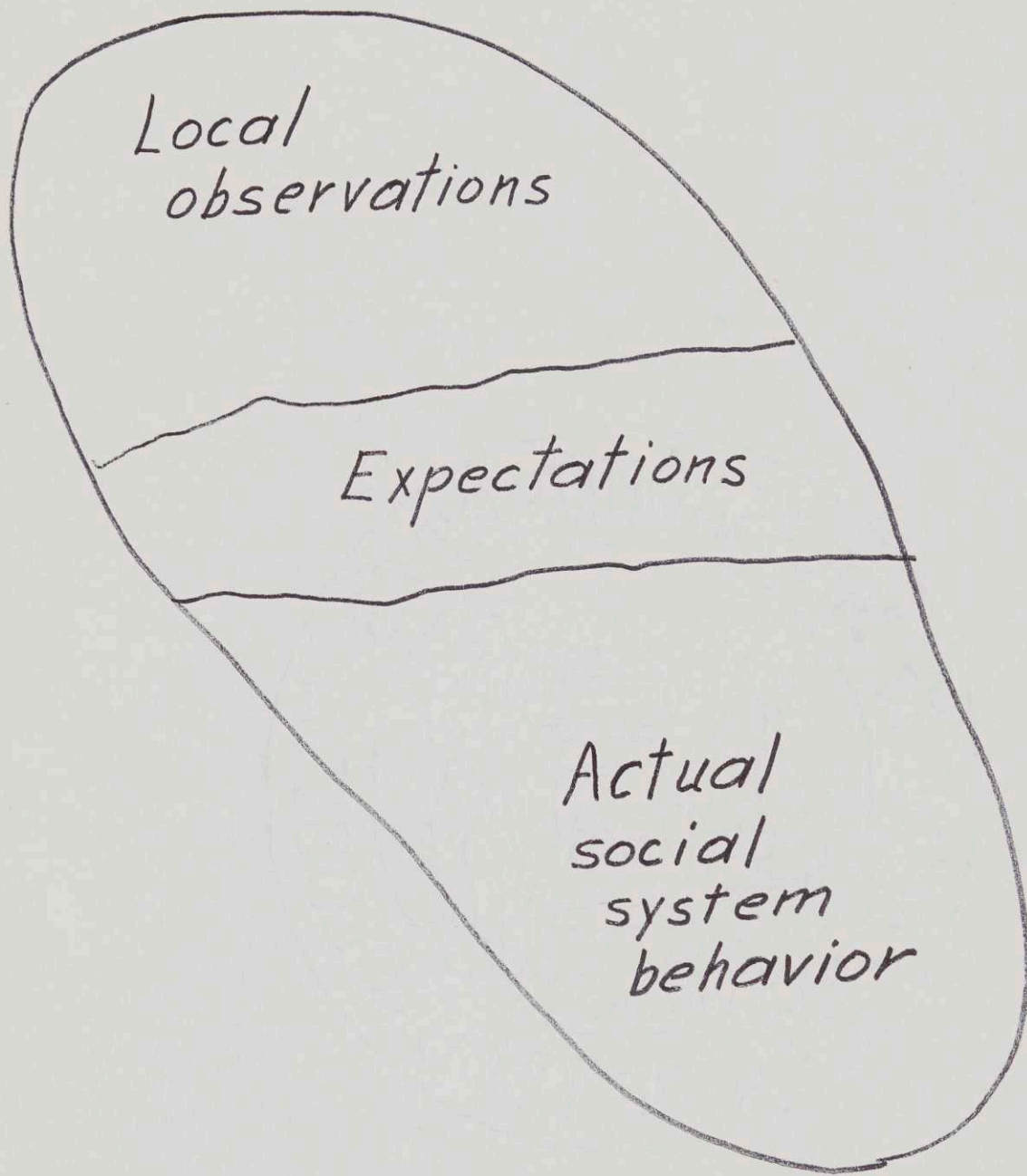


Figure 1 Content of mental images.

not yet used.



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The computer model presents its underlying assumptions concretely and explicitly so that they are accessible for criticism and revision. The assumptions are interrelated in clearly stated ways that divulge the assumed structure for others to analyze. Because the structure has been made unambiguous and the numerical assumptions have been made quantitative, the resulting model (which is a theory of social structure) can be used by a computer to expose the behavioral consequences of the assumptions that have been made.

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INTER-OFFICE
CORRESPONDENCE

Extra

Gordon Brown, Frank Davidson, Carroll Wilson
and Jørgen Randers

TO _____ DATE November 16, 1972

FROM Jay W. Forrester

SUBJECT "On Criticism of World Dynamics"

FOLLOW-UP	
FILE	

Please review the attached manuscript, and give me your editorial comments at your earliest opportunity.

eac
Attached: Manuscript (D-1730)

~~DSB~~

ORIGINATOR REMOVES THE DUPLICATE (YELLOW COPY), SENDING THE ORIGINAL AND TRIPPLICATE TO CORRESPONDENT WHO RETURNS THE ORIGINAL WITH COMMENT AND RETAINS THE PINK TRIPPLICATE COPY.

On Criticisms of World Dynamics

by

Jay W. Forrester
Germeshausen Professor
Massachusetts Institute of Technology

Since the publication of World Dynamics¹ in 1971 and the successor book, Limits to Growth² by Meadows and others in 1972, an often repeated set of criticisms has appeared in reviews and commentaries. These reactions have appeared enough times to justify analysis and comment.

The two books deal with the dynamic interactions between population, capital, natural resources, pollution, and agriculture. They do this through the medium of computer models that have been built to capture the essence of assumptions that now seem to underlie political decision-making.

Although the debate involves both World Dynamics and Limits to Growth, I will respond only in terms of World Dynamics because some of the comments revolve around specific numerical assumptions that are available in the earlier book. Although the corresponding numerical and quantitative assumptions for Limits to Growth have been available to serious research groups since the spring of 1972, they are not yet at this writing generally available through a commercial publisher. The use of models in decision-making is old and familiar. Human thinking depends on models. One does not have a real city or nation in his head--only assumptions and simplifications that are a model that we use instead of the real system. Nations and the world are now managed entirely on the basis of models. The mental model starts from various assumptions about the parts of a social system, draws conclusions about the future dynamic implications of those assumptions, and goes on to propose modifications of laws and policies that are presumed to lead toward a better future. The computer modeling process on which the two books are based is, in general, the same as the mental modeling process. The differences are in degree rather than in kind. The computer

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Why has the public and press given so much attention to these two books? Some have attempted an explanation in terms of publicity efforts by publishers and authors. But World Dynamics was released by a previously unknown publisher with nothing more than the mailing of literature and review copies. Yet within three months it was being discussed in the daily press, business periodicals, and in many special-interest publications. Clearly, the issues touched on deep public concerns.

The resulting controversy has arisen because the computer modeling process exposes internal contradictions that exist in the currently prevalent mental models. The computer models are essentially consistent with present assumptions about major world interactions. The behavior of the models is consistent with the observed rising social, technical, economic, and environmental pressures around the world. But the models come as a shock because they suggest a future that is quite different from the one our mental models have been anticipating. The critics seem to assume that the inconsistency between assumptions and expectations will be resolved by altering the basic assumptions until models behave in accordance with our future hopes. But it has been repeatedly shown that mental models are more reliable in their basic assumptions than in anticipating future behavior that follows from the assumptions.

The reactions to the books seem to rest on nine viewpoints and attitudes that the critics bring to the subject:

1. Assuming that analysis of social systems is premature and hopeless because sufficient information is thought not to exist.

2. Seeing the world from a narrow technical and materialistic viewpoint that excludes important social forces.
3. Addressing only limited physical and economic issues while ignoring the successive layers of limits to growth.
4. A sense of impotence toward altering present world attitudes becomes a sense of futility when the future is discussed.
5. Believing capital accumulation is the key to the future in spite of past inability in most cultures to acquire capital faster than population has grown and in spite of the rising forces that will lower the marginal productivity of capital and reduce the social feasibility of more rapid accumulation.
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7. Adopting a narrow disciplinary view so that the degree of aggregation represented in the models is not interpreted correctly.
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9. Overlooking the way computer models are changing the rules of debate so that vague and nonspecific complaints are addressed to the clear and specific assumptions that are given in a computer model.

Taking each of these nine points in turn:

1. Analysis Not Possible. It is commonly stated by academic critics that analysis of social systems as presented in World Dynamics should not yet be undertaken because sufficient information is not available. This is a viewpoint that can be taken only by a critic who is free to stand on the sidelines and wait for certainty. It is a rational viewpoint for the person who need not act and wishes to avoid professional risk. It is, however, an alternative that is not available to the manager, the political leader, or the citizen. We all live now. We all act in the present. What we do or avoid today determines the future. We do not have the option of stopping time while knowledge accumulates. Furthermore, every decision that is made is made on the basis of models. Those models are now the mental models in the heads of citizens, members of parliament, heads of government, and representatives at the United Nations. In general those mental models are less comprehensive than the models that can now be assembled

and put on a computer. They are also less accessible and less specific. In addition they contain internal contradictions between the basic assumptions and the assumed behavior. The critic, by suggesting that formal models should be delayed, implies that he has more confidence in existing mental models than he could ever have in an explicit formal model. He is saying that ignorance is bliss. He would rather depend on a mental model whose assumptions are unknown to him than to depend on the best available model that explicitly states those assumptions. The computer models are now beginning to compete with the mental models in plausibility and influence. The proper rejoinder to an explicit computer model should be to offer equally explicit alternatives and improvements so that our understanding of social systems can rapidly advance.

2. Materialistic Viewpoint. Criticisms have tended to focus only on issues of resources; pollution, and capital. This betrays a narrow materialistic perspective that misses the social, psychological, and political aspects of existence. In fact the consequences of rapid technological change, crowding, pressures on resources, and the need for rising resource flows from the underdeveloped countries to sustain economic growth in the developed countries, all are manifesting themselves in economic stress, genocide, rising crime rates, drug addiction, and an increasing probability of a third world war. The fundamental issue here arises from the way that pressures created by growth redistribute themselves within the social system. If some of the pressures are relieved, growth continues until remaining pressures intensify in other parts of the system.

We know better how to relieve technological pressures than we do economic pressures. In turn, we are more able to deal with economic issues than the social and psychological issues. Therefore, the tendency is to release the technological pressures and allow further growth to shift the stresses into the economic and social realms. Then by partially succeeding in the counteraction of economic pressures, we make the ultimate transition into unresolvable social stresses. In other words, the narrow materialistic view that sees solutions to all problems as achievable through technology will be responsible for intensifying psychological and social disturbance.

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9. Changed Rules of Debate. In the past men have debated the merits of mental models and their implications for the future of society. But the underlying assumptions have seldom been made specific and the arguments have been equally vague. But computer models of social structure are explicit, the assumptions have meaning to an ordinary person who has knowledge of corresponding parts of the real system, and any concept that can be expressed in explicit verbal language can be put into computer language. Translation from ordinary language to computer language is simpler than translation between French and English. The grammar is more specific, the constructions are unambiguous. All statements must be made in quantitative form and murky thinking is suppressed.

With a clear and precise statement of assumptions, with an explicit statement about structure, and with an unassailable presentation of the implications of the assumptions as presented in computer output, a new rigor in debate is called for. Contrary assumptions about structures and influences should be presented with equal quantitative clarity. It would then be possible to determine whether or not the alternative suggestions would change the conclusions. But so far most critics are standing outside of the new arena. They throw stones at explicit assumptions that are offered, but do not risk opening themselves to similar inspection. Although far better and more comprehensive models can and will be developed, no one has yet offered an alternative quantitative model that he suggests is better.

The system dynamics methodology illustrated in World Dynamics gives a new basis for drawing together the interactions ^{among} between technology, politics, economics, law, ethics, and religion.* The interactions between disciplines account for social behavior much more than influences from within any single discipline. System dynamics, by providing a common framework, allows the interconnections to be established. But more than a systems methodology is necessary. Knowledge about the subsystems is required. Time is needed to put each subsystem into a common framework. As the world becomes more congested, the interactions become more significant. If the

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Now is the time to develop concrete theories of how this knowledge is linked together. Computer models are such theories. They show the interrelationships; they allow a derivation of the consequences; they permit a test of the theories against the evidence from reality. Toward achieving this better understanding, I suggest that several major research institutes need to be established. Each should contain men from every significant field of endeavor. All should amalgamate existing knowledge into unified theoretical structures (computer models), so that we can better determine the future implications of what we now know and are now doing. Alternative courses of action could then be evaluated to suggest roads toward the most acceptable of available futures.

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On Criticisms of World Dynamics

by

Jay W. Forrester
Germeshausen Professor
Massachusetts Institute of Technology

Since the publication of World Dynamics¹ in 1971 and the successor book, Limits to Growth² by Meadows and others in 1972, an often repeated set of criticisms has appeared in reviews and commentaries. These reactions have appeared enough times to justify analysis and comment.

The two books deal with the dynamic interactions between population, capital, natural resources, pollution, and agriculture. They do this through the medium of computer models that have been built to capture the essence of assumptions that now seem to underlie political decision-making.

Although the debate involves both World Dynamics and Limits to Growth, I will respond only in terms of World Dynamics because some of the comments revolve around specific numerical assumptions that are available in the earlier book. Although the corresponding numerical and quantitative assumptions for Limits to Growth have been available to serious research groups since the spring of 1972, they are not yet at this writing generally available through a commercial publisher. The use of models in decision-making is old and familiar. Human thinking depends on models. One does not have a real city or nation in his head--only assumptions and simplifications that are a model that we use instead of the real system. Nations and the world are now managed entirely on the basis of models. The mental model starts from various assumptions about the parts of a social system, draws conclusions about the future dynamic implications of those assumptions, and goes on to propose modifications of laws and policies that are presumed to lead toward a better future. The computer modeling process on which the two books are based is, in general, the same as the mental modeling process. The differences are in degree rather than in kind. The computer

1. Forrester, Jay W., World Dynamics, Wright-Allen Press, 238 Main Street, Cambridge, Mass., U.S.A.

2. Meadows, Donella H., et al, The Limits to Growth, Universe Books, 381 Park Avenue South, New York.

model is more clearly stated and its implications can be determined with more certainty.

The computer model presents its underlying assumptions concretely and explicitly so that they are available for criticism and revision. The assumptions are interrelated in clearly stated ways that divulge the assumed structure for others to analyze. Because the structure has been made unambiguous and the numerical assumptions have been made quantitative, the resulting model (which is a theory of social structure) can be used by a computer to expose the behavioral consequences of the assumptions that have been made.

Why has the public and press given so much attention to these two books? Some have attempted an explanation in terms of publicity efforts by publishers and authors. But World Dynamics was released by a previously unknown publisher with nothing more than the mailing of literature and review copies. Yet within three months it was being discussed in the daily press, business periodicals, and in many special-interest publications. Clearly, the issues touched on deep public concerns.

The resulting controversy has arisen because the computer modeling process exposes internal contradictions that exist in the currently prevalent mental models. The computer models are essentially consistent with present assumptions about major world interactions. The behavior of the models is consistent with the observed rising social, technical, economic, and environmental pressures around the world. But the models come as a shock because they suggest a future that is quite different from the one our mental models have been anticipating. The critics seem to assume that the inconsistency between assumptions and expectations will be resolved by altering the basic assumptions until models behave in accordance with our future hopes. But it has been repeatedly shown that mental models are more reliable in their basic assumptions than in anticipating future behavior that follows from the assumptions.

The reactions to the books seem to rest on nine viewpoints and attitudes that the critics bring to the subject:

1. Assuming that analysis of social systems is premature and hopeless because sufficient information is thought not to exist.

2. Seeing the world from a narrow technical and materialistic viewpoint that excludes important social forces.
3. Addressing only limited physical and economic issues while ignoring the successive layers of limits to growth.
4. A sense of impotence toward altering present world attitudes becomes a sense of futility when the future is discussed.
5. Believing capital accumulation is the key to the future in spite of past inability in most cultures to acquire capital faster than population has grown and in spite of the rising forces that will lower the marginal productivity of capital and reduce the social feasibility of more rapid accumulation.
6. Hoping that market forces and prices can solve the problem of shortages.
7. Adopting a narrow disciplinary view so that the degree of aggregation represented in the models is not interpreted correctly.
8. Failing to perceive correctly the implications of aggregation, leading to the belief that technical progress has been omitted from the models.
9. Overlooking the way computer models are changing the rules of debate so that vague and nonspecific complaints are addressed to the clear and specific assumptions that are given in a computer model.

Taking each of these nine points in turn:

1. Analysis Not Possible. It is commonly stated by academic critics that analysis of social systems as presented in World Dynamics should not yet be undertaken because sufficient information is not available. This is a viewpoint that can be taken only by a critic who is free to stand on the sidelines and wait for certainty. It is a rational viewpoint for the person who need not act and wishes to avoid professional risk. It is, however, an alternative that is not available to the manager, the political leader, or the citizen. We all live now. We all act in the present. What we do or avoid today determines the future. We do not have the option of stopping time while knowledge accumulates. Furthermore, every decision that is made is made on the basis of models. Those models are now the mental models in the heads of citizens, members of parliament, heads of government, and representatives at the United Nations. In general those mental models are less comprehensive than the models that can now be assembled

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To: Prof. Forrester

From: G.W. Low

Re: "On Criticisms of World Dynamics"

I suggest a reorganization of the nine "viewpoints and attitudes" of the critics into eight. The modified list combines your points 2 and 3 (virtually the same) as well as your points 5 and 8 (where 8 is more a specific criticism of W.D. than a viewpoint or attitude). Numerous critics have objected to your "predictions", as if prediction is the goal of the W.D. model. I have added, therefore, another "viewpoint" (number 2) which I call "A short-term perspective that seeks prediction from formal models". It alludes, by the way, to the existence of other types of formal modeling besides System Dynamics.

Low.

Gil Lowe

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Since the publication of World Dynamics¹ in 1971 and the successor book, Limits to Growth² by Meadows and others in 1972, an often repeated set of criticisms has appeared in reviews and commentaries. These reactions have appeared enough times to justify analysis and comment.

The two books deal with the dynamic interactions between population, capital, natural resources, pollution, and agriculture. They do this through the medium of computer models that have been built to capture the essence of assumptions that now seem to underlie political decision-making.

Although the debate involves both World Dynamics and Limits to Growth, I will respond only in terms of World Dynamics because some of the comments revolve around specific numerical assumptions that are available in the earlier book. Although the corresponding numerical and quantitative assumptions for Limits to Growth have been available to serious research groups since the spring of 1972, they are not yet at this writing generally available through a commercial publisher. ¶ The use of models in decision-making is old and familiar. Human thinking depends on models. One does not have a real city or nation in his head--only assumptions and simplifications that are a model that we use instead of the real system. Nations and the world are now managed entirely on the basis of models. The mental model starts from various assumptions about the parts of a social system, draws conclusions about the future dynamic implications of those assumptions, and goes on to propose modifications of laws and policies that are presumed to lead toward a better future. The computer modeling process on which the two books are based is, in general, the same as the mental modeling process. The differences are in degree rather than in kind. The computer

1. Forrester, Jay W., World Dynamics, Wright-Allen Press, 238 Main Street, Cambridge, Mass., U.S.A.

2. Meadows, Donella H., et al, The Limits to Growth, Universe Books, 381 Park Avenue South, New York.

model is more clearly stated and its implications can be determined with more certainty.

The computer model presents its underlying assumptions concretely and explicitly so that they are available for criticism and revision. The assumptions are interrelated in clearly stated ways that divulge the assumed structure for others to analyze. Because the structure has been made unambiguous and the numerical assumptions have been made quantitative, the resulting model (which is a theory of social structure) can be used by a computer to expose the behavioral consequences of the assumptions that have been made.

Why has the public and press given so much attention to these two books? Some have attempted an explanation in terms of publicity efforts by publishers and authors. But World Dynamics was released by a previously unknown publisher with nothing more than the mailing of literature and review copies. Yet within three months it was being discussed in the daily press, business periodicals, and in many special-interest publications. Clearly, the issues touched on deep public concerns.

The resulting controversy has arisen because the computer modeling process exposes internal contradictions that exist in the currently prevalent mental models. The computer models are essentially consistent with present assumptions about major world interactions. The behavior of the models is consistent with the observed rising social, technical, economic, and environmental pressures around the world. But the models come as a shock because they suggest a future that is quite different from the one our mental models have been anticipating. The critics seem to assume that the inconsistency between assumptions and expectations will be resolved by altering the basic assumptions until models behave in accordance with our future hopes. But it has been repeatedly shown that mental models are more reliable in their basic assumptions than in anticipating future behavior that follows from the assumptions.

The reactions to the books seem to rest on ^{eight}~~nine~~ viewpoints and attitudes that the critics bring to the subject:

1. Assuming that analysis of social systems is premature and hopeless because sufficient information is thought not to exist.

2. A short-term perspective that seeks prediction from formal models.
3. A narrow technical and materialistic viewpoint that ignores important social issues and the successive limits to growth.
4. Believing that capital accumulation is the key to the future and that technical progress has been omitted from the models.
5. Hoping that market forces and prices can solve the problem of shortages.
6. Adopting a narrow disciplinary view so that the degree of aggregation represented in the models is not interpreted correctly.
7. A sense of impotence toward altering present world attitudes becomes a sense of futility when the future is discussed.
8. Overlooking the advantages of computer simulation models.

These two points are more similar than different and should be considered together.

2. Seeing the world from a narrow technical and materialistic viewpoint that excludes important social forces.
3. Addressing only limited physical and economic issues while ignoring the successive layers of limits to growth.
4. A sense of impotence toward altering present world attitudes becomes a sense of futility when the future is discussed.
5. Believing capital accumulation is the key to the future in spite of past inability in most cultures to acquire capital faster than population has grown and in spite of the rising forces that will lower the marginal productivity of capital and reduce the social feasibility of more rapid accumulation.
6. Hoping that market forces and prices can solve the problem of shortages.
7. Adopting a narrow disciplinary view so that the degree of aggregation represented in the models is not interpreted correctly.
8. Failing to perceive correctly the implications of aggregation, leading to the belief that technical progress has been omitted from the models.
9. Overlooking the way computer models are changing the rules of debate so that vague and nonspecific complaints are addressed to the clear and specific assumptions that are given in a computer model.

unclear

This is not so much a viewpoint or attitude as a specific criticism of the W.D. model

Taking each of these ^{eight} ~~nine~~ points in turn:

1. Analysis Not Possible. It is commonly stated by academic critics that analysis of social systems as presented in World Dynamics should not yet be undertaken because sufficient information is not available. This is a viewpoint that can be taken only by a critic who is free to stand on the sidelines and wait for certainty. It is a rational viewpoint for the person who need not act and wishes to avoid professional risk. It is, however, an alternative that is not available to the manager, the political leader, or the citizen. We all live now. We all act in the present. What we do or avoid today determines the future. We do not have the option of stopping time while knowledge accumulates. Furthermore, every decision that is made is made on the basis of models. Those models are now the mental models in the heads of citizens, members of parliament, heads of government, and representatives at the United Nations. In general those mental models are less comprehensive than the models that can now be assembled

and put on a computer. They are also less accessible and less specific. In addition they contain internal contradictions between the basic assumptions and the assumed behavior. The critic, by suggesting that formal models should be delayed, implies that he has more confidence in existing mental models than he could ever have in an explicit formal model. He is saying that ignorance is bliss. He would rather depend on ^{vague assumptions} a mental model whose ~~assumptions are unknown to him~~ ^{a formal} than to depend on ~~the best available~~ model that explicitly states those assumptions. ~~The computer models are now beginning to compete with the mental models in plausibility and influence.~~ The proper rejoinder to an explicit computer model should be to offer equally explicit alternatives and improvements so that our understanding of social systems can rapidly advance.

~~must~~ →

2. Short-term perspective.

2. The inclination to avoid analysis of systems for which data is not obtainable ~~often~~ leads ^{many} the academic critics to focus on a narrow range of problems over a short time horizon. Available data, often developed in the first place to satisfy a short-term perspective, leads one to make "predictions" and to expect other formal models to "predict" the future. The World Dynamics model suggests that some of the most crucial problems facing mankind develop over a longer time period and involve system elements for which data is not available. The simulated behavior resulting from such complex models represents the interaction of the assumed state variables and the logical outcome of presently pursued objectives and mental models. The computer output is not, therefore, predictive in the sense that econometric and other types of formal models "predict" future events.

3. Materialistic Viewpoint. Criticisms have tended to focus only on issues of resources, pollution, and capital. This betrays a narrow materialistic perspective that misses the social, psychological, and political aspects of existence. In fact the consequences of rapid technological change, crowding, pressures on resources, and ^{international competition among} ~~the need for rising resource~~ ~~flows from the underdeveloped countries to sustain economic growth in the~~ developed countries, all are manifesting themselves in economic stress, genocide, rising crime rates, drug addiction, and an increasing probability of a third world war. The fundamental issue here arises from the way that pressures created by growth redistribute themselves within the social system. If some of the pressures are relieved, growth continues until remaining pressures intensify in other parts of the system. We know better how to relieve technological pressures than we do economic pressures. In turn, we are more able to deal with economic issues than the social and psychological issues. Therefore, the tendency is to release the technological pressures and allow further growth to shift the stresses into the economic and social realms. Then by partially succeeding in the counteraction of economic pressures, we make the ultimate transition into unresolvable social stresses. In other words, the narrow materialistic view that sees solutions to all problems as achievable through technology will be responsible for intensifying psychological and social disturbance.

~~3. Layers of Limits.~~⁴ The narrow economic viewpoint tends to see world problems only in terms of resources and capital accumulation. Yet the limits to growth exist in a succession of layers. To the extent that the immediate layer can be relaxed, another layer is encountered. This succession is shown in World Dynamics where, with the particular assumptions that were chosen, the first limit to be encountered arises from resources. Page 73 of World Dynamics, in referring to the resource-limited mode that results in a population peak in 50 years, states,

. . . the figure should be interpreted as one of the possible modes of behavior of the world system. One can argue that exhaustion of natural resources is not the most likely limitation on population growth. Actual stocks of natural resources may be greater than the 250-year supply that has been assumed here. Furthermore, science may make continuing substitutions to delay the impact of resource shortage. If natural resources do not limit population growth and slow the pace of industrialization, however, some other force in the world system will eventually do so.

. . . natural resources may not be the most critical aspect of the world environment. (page 74) . . .

The effect of reducing the demand for natural resources is to take one layer of restraint off the growth forces of the system. (page 75) . . .

. . . [this] teaches a fundamental lesson about complex systems. When one pressure or difficulty is alleviated, the result may be merely to substitute a new problem for the old. Often the new mode is less desirable than the old. In particular, the industrialized societies have come to depend on technology to solve their problems. This succeeded when technology was improving so rapidly that it could exploit geographical space and natural resources faster than the population could increase. But now, as technology reaches the point of diminishing returns and begins to run short on space and resources, the technological "solution" may more and more be only a substitution of one crisis for another. (page 80)

The book then continues to examine pollution as a possible limit, food shortage as another possible limit, and crowding as the ultimate limit. Those who depend only on technology should ask themselves what the next set of limits will be. Will pursuit of technical goals simply lead to more intractable pressures in the economic and social sectors? I believe they will. If so, the arguments presented by the materialistic technologists will in time be recognized as having been a route to greater social disorientation.

4. Confidence in Capital Accumulation. The technical optimism is based on the assumption that massive accumulation of capital can solve all problems. It is often suggested that additional capital investment can increase agricultural output, reduce pollution, and use lower grade resources. This may be true if the capital accumulation can and does occur. But the optimists do not address themselves to the feasibility of such massive capital accumulation. Two developing trends suggest that it will be more difficult than in the past, while, even in the past, capital accumulation has been possible for only that quarter of the world's population that has lived under particularly fortuitous circumstances. As environmental limits are pressed more tightly, the cost of generating capital will increase at the same time that its marginal productivity declines. Furthermore, as population continues to grow while production comes under ever heavier restraint, there will be growing social pressures to divert current production into current consumption. As the pressures for medical programs, old age support, unemployment compensation, and public welfare payments mount, there may be a declining capability for accumulating capital.

~~Faith in the Price System~~
5. Rising Prices.

Prices have not been included in the variables of the World Dynamics model. Many have seen the absence of prices as a major weakness, and have asserted that price mechanisms would ^{encourage the utilization} ~~curtail use~~ of relatively abundant resources and discourage continued ~~of scarce goods and thereby prevent their disappearance.~~ But rising prices ~~depletion of scarce resources.~~

→ Continue this point by adding from Nordhaus rebuttal p. 25, last para. "That is true..." and p. 26, 1st para. "As resource extraction costs..."

imply more effort expended per unit of product. Higher real prices are equivalent to lower productivity and a falling standard of living. It matters very little to the consumer whether he cannot procure goods because they are unavailable or because the price is higher than he can afford. Prices are intervening variables between supply and demand, they are communicators of shortage, and they encourage the use of more abundant alternatives for scarce goods. But prices cannot correct a situation of total demand exceeding total supply such as will exist if population and industrialization extend beyond the limits of the world environment. This viewpoint parallels the U. S. National Academy of Science report of August 1972, Elements of a National Materials Policy, that states, "there was but small support for the view that market forces alone will solve the foreseeable problems."

6. Misinterpretation of Aggregation. An overview of a social system discards fine detail so that broad issues can be more clearly accentuated. When this is done, many of the intermediate relationships in a chain of causality are omitted. A critic who is accustomed to taking a narrow subsystem view may observe the omission of the direct elements of causality without looking beyond them to see if they are adequately represented by a more fundamental set of causes. This failure to judge from the appropriate perspective is illustrated by reactions to the demographic sector of World Dynamics. In the model birth rate depends on the material standard of living, crowding, pollution, and food per capita. But critics suggest alternative effects on birth rate without asking whether or not these might in turn be related to the more fundamental variables already represented in the model. For example, the suggestion is made that social attitudes and institutional factors affect birth rate. Indeed they do but are they not themselves apt to be a reflection of the availability of space, food, material goods, and a satisfactory environment? Social attitudes and institutional factors reflect the self-discipline necessary for man to fit himself into his environment and to the proximity of his fellow man.

As a more specific example, the suggestion has been offered that the decline in ^{the net birth rate} French fertility in the nineteenth century might be due to changes in the laws of inheritance, changed social attitudes, and the easier life that fewer children make possible. But one should look back into the

I would cut this paragraph

economic and political situation to see why the laws were changed and the social attitudes were altered. And what was it in the changing technology and rising industrialization that made fewer children advantageous? The intervening variables that are suggested will often be but mere reflections of the more fundamental variables dealt with in World Dynamics.

The revived birth rate in the United States after World War II and the more recent decline are often alleged to be contrary to the assumptions in the computer model. But depressed birth rates in the 1930's followed by a rise in the 50's and a fall in the late 60's coincides closely with the varying economic, psychological, and environmental pressures on the population.

8. Technical Change. The erroneous belief that the World Dynamics model takes no account of technical change is also traceable to lack of familiarity with models that take a broad overview. Technical change is represented in the World Dynamics model as part of capital investment. From page 53 we find, "Capital includes buildings, roads, and factories. It also includes education and the results of scientific research, for the latter are not represented elsewhere in the model system and the investment in them decays at about the same rate as for physical capital." Physical capital, education, and technical advancement have very similar dynamic behavior. Each, in a real sense, as it interacts with population, tends to reproduce itself. Physical capital tends to make possible a higher rate of accumulation of physical capital. Knowledge makes it possible to accumulate still more knowledge. Technical accomplishment becomes the foundation for further technical accomplishment. They all, under the proper circumstances, regenerate themselves in a positive feedback loop as in World Dynamics. Dynamically speaking, they are very similar and can be aggregated together as a first approximation. If this had not been done with some success, ~~how otherwise would the behavior of the model, which starts with conditions of the year 1900, by itself generate a trajectory that passes through the conditions of 1970?~~ ^{it would not be possible for the model as it does to} ~~and~~ ^{and} Certainly the seventy intervening years have been marked by rapid technological change. The several effects could have been separated and represented individually in the model. Doing so would have made details easier to describe, but would have obscured the broad overall structure of world interactions.

7. Futility in the Face of Past Traditions. In effect, some critics plead that we need not address ourselves to the future because we cannot change the present traditions, actions, and value structures of society. This is the voice of resignation and hopelessness. But it arises from misjudging the interest of the public in the longer-term future and the sensitivity of the public to present omens. The public viewpoint has changed markedly in the last ten years toward an increasing concern for environmental issues, an acceptance of the necessity for population limitation, and a recognition that continued dependence on technology alone to solve problems will produce rapidly intensifying stresses in the nontechnical aspects of the world system. I believe the critics' futility is unjustified and that citizens, managers, and political leaders are beginning to recognize deteriorating interactions between technical, economic, and social forces as issues to which they must be increasingly responsive.

8. Changed Rules of Debate. ~~In the past men have debated the merits of mental models and their implications for the future of society. But the underlying assumptions have seldom been made specific and the arguments have been equally vague.~~ But Computer models of social structure are explicit, the assumptions have meaning to an ordinary person who has knowledge of corresponding parts of the real system, and any concept that can be expressed in explicit verbal language can be put into computer language. Translation from ordinary language to computer language is simpler than translation between French and English. The grammar is more specific, the constructions are unambiguous. All statements must be made in quantitative form and murky thinking is suppressed.

(discussion has been on particular models, not "the merits of mental models")

With a clear and precise statement of assumptions, with an explicit statement about structure, and with an unassailable presentation of the implications of the assumptions as presented in computer output, a new rigor in debate is called for. Contrary assumptions about structures and influences should be presented with equal quantitative clarity. It would then be possible to determine whether or not the alternative suggestions would change the conclusions. But so far most critics are standing outside of the new arena. They throw stones at explicit assumptions that are offered, but do not risk opening themselves to similar inspection. Although far better and more comprehensive models can and will be developed, no one has yet offered an alternative quantitative model that he suggests is better.

The system dynamics methodology illustrated in World Dynamics gives a new basis for drawing together the interactions between technology, politics, economics, law, ethics, and religion.* The interactions between disciplines account for social behavior much more than influences from within any single discipline. System dynamics, by providing a common framework, allows the interconnections to be established. But more than a systems methodology is necessary. Knowledge about the subsystems is required. Time is needed to put each subsystem into a common framework. As the world becomes more congested, the interactions become more significant. If the

*For a discussion of religion in the context of these issues, see my chapter, "Churches at the Transition Between Growth and World Equilibrium" in Toward Global Equilibrium, Dennis L. Meadows, editor, Wright-Allen Press, 238 Main Street, Cambridge, Mass., U.S.A.

changing patterns of social forces are to be understood and controlled, the multiple interactions within society must be better understood. This, I suggest, is the great challenge of the next one or two decades. The task now is not the gathering of more detailed and elementary information. That has been going on for years. We are overwhelmed with bits and pieces of knowledge.

Now is the time to develop concrete theories of how this knowledge is linked together. Computer models are such theories. They show the interrelationships; they allow a derivation of the consequences; they permit a test of the theories against the evidence from reality. Toward achieving this better understanding, I suggest that several major research institutes need to be established. Each should contain men from every significant field of endeavor. All should amalgamate existing knowledge into unified theoretical structures (computer models), so that we can better determine the future implications of what we now know and are now doing. Alternative courses of action could then be evaluated to suggest roads toward the most acceptable of available futures.

Jay W. Forrester, Germeshausen Professor, Massachusetts Institute of Technology; recipient of the Valdemar Poulsen Gold Medal from the Danish Academy of Technical Sciences, 1969; Medal of Honor of the Institute of Electrical and Electronic Engineers, 1972; Benjamin Franklin Fellow of the Royal Society of Arts, 1972; Award for Outstanding Accomplishment by the Systems, Man and Cybernetics Society, 1972; author of Industrial Dynamics, 1961, and Urban Dynamics, 1969, (M.I.T. Press, Cambridge, Massachusetts) and of Principles of Systems, 1968, and World Dynamics, 1971 (both Wright-Allen Press, Cambridge, Massachusetts, in England through John Wiley.)

Nathaniel Mass

On Criticisms of World Dynamics

by

Jay W. Forrester
Germeshausen Professor
Massachusetts Institute of Technology

Since the publication of World Dynamics¹ in 1971 and the successor book, Limits to Growth² by Meadows and others in 1972, an often repeated set of criticisms has appeared in reviews and commentaries. These reactions have appeared ^{freely} enough times to justify analysis and comment.

The two books deal with the dynamic interactions between population, capital, natural resources, pollution, and agriculture. They do this through the medium of computer models that have been built to capture the essence of assumptions that now seem to underlie political decision-making. *at the global level*

Although the debate involves both World Dynamics and Limits to Growth, I will respond only in terms of World Dynamics because some of the comments revolve around specific numerical assumptions that are available in the earlier book. Although the corresponding numerical and quantitative assumptions for Limits to Growth have been available ^{in limited distribution} to serious research groups since the spring of 1972, they are not yet at this writing generally available through a commercial publisher. The use of models in decision-making is old and familiar. Human thinking depends on models. One does not have a real city or nation in his head--only assumptions and simplifications that ^{compose} are a model that we use instead of the real system. Nations and the world are now managed entirely on the basis of models. The mental model starts from various assumptions about the parts of a social system, draws conclusions about the future dynamic implications of those assumptions, and goes on to propose modifications of laws and policies that are presumed to lead toward a better future. The computer modeling process on which the two books are based is, in general, the same as the mental modeling process. The differences are in degree rather than in kind. The computer

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The computer model presents its underlying assumptions concretely and explicitly so that they are available for criticism and revision. The assumptions are interrelated in clearly stated ways that divulge the assumed structure for others to analyze. Because the structure has been made unambiguous and the numerical assumptions have been made quantitative, the resulting model (which is a theory of social structure) can be used by a computer to expose the behavioral consequences of the assumptions that have been made.

Why has the public and press given so much attention to these two books? Some have attempted an explanation in terms of publicity efforts by publishers and authors. But World Dynamics was released by a previously unknown publisher with nothing more than the mailing of literature and review copies. Yet within three months it was being discussed in the daily press, business periodicals, and in many special-interest publications. Clearly, the issues touched on deep public concerns.

The resulting controversy has arisen because the computer modeling process exposes internal contradictions that exist in the currently prevalent mental models. The computer models are essentially consistent with present assumptions about major world interactions. The behavior of the models is consistent with the observed rising social, technical, economic, and environmental pressures around the world. But the models come as a shock because they suggest a future that is quite different from the one our mental models have been anticipating. The critics seem to assume that the inconsistency between assumptions and expectations will be resolved by altering the basic assumptions until models behave in accordance with our future hopes. But it has been repeatedly shown that mental models are more reliable in their basic assumptions than in anticipating future behavior that follows from the assumptions.

The reactions to the books seem to rest on nine viewpoints and attitudes that the critics bring to the subject:

1. Assuming that analysis of social systems is premature and hopeless because sufficient information is thought not to exist.

2. Seeing the world from a narrow technical and materialistic viewpoint that excludes important social forces.
3. Addressing only limited physical and economic issues while ignoring the successive layers of limits to growth.
4. A sense of impotence toward altering present world attitudes becomes a sense of futility when the future is discussed.
5. Believing capital accumulation is the key to the future in spite of past inability in most cultures to acquire capital faster than population has grown and in spite of the rising forces that will lower the marginal productivity of capital and reduce the social feasibility of more rapid accumulation.
6. Hoping that market forces and prices can solve the problem of shortages.
7. Adopting a narrow disciplinary view so that the degree of aggregation represented in the models is not interpreted correctly.
8. Failing to perceive correctly the implications of aggregation, leading to the belief that technical progress has been omitted from the models.
9. Overlooking the way computer models are changing the rules of debate so that vague and nonspecific complaints are addressed to the clear and specific assumptions that are given in a computer model.

Taking each of these nine points in turn:

1. Analysis Not Possible. It is commonly stated by academic critics that analysis of social systems as presented in World Dynamics should not yet be undertaken because sufficient information is not available. This is a viewpoint that can be taken only by a critic who is free to stand on the sidelines and wait for certainty. It is a rational viewpoint for the person who need not act and wishes to avoid professional risk. It is, however, an alternative that is not available to the manager, the political leader, or the citizen. We all live now. We all act in the present. What we do or avoid today determines the future. We do not have the option of stopping time while knowledge accumulates. Furthermore, every decision that is made is made on the basis of models. Those models are now the mental models in the heads of citizens, members of parliament, heads of government, and representatives at the United Nations. In general those mental models are less comprehensive than the models that can now be assembled

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are preliminary efforts to depict the
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and put on a computer. They are also less accessible and less specific. In addition they contain internal contradictions between the basic assumptions and the assumed behavior. The critic, by suggesting that formal models should be delayed, implies that he has more confidence in existing mental models than he could ever have in an explicit formal model. He is saying that ignorance is bliss. He would rather depend on a mental model whose assumptions are unknown to him than to depend on the best available model that explicitly states those assumptions. The computer models are now beginning to compete with the mental models in plausibility and influence. The proper rejoinder to an explicit computer model should be to offer equally explicit alternatives and improvements so that our understanding of social systems can rapidly advance.

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3. Layers of Limits. The narrow economic viewpoint tends to see world problems only in terms of resources and capital accumulation. Yet the limits to growth exist in a succession of layers. To the extent that the immediate layer can be relaxed, another layer is encountered. This succession is shown in World Dynamics where, with the particular assumptions that were chosen, the first limit to be encountered arises from resources. Page 73 of World Dynamics, in referring to the resource-limited mode that results in a population peak in 50 years, states,

. . . the figure should be interpreted as one of the possible modes of behavior of the world system. One can argue that exhaustion of natural resources is not the most likely limitation on population growth. Actual stocks of natural resources may be greater than the 250-year supply that has been assumed here. Furthermore, science may make continuing substitutions to delay the impact of resource shortage. If natural resources do not limit population growth and slow the pace of industrialization, however, some other force in the world system will eventually do so.

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The book then continues to examine pollution as a possible limit, food shortage as another possible limit, and crowding as the ultimate limit. Those who depend only on technology should ask themselves what the next set of limits will be. Will pursuit of technical goals simply lead to more intractable pressures in the economic and social sectors? I believe they will. If so, the arguments presented by the materialistic technologists will in time be recognized as having been a route to greater social disorientation.

4. Futility in the Face of Past Traditions. In effect, some critics plead that we need not address ourselves to the future because we cannot change the present traditions, actions, and value structures of society. This is the voice of resignation and hopelessness. But it arises from misjudging the interest of the public in the longer-term future and the sensitivity of the public to present omens. The public viewpoint has changed markedly in the last ten years toward an increasing concern for environmental issues, an acceptance of the necessity for population limitation, and a recognition that continued dependence on technology alone to solve problems will produce rapidly intensifying stresses in the nontechnical aspects of the world system. I believe the critics' futility is unjustified and that citizens, managers, and political leaders are beginning to recognize deteriorating interactions between technical, economic, and social forces as issues to which they must be increasingly responsive.

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6. Rising Prices. Prices have not been included in the variables of the World Dynamics model. Many have seen the absence of prices as a major weakness, and have asserted that price mechanisms would curtail use of scarce goods and thereby prevent their disappearance. But rising prices

This section on prices ought to be revised in accord with the most recent draft of the Nordhaus rebuttal.

imply more effort expended per unit of product. Higher real prices are equivalent to lower productivity and a falling standard of living. It matters very little to the consumer whether he cannot procure goods because they are unavailable or because the price is higher than he can afford. Prices are intervening variables between supply and demand, they are communicators of shortage, and they encourage the use of more abundant alternatives for scarce goods. But prices cannot correct a situation of total demand exceeding total supply such as will exist if population and industrialization extend beyond the limits of the world environment. This viewpoint parallels the U. S. National Academy of Science report of August 1972, Elements of a National Materials Policy, that states, "there was but small support for the view that market forces alone will solve the foreseeable problems."

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As a more specific example, the suggestion has been offered that the decline in French fertility in the nineteenth century might be due to changes in the laws of inheritance, changed social attitudes, and the easier life that fewer children make possible. But one should look back into the

This is a fundamental issue that needs to be explained more clearly. The World Dynamics model emphasizes the fundamental continuity of historical processes,

economic and political situation to see why the laws were changed and the social attitudes were altered. And what was it in the changing technology and rising industrialization that made fewer children advantageous? The intervening variables that are suggested will often be but mere reflections of the more fundamental variables dealt with in World Dynamics.

The revived birth rate in the United States after World War II and the more recent decline are often alleged to be contrary to the assumptions in the computer model. But depressed birth rates in the 1930's followed by a rise in the 50's and a fall in the late 60's coincides closely with the varying economic, psychological, and environmental pressures on the population.

8. Technical Change. The erroneous belief that the World Dynamics model takes no account of technical change is also traceable to lack of familiarity with models that take a broad overview. Technical change is represented in the World Dynamics model as part of capital investment. From page 53 we find, "Capital includes buildings, roads, and factories. It also includes education and the results of scientific research, for the latter are not represented elsewhere in the model system and the investment in them decays at about the same rate as for physical capital." Physical capital, education, and technical advancement have very similar dynamic behavior. Each, in a real sense, as it interacts with population, tends to reproduce itself. Physical capital tends to make possible a higher rate of accumulation of physical capital. Knowledge makes it possible to accumulate still more knowledge. Technical accomplishment becomes the foundation for further technical accomplishment. They all, under the proper circumstances, regenerate themselves in a positive feedback loop as in World Dynamics. Dynamically speaking, they are very similar and can be aggregated together as a first approximation. If this had not been done with some success, how otherwise would the behavior of the model, which starts with conditions of the year 1900, by itself generate a trajectory that passes through the conditions of 1970? Certainly the seventy intervening years have been marked by rapid technological change. The several effects could have been separated and represented individually in the model. Doing so would have made details easier to describe, but would have obscured the broad overall structure of world interactions.

whereby political developments emanate from visible economic and social forces. This viewpoint seems to be in accord with a now popular school of historical thought.

9. Changed Rules of Debate. In the past men have debated the merits of mental models and their implications for the future of society. But the underlying assumptions have seldom been made specific and the arguments have been equally vague. But computer models of social structure are explicit, ^{and} the assumptions have meaning to an ordinary person who has knowledge of corresponding parts of the real system, ^{and} any concept that can be expressed in explicit verbal language can be put into computer language. Translation from ordinary language to computer language is simpler than translation between French and English. The grammar is more specific, the constructions are unambiguous. All statements must be made in quantitative form and murky thinking is suppressed.

With a clear and precise statement of assumptions, with an explicit statement about structure, and with an unassailable presentation of the implications of the assumptions as presented in computer output, a new rigor in debate is called for. Contrary assumptions about structures and influences should be presented with equal quantitative clarity. It would then be possible to determine whether or not the alternative suggestions would change the conclusions. But so far most critics are standing outside of the new arena. They throw stones at explicit assumptions that are offered, but do not risk opening themselves to similar inspection. Although far better and more comprehensive models can and will be developed, no one has yet offered an alternative quantitative model that he suggests is better.

The system dynamics methodology illustrated in World Dynamics gives a new basis for drawing together the interactions between technology, politics, economics, law, ethics, and religion.* The interactions between disciplines account for social behavior much more than influences from within any single discipline. System dynamics, by providing a common framework, allows the interconnections to be established. But more than a systems methodology is necessary. Knowledge about the subsystems is required. Time is needed to put each subsystem into a common framework. As the world becomes more congested, the interactions become more significant. If the

*For a discussion of religion in the context of these issues, see my chapter, "Churches at the Transition Between Growth and World Equilibrium" in Toward Global Equilibrium, Dennis L. Meadows, editor, Wright-Allen Press, 238 Main Street, Cambridge, Mass., U.S.A.

changing patterns of social forces are to be understood and controlled, the multiple interactions within society must be better understood. This, I suggest, is the great challenge of the next one or two decades. The task now is not the gathering of more detailed and elementary information. That has been going on for years. We are overwhelmed with bits and pieces of knowledge.

Now is the time to develop concrete theories of how this knowledge is linked together. Computer models are such theories. They show the interrelationships; they allow a derivation of the consequences; they permit a test of the theories against the evidence from reality. Toward achieving this better understanding, I suggest that several major research institutes need to be established. Each should contain men from every significant field of endeavor. All should amalgamate existing knowledge into unified theoretical structures (computer models), so that we can better determine the future implications of what we now know and are now doing. Alternative courses of action could then be evaluated to suggest roads toward the most acceptable of available futures.

Jay W. Forrester, Germeshausen Professor, Massachusetts Institute of Technology; recipient of the Valdemar Poulsen Gold Medal from the Danish Academy of Technical Sciences, 1969; Medal of Honor of the Institute of Electrical and Electronic Engineers, 1972; Benjamin Franklin Fellow of the Royal Society of Arts, 1972; Award for Outstanding Accomplishment by the Systems, Man and Cybernetics Society, 1972; author of Industrial Dynamics, 1961, and Urban Dynamics, 1969, (M.I.T. Press, Cambridge, Massachusetts) and of Principles of Systems, 1968, and World Dynamics, 1971 (both Wright-Allen Press, Cambridge, Massachusetts, in England through John Wiley.)

On the whole, I believe that this paper is quite good.

INTER-OFFICE
CORRESPONDENCE

TO Gordon Brown, Frank Davidson, Carroll Wilson
and Jørgen Randers DATE November 16, 1972

FROM Jay W. Forrester

SUBJECT "On Criticism of World Dynamics"

FOLLOW-UP	
FILE	

Please review the attached manuscript, and give me your editorial comments at your earliest opportunity.

eac
Attached: Manuscript (D-1730)

Randers.

ORIGINATOR REMOVES THE DUPLICATE (YELLOW COPY), SENDING THE ORIGINAL AND TRIPPLICATE TO CORRESPONDENT WHO RETURNS THE ORIGINAL WITH COMMENT AND RETAINS THE PINK TRIPPLICATE COPY.

HANSON PRINTING COMPANY, INC.—HANSON NO-CARBS—BROCKTON, MASS.

JWF
Sorry my comments are so unimaginitive, but I could not spend much time!

Jørgen
rec'd 11/27/72
Nat and Bill will reply together 11/29.

On Criticisms of World Dynamics

by

Jay W. Forrester
Germeshausen Professor
Massachusetts Institute of Technology

means that I
consider your
writing style
too dense and
inaccessible for
ordinary readers

Since the publication of World Dynamics¹ in 1971 and the successor book, Limits to Growth² by Meadows and others in 1972, an often repeated set of criticisms has appeared in reviews and commentaries. These reactions have appeared enough times to justify analysis and comment.

The two books deal with the dynamic interactions between population, capital, natural resources, pollution, and agriculture. They do this through the medium of computer models that have been built to capture the essence of assumptions that now seem to underlie political decision-making.

Although the debate involves both World Dynamics and Limits to Growth, I will respond only in terms of World Dynamics because some of the comments revolve around specific numerical assumptions that are available in the earlier book. Although the corresponding numerical and quantitative assumptions for Limits to Growth have been available to serious research groups since the spring of 1972, they are not yet at this writing generally available through a commercial publisher. The use of models in decision-making is old and familiar. Human thinking depends on models. One does not have a real city or nation in his head--only assumptions and simplifications that are a model that we use instead of the real system. Nations and the world are now managed entirely on the basis of models. The mental model starts from various assumptions about the parts of a social system, draws conclusions about the future dynamic implications of those assumptions, and goes on to propose modifications of laws and policies that are presumed to lead toward a better future. The computer modeling process on which the two books are based is, in general, the same as the mental modeling process. The differences are in degree rather than in kind. The computer

I do not think you should say this, since so very few groups have received the techn. report.

1. Forrester, Jay W., World Dynamics, Wright-Allen Press, 238 Main Street, Cambridge, Mass., U.S.A.

2. Meadows, Donella H., et al, The Limits to Growth, Universe Books, 381 Park Avenue South, New York.

model is more clearly stated and its implications can be determined with more certainty.

The computer model presents its underlying assumptions concretely and explicitly so that they are available for criticism and revision. The assumptions are interrelated in clearly stated ways that divulge the assumed structure for others to analyze. Because the structure has been made unambiguous and the numerical assumptions have been made quantitative, the resulting model (which is a theory of social structure) can be used by a computer to expose the behavioral consequences of the assumptions that have been made.

Why has the public and press given so much attention to these two books? Some have attempted an explanation in terms of publicity efforts by publishers and authors. But World Dynamics was released by a previously unknown publisher with nothing more than the mailing of literature and review copies. Yet within three months it was being discussed in the daily press, business periodicals, and in many special-interest publications. Clearly, the issues touched on deep public concerns.

The resulting controversy has arisen because the computer modeling process exposes internal contradictions that exist in the currently prevalent mental models. The computer models are essentially consistent with present assumptions about major world interactions. The behavior of the models is consistent with the observed rising social, technical, economic, and environmental pressures around the world. But the models come as a shock because they suggest a future that is quite different from the one our mental models have been anticipating. The critics seem to assume that the inconsistency between assumptions and expectations will be resolved by altering the basic assumptions until models behave in accordance with our future hopes. But it has been repeatedly shown that mental models are more reliable in their basic assumptions than in anticipating future behavior that follows from the assumptions.

The reactions to the books seem to rest on nine viewpoints and attitudes that the critics bring to the subject:

1. Assuming that analysis of social systems is premature and hopeless because sufficient information is thought not to exist.

is that really the reason. If it is you must explain in a more credible way.

sequence *put all on same common form*

2. Seeing the world from a narrow technical and materialistic viewpoint that excludes important social forces.
3. Addressing only limited physical and economic issues while ignoring the successive layers of limits to growth.
4. A sense of impotence toward altering present world attitudes becomes a sense of futility when the future is discussed.
5. Believing capital accumulation is the key to the future in spite of past inability in most cultures to acquire capital faster than population has grown and in spite of the rising forces that will lower the marginal productivity of capital and reduce the social feasibility of more rapid accumulation.
6. Hoping that market forces and prices can solve the problem of shortages.
7. Adopting a narrow disciplinary view so that the degree of aggregation represented in the models is not interpreted correctly.
8. Failing to perceive correctly the implications of aggregation, leading to the belief that technical progress has been omitted from the models.
9. Overlooking the way computer models are changing the rules of debate so that vague and nonspecific complaints are addressed to the clear and specific assumptions that are given in a computer model.

the same
who says what??
what?
put all of these on some common form.
Make the points clearer and more self-explanatory. Put them in some reasonable sequence.

Taking each of these nine points in turn:

1. Analysis Not Possible. It is commonly stated by academic critics that analysis of social systems as presented in World Dynamics should not yet be undertaken because sufficient information is not available. This is a viewpoint that can be taken only by a critic who is free to stand on the sidelines and wait for certainty. It is a rational viewpoint for the person who need not act and wishes to avoid professional risk. It is, however, an alternative that is not available to the manager, the political leader, or the citizen. We all live now. We all act in the present. What we do or avoid today determines the future. We do not have the option of stopping time while knowledge accumulates. Furthermore, every decision that is made is made on the basis of models. Those models are now the mental models in the heads of citizens, members of parliament, heads of government, and representatives at the United Nations. In general those mental models are less comprehensive than the models that can now be assembled

this point is good.

and put on a computer. They are also less accessible and less specific. In addition they contain internal contradictions between the basic assumptions and the assumed behavior. The critic, by suggesting that formal models should be delayed, implies that he has more confidence in existing mental models than he could ever have in an explicit formal model. He is saying that ignorance is bliss. He would rather depend on a mental model whose assumptions are unknown to him than to depend on the best available model that explicitly states those assumptions. The computer models are now beginning to compete with the mental models in plausibility and influence. The proper rejoinder to an explicit computer model should be to offer equally explicit alternatives and improvements so that our understanding of social systems can rapidly advance.

2. Materialistic Viewpoint. Criticisms have tended to focus only on issues of resources, pollution, and capital. This betrays a narrow materialistic perspective that misses the social, psychological, and political aspects of existence. In fact the consequences of rapid technological change, crowding, pressures on resources, and the need for rising resource flows from the underdeveloped countries to sustain economic growth in the developed countries, all are manifesting themselves in economic stress, genocide, rising crime rates, drug addiction, and an increasing probability of a third world war. The fundamental issue here arises from the way that pressures created by growth redistribute themselves within the social system. If some of the pressures are relieved, growth continues until remaining pressures intensify in other parts of the system. ——— We know better how to relieve technological pressures than we do economic pressures. In turn, we are more able to deal with economic issues than the social and psychological issues. Therefore, the tendency is to release the technological pressures and allow further growth to shift the stresses into the economic and social realms. Then by partially succeeding in the counteraction of economic pressures, we make the ultimate transition into unresolvable social stresses. In other words, the narrow materialistic view that sees solutions to all problems as achievable through technology will be responsible for intensifying psychological and social disturbance.

do not
our looks
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3. Layers of Limits. The narrow economic viewpoint tends to see world problems only in terms of resources and capital accumulation. Yet the limits to growth exist in a succession of layers. To the extent that the immediate layer can be relaxed, another layer is encountered. This succession is shown in World Dynamics where, with the particular assumptions that were chosen, the first limit to be encountered arises from resources. Page 73 of World Dynamics, in referring to the resource-limited mode that results in a population peak in 50 years, states,

. . . the figure should be interpreted as one of the possible modes of behavior of the world system. One can argue that exhaustion of natural resources is not the most likely limitation on population growth. Actual stocks of natural resources may be greater than the 250-year supply that has been assumed here. Furthermore, science may make continuing substitutions to delay the impact of resource shortage. If natural resources do not limit population growth and slow the pace of industrialization, however, some other force in the world system will eventually do so.

. . . natural resources may not be the most critical aspect of the world environment. (page 74) . . .

The effect of reducing the demand for natural resources is to take one layer of restraint off the growth forces of the system. (page 75) . . .

. . . [this] teaches a fundamental lesson about complex systems. When one pressure or difficulty is alleviated, the result may be merely to substitute a new problem for the old. Often the new mode is less desirable than the old. In particular, the industrialized societies have come to depend on technology to solve their problems. This succeeded when technology was improving so rapidly that it could exploit geographical space and natural resources faster than the population could increase. But now, as technology reaches the point of diminishing returns and begins to run short on space and resources, the technological "solution" may more and more be only a substitution of one crisis for another. (page 80)

The book then continues to examine pollution as a possible limit, food shortage as another possible limit, and crowding as the ultimate limit. Those who depend only on technology should ask themselves what the next set of limits will be. Will pursuit of technical goals simply lead to more intractable pressures in the economic and social sectors? I believe they will. If so, the arguments presented by the materialistic technologists will in time be recognized as having been a route to greater social disorientation.

4. Futility in the Face of Past Traditions. In effect, some critics plead that we need not address ourselves to the future because we cannot change the present traditions, actions, and value structures of society. This is the voice of resignation and hopelessness. But it arises from misjudging the interest of the public in the longer-term future and the sensitivity of the public to present omens. The public viewpoint has changed markedly in the last ten years toward an increasing concern for environmental issues, an acceptance of the necessity for population limitation, and a recognition that continued dependence on technology alone to solve problems will produce rapidly intensifying stresses in the nontechnical aspects of the world system. I believe the critics' futility is unjustified and that citizens, managers, and political leaders are beginning to recognize deteriorating interactions between technical, economic, and social forces as issues to which they must be increasingly responsive.

5. Confidence in Capital Accumulation. The technical optimism is based on the assumption that massive accumulation of capital can solve all problems. It is often suggested that additional capital investment can increase agricultural output, reduce pollution, and use lower grade resources. This may be true if the capital accumulation can and does occur. But the optimists do not address themselves to the feasibility of such massive capital accumulation. Two developing trends suggest that it will be more difficult than in the past, while, even in the past, capital accumulation has been possible for only that quarter of the world's population that has lived under particularly fortuitous circumstances. As environmental limits are pressed more tightly, the cost of generating capital will increase at the same time that its marginal productivity declines. Furthermore, as population continues to grow while production comes under ever heavier restraint, there will be growing social pressures to divert current production into current consumption. As the pressures for medical programs, old age support, unemployment compensation, and public welfare payments mount, there may be a declining capability for accumulating capital.

6. Rising Prices. Prices have not been included in the variables of the World Dynamics model. Many have seen the absence of prices as a major weakness, and have asserted that price mechanisms would curtail use of scarce goods and thereby prevent their disappearance. But rising prices

good

material

or quality of life

imply more effort expended per unit of product. Higher real prices are equivalent to lower productivity and a falling standard of living. It matters very little to the consumer whether he cannot procure goods because they are unavailable or because the price is higher than he can afford. Prices are intervening variables between supply and demand, they are communicators of shortage, and they encourage the use of more abundant alternatives for scarce goods. But prices cannot correct a situation of total demand exceeding total supply such as will exist if population and industrialization extend beyond the limits of the world environment. This viewpoint parallels the U. S. National Academy of Science report of August 1972, Elements of a National Materials Policy, that states, "there was but small support for the view that market forces alone will solve the foreseeable problems."

I would rather argue that prices are in the model implicitly.

7. Misinterpretation of Aggregation. An overview of a social system discards fine detail so that broad issues can be more clearly accentuated. When this is done, many of the intermediate relationships in a chain of causality are omitted. A critic who is accustomed to taking a narrow subsystem view may observe the omission of the direct elements of causality without looking beyond them to see if they are adequately represented by a more fundamental set of causes. This failure to judge from the appropriate perspective is illustrated by reactions to the demographic sector of World Dynamics. In the model birth rate depends on the material standard of living, crowding, pollution, and food per capita. But critics suggest alternative effects on birth rate without asking whether or not these might in turn be related to the more fundamental variables already represented in the model. For example, the suggestion is made that social attitudes and institutional factors affect birth rate. Indeed they do but are they not themselves apt to be a reflection of the availability of space, food, material goods, and a satisfactory environment? Social attitudes and institutional factors reflect the self-discipline necessary for man to fit himself into his environment and to the proximity of his fellow man.

As a more specific example, the suggestion has been offered that the decline in French fertility in the nineteenth century might be due to changes in the laws of inheritance, changed social attitudes, and the easier life that fewer children make possible. But one should look back into the

economic and political situation to see why the laws were changed and the social attitudes were altered. And what was it in the changing technology and rising industrialization that made fewer children advantageous? The intervening variables that are suggested will often be but mere reflections of the more fundamental variables dealt with in World Dynamics.

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Good.

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