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[Club of Rome papers and correspondence]

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Room 26-167

December 20, 1970

Dr. Aurelio Peccei
The Club of Rome
Via Giorgione 163
00147 Rome, Italy

Dear Aurelio:

I found the review of Phase One on Friday one of the most interesting days I ever spent. The exposition in the morning by Jay and Dennis was brilliant. The "runaway character" of exponentially growing phenomena was explained in unforgettable terms by Jay. Having arrived at the brink--with perhaps one or two more doublings--in population growth, natural resource usage, food production and so on, it seems to me that the real "predicament of mankind" arises from the absolute necessity of finding an equilibrium but instead we find wide open "throttles" on each of these several matters.

I look forward to talking with Dennis and Dana concerning the runs on the developed world and the runs on the LDC's separately and some of the interesting questions of relationship which these imply. I also look forward to more discussions about the pollution table functions. The control and abatement of pollution seems to me infinitely easier than any of the other pieces of the puzzle. It is the one part peculiarly susceptible to the application of science and technology for early change. I expect that before a decade has passed most kinds of pollution which now degrade our environment will be way below present levels despite the growth that occurs in that decade. However, this does not in any sense, I believe, seriously modify the general probability of catastrophic change arising from things that aren't so easily modified, such as population growth and the growth of everything including the growth fixation of modern industrial economies wherever they are.

We intend to do a re-examination of the implications of man's activities as they may affect climate in the summer of 1971 in

Europe. Some of the people engaged in the SCEP study in Williamstown joined by a number of others from other countries will, we hope, gather to re-examine these matters and to revise or modify our judgments of 1970 by a distinguished international group.

In this connection I expect I may be going to London for meetings on the 12th and 13th of January, then probably to Amsterdam and to Stockholm, in each case for a day or two.

It occurs to me that there are several matters which I could very usefully discuss with Gvishiani if I were to go on to Moscow from Stockholm and then home.

It would be extremely useful if one of the able men Gvishiani sent to the Sloan Fellows Program for the year 1969-70 could return and spend the time through June with Dennis and others on the Phase One project.

At the meeting last Friday Maurice Strong discussed in a preliminary way with Dennis Meadows the possibility that the able Soviet staff member whom Strong expects to be added to his team soon might spend enough time at M.I.T. to understand fully the nature of the Phase One project.

There are other things I could do with Gvishiani. I am sending you this note at once because the time is short and the last thing you mentioned to me was the possibility of writing to Gvishiani to second your own letter to him.

Do let me know what might in your opinion be a useful purpose of my meetings with Gvishiani if I do stop and see him about the 20th of January.

It was a brilliant idea to bring Lester Brown into the discussions the other day. I know he can develop linkages for the M.I.T. group with those who can bring great wisdom and judgment to bear on the agriculture part whether it be pollution and its effects on agriculture or agricultural productivity. When leaving Lester remarked that the Club of Rome project was the most interesting intellectual activity he knew of anywhere at this time.

The issues posed for Phase Two are indeed formidable. I can understand the need for some very hard thinking about the options of national and international behavior which exist depending upon the behavior of the world system and one's estimate of the prospects of modifying the behavior or doing those difficult things like reducing birth rate and altering a growth philosophy to one of equilibrium. I suspect the relationship between the developed and the less developed countries will come into bold relief and a progressive attenuation of the relations between the two groups may arise. One already sees this beginning from the LDC end.

You are to be congratulated on the extraordinary contribution you have already made through your untiring initiative and imagination in creating the Club of Rome and leading it on to this Phase One project.

I regret very much that I shall miss the Ottawa meeting on April 4th and 5th because I will be in Europe at that time. However, I shall try to pass on any thoughts I have to Jay and if I should see Gvishiani in January I will surely be in touch with you as to what prospects he may see of linkages with the Phase One project, if not any formal connection.

With best wishes for the Christmas season,

Sincerely,

Carroll L. Wilson

CLW:F

cc: Professor Forrester
Professor Meadows

Forester

D-1481
World Dynamics Series

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Alfred P. Sloan School of Management
System Dynamics Group--Working Papers

TITLE: Meeting Notes, Club of Rome Conference.

AUTHOR: Nancy Roche

DATE: December 18, 1970

Morning Session

Meadows: Introduction to the Club of Rome Project; Phase One, the research program, will last until the end of June. Growth cannot continue indefinitely; it will be stopped either by nature or by policies of our own choice. The Club of Rome team is pragmatic, non-ideological group trying to understand how one might bring about alternative patterns of change to minimize the stresses on humanity as exponential growth gives way to equilibrium. Difficult because concept of growth part of Western value system.

Forrester

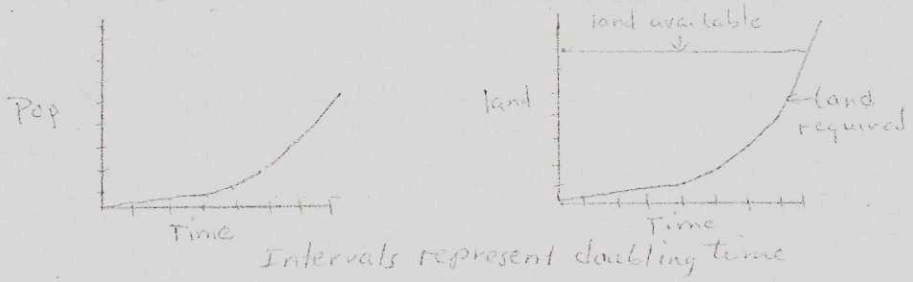
Forrester: Extensive training is needed to learn the theory and technique of system dynamics. We are involved here in studying feedback structure that governs growth and equilibrium in systems. The theory was pioneered at M.I.T. in the 1930's with work on the differential analyzer. The theory of models with multiple loop, non-linear system structure was slow in developing. The linear systems found in math, engineering, etc. do not contain major modes of operation important in social systems. In non-linear systems, we give up idea that there is a best solution; there are only better solutions with which managers and politicians are interested.

All decisions are based on models: only alternative is between a mental model that is unclear and fragmentary, and more rigorous models. Human mind unable to see consequences of set of assumptions acting on each other. Problem is not lack of information as is stated in social sciences. Problem is too much information that obscures what is relevant. Today, computers used to gather information; human mind analyzes results. Best use of both is reverse.

Whether feedback loop is positive or negative depends on the values of the coefficients and parameters. These values,

in turn, may be governed by other loops in the system. Exponential growth curves have a doubling time, i.e. period of time where variables double. Curve is function of plotting of scale; this is usually done so that the middle is the point of concern. This is where growth has begun to impinge on something else which is important. As growth increases, the space within which the system can operate declines.

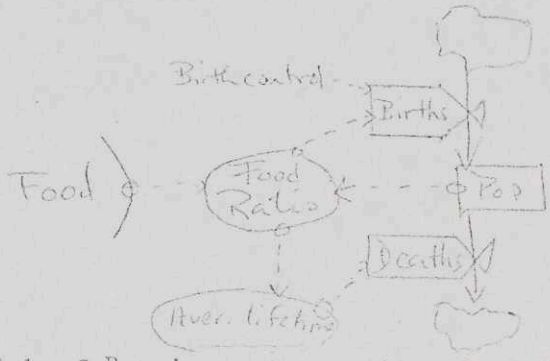
For example, let us consider the case where each person needs one acre of land for occupancy, and two acres for food. Assuming there are 4 billion people and 24 billion acres of land, the result is 20 billion acres for food, or 5 acres per person. Doubling the population to 8 billion, there are 16 billion acres for food, or 2 acres per person. When the population doubles again, only one-half acre of food land is left for each person. Therefore, the last doubling cannot occur; the environment can no longer support the population. Technological improvements may help in the short-run, but not in the long-run. See following diagrams:



The malaise that now affects the world may reflect the adjustment to the beginning of the equilibrium which is replacing exponential growth. Our expectations about the quality of life are based on the previous pattern of change; the absence of continued improvements creates unhappiness. The quality of life reflects the rising pressures that come from the system impinging on the upper limits of the environment. Attempts to raise the quality of life will simply raise the population in the long-run, because attempts to alleviate the pressures will only delay the reckoning 10 to 20 years. Higher population and industrialization will lower the quality of life even more. These growth proccesses must be halted.

L. Brown: Suggests that a voluntary birth control program could alleviate the problem in the short run.

Forrester: Reducing births will increase the amount of food available, thus reducing the death rate and resulting in an increase in population. This can be shown in the following diagram:



Thiemann: Asks if the Club of Rome's actions will only delay the eventual collapse. Forrester has suggested that the growth curve only flattens due to system pressures, and not due to human actions.

Forrester: There are pressure points in systems that, if acted upon, will have enough leverage to influence the system. When these are acted upon, system appearance changes, causing people to change their behavior. Birth control is not one of these pressure points. Intervention in systems with programs such as birth control can be destructive because it may destroy processes in the system that act as pressures and yet be ineffective in providing greater pressures. When the program is removed, no pressures are left, and the system is worse off than it was initially.

Peccei: It is possible to influence population growth by reducing the Birth Rate to zero. Holding population fixed, however, is not sufficient.

Afternoon Session

Meadows

Meadows: Discussion of World Model. The model is not derived from empirical data, but data is drawn upon to integrate the the system structure. Wish to make model understandable to experts in specific fields.

System dynamics is a theory of structure, i.e. the relationships among elements in the real world. The interactions are

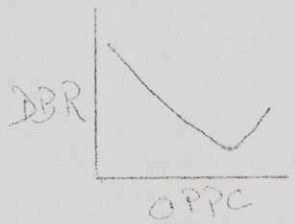
represented as feedback loops; a positive feedback loop is a reinforcing loop that brings growth; a negative feedback loop is a controlling loop bringing oscillation or goal-seeking behavior. The variables are levels and rates; policy changes are exercised by altering the rates. The major focus of the model is the relationship of population to capital. For example, as a country develops economically, the Birth Rate declines because large families are no longer economic necessities. In the model, the relationship between population and births is a positive feedback loop, as is the relationship of industrial capital and industrial output.

The industrial capital sector can be stagnant if most of the available capital is used for food production. This is true in the less developed countries.

The model is not predictive; it simply tests the outcome of one's assumptions.

Question: Are time delays incorporated in the model?

Meadows: Yes, the model is very flexible and incorporates many assumptions. Cause and effect are not simultaneous. Delays in the perception of effect are also a factor. Can express intuition through table functions. For example, we can graph the relationship between Desired Birth Rate (DBR) and Output per Capita (OPPC) in the following way:



L. Brown: Is the historical and international data on the relationship between DBR and OPPC similar to the graph you have just drawn?

Dana Meadows: Yes, the data is quite convincing.

Platt: What about the place of philosophical ideas in the system? Events like the publication of Uncle Tom's Cabin produce psychological results that cannot be provided for in the model.

Forrester: Ideas, visions, etc. are embedded in the realities of the system structure. Books can precipitate but not cause a change in the system.

Platt: You are assuming a one-dimensional path of change, and denying that there are points where small changes can have a flip-flop effect on the system.

Forrester: The World Model displays the flip-flop effect in shifting, for example, from a natural resource crisis to a pollution crisis with only slight changes in policies.

Randers

Randers: Discussion of the pollution sector of World Model. Is it possible to say anything meaningful about pollution in terms of only one variable? One aggregates quantities in order to make the model understandable and disaggregates in order to give details. The highest useful level of aggregation is the highest level where one can answer the question one has asked. If we want to ask a question about the ecological limits of the globe, it is useful to talk about one "pollution". However, one must be sure that the level of aggregation is low enough so that it is meaningful. In our example, this means that we must be able to prove that the "pollution" has stable, well-defined relationships with other variables, so that we can say, for example: When pollution doubles, the average life-time declines one year. For the level of aggregation to be meaningful, this must always be true, regardless of the kind of pollution.

We have identified four causes and two effects of pollution: the four causes are 1) population 2) output per capita 3) arable land 4) capital/land ratio. They affect 1) average life-time 2) land effectiveness.

A table function is easy to draw when the two quantities on the axes are well-defined. However, pollution is very badly defined, and we must find a way to define it better before we can draw the table functions showing its causes and effects. It is possible to define pollution as the weighted sum of different pollutants. The sum that we choose will depend on the purpose of the sum. In the model we wish to know the effect on the average lifetime and land effectiveness. Therefore, we include all the pollutants that affect lifetime and land.

For lifetime we weigh air pollution, water pollution, soil contamination, livestock contamination, radiation level. We do the same for land and it is only if the weights in these two sums are similar that it is meaningful to use only one

pollution variable--namely, the average of the two weighted sums. The averaged weighting factors are called "problem factors" (measured in "general pollution units/specific pollutant unit") and the one level of general pollution (measured in "general pollution units") can be written:

$$\text{General Pollution} = \sum_i (\text{problem factor for pollutant } i)(\text{level of pollutant } i)$$

or

$$P = \sum_i w_i p_i$$

Question: I am surprised that you are using linear functions in this case. I would expect some concentration on the non-linear aspects of the interacting effects of pollutants.

Randers: To do this may mean greater disaggregation.

Weiss: The constant here is man who is adaptable to stress.

Thiemann: Refers to the CO_2 cycle. There are localized effects of pollution that we can act on such as SO_2 pollution.

Forrester: We are looking for the major effects of the components. Small changes in pollution are unimportant because of the pressures in the total system.

Thiemann: A criticism of the first model was that pollution was the crucial factor in the collapse.

Forrester: The danger point is threshold beyond which pollution cannot be broken down by the pollution absorption process.

Giarini: The long-range effects of pollutants, such as DDT, are important as well. DDT is good in the short-run for food, but bad for man in the long-run.

Weiss: You have left out the differential distribution of pollution through the homogenizing you have done in the model.

Thiemann: The art of modeling is to keep the model simple.

Schroeder

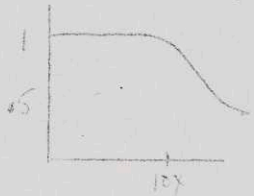
Schroeder: Discusses the effect of pollution on land effectiveness. The three major forms of pollution that affect agriculture are 1) pesticides which upset the ecological balance, 2) air pollution 3) water pollution.

In the April 1969 issue of the Scientific American there is a discussion of the relationship of soil fertility to the number of invertebrates in the soil, and the effect of pollution on these invertebrates. It states that a tenfold increase in pollution over today's level would kill one-half the invertebrates.

It is difficult to find data on air pollution in relationship to agriculture. However, water pollution is extremely important in terms of its effect on agriculture. The saline quality of the soil affects food production. Pollution affects salinity if it alters the quantity or quality of water available for irrigation. The first assumption I made in this regard was to equate pollution and salinity. Secondly, I related land efficiency at a a given level of salinity to crop yields.

We find that a three- or fourfold increase in the current salinity levels would mean a .5 decrease in crop yields. We are referring here to the 20% of the world's land area which is irrigated.

A tenfold increase over the current pollution level (air, water, pesticides) would result in a .5 decrease in land efficiency as shown in the following graph:



Statement: Land efficiency should also include forests, which are the main regenerators of oxygen. Here we see the tremendous effect of air pollution.

Kaya

Kaya: Discusses work of Japanese team in Club of Rome project. Whereas the variable approach dominates the work at M.I.T., in Japan we are looking at real world problems, and trying to derive a structure from them. We have concentrated on Japanese problems, because we know them best. Later, we will deal with world problems. We have tried to identify continuous, important social problems.

To do this, we first brainstormed, identifying 200 social problems. Then, we surveyed these problems through use of

newspapers, periodicals, and books. We then modified our list, leaving about 150 problems. We are now trying to visualize a non-mathematical structure. The first method we tried was the KJ method. After writing each problem on a card, and spreading the cards on the floor, we then collected them by subject matter. However, we did not find this a useful method for deriving structure. Next, we tried classifying the problems based on specific critieria.

We have also applied two mathematical methods: one is the quasi-diagonalization of the problem matrix; the other is the use of principal component analysis.

Thiemann: I think that the matrix method is excellent and a good complement to dynamics. It is the one we originally considered when first thinking how to structure world problems.

Weiss: The primary difference is that the Japanese method is a cross-section of problems at a specific point in time, whereas the M.I.T. group is interested in the system behavior over time.

Discussion and Questions

Baer: Suppose you had all the relationships, parameters, rates, etc. I wonder if you can show:

1) what will occur 10 years from now;
2) the instruments through which we can achieve our objectives.

There are very few variables that a policy-maker can tamper with. For example, how would you reduce pollution?

Meadows: Assuming that we have a useful model, our objective is not to predict 10 years in the future, since social systems are influenced by random factors. Rather, we wish to understand the behavior mode of the system, and to see in what ways behavior changes in response to specific policy changes.

What would you do in a pollution crisis?

Baer: A possibility is an economic disincentive for pollution.

Meadows: That policy could be represented simply by changing several of the model's table functions. In this case,

the amount of pollution generated by a given level of capital investment would decrease. In controlling pollution, the capital base would become less efficient. We could also make a statement about the industrial output for each unit of capital and trace the effects.

Forrester: There are two ways to do this:

1) we can take the basic structure and make specific changes.
2) we can model the dynamics of the changes into the system.

Platt: The model permits a high degree of complexity. You can vary 40 to 50 parameters simultaneously and see the consequences rather than being limited to making only two or three policy changes at a time.

Strong: Decisions are not usually made on the global level. We should determine which factors can be changed at which levels of decision-making. We can then decide where to apply leverage.

I am not clear about the space-time relationship. In the real world, cause and effect are not global.

Forrester: Kaya's 150 problems are a result of rising population and industrialization. They show the tightening up of the administrative processes as a result of pressure against bureaucratic limits. The psychological factors are consequences of too much growth.

Neu: Both methods are complementary. Difficulty in quantification.

Forrester: We want to combine methods. However, I object to the idea of non-quantifiability. Anything can be quantified. It is important to distinguish the ability to quantify from the question of accuracy. However, generally, quantifying an assumption leads to improving its accuracy.

Thiemann: In summary, discusses in general terms the Club of Rome's search for a methodology which resulted in choosing Professor Forrester's system dynamics during Phase One of the project. Phase Two will continue research and will attempt to put the research program into action. It will be based at the Battelle Institute in Geneva, Switzerland, and will have an international staff. The program will be directed towards understanding the consequences of the model, and towards assuring its implementation by decision-makers.

JWF 1/5/71

MASSACHUSETTS INSTITUTE OF TECHNOLOGY CAMBRIDGE, MASSACHUSETTS 02139

Room 26-167

December 29, 1970

Professor Dennis Meadows
M.I.T.

Dear Dennis:

I sent some of the Club of Rome papers to a very interesting Belgian or Polish friend of mine and I send you his long-hand reply. Some of his remarks are wide of the mark but others seem to me highly relevant. Perhaps we can put them on the agenda of things you and I should talk about sometime.

Incidentally, I think you have a copy of my letter to Aurelio concerning my prospective visit to Moscow.

One thing troubled me in the presentation by Randers concerning pollution. The table function which shows pollution increasing exponentially with industrialization seems to me potentially wrong. My own hunch is that within five years in the United States, at least, and probably in some other highly developed countries it will be cheaper for industry to contain and use, if they can, gaseous and liquid effluents than to pay fines, law suit damages and suffer the adverse public relations that goes along with it. I also think the cost is not going to be very big in most cases.

A number of firms I know now have decided as a routine policy that new plants will not spew any gaseous effluents into the atmosphere nor liquid effluents into water courses. They haven't yet done much about the fate of their end products when they meet the solid waste disposal center but this may come in time and in any case in terms of the cumulative effects of global pollution I think the solid wastes are not at the top of the list.

The adoption of load-on-top procedures by oil tankers will reduce by a factor of 10 the tanker dumpings of petroleum into the seas. I think that the spurring level of fines and public suits against oil companies and others for not putting in safety chokes in their off-shore drilling rigs is going to have a very prompt and effective result.

Thus I think that that table function which shows an exponentially soaring curve of pollution strongly influenced by industrialization is likely to be wrong. I also think there is a fair chance that within a few years insect control, which is species-specific, non-persistent, biodegradable and with minimum ecological side effects will be standard in many parts of the world. I also think we are going to deal with the nutrients we throw away from feedlots, sewage and other things.

Sometime I would welcome discussing these matters with you and Randers and others but I thought I'd send you this note now to tell you that I am unhappy about that table function and think it is likely to be wrong.

Sincerely,

Carroll L. Wilson

CLW:F

Enclosure

CAN WE AFFORD TOMORROW?

The Economy: Our Deceptive "Growth Dividend"

by JOHN R. MEYER

The policy revolution known as the new economics is an accomplished fact. Where do we go now? Today the central economic issue is the trade-off between price inflation and unemployment, but new issues increasingly are coming to the fore—those involving national priorities and the relationship among our various private and public economic goals.

A major concern of the new economics is the concept of economic potential: where the economy could be, would be, or should be if it were to realize full or near-full employment. The embodiment of this new focus is potential Gross National Product (GNP). Potential GNP is increasingly the reference point against which policy alternatives are measured. This is manifested by the attention paid to the government's full-employment budget (based on what tax revenues would be if full employment existed) or the so-called GNP gap (the difference between actual and potential GNP). This gap has come into greater prominence as it is increasingly thought to influence many other important economic phenomena, such as the rate of overall price increase. And now, as if to prove that the revolution is complete, there is the newest concept of the business cycle: what some of my colleagues call a "growth recession," which they define as the existence of a persistent gap between potential and actual GNP. Those who advance this new definition of the cycle unhesitatingly would label current circumstances in the United States as constituting a growth recession—not foreclosing the increasingly strong probability that our economy has also been in a state that could be termed a recession by conventional definitions.

While economic potential is an ambiguous concept, some rough agreement does exist on what potential growth might constitute. We usually say, for example, that our economy can expand at more than 3 per cent a year because of productivity gains alone, and we can add another percentage point as a result of work force expansion. Thus, Gross National Product can be expected to expand by 4 to 4.5 per cent a year. Nor is the distinction between 4 and 4.5 per cent growth a year trivial in a trillion-dollar economy. It clearly makes a great deal of difference in a trillion-dollar economy whether GNP grows at 4.4 or 4.5 per cent, let alone 4.0 or 4.5 per cent. The difference over a few years could run into tens of billions of dollars.

More interesting than these measurement problems are the new policy issues that come to the fore when the focus is on economic growth. We have been confronted with the grim realization that there are definite limits on the economic and social needs that can be met from growth alone. If the economy grows by 4.5 per cent, only that much in the way of *new* assets will be available for meeting new requirements. If demands exceed this capability, then some hard choices must be made. This may seem terribly obvious, but it should be noted that it has not always been part of the common economic policy concern, particularly when the assumption was that the main problems were cyclical stabilization and putting unutilized resources to work. Only with the last report of the Council of Economic Advisers, in fact, was a start made on focusing public discussion on this simple but important factor.

The first step in analyzing this "growth dividend" or allocation question is to subdivide potential GNP into its three functional components: the public sector, the private sector, and the amount of growth we forgo for purposes of fighting inflation. How will these various components mesh with one another? Are our public and private aspirations, taken together, consistent with what we can achieve? In the financial area, for example, a key question is whether present financial institutions can generate the funds required by our private markets and our public policy decisions. State and local governments rely heavily on debt financing, which is sometimes subject to severe interest rate ceilings. Accordingly, we must ponder whether the potential price inflation generated by full employment would lead to interest rates that pose a hardship for states and municipalities. Similarly, is full employment consistent with our goals for housing, a sector that is also heavily dependent on debt financing?

A continuous price inflation may make it difficult to fund activities that historically depend on debt as their major source of financing. Institutional adjustments, of course, can be made to meet these problems. Indeed, we have already discovered new ways to finance activities that rely on debt in times of substantial price inflation. One example is the equity participation that is now being built into the financing of large-scale commercial and industrial real estate developments. We also see many special subsidies or other techniques used to divert funds into home mortgage markets. Even AT&T is discovering the virtues of warrants and equity-oriented financial devices.

But this may not be enough. For example, I would not entirely rule out the possibility of moving to variable interest rates on home mortgages in a pattern now employed by the British. Indeed, there has already been some experimentation, not always successful, with such devices in the United States. Perhaps we shall also come to experiment with index bonds, where the level of repayment is tied to the price level. Or we may increasingly employ tax penalties or incentives to induce private enterprise to undertake social activities such as pollution control and thus reduce the burden that might otherwise be placed on public funds. Similarly, revenue sharing, federalization of welfare, the administration's family support program, or an out-and-out negative income tax would all tend to shift tax incidence and revenue support in ways that might be more compatible with continued high rates of economic growth.

I mention these possibilities not by way of endorsement but to direct attention to the issues we must face as we pursue new public objectives. At the same time, we must try to accommodate the needs generated by continued growth in our population and in our private sector. They are questions we must answer as the nation moves closer to full employment in an economy with a strong inflationary potential.

It is not clear, for example, that our financial institutions are readily consistent with attempts to channel

minimum use of pesticides with maximum use of biological control, and greatly increased financial support for that effort.

• As to the amount of oil in the oceans, we guessed that it might be two to five million tons. This is a very small percentage of the amount that is carried by tanker, but in absolute amounts it is large. We don't know where it goes; we don't know what it does. But we do know that in the few cases where spills have been closely monitored the effect on bottom life has been severe. SCEP recommended a much greater study of oil spills. We also urged that the load-on-top procedure of tankers be used universally—a move recently supported by the U.S. Secretary of Transportation. An estimated 80 per cent of the tanker fleet that now practices this method dumps 30,000 tons of oil into the sea each year; the 20 per cent that doesn't dumps an estimated 500,000 tons each year.

• Many heavy metals are highly toxic to specific life stages of a variety of organisms, especially shellfish. Most are concentrated in terrestrial and marine organisms by factors ranging from a few hundred to several hundred thousand times the concentrations in the surrounding environment. The major sources of mercury are industrial processes and biocides. Although the use of mercury in biocides is relatively small, it is a direct input into the environment. There are many other possible routes, but scanty data exist about the rates of release to the environment.

SCEP recommended 1) that pesticidal and biocidal uses of mercury should continue to be drastically curtailed, particularly where safer, less persistent substitutes can be used; 2) that industrial wastes and emissions of mercury should be controlled and recovered to the greatest extent possible, using available control and recovery methods; and 3) that world production, uses, and waste products should be carefully monitored.

• Eutrophication of waters through over-fertilization (principally with nitrogen and phosphorus) produces an excess of organic matter that decomposes, removes oxygen, and kills fish. Estuaries increasingly are being eutrophied. Pollution of in-shore regions eliminates the nursery grounds of fish, including many commercial species that inhabit the oceans.

Most (probably between 60 per cent and 70 per cent) of the phosphorus causing over-enrichment of water bodies comes from municipal wastes. In the United States about 75 per cent of the total phosphorus in these waters comes from detergents. Urban and rural land runoff contributes the remainder (approximately 30 per cent to 40 per cent). A major contributor is runoff from feed lots, manured lands, and eroding soil.

Trends in both nutrient use and loss are rising. Fertilizer consumption is expected to increase greatly in both developed and developing countries in the next decade, increasing the nutrient runoff from agricultural lands. Concentration of animal production will continue with the result that losses of nutrients from feed-lot runoff will quadruple by 2000. Urban waste production is expected to quadruple by 2000, which means greater potential loss of nutrients directly into coastal waters.

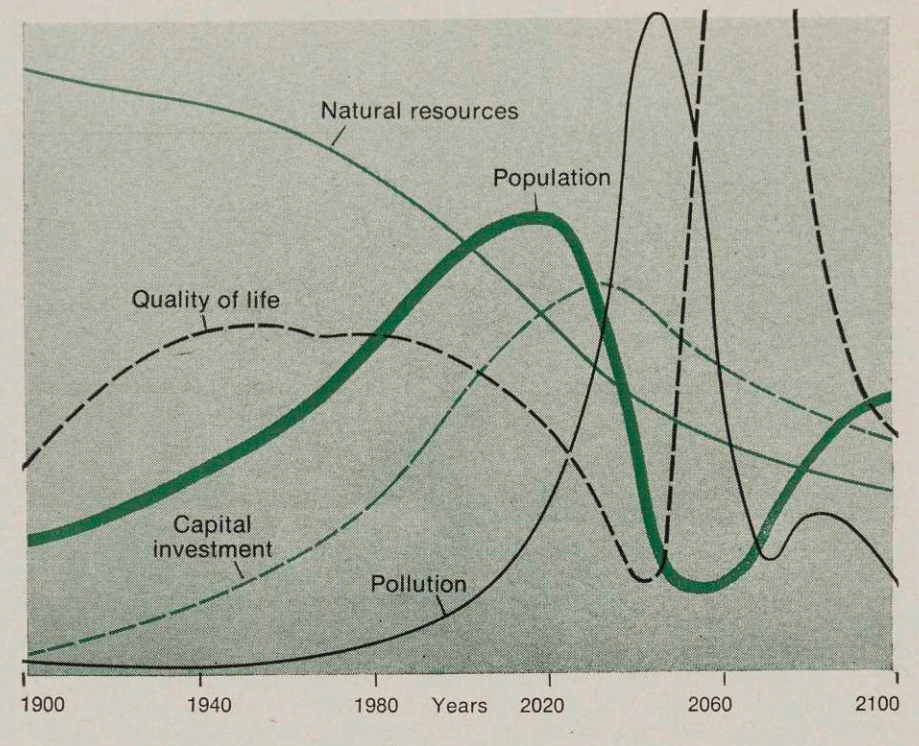
We should develop and apply technology to reclaim and recycle nutrients in areas of high concentrations, such as sewage treatment plants and feed lots. We also should avoid use of nutrients in products that are discharged in large quantities into air or water. For example, reformulate detergents to eliminate or reduce waste phosphates, but be certain the substitutes degrade and do not poison the ecosystem. Finally, there should be control of nutrient discharges in natural regions, such as river basins, estuaries, and coastal oceans, through appropriate institutions.

• To prevent further deterioration of the biosphere, and to repair some of the present damage, action is urgently needed. In addition to a variety of specific recommendations such as those accompanying the specific problem areas, SCEP recommends that the following activities be developed in national and international programs:

1) *Technology Assessment*: An information center that centralizes data on products of industry and agriculture,

(*Continued on page* 93)

Computer Simulation of Pollution Limit to World Growth



Modern life has become so complex that man is no longer able to forecast the long-term consequences of his policies and activities. At MIT, a program directed by Professor Jay W. Forrester is using computer simulation models to study the dynamic behavior of interacting systems and how they would react to certain policy changes. The simulation above shows what might happen if capital investment were increased now by 20 per cent in an effort to reverse a decline in the quality of life. The pollution crisis worsens when the upsurge of industrialization overtaxes the environment before a depletion of natural resources has a chance to depress industrialization. An apparently desirable change in policy has caused unexpected consequences. The quality of life continues to decline until rising pollution and other factors produce a drop in total population and an increase in the availability of goods and services.

CAN WE AFFORD TOMORROW?

Environment: Preparing for the Crunch

by CARROLL L. WILSON

There was a time in our history when the prevailing value system assigned an overriding priority to the primary effects of applied science and technology: the goods and services produced. We took side effects such as pollution in stride. There now seems to be a shift in values that assigns a much higher priority to the control of the side effects. But when the crunch comes and the implications of remedial action and necessary choices become clear, will we have second thoughts? Will we bog down in confusion and frustration? Or will we hold to our course, insisting that our society make a more thorough and imaginative effort to achieve a much better balance between the production we need and the side effects that we must bring under control?

Last July, a group of fifty scientists and professionals wrestled with some of these questions at Williams College in Williamstown, Massachusetts, where a month-long study was conducted to assess man's impact on the global environment. The project, called the Study of Critical Environmental Problems (SCEP), focused on the need to gather more information about pollution of the planet. Our hope was that this information would improve our understanding of the impact of man's activities on the Earth's resources of air, water, and land: that is, the ecological demand of man's activities.

The study, sponsored by the Massachusetts Institute of Technology, explored the climatic effects of increasing carbon dioxide in the atmosphere and of increasing the particle load. It also investigated the atmospheric effects of contamination produced by combustion from supersonic transport aircraft (SST). DDT and other toxic insecticides were studied for their ecological effects, as were mercury and other toxic heavy metals, petroleum in the oceans, and nutrients in estuaries. In each case, we tried to estimate the background level of naturally occurring products, for example carbon dioxide and particles, in order to assess the amount and effect of increments arising from man's activities. We formulated recommendations on measurement, research, and abatement action, where we considered it justified. *Man's Impact on the Global Environment*, a detailed report of the project, has been published by the MIT Press. Its major findings and recommendations can be summarized as follows:

• The concentration of carbon dioxide in the atmosphere is increasing steadily as a result of man's activities. It may be up nearly 20 per cent by the year 2000. This could lead to an increase of global temperature of a half degree centigrade, which is not alarming. But if carbon dioxide concentration doubled, it could raise the global temperature two degrees centigrade, and this could be disturbing: It takes only a two-degree change in the global temperature to initiate the kind of warming of the planet that has been predicted by those who said the icecaps were going to melt, the oceans were going to rise, and we were all going to drown. We didn't find a crisis here, but we thought the consequences of having to change our habits and not generate too much carbon dioxide were so great that we should begin measuring it carefully.

• Man puts large quantities of sulfates, nitrates, and hydrocarbons into the atmosphere that become fine particles, including such special species as urban smog. These particles change the heat balance of the Earth because they both reflect and absorb radiation from the sun and Earth. Large amounts of such particles enter the troposphere (the zone up to 40,000 feet) from natural sources such as sea spray, wind-blown dust, volcanoes, and from the conversion of naturally occurring gases—sulfur dioxide, nitrogen oxides, and hydrocarbons. We don't know enough about the optical properties (reflection vs. absorption) of particles to know whether they produce warming or cooling of the Earth's surface. Therefore, we recommended studies to determine their characteristics, as well as their sources, transport processes, size distributions, and concentrations in the atmosphere.

• As expected, SCEP's findings concerning the SST received the most public attention. We examined the Federal Aviation Administration's estimates of the effects of 500 SSTs being operational in 1985, flying at 65,000 feet for seven hours a day. Such a fleet would consume sixty million tons of fuel a year. SCEP's meteorologists, atmospheric chemists, and other experts considered the duration that the gases and particles produced by jet exhaust remain in the stratosphere—about two years. Then we looked for a yardstick. The only one we could find was the volcanic eruption in Bali in 1963. We thought it might be possible that such a fleet of 500 SSTs could create similar effects and these might disturb the climate significantly, especially in the Northern Hemisphere, the region of highest traffic density. Hence, we recommended that uncertainties about SST contamination and its effects be resolved before large-scale operation of SSTs begins, and that a program to measure and monitor the impact of the SST on the stratosphere be made as soon as possible.

• The ecological effects of DDT were found to be globally distributed. Pest control in crops generally requires continued and increased use of different and stronger pesticides. This is the result of a complex ecological system in which a reduction of one pest and of several predators (innocuous to man) allows new pests to become dominant. DDT also can have specific effects on species other than pests. For example, the eggshells of many birds are becoming thinner, reducing hatching success, and in several species these effects now seriously threaten reproductive capabilities. In an ecological system, damage to these predators tends to create a situation in which pest outbreaks are likely to occur. SCEP recommended a drastic reduction of the use of DDT as soon as possible and urged that subsidies be furnished to developing countries to enable them to use non-persistent but more expensive pesticides and other pest control techniques. We also proposed a greatly expanded effort in research and development of integrated pest control, combining

In the first half of the 1960s prices were stable, but unemployment was high. In the second half of the decade we moved toward fuller use of the labor force, but prices also climbed rapidly.

funds spent for manpower purposes, private as well as public. On the government side, our fledgling manpower policy is financed by an amount that is less than 1 per cent of the federal budget—accompanied by limited local funding. An active manpower policy that supports national economic policies requires steady growth of the federal allocation of resources, moving to 2 per cent or even 3 per cent of the federal budget in the next several years. Only with that level of investment can manpower policy have a meaningful effect at the national level. And only through such careful attention to solving manpower problems can we be assured that the labor force of 100 million in 1980 will be efficient and productive.

During the past decade, the nation has been too complacent about youth employment problems. True, some remedial programs were initiated, such as the Neighborhood Youth Corps and the Job Corps. But these programs tried to pick up pieces after the failure occurred. We must get to the roots of the problem and reform our system of youth employment so that new problems are not created.

What was already a high youth unemployment rate when we entered the decade—high by European standards—became worse. I don't think there is wide enough recognition of what has been happening in the youth labor market. When the census was taken in 1930, before the Depression began, the teen-age unemployment rate was about 1.5 times the national rate; by 1969, it was four times as high.

More distressing is the fact that black teen-agers have fared even worse. In 1948, when the white teen-age unemployment rate was 8.9 per cent, the black teen-age rate was 11.2 per cent. By 1969, the black rate was 24.0 per cent, about 2.5 times the white rate of 10.7 per cent. The ratio stands the same today.

We should not exaggerate. It is a fact that a lot of the unemployment is very short-term. Partly, it is growing relative to the adult rate because there is such frequent entry and exit from the labor market as in-school youth take part-time jobs, change them, and also look for full-time jobs during the summer. All this milling-about enlarges the youth unemployment rate, and as more youths stay in school longer there is more entry and exit.

Also, some of the rise in the unemployment ratio can be traced to the post-World War II babies rolling through the labor force as teen-agers in a classic case of supply outstripping demand.

It is not merely a problem of the spell of unemployment. Youth under twenty or twenty-one seem to be confined to youth-type jobs that do not themselves lead toward permanent adult jobs. The youth "job-hops" and typically does not land a more desirable job until he ages sufficiently for the labor market to accept him.

When you combine the movement into and out of the labor force that increasingly exists in the school years, the ins and outs of youth jobs in the long quest for satisfactory employment, and movement of young men into and out of the military, a picture of turmoil emerges in the youth labor market, where the high unemployment rates reflect the chaotic condition of the labor market as much as an overall job shortage.

We give a lot of individual attention to youth in school. If a young person is going on to college, high school is designed to prepare him for college entry. Not so in the case of the non-college-bound. Their courses typically do not equip them with a salable skill. School counselors know much about colleges but little about the labor market. In fact, very little faculty time or curriculum is earmarked for the non-college-bound. They finish school and are dumped on a labor market that doesn't want them because of their age, lack of skills, or inexperience. High school is completed at about eighteen. But the labor market does not open its doors wide until about the age of twenty-one, leaving a gap of three or four years. Employers and youth just don't seem to "put it together" until age twenty-one or so. Of course, the young do get jobs, but they are concentrated heavily in the sublabor market, in industries and occupations that are heavy users of youth labor—the kind of jobs that lead nowhere, pay low, alienate young people, and are abandoned as soon as something better comes along.

A precise accounting for the cost of this system is impossible. But it is reckoned in terms of lost time for youth in getting a toehold on a permanent job with advancement possibilities, in loss of manpower and skill development to the economy as a whole in the three or more years of floundering, in the attitudes of youth toward

(*Continued on page* 48)

Environment

Continued from page 43

especially new products and new increases in production. Such a center should also identify potentially hazardous materials and promote research on their toxicity and persistence in nature.

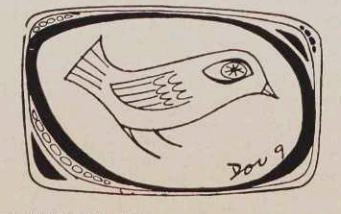
2) *Environmental Assessment*: Another information facility that centralizes data on the distributions of pollutants, and on the health and pollution loads of organisms.

3) *Problem Evaluation*: A think center to evaluate problems on the basis of the above information, to determine the urgency for action, and to identify options. Developing controls presents a most complex challenge. Efforts must be carefully evaluated in terms of their impact upon such elements as population, natural resources, and capital investment. The interaction of these factors, particularly how adjustments in one alter the others, is the topic of a most important study directed by Professor Jay W. Forrester of MIT. (See chart on page 43.)

4) *Public Education*: A service center to present the results in simple form and to distribute such materials to educational institutions and news media.

The existence of global pollution does not imply the need for a global solution. The activities of man that befoul his environment may often be effectively regulated wherever they occur. Most corrective action will probably have to be taken at national, regional, or local levels. At the same time, it is not enough for the United States, or any single nation, to exercise control. If other nations pollute our common resources of the air and the oceans, the perils remain. Research and development programs offer a great potential for international cooperation, and this could increase the likelihood of smooth international relations should a global pollution problem ever demand strict international regulation or control. The U.N. Conference on Man and the Environment, which will take place in Stockholm in 1972, is an ideal world forum for a serious deliberation of these issues.

Answer to Wit Twister, page 53: peals, pales, leaps, pleas, lapse, salep, sepal.



(Continued on page 94)

CLASSIFIED

(Continued from page 93)

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JWF

MEMORANDUM

TO: Members of The Club of Rome

FROM: Professor Jay W. Forrester

DATE: January 25, 1971

SUBJECT: Paper on "Counterintuitive Behavior of Social Systems"

Aurelio Peccei has suggested that I send to you the enclosed paper.

The paper was originally prepared as testimony for the Urban Growth Subcommittee of the United States House of Representatives Committee on Banking and Currency. It has since been reprinted in the Technology Review published by the MIT Alumni Association. References to it have also been made in the New York Times and the Saturday Review. The paper seems to have been particularly effective in conveying the possibilities of a better understanding of our social systems to men in business and political positions. The response from those who want to see applications to city and state government has been strong as well as those concerned about national and world affairs.

I hope the paper will help strengthen financial support for the future activities of The Club of Rome and also for the broader development of trained people who have professional competence to deal with the major problems of our social systems.

I expect to be at the Spring meeting in Canada and hope to see you there.

JWF:nk
Enc.: Testimony

JWF 12/14/70

Massachusetts Institute of Technology
Alfred P. Sloan School of Management
50 Memorial Drive
Cambridge, Massachusetts, 02139

Memorandum

To: J. W. Forrester, G. S. Brown, J. Collins, C. Wilson, J. A. Seeger

From: Dennis L. Meadows

Date: December 13, 1970

Subject: Attendance and Schedule of Club of Rome meeting, December 18, Cambridge, Massachusetts

Planning to attend the conference are:

Dr. Hugo Thiemann
Dr. Aurelio Peccei
Dr. Vittorio Giarini (of Battelle Institute)
Dr. Yoichi Kaya (Director Japanese Project)
Prof. Jay W. Forrester
Dr. Gyorgy Kepes
Dr. John Platt
Dr. Paul Weiss
Mr. J. R. Whitehead
Mr. Pierre R. Gendron
Dr. Strong (Director of 1972 Stockholm Conference on the Environment)

The schedule for Friday, December 18 is as follows:

11:00 a.m.	Jay's office
12:00 p.m.	Lunch (Faculty Club)
1:30 p.m. to 5:00 p.m.	Schell Room

***

DLM:jm

Massachusetts Institute of Technology
Alfred P. Sloan School of Management
50 Memorial Drive
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DLM:jm

JWF

December 9, 1970

Dr. Yoichi Kaya
Department of Electrical Engineering
The Faculty of Engineering
University of Tokyo
Bunkyo-Ku, Tokyo
Japan

Dear Dr. Kaya:

Let me give you more complete information about the December 18 meeting so that you can plan your trip. Dr. Peccei, Dr. Thiemann, Mr. Strong, director of the 1972 Stockholm conference, and several members of the Club of Rome will attend. It is not a Social Systems Dynamics conference in the sense of the meeting last July. It is rather an opportunity for some of the Club of Rome members to learn about our work to date and to make plans for the April meeting and Phase II.

We would be interested in your giving a talk, however long or short you would like, on your own work. Also we can discuss your participation in the April meeting and the means for closer cooperation between the Japanese and American groups in this phase. It was especially this last which led Aurelio to ask if you could attend.

Schedule for the meeting is:

Friday, December 18

11:00 Informal meeting with Forrester, Meadows, Thiemann, Peccei Kaya, Giarini

12:00 Lunch

1:30 Presentation of M.I.T. and Japanese work

4:00 Discussion and Questions

Saturday, December 19 would be devoted to informal discussions between Kaya, Meadows, Giarini and the Canadians arranging the April meeting.

I have reserved a room for you at the Hotel Continental. Please cable to confirm your time of arrival.

We look forward to meeting with you again.

Cordially,

Dennis L. Meadows

DLM:jm

Plans for Dec 18-19

Strong (canada, Stockholm '72 director)
wants to go into Stockholm with some good operating projects.

→ Lunch thru dinner ——

11-12 discussion.

Dec. 14.

Giarini, Battelle, Italian.
one of Thieman right hand man.
~~He will~~ Will arrive tomorrow evening,
just in time for meeting.

Kaya

Strong & misc C.R members are
principal ~~aug~~ audience.
mostly introductory.
will be here
night before.

I give a few min of introduction
at 11 +
nature of systems
History of group.

no official dinner Fri evening.

December 11, 1970

Dr. Eduard Pestel
Rector
Institut fur Mechanik
Technische Universitat Hannover
Appelstrasse 24/B
3 Hannover, Germany

Dear Eduard:

I am sorry we will not be seeing you next week. Actually it will be much better for you to come in the spring when you have more time. We can then cover more subjects and in greater depth.

Dennis Meadows reports to me that the two of you discussed your plan to meet with some of the Foundation people when you are over here in March. Dennis tells me that the two of you discussed whether or not this would lead to competition for support between the Club of Rome and plans we have here for the further development of the dynamics of social systems.

I assure you that I believe your efforts will strengthen both our program and that of the Club of Rome rather than representing any kind of competition. The problem is not the existence of a fixed sum of money to be divided between people interested in the dynamics of social systems. Instead, the problem is lack of general understanding of the importance of the area and the possibilities of shedding new light on how the directions of our societies can be altered. I believe any effort you can make here will lend greater visibility to the total effort and greatly increase the appreciation of the importance and consequently the total amount of financial support to this area.

I hope you will be able to arrange appointments with the presidents of organizations such as the Ford Foundation and the Rockefeller Foundation.

We will be looking forward to having you with us in the spring.

Sincerely yours,

Jay W. Forrester
Professor of Management

JWF:ie
cc - Dr. Aurelio Peccei, Professors Brown, Collins, and Meadows

Air Mail

THE CLUB OF ROME

PROJECT ON THE PREDICAMENT OF MANKIND

PHASE ONE: THE DYNAMICS OF GLOBAL EQUILIBRIUM

NOVEMBER 6, 1970

MASSACHUSETTS INSTITUTE
OF TECHNOLOGY

Given the present outlook, only the faithful who believe in miracles from heaven, the optimistic who anticipate superwonders from science, the parochial fortunate who think they can continue to exist on islands of affluence in a sea of world poverty and the naive who anticipate nothing can look to the future with equanimity.

--- Philip M. Hauser
Director of the Population
Research and Training Center
and Professor of Sociology,
University of Chicago

NOVEMBER 6, 1970

CLUB OF ROME PROJECT ON THE PREDICAMENT OF MANKIND

PHASE ONE: THE DYNAMICS OF GLOBAL EQUILIBRIUM

CONTENTS

THE CLUB OF ROME PROJECT ON THE PREDICAMENT OF MANKIND

PHASE ONE: THE DYNAMICS OF GLOBAL EQUILIBRIUM

INTRODUCTION

For some four thousand years the condition of the human race has been characterized by growth and change. Technological development has accelerated. Natural resources have been depleted. Our environment has been polluted at an ever-increasing rate. Population has multiplied at least 50-fold and may double again within this century. Now there is evidence that growth is occurring too quickly to permit adaptation by the planet's social institutions and its ecological systems.

Growth cannot continue indefinitely on a finite planet. We are faced with an inevitable transition from world-wide growth to global ecological equilibrium. Because of the time delays inherent in social system change, decisions made now are already influencing the nature of that future equilibrium. Will it be an equilibrium of poisoned lakes, of oppressive crowding, of food shortage and a declining standard of living? Or will we choose a different mode of equilibrium characterized by a more desirable set of conditions? The shift from growth to dynamic balance may be initiated by a catastrophe such as war or starvation. Alternatively, transition could result from an enlightened, concerted, international effort to adopt new values and define new goals.

The predicament of mankind is that we can perceive the individual symptoms and the components of profound social problems, but we are stymied in our efforts to comprehend the total situation and develop

global solutions. While perceptive individuals everywhere have begun to recognize the inevitability and the dangers of transition to equilibrium, thinking and action have been confined to individual problem areas. Demographers press for effective birth control measures. Ecologists seek an end to the destruction of our natural environment. Agricultural experts search for more efficient food production. All would admit that there are important interactions among their various approaches, but the conceptual framework, the analytical methodologies and the vocabulary to unite the different fields have been lacking.

Recognition of these deficiencies by Dr. Aurelio Peccei and others led to the formation of the Club of Rome and to its plans for an action-oriented program on the 'Predicament of Mankind' to develop a formal basis for concerted action on global problems. Phase One of that program will evaluate the present world situation and the policy options available to mankind as we move toward the equilibrium phase of our development.

THE CLUB OF ROME

The Club of Rome is a group of individuals deeply concerned about the future of the world and the looming problems which threaten human society. The Club is informal, multinational and non-political. Its members include scientists, humanists, economists, educators and business leaders. None of its members are involved in current political decisions, nor has the Club itself any ideological, political or national commitments.

Many organizations, national and international, have been formed in response to global problems. The special strength of the Club of Rome lies in its flexibility. It is not pre-committed to any doctrine or to the welfare of any particular nation or group. Its membership, though limited, is being deliberately extended to include representatives of all cultures, and it is expected that the funds for its projects will be derived from organizations and individuals in several different nations.

To carry out its program, the Club of Rome has been incorporated in Geneva as a non-profit association under the Swiss Civil Code. It has established numerous contacts with key people in Ottawa, Moscow, Washington, Tokyo, Buenos Aires, Stockholm, Berne, Vienna and other capitals, as well as in international organizations. While this high-level exchange of views will continue, the Club of Rome believes that it can

now undertake a program of research that will succeed in penetrating and describing the complex nature and dimensions of the world's problems.

As a small organization, the Club recognizes its limitations in directly affecting significant global change. It views its role rather as that of a catalyst. It realizes that its program can succeed only if its achievements are sufficiently new and important that they attract a lasting group of adherents from different cultures and various branches of scientific and political activity. To do that the Club seeks to identify a new class of global problems and to provide the language, the methodologies and the criteria of success appropriate for their solution.

THE CLUB OF ROME PROGRAM: PHASE ONE

Before initiating the first phase of its program, the Club of Rome undertook a search for formal analytical methods which could integrate rationally the many disciplines required for any overall assessment of the current world situation. Meetings in Berne, Switzerland and Cambridge, Massachusetts in June and July of 1970 led to selection of one specific method, System Dynamics[1], as the foundation of Phase One.

An important part of the conference work in Cambridge involved formulation and analysis of a preliminary model (World2) developed through the System Dynamics approach and incorporating many of the global relationships underlying the complex of critical global problems previously identified by the Club. Most of these problems, such as malnutrition and pollution, result from the exponential growth of population and industrialization. Phase One thus focuses explicitly on the dynamics of growth in population and production. Hunger, pollution and other environmental factors are already acting to limit that growth. Thus an important objective of the project has become the study of problems

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1. System Dynamics is a theory of system structure and a set of tools for representing complex systems and analyzing their dynamic behavior. Originally developed at M.I.T. by Professor Jay W. Forrester for application to industrial problems, these tools are widely known as Industrial Dynamics. However that name is a misnomer since the method has been applied to over a hundred different systems ranging from internal medicine to urban decay and the management of research and development projects.

inherent in negotiating a deliberate transition from world-wide growth to global equilibrium.

Development of appropriate models, identification of relevant data and conduct of preliminary analyses are the most important tasks of the first phase. The research will be conducted by an international group under the joint direction of Professors Dennis L. Meadows and Jay W. Forrester at the Massachusetts Institute of Technology.

Later phases which extend the research initiated in Phase One, diffuse knowledge about the critical problems, and propose appropriate solutions will require a sustained, decentralized effort involving the participation of many peoples and organizations. The effort must be multinational and, therefore, research will move from Cambridge to Switzerland upon the completion of Phase One in June, 1971.

METHODOLOGY OF PHASE ONE

History of System Dynamics

The field of System Dynamics has been developed at the Massachusetts Institute of Technology through more than thirty years of continuous effort directed toward the analysis and control of complex system behavior. From its birth in the study of relatively simple mechanical systems it has grown to provide a single framework for understanding the behavior of all electronic, chemical, biological and social systems whose elements interact through time to produce system changes. Four lines of historical development prior to 1956 led to Industrial Dynamics and then to System Dynamics. They are:

- the theory of information-feedback systems
- a knowledge of human decision-making processes
- the experimental model approach to complex systems
- the digital computer as an inexpensive means to simulate realistic mathematical models

Study of mechanical servo-mechanisms at M.I.T. led to an awareness in the early 1940's that time delays, amplifications and structural relationships among a system's elements could be more important in

determining aggregate system behavior than the individual components themselves. The concepts of information feedback and control were developed to express the relation between structure and behavior. More recent efforts to design automatic self-regulating control systems have extended these concepts and shown them to underlie behavior in all systems.

The potential of competitive advantages obtainable through the automation of data processing and routine decisions in large organizations has focused much attention on the nature of human decision making. Research conducted since the early 1950's suggests that important components of the decision-making process are not entirely "free will" but are strongly conditioned by the information present in the environment. Progress has been made in this field to the point where we are now able to model the basic structure of decision making.

It is not yet possible to derive general analytical solutions for realistic models of systems as complex as those encountered in social systems. The alternative is an experimental approach based on quantitative models of the system. First a mathematical model of the social system is constructed. This model is a detailed description of the decision processes in the system. It indicates how the conditions at one point in time lead to subsequent conditions at later points in time. The behavior of the model is observed and experiments are conducted to answer specific questions about the system that is represented by the model. "Simulation" is the name generally applied to this process

of conducting experiments on a model instead of attempting the experiments with the real system. In simulation studies the goal is not to predict the future, but rather to understand, in a pragmatic way, how alternative changes in the current system are associated with different modes of behavior over time.[2] The simulation approach, a fundamental element of System Dynamics methodology, was developed at M.I.T. in the early 1950's as engineers were forced to analyze systems too complex to solve analytically.

The fourth foundation element of System Dynamics is the electronic digital computer, which made the vast number of calculations required to trace the behavior of a specific system through time economically feasible. In the past fifteen years the cost of arithmetic computation has fallen by a factor of 10,000 or more. Such a cost reduction creates a totally different research environment. Computing machines have become so widely available, and the cost of computation and machine programming is now so low relative to other costs, that the former difficulties in conducting a simulation study no longer determine the rate of progress in understanding system behavior.

A group of individuals from the engineering and social sciences came together in 1956 under Professor Jay W. Forrester at M.I.T.'s Sloan School of Management to exploit these four developments. Their initial

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2. This is an extremely important point. One can imagine many states which could characterize the globe several decades from now: international warfare, rampant epidemics or prosperous tranquility. A System Dynamics study would be less useful in predicting which will exist than in indicating how alternative international agreements would alter the tendency to move toward each of those conditions.

work focused on industrial applications and the field thus came to be called Industrial Dynamics. The first major work was published under that title by Professor Forrester in 1961.[3] It detailed the general principles of complex system analysis and described their applications to inventory-workforce control problems in large industrial organizations. As the perspectives of the Sloan School widened from business administration to the management of broad social systems, the Industrial Dynamics group undertook a larger range of problems. The methodology was extended and refined through application to several hundred problems over the next decade. Studies ranged from the mechanism of homeostasis in the human body, to social problems of drug addiction and predator-prey relationships in animal populations. The general principles and the analytical tools which were developed in the course of these studies are now called System Dynamics.

Several major System Dynamics studies have resulted in books. In Dynamics of Research and Development Professor Edward B. Roberts relates resource allocation, policies, scheduling rules and individual motivation to the performance of large scale research programs.[4] As urban problems involving social unrest and economic decline became important in the United States, Professor Forrester employed the principles of System Dynamics to unify information from the fields of economics, sociology and political science in a radical new theory of urban decay.[5] His

3. Forrester, J.W., Industrial Dynamics, The M.I.T. Press, Cambridge, Massachusetts, 1961.
4. Roberts, E.B., Dynamics of Research and Development, Harper and Row, New York, New York, 1964.
5. Forrester, J.W., Urban Dynamics, The M.I.T. Press, Cambridge, Massachusetts, 1969.

prescriptions for the ills of stagnant cities have brought support to the Sloan School for a broadly based study of urban problems.

Developing countries receive more than ninety percent of their foreign exchange earnings from the export of primary commodities like cocoa and tin. Thus the pronounced instability in the prices of these products has disrupted the development programs of many poorer nations. Using System Dynamics methodology, Professor D. L. Meadows has identified for the first time a general theory relating the factors which make all commodities prone to price fluctuations.[6] Published in The Dynamics of Commodity Production Cycles this theory is being extended now to permit the design of more effective control methods.

The application of System Dynamics to those problems identified by the Club of Rome will be a logical extension of work conducted over the last decade. Implications of the research will be more profound, but the elements of the approach, the underlying methods, will be the same.

Application to World Problems

One important advantage of System Dynamics for the Club of Rome program is that it represents real world relationships pictorially or mathematically in terms quickly learned by everyone. Sophisticated mathematical ability is not a prerequisite for understanding and using the results of a System Dynamics study. Thus demographers, economists,

6. Meadows, D. L., The Dynamics of Commodity Production Cycles, Wright-Allen Press, 238 Main Street, Cambridge, Massachusetts, 1970.

governmental leaders and others interested in global problems will be able to apply the Phase One results readily to their own fields.

A detailed description of the System Dynamics approach is available in Principles of Systems.[7] A preliminary System Dynamics model of the world, that developed by Professor Forrester for the July 1970 Cambridge meeting, is briefly described here. It will illustrate the use of System Dynamics in understanding the characteristics of global equilibrium. Figure 1 is a flow diagram or pictorial representation of the assumptions in the model. The assumptions deal explicitly with the interrelations among the world's population, economic development, natural resources, pollution and food production capabilities.

These interrelationships depend on many aspects of the real world. Psychological factors influencing desired family size, biological effects of pollutants, physical determinants of capital depreciation and the economic influence of declining natural resource stocks are among the hundreds of factors which were considered in constructing the model.

Using the computer to conduct studies of model behavior requires that each assumption be expressed very precisely. According to the theory of System Dynamics only two types of variables, "levels" and "rates", are necessary to express any relationship in a system. Levels are the state variables which characterize the system at any point in time. Population, pollution, natural resources, capital investment and agricultural capacity (represented by the fraction of capital invested in agriculture) are the five levels in this preliminary model. All levels are represented by rectangles [▭]. Model behavior depends

7. Forrester, J. W. , Principles of Systems, Wright-Allen Press, 238 Main Street, Cambridge, Massachusetts, 1968.

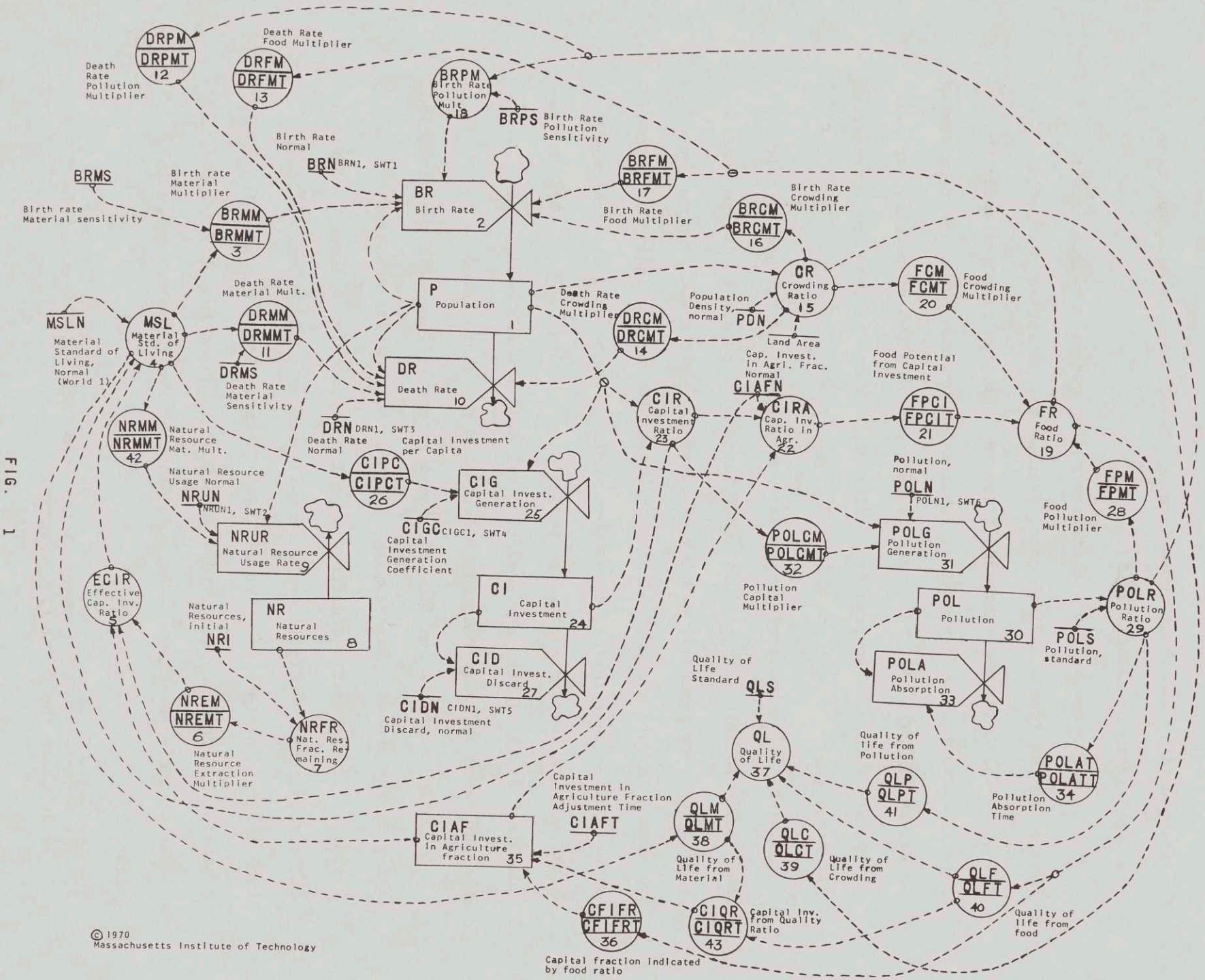


FIG. 1
FLOW DIAGRAM
OF WORLD2

on the quantity in each of those levels. Levels which are unimportant are represented by clouds [ ].

Rates are the system's action or policy variables which effect changes in the levels. Birth rate, death rate, pollution generation rate, capital investment rate and resource depletion rate are among the rates important in understanding global equilibrium. Rates are represented as valves [ ]. In this model rates control flows of people, capital equipment, natural resources and pollutants. These streams are represented by solid lines.

Since the rates acting on a level summarize all the biological, political, social, economic and other factors which act to change that level, they are generally complex expressions. Often one or more components of a rate are sufficiently important to warrant individual attention. Called auxiliaries, these components are separated algebraically from the rate and represented pictorially as circles [ ]. One such auxiliary is the death rate pollution multiplier which represents the influence of environmental pollution on the death rate.

Dotted lines in the flow diagram indicate influence in the direction shown by the arrows. For example, food ratio, material standard of living, pollution ratio and crowding all influence the death rate through their respective multipliers. Whenever a sequence of influences leads back to its own starting point and thus forms a closed circuit, it constitutes a feedback loop. One important feedback loop is that relating pollution and population.[8] The components of that loop are shown in Figure 2.

8. The numbers on each element of the loop indicate the element's location in the total flow diagram.

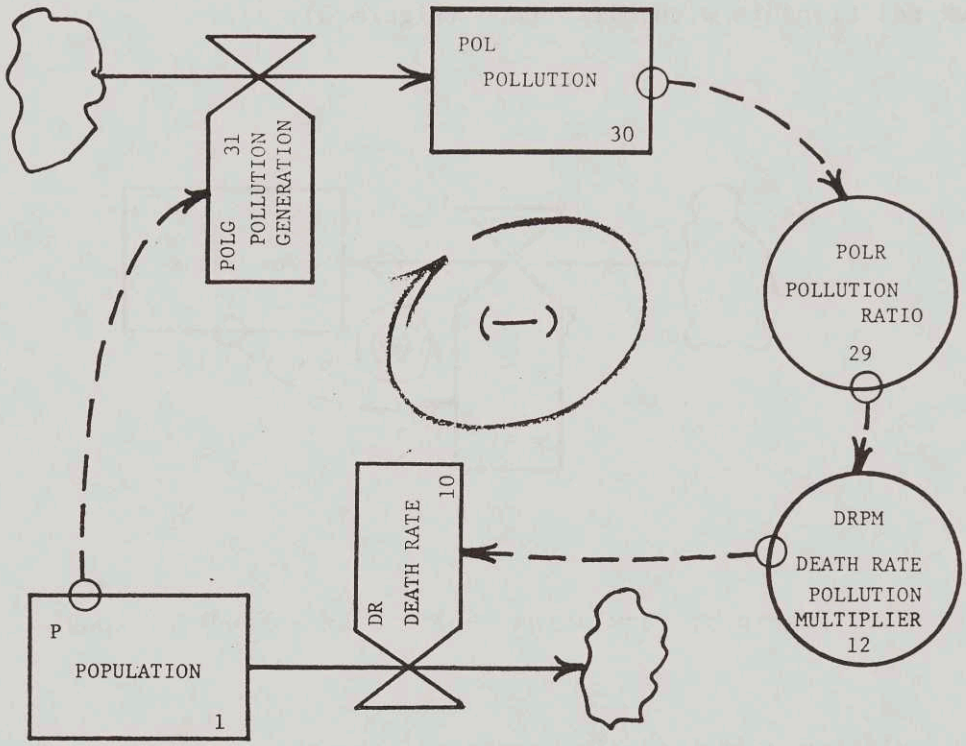


Figure 2: Population -- Pollution Feedback Loop

This particular sequence of influences is a negative feedback loop. In any negative loop a change in one element sets in motion a chain of events around the loop which eventually produces a counteracting influence on that element. For example, a decrease in population decreases pollution generation and thereby lowers the level of pollution. As a result, the pollution ratio decreases and death rate is lowered, leading ultimately to greater population.

Feedback relations may also be positive. In that case a change in one element is propagated about the loop to result ultimately in a reinforcing change in the same element. Usually each element in a

system will be influenced by several positive and negative loops simultaneously. For example population is also involved in a positive feedback relationship with birth rate (Figure 3).

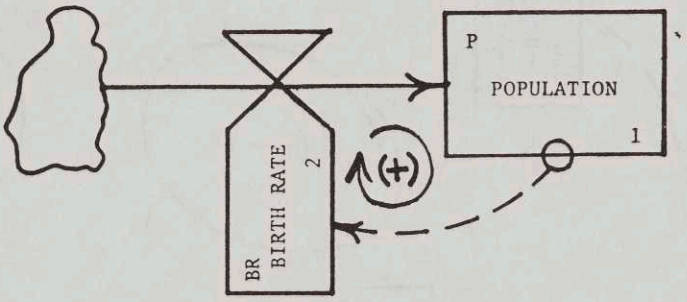


Figure 3: Population -- Birth Rate Feedback Loop

If population were suddenly increased, the number of people born per year would increase and thereby raise population even more.

Feedback loops differ not only in their polarity, positive and negative, but also in the delay with which their responses are propagated around the loop. The delays inherent in the second loop, shown in Figure 3, are about fifteen to twenty years. Delays in the former loop involving pollution and population may be fifty years or more. Thus it is in general very difficult to determine intuitively the exact implications of a given change for a particular level. An initial decrease in population might lead in the model above to either more or less population ultimately than if the decrease had not occurred. The final direction of the response would depend on the strength and the delay of relationships inherent in each loop where population is an element.

The fund of human experience contains much good information on the nature of the individual relationships underlying global problems. However, these relationships constitute feedback loops like those illustrated in Figures 2 and 3. Thus when it is necessary to analyze the probable effects of several simultaneous policy changes, human intuition is completely inadequate. Our failure to control complex social systems is not primarily due to any lack of data about their components. It stems rather from lack of the necessary tools for structuring that data and analyzing its dynamic consequences. Now, however, it is possible to include in formal models all the information available. Any real world relationship which can be expressed verbally can be incorporated in a System Dynamics model. Then computer simulation experiments can provide analyses very quickly and inexpensively.

During Phase One a world model will be constructed which contains the relationships necessary to represent and study many of the critical global problems identified by the Club of Rome. Among them are:

- explosive population growth with consequent escalation of social, economic and other problems.
- widespread poverty.
- generalized malnutrition.
- destructive agricultural practices.
- irrational practices in resource usage.
- increasing pollution.
- limited understanding of what is feasible in the way of corrective measures.

One dimension of our current dilemma is that actions made to alleviate

any of these problems often aggrevate the others. Intensive use of fertilizers, for example, does increase food production, but it exacerbates water pollution. Accelerated economic development raises material standards, but increases social tensions, pollution and the depletion of natural resources. There are many alternative policies. Birth control, development of more efficient crops, increased recycling of natural resources and changes in the societal values which govern investment in capital. Some combination of these policies can be effective, but alternatives must be evaluated in the context of their total impact on all elements of our global society. The following simulations with the preliminary world model illustrate the mechanisms of policy studies based on System Dynamics models.

ANALYSES OF THE PRELIMINARY MODEL

Each of the following simulation runs is essentially an experiment to determine the effect on total system behavior of one or more specific policy changes made in year 1970 of the system's evolution.

- Run STD.S — Standard run provided for reference.
- Run 12S — Technological changes are introduced in 1970 which permit natural resources to be used four times more efficiently.
- Run 22S — Conditions in Run 12 are supplemented by technological change which reduces the generation of pollution by 50% and by a shift in social priorities which increases capital investment generation by 20%

Because these analyses are based on the preliminary model WORLD2 they should be viewed primarily as illustrations of the approach, not predictions of outcomes which could be expected if the policy changes were actually implemented.

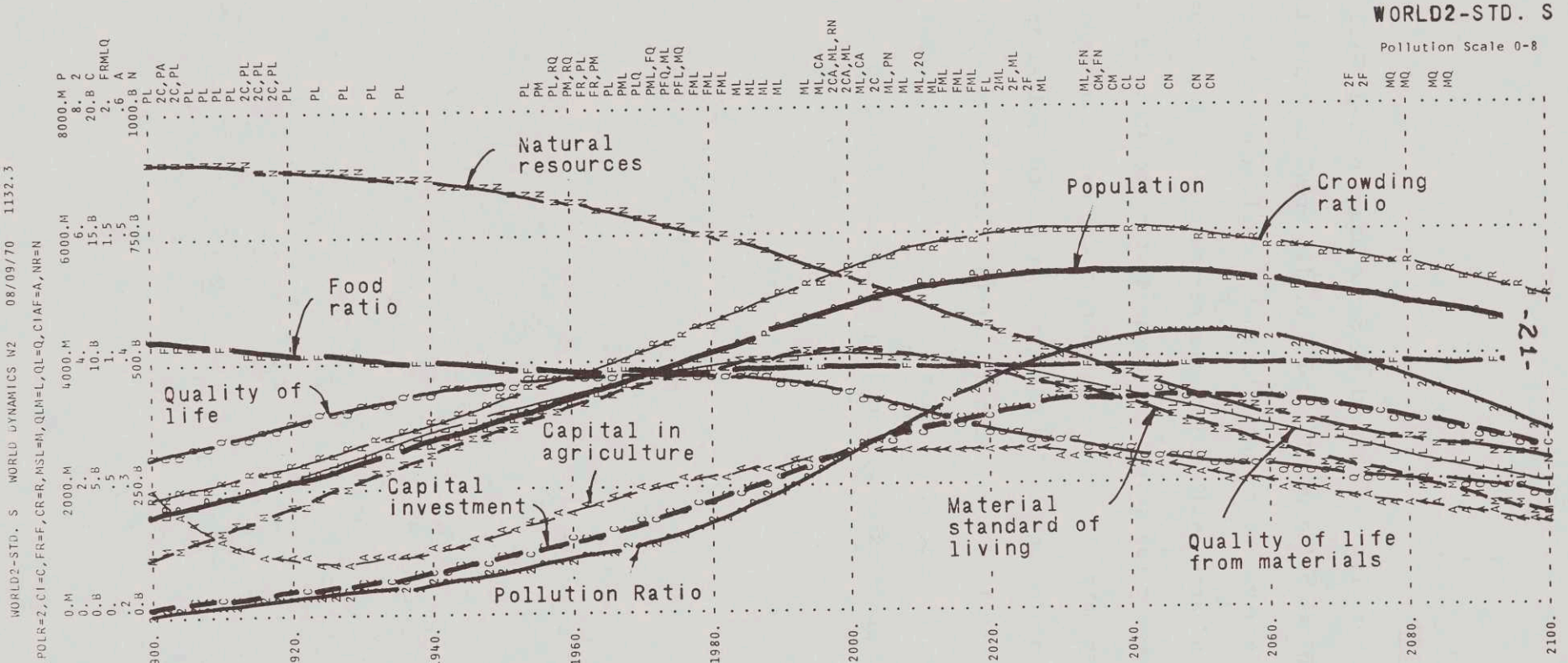
DESCRIPTION OF WORLD2 MODEL RUNS

WORLD2-STD.S

This is the standard computer run from the WORLD2 model. The "S" suffix indicates that the plot card has been changed to give predetermined plotting scales and is done so that the curves can be more easily compared. The standard computer run shows a peak in population at about year 2030 and gradual decline thereafter. The population decline is occurring because of the depressing effect of declining natural resources.

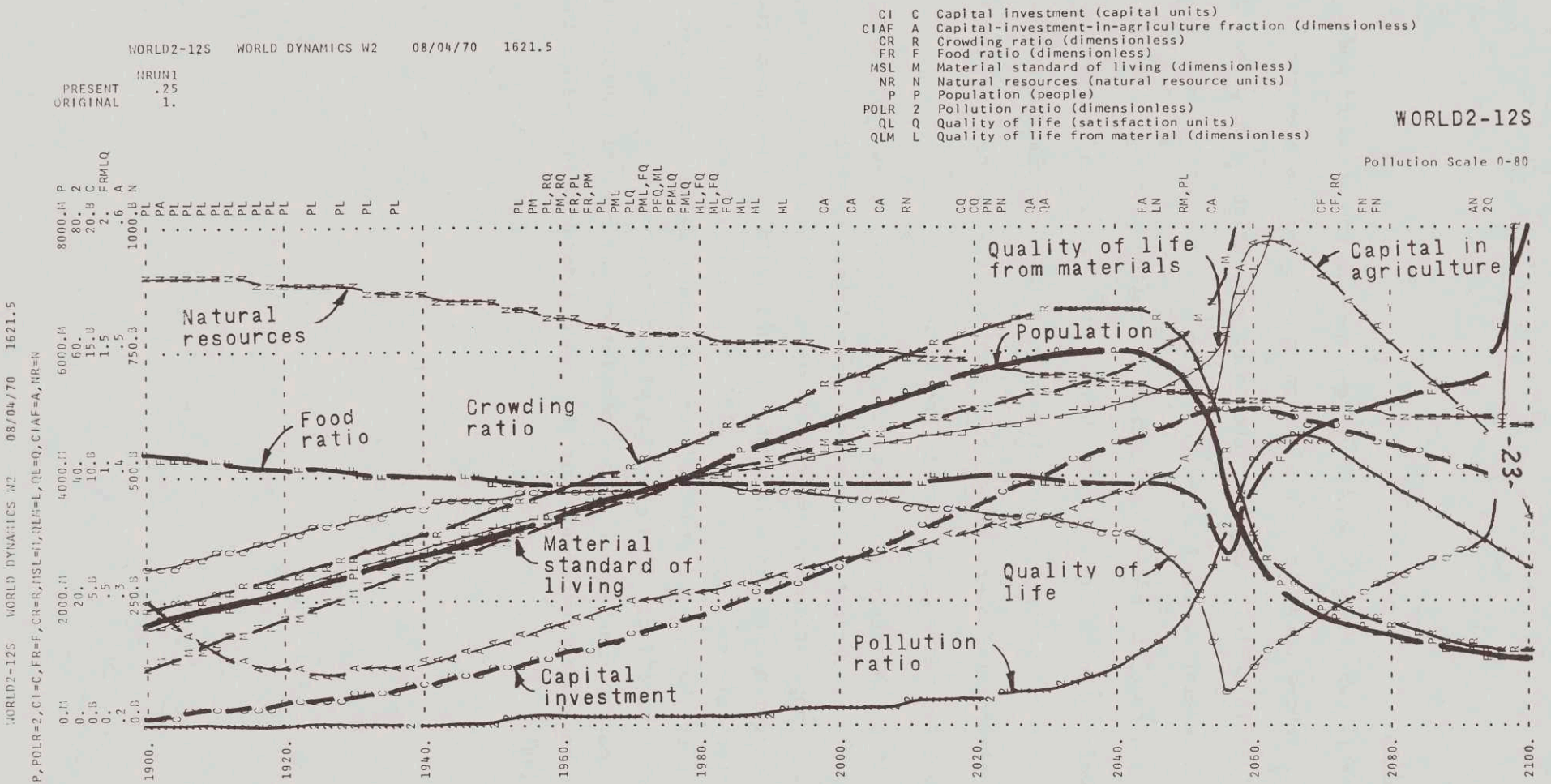
It is interesting to note that quality of life reaches its highest point at 1970. Can this be reasonable considering today's strong worldwide feeling of distress and disenchantment? Perhaps so. A sense of well-being may be related more to "progress" and to improvements since the recallable past than to the absolute level of quality of life. A feeling of malaise could therefore occur at the peak of the quality of life curve because little improvement has been observed in the preceding two decades.

In this standard run, pollution peaks in year 2050 at about 4.5 times the pollution intensity of 1970. This is not a high enough value for pollution to enter importantly into the overall dynamic behavior.


CI C Capital investment (capital units)
CIAF A Capital-investment-in-agriculture fraction (dimensionless)
CR R Crowding ratio (dimensionless)
FR F Food ratio (dimensionless)
MSL M Material standard of living (dimensionless)
NR N Natural resources (natural resource units)
P P Population (people)
POLR 2 Pollution ratio (dimensionless)
QL Q Quality of life (satisfaction units)
QLM L Quality of life from material (dimensionless)
WORLD2-STD. S
Pollution Scale 0-8
WORLD2-STD. S WORLD DYNAMICS W2 08/09/70 1132.3
P=P,POLR=2,CI=C,FR=F,CR=R,MSL=M,QLM=L,QL=Q,CIAF=A,NR=N
Natural resources
Population
Crowding ratio
Food ratio
Quality of life
Capital in agriculture
Capital investment
Material standard of living
Quality of life from materials
Pollution Ratio
1900.
1920.
1940.
1960.
1980.
2000.
2020.
2040.
2060.
2080.
2100.

WORLD2-12S

In this run the natural resource usage normal NRUN1 has been reduced, other things being equal, to 25% of its previous value in the year 1970. This is equivalent to assuming that recycling of waste and new technological advances will reduce the seriousness of declining natural resources. This computer run should be compared with the standard run. We see that declining natural resources no longer depress population through their effect on production. Instead, population and capital investment continue to rise until an environmental crisis arising from pollution asserts itself. Note that the pollution scale has been changed from that in the standard run. Here the scale extends from 0 to 80 rather than 0 to 8.

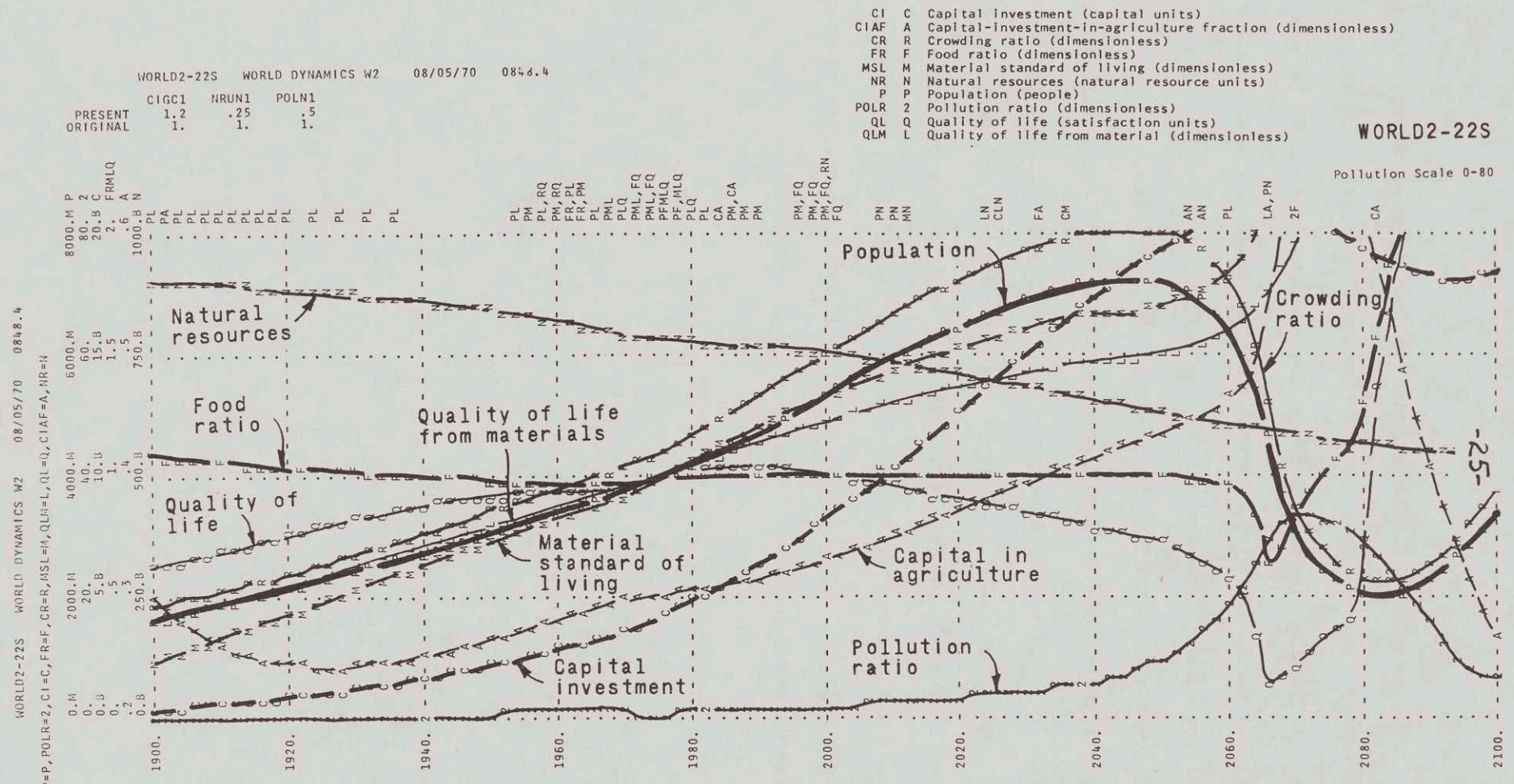

CI C Capital investment (capital units)
CIAF A Capital-investment-in-agriculture fraction (dimensionless)
CR R Crowding ratio (dimensionless)
FR F Food ratio (dimensionless)
MSL M Material standard of living (dimensionless)
NR N Natural resources (natural resource units)
P P Population (people)
POLR 2 Pollution ratio (dimensionless)
QL Q Quality of life (satisfaction units)
QLM L Quality of life from material (dimensionless)
WORLD2-12S
WORLD2-12S WORLD DYNAMICS W2 08/04/70 1621.5
NRUN1
PRESENT .25
ORIGINAL 1.
Pollution Scale 0-80
Natural resources
Food ratio
Crowding ratio
Material standard of living
Capital investment
Quality of life from materials
Population
Capital in agriculture
Quality of life
Pollution ratio
1900.
1920.
1940.
1960.
1980.
2000.
2020.
2040.
2060.
2080.
2100.
-23-

WORLD2-22S

For this run three changes have been made in the standard model. Natural resource usage is reduced to one quarter of its previous rate as in Run 12S. In addition capital investment generation is increased 20% and pollution generation has been reduced from 1 to 0.5.

We see that the reduced pollution generation allows population to rise longer before the collapse occurs. With a smaller rate of pollution generation, other things being equal, population and capital investment continue to rise until environmental overloading again occurs. Here the peak population occurs about ten years later than in Run 27S.

In 1970, the usage rate of natural resources was substantially reduced and we see that the natural resource curve levels slightly at that time. However, as population and capital investment both continue to rise, the natural resource usage rate is pushed upward again by sheer magnitude of consumption rate and, by the year 2100, the natural resource level has fallen lower than in the standard computer run. Again, we see the self-defeating effect of many policy changes in complex systems. A reduced natural resource usage rate allows population and capital investment to rise far enough to compensate for the reduced consumption, other things being equal.


WORLD2-22S WORLD DYNAMICS W2 08/05/70 0848.4
CIGC1 NRUN1 POLN1
PRESENT 1.2 .25 .5
ORIGINAL 1. 1. 1.
CI C Capital investment (capital units)
CIAF A Capital-investment-in-agriculture fraction (dimensionless)
CR R Crowding ratio (dimensionless)
FR F Food ratio (dimensionless)
MSL M Material standard of living (dimensionless)
NR N Natural resources (natural resource units)
P P Population (people)
POLR 2 Pollution ratio (dimensionless)
QL Q Quality of life (satisfaction units)
QLM L Quality of life from material (dimensionless)
WORLD2-22S
Pollution Scale 0-80
Population
Crowding ratio
Natural resources
Food ratio
Quality of life from materials
Quality of life
Material standard of living
Capital in agriculture
Capital investment
Pollution ratio
1900.
1920.
1940.
1960.
1980.
2000.
2020.
2040.
2060.
2080.
2100.
P=P,POLR=2,CI=C,FR=F,CR=R,MSL=M,QLM=L,QL=Q,CIAF=A,NR=N

In Phase One all of the relationships in this preliminary model will be subjected to vigorous scrutiny by those with expertise in the appropriate areas. A thorough review of the relevant literature will be made. The model will be extended to represent relations among the advanced and the less developed countries. Experts in population, economic development, and other relevant fields will be involved in these efforts.

The preliminary efforts illustrate that one can cut across traditional boundaries in a study of global problems. The psychological, economic, biological, social, and political aspects of our current dilemma can be incorporated in formal modals. It is the Club of Rome's profound hope that such models will permit an improvement in our ability to consider rationally and productively the implications of current world trends and the options associated with the ultimate transition to global equilibrium.

cc. JWF
GSB
JAS

43.965

16 November 1970

Dear Dr. Thiemann,

The purpose of this note is simply to summarize our several telephone conversations of last week with regard to a possible presentation of the work on the "World 2 Model" (being carried out at MIT under the sponsorship of the Club of Rome) at the time of:

1) the meeting of Senior Governmental Advisers (SGA) later this month in Geneva, and/or

2) the Prague Conference on the Environment, to be held in May 1971.

As we all have agreed, any presentation of this nature would necessarily fall outside of the official sessions of these meetings and attendance at it would be optional on the part of the delegates. With this understanding in mind, we discussed several possibilities in connexion with the SGA meeting:

a) the simple distribution to delegates of a brief write-up on the nature and goal of the work, with the expectation that an oral presentation on the experimental results might be made at the time of the Prague Conference;

b) a brief oral presentation late in the afternoon at the Vieux Bois restaurant (adjacent to the Palais des Nations), possibly in connexion with a cocktail sponsored by the Club of Rome;

c) a more complete oral presentation which might be given (with simultaneous translation) at the Battelle Institute on Thursday morning, December 3 - a time when the delegates have no scheduled sessions;

+: Dennis Meadows

Dr. Hugo Thiemann
Director
Battelle Memorial Institute
7 route Drize
CAROUGE - Geneva

Copies to: Dr. Peccei, Rome
→Dr. Meadows, MIT; USA

I'll be writing you in just a day or two in reply to your note of two weeks ago. Some problems have arisen with regard to my coming to the States in

d) a presentation in the Palais des Nations after the close of one of the afternoon sessions. It must be stressed that a presentation of this nature, carried out with the use of UN facilities, could be accomplished only with the concurrence of the delegates. As mentioned to you, a procedure of this nature is somewhat unusual, but should nevertheless be feasible.

With regard to the possibility of a presentation at the Prague Conference, I am enclosing, for your information, a copy of the programme of that Conference (document ENV/CONF/A.1), which gives an indication of the times which have been designated as "free" to the delegates. Presumably, it would be feasible to make a presentation of the type you envisage during one of these "free" periods. It would, however, be desirable to keep the Czechoslovak host authorities fully informed of any such intention.

It is my understanding that, on the basis of your telephone discussion with Dr. Pecceì, you are presently considering alternative (a). Whatever your choice, we would be glad to help, in whatever way seems appropriate, in facilitating the arrangements.

Sincerely yours,

Amasa S. Bishop
Director
Environment and Housing Division
Economic Commission for Europe

M'NAMARA CITES GROWTH OF SLUMS

He Tells U.N. Problem Is Acute in New Nations

By SAM POPE BREWER

Special to The New York Times

UNITED NATIONS, N.Y., Nov. 14—Robert S. McNamara, president of the World Bank, told the Economic and Social Council yesterday that an unexpected problem encountered in world development was the growth of slum-infested capitals in the newer countries.

"The less developed countries are urbanizing faster today than today's high-income countries have done at any time in their history," he said. "Already, half the cities of the world with populations over half a million are in the developing countries.

"Many of these cities are crowding people together without the necessary industrial facilities to provide employment and with wholly inadequate services in health, education and transport."

Mr. McNamara said that "the result is squalor on a staggering scale," often with half the population crammed into squatter towns, where the usual home has a single room.

Report on Programs

Mr. McNamara was reporting to the council on the great expansion in the work of the World Bank, or the International Bank for Reconstruction and Development; the International Finance Corporation and the International Development Association. Mr. McNamara is president of the three organizations.

He said that in the past the World Bank helped in urbanization on a project-by-project basis. But "what we seek now is a more comprehensive view of the problems of the cities, a strategy by which the Bank Group can support programs of over-all urban development rather than merely isolated and unrelated projects," he said.

He announced that a pilot study on this work was beginning in Bombay.

He also mentioned increased interest by the bank in helping raise agricultural productivity for the benefit of the rural poor.

He said the bank was carrying on talks for the formation of a consultative group on organization and on use of new strains of wheat and rice to raise production.

Environmental Concern Cited

He also cited increase concern of the World Bank with environment. He said that because of focus on urban problems some of the ecological dangers raised by rural development projects had been overlooked and that the bank was studying ways to help offset this.

Mr. McNamara said that the bank was also investigating the possibilities of establishing an international agency to insure investments.

He also reported on the development of the Economic Development Institute, which was founded 15 years ago by the World Bank as a "staff college for senior officials concerned with economic affairs in developing countries."

He said that the institute had graduated 1,165 fellows so far from courses in development and in project evaluation and that their influence on development in their own countries "has in some cases been profound."

He said the demand for places had outrun the teaching capacity of the institute and that the bank had decided to increase its capacity enough to double the rate of graduation by 1976. Last year there were 150 participants.

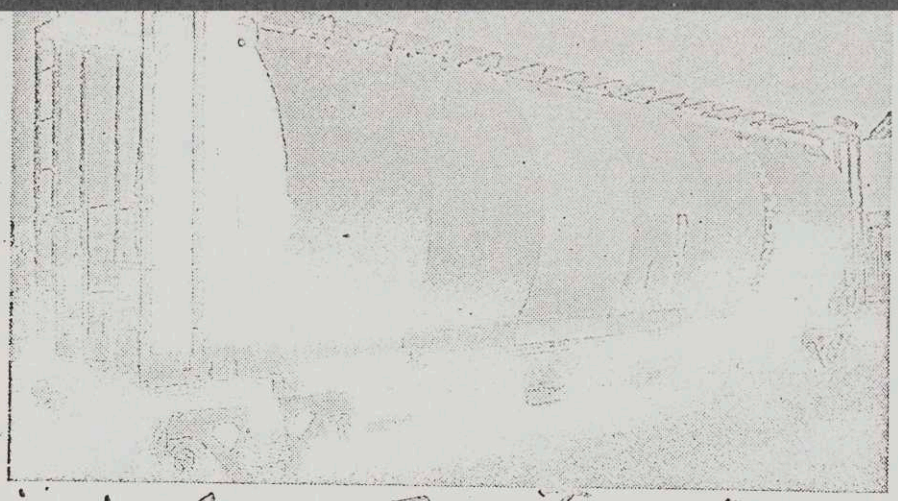
THE NEW YORK TIMES, SUNDAY, NOVEMBER 15, 1970

11/17/70

I would like
2 more copies - attached
of the gulf oil
article of from
the Monitor. Did
you or Seeger keep
the orig?

John Seeger said he received a Xerox copy from a friend. Xeroxes were made from the Xerox copy.

DE



Christian Science Monitor Nov 7-70

Gulf Oil chief questions growth that hurts environment

Special to The Christian Science Monitor

New York

The president of Gulf Oil Corporation has questioned the traditional concept that economic growth is good since it has added to pollution of the environment and has been accompanied by rapidly rising prices.

Speaking at Columbia University, Bob R. Dorsey said: "The well-managed use of our natural resources and continued advancing technology must create an economy with growth controlled by environmental needs."

Mr. Dorsey also said that he believes the threatened energy shortage in the Northeast this winter will not materialize "because the oil companies are turning their refineries and transportation systems inside out to prevent it."

Recycling envisioned

Mr. Dorsey was the first guest of Dr. William J. McGill, president of Columbia University, in a new program at the university to strengthen new dialogue between industry and the campus. He addressed 300 students and faculty members of the Graduate School of Business on Columbia's Morningside Heights campus in New York City.

"The concept of a growing economy and the energy sources it needs seem to be on a collision course with the ecology of our environment," said Mr. Dorsey. "If so, then something has to give—and in that case it would have to be the growing economy or we'd all be committing mass suicide."

Growth controlled by environmental needs must eventually "bring us to a spaceman economy with waste-recycling capabilities," he said.

He suggested that the major force behind this change is a combination of the broadened self-interest of the public and "the desire, or the demand, of young people to assert themselves as free and spontaneous individuals, resisting and changing the institutions and customs which thwart this desire."

"Self-interest, after all, is what makes us go," he said, noting that the public self-interest has broadened to cause real conflict between its traditional demand for more consumption and a growing demand for a balanced environment.

Northeast shortage doubted

He cited the threatened energy shortage in the Northeast as an example of this conflict, stating that the public interest restricted expansions of power utilities and had limited their selection of fuels to low-sulfur types that were in short supply, "yet electrical demand kept increasing."

"I don't believe there will be any shortage," he said, "because the oil companies are turning their refineries and transportation systems inside out to prevent it. It's costly and inefficient, but we're doing it—because no matter who or what caused the shortage—it's up to us to prevent it."

Such responsibility, he said, transcends the traditional business purpose of making money, because "the first responsibility of business is to operate for the well-being of society."

U.S. inflation eases?

By the Associated Press

New

Inflationary pressures are lessening, accordin the First National City Bank.

The bank said in its monthly economic letter th despite recent increases in prices of consumer g and of industrial commodities.

The bank said the degree of slack in the econ was growing. It said the slim gain in real gross tional product in the third quarter was due to pu rather than private, spending.

Real output, the bank said, may decline in the fo quarter if the General Motors strike continues n longer.

The bank said there are some favorable signs in economy.

It said consumers had continued to build a str base for future spending by saving what by "histor standards" is a large percentage of disposable inco

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JWF 11/18/70

SIMULATION COUNCILS, INC.
Post Office Box 2228, La Jolla, California 92037 • Telephone (714) 459-3888

WORLD SIMULATION

In reply please refer to NF 68

9 November 1970

Dr. Dennis L. Meadows
Alfred P. Sloan School of Management
MIT
50 Memorial Drive
Cambridge, Massachusetts 02139

Dear Dr. Meadows:

I have just finished reading ". . .the dynamics of global equilibrium" with great interest and mixed emotions. It would seem at first reading that you and your group have already accomplished, at least in part, that which the World Simulation Organization had planned to strive for over the next few years!

However, the fact that I have been in correspondence with people interested in a world simulation (by whatever name) for at least 18 months, and that that list has now grown to more than 200 people, and that it was not until I received a letter from Japan on 14 September 1970 which mentioned (almost incidentally) the existence of the Club of Rome, indicates that there are still serious problems to be overcome. First, we must improve communications so that groups like ours and yours (and I could name many more) don't continue to spend their initiative, manpower, and dollars thinking that they alone are working toward the objective for which we are all striving.

Second, having established communication among those concerned, there will still remain the extremely difficult (in the absence of an overall authority) problem of preventing, or at least reducing duplication of effort on the one hand, and redirecting efforts to fill gaps, on the other.

The SCi proposal,"Toward a World Simulation", is aimed at alleviating exactly these imbalances. (I must admit, however, that my recognition of the two-sided problem was largely intuitive; at the time of drawing up the proposal I was unaware of the Club of Rome or of several other related major projects currently under way.)

Now I know! Can Mr. Randers bring about 20 copies of "Phase I: . . ." for distribution at our Workshop?

Sincerely,

John

John McLeod, P.E.
Executive Director
SCi World Simulation

Enclosure: Agenda; Gerini Letter

November 12, 1970

Dr. Aurelio Peccei
Managing Director
Italconsult
Via Pastrengo 16
Rome, Italy

Dear Aurelio:

It was good to hear through Dennis Meadows that the Volkswagen Foundation has approved funds for the planned program here. We can now go ahead full speed.

It seems to me that things are progressing very well. Dennis has a competent and enthusiastic group and seems to be making effective contacts with other organizations.

I would appreciate hearing from you giving me your impressions of how the work is going and how Dennis is handling the situations for which you have information. Is there any advice that I should pass on to him?

Sincerely yours,

Jay W. Forrester
Professor of Management

JWF:ie
Air Mail

November 12, 1970

Professor Dr. Ing. Eduard Pestel
Rector
Institut fur Mechanik
Technische Universitat Hannover
Appelstrasse 24/B
3 Hannover, Germany

Dear Eduard:

It was good to hear through Aurelio and Dennis Meadows that the Volkswagen Foundation has approved the budget to continue the program here. We had been proceeding as if the funds were assured but it is comfortable to know that action has been taken.

Progress appears to be good and the group seems to be competent and enthusiastic. If you have any advice on the conduct of the project or on the way Dennis is handling his contacts with other organizations, I would appreciate hearing from you.

Are there any interesting or significant sidelights on the Volkswagen Foundation attitude toward the project? Were they enthusiastic or reluctant in their approval?

Sincerely yours,

Jay W. Forrester
Professor of Management

JWF:ie
Air Mail

JWF home

July 17, 1970

PROGRAM

CLUB OF ROME CONFERENCE

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

JULY 20-31, 1970

Monday, July 20

9:00	Welcome, outline of program.	Jay W. Forrester
9:30	Club of Rome objectives while at M.I.T.	Aurelio Peccei
10:00	M.I.T. historical perspective related to dynamics of social systems.	Gordon S. Brown
10:30	Coffee	
11:00	Basic concepts, system structure.	Dennis Meadows
12:00	Lunch	
1:30	Formulation of simple Malthus model.	Gerald Barney
2:30-5:00	Sub-groups put Malthus model on computer. Learn techniques of computer time-sharing usage and experience all phases of a simple system study.	
Evening	Free, reading	

Tuesday, July 21

9:00	Sources of models, information, data, relation to mental models, sources of structure.	Jay W. Forrester
9:30	Extension of the Malthus model.	Gerald Barney
10:30	Coffee	
11:00	A model of generation of solid waste.	Jorgen Randers
12:00	Lunch	
1:30-5:00	Develop the World Model (population, pollution, food, natural resources).	Jay W. Forrester
Evening	Dinner - Faculty Club. Prof. Raymond Bauer, Harvard, former Senior Consultant, "Goals for America" Project.	

Wednesday, July 22

9:00	Positive feedback, transition between positive and negative loops, growth, equilibrium, decay.	Jay W. Forrester
9:30	Biological dynamics: insulin-glucose control.	Richard Foster
10:30	Coffee	
11:00	Crisis of the Cities.	John F. Collins
12:00	Lunch	
1:30-5:00	Sub-groups work with World Model	
Evening	Reading assignments	

Thursday, July 23

9:00	Urban Dynamics.	Jay W. Forrester
10:30	Coffee	
11:00	Urban Dynamics, (cont.)	
12:00	Lunch	
1:30	Urban Dynamics, (cont.)	
Evening	Dinner: Meet M.I.T. faculty members	

Friday, July 24

9:00	System similarities, common structures, continuity of past to future.	Jay W. Forrester
9:30	Model of Drug Addiction and the Community.	Gilbert Levin and Edward B. Roberts
10:30	Coffee	
11:00	Drug addiction, (cont.)	
12:00	Lunch	
1:30	Discussion of behavior of World Model.	
2:30	Sub-groups on World Model.	

Monday, July 27

9:00	Alternative policy formulation.	Dennis Meadows
9:30	Corporate Growth model.	Jay W. Forrester
10:30	Coffee	
11:00	Corporate Growth, (cont.)	
12:00	Lunch	
1:30	Club of Rome Executive Committee, preliminary discussion of Predicament of Mankind Project. Other members: free, reading, staff and computer available.	
5:30	Reception by Howard W. Johnson, President of M.I.T. At the President's House, 111 Memorial Drive	
7:00	Dinner - M.I.T. guests - at the Faculty Club	

Tuesday, July 28

9:00	Skills and Training needed for social systems dynamics.	Jay W. Forrester
9:30	Dynamics of Commodity Stabilization, Basic Model.	Dennis Meadows
10:30	Coffee	
11:00	Representation and Analysis of Past International Control Efforts.	Dennis Meadows
12:00	Lunch	
1:30	Club of Rome Executive Committee on Project planning. Other members: free, reading, staff and computer available.	
Evening	Free, reading	

Wednesday, July 29

9:00	Modeling of social systems.	Jay W. Forrester
9:30	Designing a System for Comprehensive Community Health Care.	Edward B. Roberts
10:30	Coffee	
11:00	Dynamics of Land Use and Food Production.	Gerald Barney
12:00	Lunch	
1:30	Club of Rome Executive Committee on Project planning. Other members: free, reading, staff and computer available.	

Wednesday, July 29, (cont.)

Evening	Free, reading.	

Thursday, July 30

9:00	Modeling of social systems.	Jay W. Forrester
9:30	Subject To Be Announced	
10:30	Coffee	
11:00	The Urban Dynamics Research Program.	Walter Schroeder
12:00	Lunch	
1:30	Group discussion of social trends led by Jay W. Forrester based on readings to be supplied from Kuhn, McGregor, Hagen.	
Evening	Free, reading.	

Friday, July 31

9:00	Characteristics of complex social systems.	Jay W. Forrester
10:30	Coffee	
11:00	Implementing new policies in social systems.	Dennis Meadows
12:00	Lunch	
1:30	Final discussion.	
3:00	Executive Committee on future plans.	

Saturday, August 1

Reserve for Executive Committee on future plans.

THE CLUB OF ROME

PROJECT ON THE PREDICAMENT OF MANKIND

PRELIMINARY DRAFT

August 11, 1970

CONTENTS

INTRODUCTION

For some four thousand years the condition of the human race has been characterized by growth and change. Technological change has accelerated. Natural resources have been depleted and our environment has been polluted at an ever-increasing rate. Population has multiplied at least 50-fold and may double again within this century. Now there is evidence that change is occurring too quickly to permit adaptation by the planet's social institutions and its ecological systems.

Growth cannot continue indefinitely on a finite planet. We are faced with an inevitable transition from world-wide growth to a global, ecological equilibrium. Because of the time delays inherent in social system change, decisions made now are already influencing the nature of that future equilibrium. Will it be an equilibrium of poisoned lakes, of oppressive crowding, of food shortage and a declining standard of living? Or will we choose a different mode of equilibrium characterized by a more desirable set of conditions? Will the transition from growth to equilibrium take place by means of catastrophes such as war and starvation, or will it result from an enlightened, concerted international effort to change our values and institutions?

While perceptive individuals everywhere have begun to recognize the inevitability and the dangers of transition to equilibrium, thinking and action have been confined to one problem area at a time. Demographers press for effective birth control measures. Ecologists

seek an end to the destruction of our natural environment. Agricultural experts search for more efficient food production. All would admit that there are important interactions among the various problems of this planet, but the conceptual framework, the analytical methodologies and the vocabulary to unite the various fields have been lacking.

Recognition of these deficiencies by Dr. Aurelio Peccei and others led to the formation of the Club of Rome and to its plans for an action-oriented study into the "Predicament of Mankind," a study to develop a basis for concerted action towards understanding and evaluating the options available to mankind as it moves towards the equilibrium phase of its development. Last June the Club of Rome drafted a proposal requesting Volkswagen Foundation support for its initial project. In response to that proposal the Foundation authorized D.M. 200,000 for a pilot study to clarify the project's objectives and to identify a specific methodology. At the June 29th, 1970, meeting of the Club of Rome in Berne, Switzerland, it was decided that the Executive Committee and other interested members of the Club should participate in a two week seminar at the Massachusetts Institute of Technology in Cambridge, Massachusetts, U.S.A., to consider the "Industrial System Dynamics" techniques developed there for the study of interactions in complex social systems. The Cambridge conference resulted in acceptance of "System Dynamics" as the foundation methodology for the Club of Rome project. A separate description of the conference is attached.

An important part of the conference work involved preliminary

formulation and analysis of a world model based on System Dynamics and incorporating the relationships necessary to study most of the Continuous Critical Problems identified in the first research proposal. The world model explicitly focuses on the nature of the interrelationships among the world's productive capital, agricultural capacity, pollution, population and natural resources. The model permits study of the problems inherent in negotiating an orderly transition from world-wide growth to a global, ecological equilibrium.

To fulfill its obligations under the initial Volkswagen Foundation grant, the Club of Rome initiated a project at M.I.T. to run through November 15, 1970. That project will extend the model developed for the seminar, use it to determine the critical problems which must be addressed and develop a detailed research schedule. The principle investigators for this initial phase will be Professors Dennis L. Meadows and Jay W. Forrester of M.I.T. and Dr. Erich Zahn and Mr. Peter Milling, assistants to Professor Kortzfleisch, at the University of Mannheim Business School. The final report on this pilot project will be available November 1st.

Although a precise research schedule is not yet available, it is already possible to prepare the research proposal requested by the Volkswagen Foundation. The following material comprises that proposal. Subsequent sections describe the objectives, the methodology, the schedule and budget for the project. One appendix provides biographic information on the priciple investigators. A second appendix describes the assumptions and presents several analyses of the preliminary world model.

OBJECTIVES

Goals of the total program of the Club of Rome remain those enunciated by Dr. Aurelio Peccei.

1). Acquire and diffuse a real in-depth understanding of the present critical state of human affairs and of the narrowing and uncertain perspectives and options which are likely for the future if present trends are not corrected.

2). Recognize and propose new policy guidelines and patterns of action capable of redressing the situation and keeping it under control.

Attaining those goals will require two types of activity: research and implementation. To acquire an understanding of the present world situation and to recognize appropriate policies will necessitate a relatively short, intensive research effort. Selection of an appropriate methodology and identification of relevant data are the most important elements of success in this phase. The research can most effectively be conducted by a small, full-time staff in one location, assisted by appropriate consultants.

Diffusing knowledge about the critical problems and proposing appropriate corrective actions are implementation activities whose success depends on a sustained, multilateral effort involving many peoples and organizations. Political factors are the major keys to successful implementation. Thus the effort must be multinational and based in a neutral country. The Club of Rome's initial project as it was proposed previously and as it is clarified in this document, addresses the research phase. A second project institutionalizing some aspects of the implementation effort may well be undertaken by

the Club of Rome in Geneva. However, in view of the Club of Rome's limited resources, it is vitally important that the research phase be conducted in such a way as to facilitate implementation of its results by the general world community. The Club of Rome project can be successful in its overall objectives only if it is an achievement sufficiently new and important that it attracts a lasting group of adherents from competing modes of scientific activity. To do that it must identify a new class of problems for solution. It must provide the methodologies, the criteria of success and the language for addressing these problems. Thus the research phase, that is development, validation and analysis of the world model, will be conducted so as to provide the following:

- a useful System Dynamics model of the interactions among the earth's population, capital equipment, human skills, agricultural capacity, pollution and natural resources.

- an "action list" of those general policies which should be implemented immediately in preparation for an orderly trasition to global equilibrium.

- a "research list" of those relationships critical to the behavior of the model about which there is still insufficient information.

- a European center of excellence in System Dynamics so that future work may be conducted outside the United States.*

- several "bench mark" research papers, published in appropriate journals to illustrate how those with no training in System Dynamics may address their traditional tools to the problems identified by the world model analysis.

* Two years ago Professor Gert von Kortzfleisch inaugurated an exchange program with M.I.T. to develop at the University of Mannheim one of the first professionally qualified System Dynamics research and teaching activities outside the United States. The Club of Rome project will provide the opportunity to achieve Professor Kortzfleisch's objectives. During the project we will train the German personnel and provide the teaching materials for independent work on future projects abroad.

- contacts with other individuals and organizations whose research efforts could usefully employ the world model and System Dynamics.

- information required by the Club of Rome in its decision on the formation and design of a Geneva-based implementation effort.

- a book aimed at the general community which treats the inevitable transition to equilibrium, outlines its various possible configurations and indicates the political choices which will have to be made.

METHODOLOGY

History

The field of System Dynamics has been developed at the Massachusetts Institute of Technology through more than thirty years of continuous effort directed toward the analysis and control of complex system behavior. From its birth in the study of relatively simple, mechanical systems it has grown to provide a single framework for understanding the behavior of all electronic, chemical, biological and social systems whose elements interact through time to produce system changes. Four lines of historical development have made the current System Dynamics methodology possible. They are:

- the theory of information-feedback systems
- a knowledge of human decision-making processes
- the experimental model approach to complex systems
- the digital computer as an inexpensive means to simulate realistic mathematical models.

J. D.

Study of mechanical servo mechanisms at M.I.T. led to an awareness in the early 1940's that time delays, amplifications and structural relationships among a system's elements could be more important in determining aggregate system behavior than the individual components themselves. The concepts of information feedback and control were developed to express the relation between structure and behavior. More recent efforts to design automatic self-regulating control systems have extended these concepts and shown them to underlie behavior in all systems. The potential of competitive advantages available

reword.

throughout the automation of data processing in large organizations has focused much attention on the nature of human decision making. Research conducted since the early 1950's suggests that important components of the decision-making process are not entirely "free will" but are strongly conditioned by the information present in the environment. Progress has been made in this field to the point where we are now able to model the basic structure of decision making.

Mathematical techniques are not yet powerful enough to yield general analytical solutions to systems as complex as those encountered in social systems. The alternative is an experimental approach based on quantitative models of the system. First a mathematical model of the social system is constructed. This model is a detailed description of the decision processes in the system. It indicates how the conditions at one point in time lead to subsequent conditions at later points in time. The behavior of the model is observed and experiments are conducted to answer specific questions about the system that is represented by the model. "Simulation" is the name generally applied to this process of conducting experiments on a model instead of attempting the experiments with the real system. In simulation studies the goal is not to predict a system's exact condition at some future point in time, but rather to understand, in a pragmatic way, how alternative changes in the current system are associated with different modes of behavior over time.* The simulation approach, a

* This is an extremely important point. Emphasis in a System Dynamics study of world copper markets would not, for example, be focused in predicting future prices on a particular date, but rather in determining the relative effects of alternative institutional agreements on the stability of copper prices over time.

fundamental element of System Dynamics methodology, was developed at M.I.T. in the early 1950's as engineers were forced to analyze systems too complex to solve analytically.

The fourth foundation element of System Dynamics is the electronic digital computer developed at M.I.T. The general purpose computer became widely available after 1955. Without it, the vast number of calculations required to trace the behavior of a specific system through time would be prohibitively expensive. In fifteen years the cost of arithmetic computation fell by a factor of 10,000 or more. Such a cost reduction created a totally different research environment than that existing even a decade ago. Computing machines became so widely available, and the cost of computation and machine programming fell so low relative to other costs, that the former difficulties in conducting a simulation study no longer determined the rate of progress in understanding system dynamics.

A group of individuals from the engineering and social sciences came together in 1957 at M.I.T.'s Sloan School of Management to exploit these four developments. Their initial work focused on industrial applications and the field came to be known as Industrial Dynamics. The first major work was published under that title by Professor J. W. Forrester in 1961. It detailed the general principles of complex system analysis and described their applications to inventory-workforce control problems in large industrial organizations. As the perspectives of the Sloan School widened from business administration to the management of broad social systems, the Industrial Dynamics group undertook a larger range of problems. The methodology was extended

and refined through application to several hundred problems over the next decade. Studies ranged from the mechanism of homeostasis in the human body, to social problems of drug addiction and predator-prey relationships in animal populations. The general principles and the analytical tools which were developed in the course of these studies are now called Systems Dynamics.

Several major System Dynamics studies have resulted in books. In Dynamics of Research and Development Professor Edward B. Roberts relates resource allocation, policies, scheduling rules and individual motivation to the performance of large scale research programs. As urban problems involving social unrest and economic decline became important in the United States, Professor Forrester employed the principles of System Dynamics to unify information from the fields of economics, sociology and political science in a radical new theory of urban decay. His prescriptions for the ills of stagnant cities have brought support to the Sloan School for a broadly based study of urban problems.

Developing countries receive more than ninety percent of their foreign exchange earnings from the export of primary commodities like cocoa and tin. Thus the pronounced instability in the prices of these products has disrupted the development programs of many poorer nations. Using System Dynamics methodology, Professor D.L. Meadows has identified for the first time a general theory relating the factors which make all commodities prone to price fluctuations. Published in The Dynamics of Commodity Production Cycles this theory is being extended now to permit the design of more effective control measures.

The application of System Dynamics to those problems identified by the Club of Rome would be a simple extension of work conducted over the last decade. Implications of the research will be more profound, but the elements of the approach, the underlying methods, would be the same.

METHODOLOGY

Elements

System Dynamics is essentially a set of tools which permit an analyst to relate a system's structure to its behavior over time. The theory is based on three cardinal assumptions:

1). Within a system there are two and only two types of elements, rates and levels.

2). Elements are arranged in feedback relationships.

3). It is possible to circumscribe the important feedbackloops of a system and thereby create a closed boundary beyond which influences can be considered exogenous and random.

These concepts of structure are powerful and effective guides in the building of models to represent social systems. By providing a simplified vocabulary for expressing complex relationships, they permit tremendous gains in our ability to relate the knowledge of one field to that of another.

In a system the two types of elements are levels and rates. Levels are the state variables which characterize the system at any point in time. POPULATION, POLLUTION, NATURAL RESOURCES, CAPITAL, AGRICULTURAL CAPACITY AND HUMAN SKILLS are important levels in the world model. Rates are the action or policy variables which effect changes in the levels. Birth rate and death rate, pollution generation rate and resource depletion rate are among the rates important in any understanding of global equilibrium.

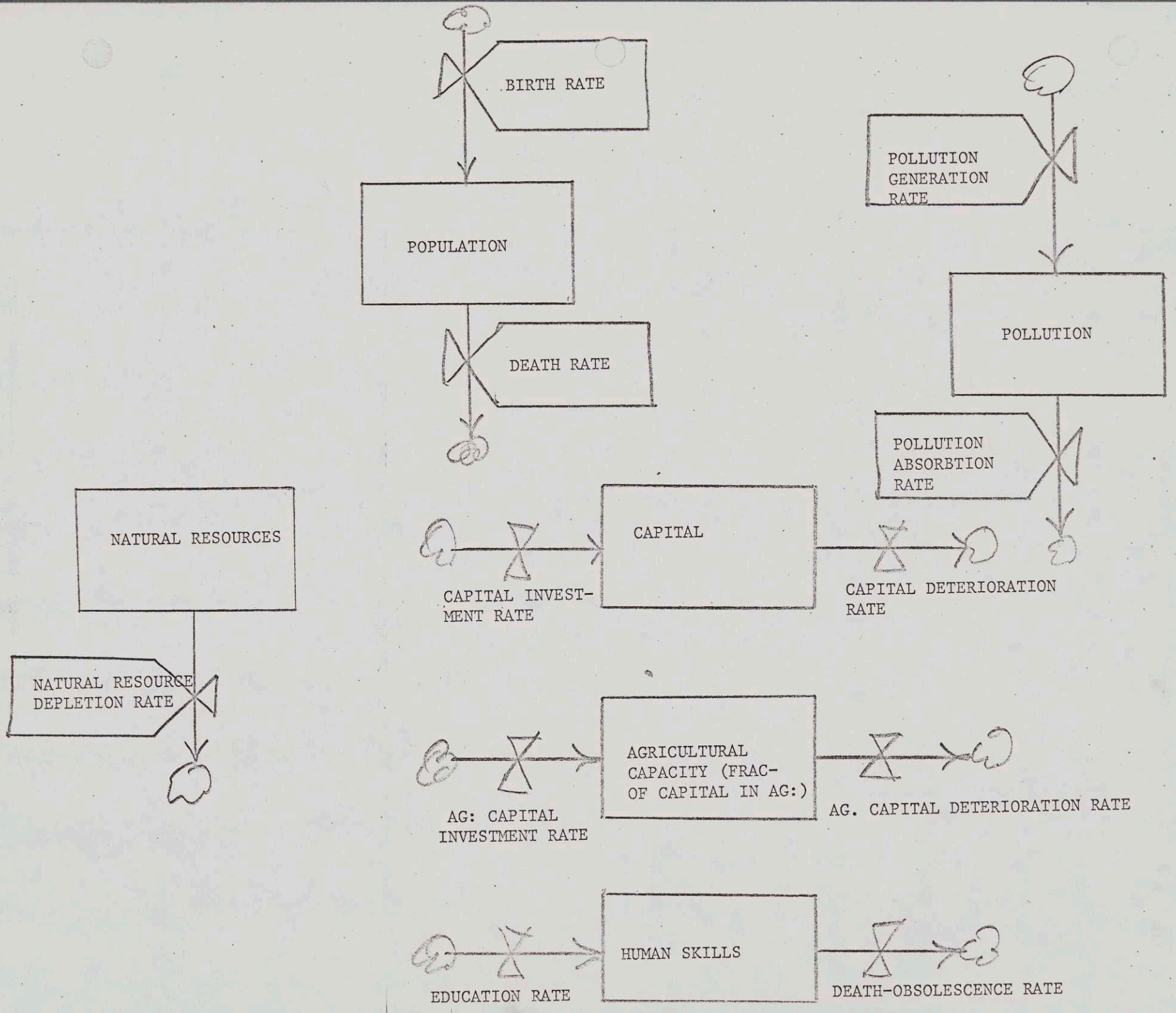
We portray the elements in a system graphically representing levels by rectangles [▭] and rates by valves [⋈]. Such a

Better to use the full diagram.

representation drawn for any specific system constitutes a flow diagram. Figure 1 is a partial flow diagram for the world equilibrium model. The values of these six level variables as they evolve through time represent the important attributes of the world as it moves from growth to equilibrium. They are sufficient to permit study of many Continuous Critical Problems listed in the initial proposal. Among them are:

- Explosive population growth with consequent escalation of social, economic and other problems.
- Widespread poverty throughout the world.
- Generalized and growing malnutrition.
- Persistance of widespread illiteracy.
- Generalized environmental deterioration.
- Limited understanding of what is "feasible" in the way of corrective measures.
- Irrational agricultural practices.
- Irrational practices in resource investment.

Every System Dynamics model is a set of assumptions about the real system. These relationships, expressed in terms of appropriate rates and levels are expressed quantitatively to facilitate their analysis through computer simulations. Of course nothing in the process of simulation guarantees the accuracy of the underlying assumptions. However, the process of specifying assumptions in objective terms facilitates discussion about the assumptions among those with relevant knowledge. The resulting model is thus more likely to be comprehensive and accurate than the mental models which are our only current alternative guides to action.


BIRTH RATE
POPULATION
DEATH RATE
POLLUTION GENERATION RATE
POLLUTION
POLLUTION ABSORBTION RATE
NATURAL RESOURCES
NATURAL RESOURCE DEPLETION RATE
CAPITAL
CAPITAL INVEST-MENT RATE
CAPITAL DETERIORATION RATE
AGRICULTURAL CAPACITY (FRAC- OF CAPITAL IN AG:)
AG: CAPITAL INVESTMENT RATE
AG. CAPITAL DETERIORATION RATE
HUMAN SKILLS
EDUCATION RATE
DEATH-OBSOLESCENCE RATE

A fuller understanding of the method can best be obtained through reference to Principles of Systems by Professor Jay W. Forrester. For this proposal the above discussion will provide the basic outline of our approach to the world problems. Appendix II describes an early version of the world model which was developed in conjunction with the Club of Rome's visit to Cambridge. Included in the appendix are several analyses of that model conducted through computer simulation. It is significant that creation of the model and conduct of the analyses required only four days of effort by one man.

Appendix II-a presents the flow diagram of the model relationships, Appendix II-b defines each equation used to represent those relationships, Appendix II-c provides sample simulations runs, each representing an analysis of one or more changes in the underlying assumptions. Notice that in this model, World2, HUMAN SKILLS are still considered a part of CAPITAL. More recent study has suggested that the two must be represented separately to fully understand equilibrium behavior. It may be that the distribution of wealth and population are also important. Verification studies to be undertaken at the outset of the formal research project will doubtlessly reveal several changes necessary before final analysis can be undertaken. It is already apparent, however, that the model will permit a tremendous improvement in our ability to rationally and usefully consider the implications and options associated with the impending transition to global equilibrium.

Schedule

Now that a specific methodology has been identified the research objectives can be achieved in less time than initially envisioned. Seven and one-half months should suffice for the initial research effort.

15. November	Decision by Volkswagen Foundation
15. November - 15. December	Present the model at United Nations Economic and Social Council and to individual experts in relevant fields. Solicit critical comment and identify relevant data banks.
16. December	Begin intensive analysis of the model.
1. January	Three field-oriented experts [eg. demographer, geologist, political scientist] join the group to undertake model-related studies.
February	Club of Rome Executive Committee meets in Cambridge to review work in progress and to consider a Geneva-based implementation effort.
30. June	Submission of final report. Publication of three field-oriented papers in appropriate professional journals.
30. September	Completion of the book.

Budget

Several factors have combined to reduce project costs significantly below those initially envisaged.

The System Dynamics methodology is extremely efficient in identifying relevant knowledge and relating assumptions from diverse fields. Thus costs of data gathering will be held to a minimum. The original proposal requested support for full-time staff members in all relevant fields. However, with System Dynamics it will be possible to rely primarily on consultants and on cooperating professionals at the United Nations.

Utilization of the computer time sharing system and software packages previously developed at M.I.T. will save substantially on data processing costs. While $900,000 had been requested originally, $200,000 will suffice to complete the proposed program.

J. W. F. Home

CLUB of ROME

Conference on World Dynamic Systems

Tentative Roster of Participants

July 16, 1970

Dr. Jeremy Bray, M.P.	House of Commons	London, England
Prof. Gordon S. Brown	Prof. Electrical Engineering, MIT	Cambridge, Massachusetts
Mr. Alexander N. Christakis	Consultant to Club of Rome Project	Washington, D. C.
Prof. John F. Collins	Visiting Prof. of Management, Pol. Science & Civil Eng., MIT	Cambridge, Massachusetts
Prof. Richard M. Douglas	Chairman Dept. of Humanities, MIT	Cambridge, Massachusetts
Prof. Jay W. Forrester	Prof. of Management, MIT	Cambridge, Massachusetts
Mr. Raymond Gastil	Batelle Seattle Research Center	Seattle, Washington
Dr. William Gouse	Office of Science and Technology	Washington, D. C.
Mr. Robert Greenleaf		Cambridge, Massachusetts
Mr. Kaya	Representing Dr. Saburo Okita	Tokyo, Japan
Prof. Dr. Gert von Kortzfleisch	Prof. of Business University Mannheim	Mannheim, Germany

Mr. Robert Maes	President of Independence Foundation	Philadelphia, Pennsylvania
Prof. Dennis Meadows	Assistant Professor of Management, MIT	Cambridge, Massachusetts
Mr. Meyer	Assistant to Prof. Dr. Ing. Pestel	Hannover, Germany
Prof. Hasan Ozbekhan	Club of Rome, Project Director	Los Angeles, California
Dr. Aurelio Peccei	Managing Director, Italconsult	Rome, Italy
Prof. Dr. Ing. Eduard Pestel	Rector, Institut fur Mechanik, Technische Universitat Hannover	Hannover, Germany
Mr. Ronald L. Ritchie	Vice-President, Imperial Oil Ltd.	Toronto, Ontario
Dr. Hugo Thiemann	Directeur General, Institut Battelle	Geneva, Switzerland
Prof. David White	Prof. Electrical Engineering, MIT	Cambridge, Massachusetts
Mr. Erich Zahn	Assistant to Prof. Dr. Kortzfleisch	Mannheim, Germany

Wyon, Neave, W. Dgroup. Nov. 6 '70.

1950 John Gordon started studies of population.

How to trace from a birth control process to the effect on a population.

Will a super-optimum program have influence with monthly visits to <u>each</u> household and a doctor available each week.

Punjab:

Less orthodox than Danger valley

Hot dry for 3 mo.

Sleep on roof in summer, mosquitos go below & bite the animals that share the house.

Houses built on houses repeatedly to a mound ht of 200 to 300 ~~people~~ feet.

5 acres of land / farming family.

First son gets the land, the others get education & move away.

25% more men than women. Birth control by letting more of females die.

after 1920 at the end of the influenza epidemic.

* model: What accounts for ratio of living to food land?

* model: Consider how higher land productivity can lead to more space used for living.

Productivity of agri. land has risen recently. 1950 was when a new set of roads was built around the older village to expand the living area.

* Did this occur as land productivity rose?

* Importance of a model explaining the situation: Deal with land usage ratio.

Wyon: ~~says~~ ~~said~~ "the land used for residence is very slight and not critical"

* But he misses the effect of living space on population.

In past, population has been cut by catastrophes, famine & epidemics.

* Epidemic may be related to degree of crowding.

now public health & irrigation & protect against failure of monsoon have taken off the pressures & allow pop. to rise!

Net out migration has declined in last 10 yrs because of increase of agric productivity.
Birth rates and death rates both declined in the interval but the net pop. increase was probably about the same.
Went in as naive medical doctor expecting there was no knowledge in villages of birth control.
But an effective birth control program had almost no effect on birth rate.

Average age of marriage has been going up.
all daughters who are married must leave to another village.
* age of first cohabitation has risen from 17½ yr to 22, from 1956 to 1969.
* marriage is still arranged by elders.

Life is now more tense, the summer 2-mo dry season is no longer a period of rest because another crop is planted & irrigated.

In 1955 each of 11 villages had a school, 1 had a high s.

* model: Does the older age of cohabitation arise from educational opportunities for women?
Does pop. pressure create education?
Refer back to younger sons being educated & moving away.
* Put in here the relationship of education and out migration.

People say they don't want to be bound down with children "til they have a chance to live."
a common

Interval from birth to menstration, 10 mo to 50% of women when baby lives a month or more
* Put in here a birth rate as dependent on no of babies.

* They work hard & always have, Here the need to work for food (the food ratio) affects birth rate.

How does education affect death rate? Even if it increases cohabitation age, it might still cause pop. change rate to increase.

Believe the high birth rate is caused by the high death rate of children.

* Birth rate should be a function of no. of children, and not just a function of total population or pressures on the population.

* Put in the long delays in perception and tradition in such matters of no of children.

* Examine the pop. fluctuation that can occur.

* The present low death rate of children may be a transient where death rate will rise again when pressures rise again.

Faction fights between men in village reduce pop. – they say it justifies higher birth rate!

* But crowding can cause the conflict.

Meave: Can't distinguish these:
- Concious vs unconcious
- Rational vs irrational

Meadow: Will now try describe the phenomena.

1. Identify the dynamic Problem-Phenomena,
2. Identify feedback loops.
3. Construct a model
4. Analyze.
5. Redesign to cause it to exhibit a new behavior.

Randers: Main thing to determine birth rate. Start by writing birth rate & put in 3 amounts to describe birth rate

X (But I would start with the levels.).

Meadows: So you want to understand b. rate.

Dana.: Is the village the proper boundry.

Wyon: Village may not be the most relevant unit to the people. Had 3 main groups of villages. Very close to one another. In all 50% farmers, 25% leather workers (lowest caste), 25% mixed. Each village is an ~~mixed~~ economic mix, do not marry outside of caste.

X (But I say we adopt an unvarying mix, because it does not seem to vary and variations in mix have not been mentioned earlier in the discussion of behavior.).

Wyon: Castes have cross-ties between their own kind in other villages.

Meadows: Assume primary source of wealth comes from land. Says ~~bec~~ being driven by land.
Let's think about farmers and assume they support

Wyon: Rate of pay has gone up a great deal.
Change in technology (fertilizer, irrigation) has stimulated many changes.

Meadows: Take a village population.
If leather workers + farmers stay in same proportion, then only total population is

Boundry: Geographical; Village boundry.

Are we interested in plagues + epidemics.

Dana: Aren't plagues a random effect.
Group: No density has an effect.
Meadows: Do we want to understand the last century with epidem. or this century without?
X But there is no major difference here.

Behrens: must recognize land & land effy.
Neave: is effy reflecting production
or income from?

Meadows: Psychological

Levels.

Pop.

~~Land for agri.~~

← Frac. Land — living area.

Perceived death rate of children

no. of children of breast feed age.

" " " ~~fellow~~ of parents — childbearing age. Out ⇒

People above " " " ".

→ Land owners.

Av. yr. of Educ. { School system —
Include cost.
Include cost of students not working.

Average cohabit age.

Average education level.

Tradition for social strife, value of life etc.

Acceptable crowding

Perceived food adequacy.

Food prod. rate: f(Pop, working pop., land,

Desired family size.

JWF
11/2/70

Massachusetts Institute of Technology
Alfred P. Sloan School of Management
50 Memorial Drive
Cambridge, Massachusetts, 02139

MEMORANDUM

To: PARTICIPANTS IN THE NOVEMBER 6 SEMINAR WITH MEMBERS OF THE HARVARD CENTER FOR POPULATION STUDIES

From: Dana Meadows

Date: November 2, 1970

As we work on the Club of Rome world project, we find ourselves generating numerous questions which cannot be answered with a totally aggregated world model. In the Principles of Complex Systems class we have discussed the possible merits of dividing the population level into different age groups, of representing several dynamically different kinds of pollution, and of duplicating the entire model to produce a "developed world" and an "underdeveloped world." In each case the decision has been to maintain the present state of aggregation in Phase I of the project, at least until the principle of world equilibrium has been fully explored on a completely global scale.

At the same time, we all realize that the logical next step in the study of world problems will be the generation of several smaller investigations of the various sectors of the world model in greater detail. These investigations will attack the exceedingly difficult questions of policy which will arise from the aggregated model. For example, an important conclusion of Professor Forrester's World2 study is that world-wide average birth rate should be reduced by at least 50%. The obvious next question is "How?" The many factors which influence human fertility are represented only vaguely in the world model. Clearly an important secondary study might be undertaken with this question in mind. It would probably include altered population and economic sectors from the present model, with the feedback relationships between the two sectors indicated much more explicitly. A proper boundary of the new model might be a given nation, a village, or perhaps just a family, where the final decisions on childbearing are made.

My own thoughts on family planning and population control have been very much influenced by conversations with Dr. John Wyon of the Center for Population Studies. Dr. Wyon has directed a monumental study in North Indian villages, which investigated some of the possible factors affecting family size, including age at marriage, duration of breast feeding, desire for a son, and availability of birth control information and devices. The results of this study are summarized in the book Dr. Wyon has written with Dr. John E. Gordon -- The Khanna Study: Population Problems in the Rural Punjab, soon to be published by Harvard University Press.

I am including in this memo copies of several tables from the concluding chapters of The Khanna Study. The tables summarize the many internal and external factors which affect family size in rural India, according to Dr. Wyon. (You will notice that he has a considerably clearer mental model of his system than most researchers.) I think that these tables are a good basis for a System Dynamics model of human fertility. The object of our seminar will be to sort through the various factors listed in the tables and any others the population experts might suggest, in order to produce a preliminary model of the determinants of human fertility.

Dr. Wyon is now planning a second and more ambitious study in the Deccan area of India near Hyderabad. His approach is more short-term than ours, less concerned with eventual equilibrium and more cognizant of the importance of individual freedom and dignity. His viewpoint is that of a public health physician, not a manager. But in his study he will be asking questions very similar to the ones we must consider in future phases of our project:

Of the many factors one may cite, which are actually most important in determining fertility?

Are there "pressure points" by which fertility can be influenced?

Are present family planning efforts aimed at pressure points or at some point of the system which is inherently very stable?

Is it reasonable to expect that economic development will naturally reduce birth rates without any outside pressure?

Would it be possible to achieve economic development more easily if an immediate decrease in fertility could be achieved?

Is there some point, perhaps in the economic sector, where pressure could be applied to reduce fertility without obvious coercion and without demeaning the essential right of a couple to choose the size of its family?

If we had a good understanding ourselves of the causes and consequences of high fertility, could we communicate that understanding to the people of any given country, so that they may make more responsible decisions in their choice of family size?

We hope that the meeting on Friday will help both Dr. Wyon and ourselves to understand better the systems with which we are dealing. See you at 1:00 in Room E52-450.

***

Table 29. Factors conceivably influencing population growth in study villages, 1956 to 1960

Influences originating from WITHIN the population			Influences originating from WITHOUT the population		
Item[a] Number	Tending to:	Reference to text section or figure	Item[a] Number	Tending to:	Reference to text section or figure
	Increase Births			*Increase Births*	
1	High risk of losing children	Sec. 7.4.3	9	No occupations for women other than marriage	Sec. 8.2.2
2	Need for sons	Sec. 3.7.1	10	Democracy means counting of heads	Sec. 3.5
3	Readiness to endure a low standard of living	Sec. 1.3.1	11	Fashion for shorter breast-feeding	Sec. 6.2.5
4	Women start cohabitation at early age	Sec. 6.2.2	12	Improved health services for mothers, less pregnancy wastage	Sec. 6.2.6
5	All women marry	Sec. 6.4	13	Possibility of civil unrest	Sec. 3.1.2
6	Ignorance of birth control	Sec. 5.3.1			
7	Low status of women	Sec. 7.1			
8	Low frequency of sterility	Sec. 6.3			
	Decrease Births			*Decrease Births*	
14	Long breast-feeding	Sec. 6.2.5	23	Low rate of coitus at older ages	Sec. 6.2.3
15	Delayed cohabitation of women	Sec. 11.5.3	24	Improved health services, less fear of losing children	Sec. 3.5
16	Knowledge of and practice of birth control	Sec. 5.3.1	25	Improved survival of children	Sec. 7.3.2
17	Ambition for higher standard of life	Sec. 3.5	26	Improved methods of birth control	Sec. 10.3.1
18	Cost of marrying daughters	Sec. 3.7.3	27	High cost of rearing children and preparing them for adult life	Sec. 3.3
19	Increasing sense of ability to control own future	Sec. 3.5	28	Occupations for women as an alternative to marriage	Sec. 3.7.1
20	Separation of husband and wife	Sec. 6.2.4	29	Higher status for women	Sec. 3.7
21	20 percent of males remain single	Table 4	30	Difficulties in finding jobs outside the village	Sec. 8.2
22	Lower fecundity with increasing age	Sec. 6.2.5			

Table 29 (continued)

Influences originating from WITHIN the population			Influences originating from WITHOUT the population		
Item[a] Number	Tending to:	Reference to text section or figure	Item[a] Number	Tending to:	Reference to text section or figure
	Increase Deaths			*Increase Deaths*	
31	Low status of: females	Sec. 7.4.4	35	Infections	Sec. 7.2.1
32	children	Sec. 7.4.4	36	Failure of rains	Sec. 7.2.2
33	aged	Sec. 7.4.4	37	Lack of materials for farming and industry	Sec. 3.3
34	low castes	Sec. 7.4.4			
	Decrease Deaths			*Decrease Deaths*	
38	Increased willingness to strive to keep children	—	39	Improved health services	Sec. 7.5
			40	Improved ability to feed children	Sec. 3.3
	Increase Out-Migration			*Increase Out-Migration*	
41	Poor chances of livelihood in home village	Sec. 8.2.1	42	Good chances of employment in other parts of India and beyond	Sec. 8.4
	Decrease Out-Migration			*Decrease Out-Migration*	
43	Desire to stay in village	Sec. 8.2	45	Unemployment outside home village	Sec. 8.4
44	Improved chances for livelihood in own village	Sec. 3.5			
	Promote Conservative Decisions				
46	Major decisions in hands of extended family	Sec. 3.7.3			
47	Struggle for subsistence precludes taking risks	—			

[a] Influences arranged under each head in approximate order of importance.

Table 30. Factors conceivably influencing resources for livelihood of study village members, 1956 to 1960

Influences originating from WITHIN the population			Influences originating from WITHOUT the population		
Item Number[a]	Tending to:	Reference to text section or table	Item Number[a]	Tending to:	Reference to text section or table
	Increase Resources			*Increase Resources*	
			50	Improved agricultural techniques	Sec. 3.3
			51	Improved varieties of crops, animals	Sec. 3.3
			52	More chemical fertilizers	Sec. 11.5.5
			53	Improved irrigation	Sec. 3.5
			54	Consolidation of land holdings	Sec. 3.5
			55	Improved crop storage and pest control	Sec. 3.3
			56	High market prices for agricultural produce	Sec. 11.5.5
			57	More power, electric and internal combustion	Sec. 3.3
			58	Improved transport	Sec 3.5
			59	Improved industry	Sec. 3.3
			60	Improved trade	Sec. 3.4
48	Higher and improved education	Sec. 8.2.1	61	Higher and improved education	Sec. 3.3
49	More secondary occupations	Sec. 9.1	62	Outside employment and remittances home	Sec. 8.2
	Diminish Resources			*Diminish Resources*	
63	Decreased land per capita	Sec. 3.3	68	Diseases of crops, livestock, and cultivators	Sec. 9.2.4
64	Further division of land holdings	—	69	Scarcity of capital to improve agriculture, industry and trade	Sec. 3.1.1
65	Decreased quality of land	—	70	More irregular rain	Sec. 11.5.5
66	More unemployment hidden by joint family support	Table 35			Sec. 3.3
67	Increased cost of educating sons, marrying daughters	Sec. 3.3			

[a] Influences arranged under each head in approximate order of importance.

Table 31. Possible ways of modifying selected influences on determinants of population pressure in study villages and rank order of considerations affecting possible modifications[a]

Item number (Tables 29, 30)	Present influences:	Possible modification intended to reduce population pressure	Rank order of: Practicability	Local desire for modification	Expected net result on influence	Expected effect on determinants of population pressure
	Affecting birth rate					
1, 12, 24, 25	High risk of losing children	Improve survival of children	1	1	1	1
6, 16, 26	Ignorance of birth control	Program for birth control	1	1	1	2
4, 15	Women start cohabiting at early age	Delay cohabitation	1	2	2	2
9, 28	No occupations for women outside the home	Promote occupations for women	2	2	2	2
5	All women marry	Promote careers for unmarried women	2	2	2	2
7, 29	Low status of women	Improve status of women	2	2	2	3
11, 14	Shorter breast-feeding	Promote breast-feeding	2	2	2	2
3, 17, 19	Readiness to endure low standard of living	Encourage higher standard of living	2	1	2	2
10	Democracy means counting of heads	Promote responsible citizenship	2	2	2	2
13	Possibility of civil unrest	Promote firm government	2	2	2	2
27, 18	Cost of rearing and educating children	More effective education, nutrition, savings	2	1	2	2
2	Need for sons	Reduce need for sons	2	3	3	3
20	Separation of husband and wife	Encourage separations	2	3	3	3
23, 22	Less coitus in later years	Promote abstinence	2	2	3	3
30	Difficulties in finding jobs	Ask parents how unborn sons will find a living	1	2	1	2
	Affecting death rate					
31 to 34 38 to 40	Low status of females, children, aged, low castes	Promote dignity and health	2	2	2	2
35 to 37	Lack of the means for gaining a livelihood	Promote initiative and technical improvements	2	1	1	2
	Affecting rate of immigration					
41 to 45	Appraisal of chances of improved livelihood by out-migration	Promote realistic appraisal of contribution of migration to health and welfare	1	1	1	1
	Affecting decisions					
46	Locus of decision makers	Educate older adolescents that they will soon encounter population pressure	1	1	1	1
47	Difficulty in taking entrepreneurial risks	Develop cooperative risk-taking with insured, low-cost capital; teach how to improve judgment of risks	1	1	1	1
	Affecting resources					
48 to 70	Table 23	Promote realistic appraisal of how to match population growth and resources	1	1	1	1

[a] Rank order: 1 = high, 2 = moderate, 3 = low.

Wyon said:
Pakistan project
Problem, How to provide
what the population
will need in the
next 30 years.

JBW 5 Nov. 1970

Seminar

November 6, 1970 A rural Indian population-resources system

M. I. T. Sloan School - Harvard Center for Population Studies

I Objectives of Khanna Study

A. Field test of the ability of a birth control program to change the birth rate of a rural population, Punjab, India, 1953 to 1960

B. Study 1) population dynamics

2) influences on births, deaths, migrations.

II Evolution of concepts

A. Cause and cure of high birth rates

1. Rural Indians have high birth rates because:

a. they are ignorant of birth control

b. they have no access to effective methods

THEREFORE - supply methods and advice

2. Field test of hypothesis on cause and cure of high birth rates:

Applied in the Khanna Study; test population of 8,000 persons provided with intensive birth control program for 4 years, and concurrent observation of two control populations of 4,000 each.

3. Response to birth control program at Khanna:

25% to 50% acceptance

approximately 50% effectiveness

BUT no change in birth rate

(To this day no birth control program has been proven to have been the cause of a declining birth rate)

THEREFORE

B. What have these people been doing to solve their own population problem?

1. History of rates of population growth, births, deaths, migration and production of resources.

2. Inferred influences acting on observed rates of birth, death, migration, production of resources, and on population structure and organization

C. Conclusions from Khanna Study

Strong evidence of effective actions on births, deaths, migrations, and production of resources (Tables 29, 30, 31)

THEREFORE

1. Rural Indians are rational

2. They have good reasons for cautious practice of birth control

D. Concepts basic to the Medak Study

1. Make a direct, scientifically controlled test of the existing birth control program.

2. Apply conclusions from the Khanna Study

a. Keep most children alive and well (Family and Community Health Service)

b. Help social units learn accurately the facts and consequences to them of their own population-resources (i) predicament (ii) system

(Demographic education)

3. Make a deeper study of population-resources in a major biological-social ecosystem of India in marked contrast to that of the Punjab.

WHY THE U.S. IS IN AN

general-purpose forces as fast as the Vietnam war would permit. These forces—the Army and Marine ground troops, the Navy's fleet (except Polaris submarines), and the tactical air wings of the Air Force, Marines, and Navy—account for roughly two-thirds of the defense budget, and have already been cut sharply. The Army has taken the bulk of the manpower cuts, losing 248,000 men, a number roughly equivalent to the size of the entire Marine Corps. For its part, the Marine Corps has deactivated one of its four divisions. The Navy is being reduced by 300 ships—far more than the number of vessels committed by our allies to NATO's Atlantic fleet. Among the ships being retired are six that the Navy particularly prizes: one attack carrier and five antisubmarine-warfare carriers.

Up to now, says Packard, "we've cut a lot of fat and done about everything that is easy." The "easy" cuts have centered on manpower, procurement, and maintenance, as well as stretch-outs of new major weapon systems. The Navy achieved considerable savings in maintenance when it mothballed part of its oversized (and rusting) destroyer fleet and those antisubmarine-warfare carriers. The battleship *New Jersey*, recommissioned at a cost of $22 million, was taken off the line after four months' service in Vietnam because she cost $10 million a year to operate. Twenty-five of the Air Force's tactical aircraft, including some used in continental air defense, have been retired from service. The swollen staff structures of the services—in the Pentagon alone each service has maintained a staff of 10,000 men—are being sliced back to a more realistic size. Some forty-five major military bases, ranging from SAC bases in the U.S. to installations in the Philippines and South Vietnam, are being closed.

The Atlantic Fleet, which has seen its force reduced by 104 ships, is saving on fuel costs by keeping its remaining units in port for longer periods. The First Fleet, based in San Diego, has cut back the extent and frequency of maneuvers. And calls at ports in Canada and Mexico are rare enough so that one First Fleet officer complains, "This duty isn't fun anymore." Even the Sixth Fleet, which is maintained in a higher state of readiness than U.S.-based units, is reducing the flight time of air groups on its carriers in the Mediterranean.

"Tight as bark on a tree"

All the services face even heavier slashes in the future, and these reductions will be harder to make—and riskier. Says Packard: "From now on we're making major decisions that will have an effect on capability." In planning the fiscal 1972 budget, the Administration has told the services, in effect, to work down to an over-all military force of between two million and 2,250,000 men (see chart, page 68). The Army is scheduled by June, 1971, to be down to thirteen and two-thirds divisions (from a peak in 1969 of eighteen), and studies are being made of an eleven-and-two-thirds division Army, to be augmented by three Marine divisions. (An Army division consists of three brigades of about 4,000 men.) Under plans now being developed, a Navy fleet of 570 ships, including twelve attack carrier task forces, is contemplated. The Air Force's tactical air wings, now numbering twenty-three, would drop to around seventeen.

Only the considerable political skill of Defense Secretary Melvin Laird, one Pentagon official comments, has prevented "blood from flowing all over the Pentagon corridors," as coveted commands melt away, promotions dry up, and morale declines. Interservice fighting, muted during the years of expansion, is intensifying as money, in one officer's words, becomes "tight as bark on a tree."

"We would have liked to, and should, make strategy without budget constraints," says Packard. "But both budget and strategy today are affected by the political situation in this country." If the defense forces were to be held at this year's level, pay increases and inflation would mean a fiscal 1972 defense budget of $78 billion. "That figure was politically unrealistic," says another of Secretary Laird's top aides, "so we were told to plan on a force which, before pay increases and inflation, would come to about $66 billion. In this way, we could hold the spending line close to today's figure of $73.6 billion."

Under the new tight budget, about all that the Pentagon has to look forward to is an increase in its strategic nuclear forces, which include the land-based intercontinental ballistic missiles, the sea-based Polaris, and the new sea-launched Poseidon missiles. The Air Force still has 450 B-52's, in addition to twenty FB-111's, but the emphasis is changing from bombers to missiles; the B-52 fleet is shrinking because of age and obsolescence—the last B-52 was built in 1961. Poseidon, which has greater range than the Polaris missile, will be equipped with as many as three independently targeted re-entry vehicles (MIRV's). The Minuteman III is also coming in fitted with MIRV's. Development is proceeding on a still longer-range sea-launched missile system (ULMS), the supersonic B-1 as a replacement for the B-52, and a new airborne continental air-defense system known as AWACS.

A budget in search of a premise

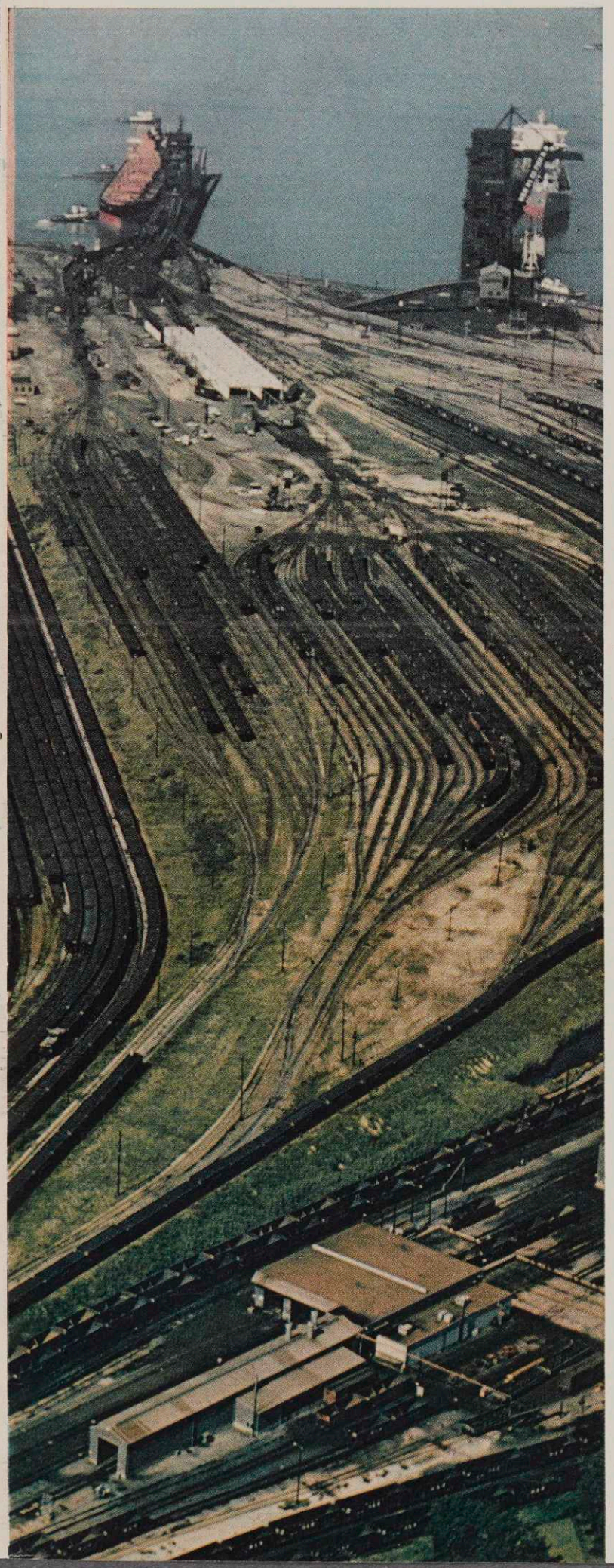
Ranking Pentagon officers, aware of the political realities that are forcing down the defense budget, speak understandingly on the record of the Administration's need to hold down the budget deficit and at the same time find additional billions for domestic programs. But off the record they, like senior force commanders from Germany to Hawaii, believe that the drawdown of conventional forces is unwise. Where they tend to look at enemy *capabilities* in determining what forces the U.S. should have, they feel the White House is relying too much on enemy *intentions*, which involves making judgments about unforeseeable political factors. To them, the Nixon defense policy boils down to a budget in search of a premise.

In general, the military commanders see danger in reducing our conventional forces at a time when Soviet conventional forces, especially the submarine fleet, are being increased. As one Army general explains: "A President hasn't the options to meet confrontations he had in the 1960's, because the nuclear superiority isn't there. As nuclear warfare becomes a less feasible alternative, we must be prepared to meet probes in the Middle East and elsewhere with general-purpose forces." But, this general contends, the cuts in these forces make it more likely that the need will arise to resort to tactical nuclear weapons. So the threshold of nuclear war is lowered.

Military planners are concerned, too, that power vacuums will develop as U.S. forces are withdrawn from the Far East. They note the new presence of Soviet naval forces in the Indian Ocean, coincident with the withdrawal of British forces. Major General William Knowlton, who served in Vietnam before becoming superintendent at West Point, asks, "How do we make the North Koreans and Chinese think we are serious about our commitment when we withdraw troops? The numbers being taken out aren't as important as the message we are sending."

continued page 166

"ENERGY CRISIS"



The era of cheap fuel is over. And an unhappy convergence of events threatens a bleak winter for utilities, industry, and homeowners.

by Lawrence A. Mayer

For the next two years and possibly longer, U.S. industry and U.S. consumers will have to live with an unprecedented power and fuel shortage. Easterners got a taste of things to come in September when an unexpected period of hot weather caused power shortages and brownouts from New England to the Carolinas. Already a number of utilities are refusing to take on new industrial customers. So short are supplies of fossil fuel that proposals have been made to cut back drastically on coal exports, and the wisdom of the oil import policy is once more being questioned.

Everywhere there is talk of an "energy crisis," and some emergency measures, such as the importation of additional Canadian crude oil, have been suggested. The competition for available fuel is adding measurably to inflation; in September fuel and power accounted for more than half of the increase in the industrial commodity index. With demand for energy continuing to grow at a rate of more than 4 percent a year, it is a safe bet that the era of cheap power in the U.S. is over.

Such marked changes in the cost and supply of energy raise grave questions about the long-term adequacy of fuel supplies. Senator Jennings Randolph of West Virginia, a state whose economy is heavily based on coal mining, has introduced a bill that would create a National Commission on Fuels and Energy. The commission would be charged with studying fuel resources and demands as well as government policies relating to energy. Mayor John Lindsay of New York, where citizens have learned to live with power interruptions since the great blackout of 1965, insists that only the federal government can ensure adequate supplies of fuel. Such proposals would have been unthinkable a few years ago, when fuel supplies were so plentiful and the energy system so resilient that interruptions in the supply of fuel or power were almost immediately rectified. But the past year has seen a series of events that seems to substantiate the rueful claim of physicists that Murphy's Law—"What can go wrong, will go wrong"—is at work in the world.

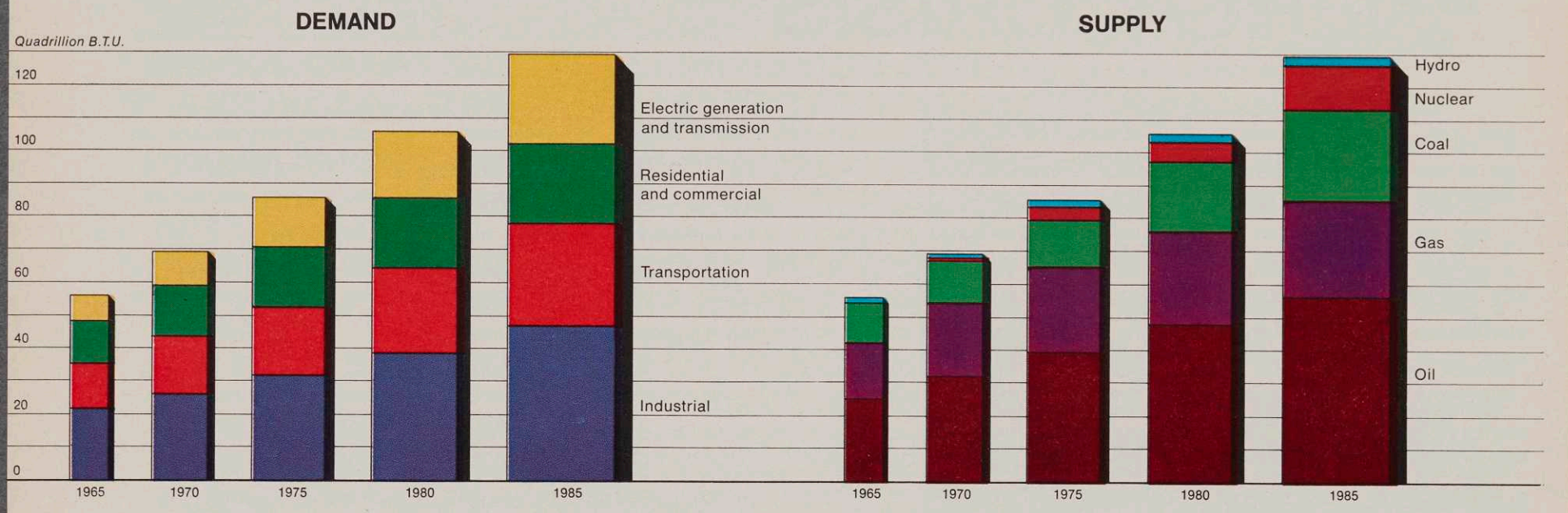
▶ A critical shortage of fuel oil has developed in New England because many utilities and industries have made a rapid switch from coal to oil. Even though there are no

Research associate: Lucretia McCalmont

A tide of hopper cars flows into Norfolk & Western yards at Hampton Roads, Virginia. Most of this coal is bound for foreign customers, while many U.S. utilities are worried about running out of fuel.

Chuck Rogers—Black Star

The Nation's Growing Energy Requirements



import quotas for residual oil on the east coast, a shortfall of 125,000 barrels a day could occur this winter.

▶ Natural-gas producers are unwilling to tap new reserves until they receive a substantial rate increase from the Federal Power Commission. Moreover, present pipeline capacity is stretched almost to the limit.

▶ Electric utilities have been unable to keep up with demand, which has been increasing at an annual rate of 7 percent or more because of delays in the construction of new generating plants. And the utilities appear to have reservations about the economic advantages of nuclear power. Only seven nuclear plants were ordered last year, compared to thirty-one in 1967. Suppliers of fossil fuel will therefore have to strain mightily to supply coal and oil to conventional steam generating plants in the last half of the Seventies.

▶ Coal companies that curtailed expansion of mining capacity because of the competitive threat of nuclear power are now swamped by new orders from the utilities. But a dramatic increase in coal production is unlikely because of the lead time in opening new mines, a shortage of labor, and stringent new federal health and safety laws.

▶ A worldwide tanker shortage, which may not ease until 1973, has doubled spot charter rates in two years.

There is now a growing realization in industry and government that this chain of events was in part caused by the national uproar about pollution. When the federal government issued guidelines for cleaner air, local communities enacted stringent regulations that brought a dramatic upsurge in demand for cleaner fuels. In general these regulations specify that only low-sulphur fuel—i.e., coal or oil whose sulphur content is 1 percent or less—should be burned in power plants and factories. Users who formerly burned high-sulphur fuels were forced to seek cleaner varieties. (See "The Long, Littered Path to Clean Air and Water," FORTUNE, October.) The sudden upsurge in demand brought about whopping increases in the price of low-sulphur coal and residual oil. It also gave natural-gas producers a new and persuasive argument for a price increase, since gas contains little or no sulphur. Altogether the resulting shortages of clean fuel have become so severe that many municipalities—particularly those in the East—are being forced to wink at their antipollution regulations. Many industries and utilities are now allowed to burn virtually any grade of fuel they can lay their hands on. Some users, for the moment at least, are living dangerously on low stocks. Some can't even get bids from suppliers, and others can't afford to pay the prices demanded.

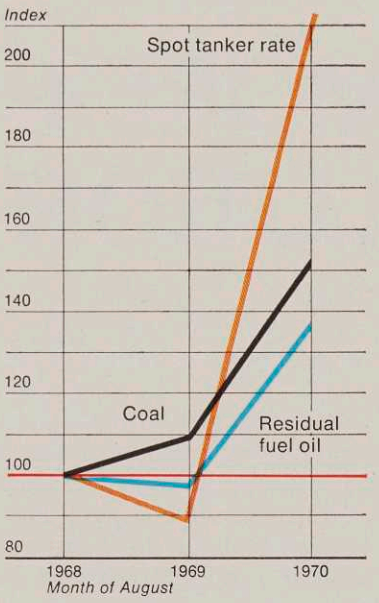
Buyers seeking low-sulphur coal find themselves competing with metallurgical industries, which also use that kind of coal. And here, too, the supply is limited. Much of the metallurgical coal comes out of the captive mines of large users such as U.S. Steel, and thus never gets to market at all. Moreover, most deposits of low-sulphur steam coal are in the West, particularly in Wyoming, and the transportation charges to the Midwest, where the coal is particularly needed, are as high as $10 a ton. Nevertheless, the shortage is so severe that some Rocky Mountain coal is now being sent as far as Chicago.

The high cost of sabotage

One of the most pressing energy problems is the lack of residual fuel oil, a grade used mostly by utilities and industry. Demand for residual grew at an annual rate of only 1.9 percent from 1959 through 1968. Now that growth rate is around 12 percent, largely because of the lack of sufficient coal, natural gas, and atomic energy, and because antipollution laws put a premium on low-sulphur residual. Around 93 percent of all residual coming to the East is imported, mostly from Caribbean refineries. This reliance on imports puts the east coast at the mercy of oil supply and transportation conditions abroad. Domestic refiners such as Humble, Gulf, and Mobil will augment supplies by increasing their production of residual oil this winter.

The closing of the Suez Canal and a worldwide shortage of tankers have sharply increased the cost of transporting residual and indeed all petroleum products. The Trans-Arabian Pipe Line (Tapline), which carries Mideast crude to the Mediterranean for shipment by tanker to Europe, has been sabotaged and the Syrian Government has refused to permit repairs. With the Suez Canal blocked, this

PRICE CHANGES



The U.S. economy's energy demands will nearly double in the next fifteen years, as the bars in the chart at far left show. The biggest increase will occur in the generation and transmission of electricity, which should rise from 16 percent of total demand this year to 21 percent. In order to meet this demand a dramatic buildup in nuclear power capacity will be necessary. If all goes well, nuclear energy will supply 11 percent of power output in 1985. But this assumes that between 1980 and 1985 a giant 1,000-megawatt plant will come onstream every two weeks. The upward movement of key prices (right) is the result of the recent frantic bidding for fuel and transport. The types of coal and residual oil in greatest demand have risen even more than the chart suggests, because it shows the average price for all grades in the U.S. (Energy statistics were assembled by the Humble Oil & Refining Co.)

means that instead of moving through the Mediterranean, all Middle Eastern crude must go all the way around Africa by tanker. The tanker shortage became even more severe this summer when the Libyan Government curtailed oil production in order to force increases in royalty payments, and European oil companies were forced to charter additional tonnage to move oil from the Persian Gulf.

The tankerage required by these lengthened trips is estimated to be about six times the amount required before the Tapline was damaged. Spot charter rates are now higher than during the 1967 Arab-Israeli War, and the cost of shipping a barrel of oil from the Persian Gulf to Rotterdam has about doubled in two years, to nearly $2.60. Costs are rising comparably for shipments everywhere in the world. Low-sulphur residual bought on the east-coast spot market now costs around $4.10 a barrel, compared to an average price of $2.20 a year ago.

While eastern customers scramble frantically for low-sulphur residual fuel, supplies remain plentiful on the West Coast. There, under a special incentive built into that area's import-quota system, a refiner gets a ticket to import an extra barrel of crude for every extra barrel of low-sulphur residual he produces. Mayor Lindsay has proposed that the "bonus barrel" system be introduced everywhere to relieve shortages. In the Midwest, too, demand for fuel oil is increasing. This is a logical market for more Canadian crude if import quotas are increased.

Barring surprises—and in the oil business that is a very large assumption—the price of residual should start to move down after two or three years even if no special measures are taken. The tanker shortage is bound to be undergoing correction by then. The world's shipyards are now fully booked, and they have an unusually large number of orders for tankers. More tankers will eventually mean lower transport costs for residual. But understandably, Congressmen from New England, where the shortage of residual is especially severe and fuel costs are the highest in the nation, don't take that long a view of the matter. They are vigorously lobbying to get a major refinery built in their region.

As the fuel pinch tightens, the coal-mining industry is beginning to enjoy extraordinary prosperity. For example, the largest independent producer, Pittston Co., enjoyed profits in the first three quarters of this year that were nearly twice as great as for the same period last year. Because demand has climbed both at home and abroad, the price of coal has more than doubled in the past three years. The industry mined 631 million tons of bituminous in 1947 and got down to only 403 million tons in 1961; this year it will produce about 580 million tons. Until U.S. demand began to revive sharply about two years ago, coal men helped keep themselves going with a vigorous drive for exports. Now they enjoy the best of both worlds.

The margin that's "killing the utilities"

Coal operators have managed almost to double exports in the past ten years, to about 60 million tons. A basic factor is the sensational rise in Japanese steel output, forcing Japanese steelmakers to scour the world for more coal. Meanwhile, despite the steel boom in Europe, the major coal-mining countries there—e.g., Germany, France, and Belgium—are not anxious to expand production. All this was made to order for the languishing U.S. producers. In some cases Japanese buyers have even helped finance new mines or new equipment in this country. And foreign buyers have been willing to sign long-term contracts at prices that were once regarded as extremely generous. Observes Glenn Wilson, vice president of the Ferroalloy Divisions of Foote Mineral: "We used to think the Japanese were signing up for coal at ridiculous prices. They don't look so ridiculous anymore."

Though exports constitute only about 10 percent of total U.S. coal output, Donald C. Cook, president of American Electric Power, claims, "It's the 10 percent margin that is killing the utilities." Utilities like to have seventy-five to ninety days' supply of coal on hand, but at the most recent count, Cook's plants were down to an average of fifty-one days' supply, the Duke Power System to thirty-four days, and the Tennessee Valley Authority was down to sixteen days. TVA has even been trucking coal from one installation to another. If any of the threatened railroad strikes should materialize and last for more than a week or two, some big generating plants will surely have to shut down. A number of utility executives, including Cook, have urged a cutback on coal exports to levels that prevailed in the late Sixties. Senator Albert Gore of Tennessee has introduced a bill to that effect.

The fight over exports is bitter, and part of it involves the shortage of hopper cars. Cars have been scarce in part because domestic demand for coal has risen, and because some coal-carrying railroads can't afford to replace old cars. But hopper cars have also been scarce because coal companies have pushed exports as much as possible, thus causing cars to pile up at ports. "As many as 20,000 cars were at Hampton Roads at one time," notes an official of the Interstate Commerce Commission. The ICC has now issued orders to ensure that hopper cars are used more efficiently, and the Norfolk & Western, as well as the Chesapeake & Ohio, has instituted a permit system to send cars to Hampton Roads only when a specific ship is available. These measures are already improving coal deliveries. Cars formerly piled up at ports partly because mines sent loads down on speculation—i.e., to await export buyers at higher prices than could be had at home.

The spot rate on steam coal today ranges from $6 to $10. This puts the utilities in a bind in states where they cannot pass on higher fuel costs to users without going

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We don't have to choose between power shortages and ever dirtier air. Advanced technologies promise. . .

NEW WAYS TO MORE POWER WITH LESS POLLUTION

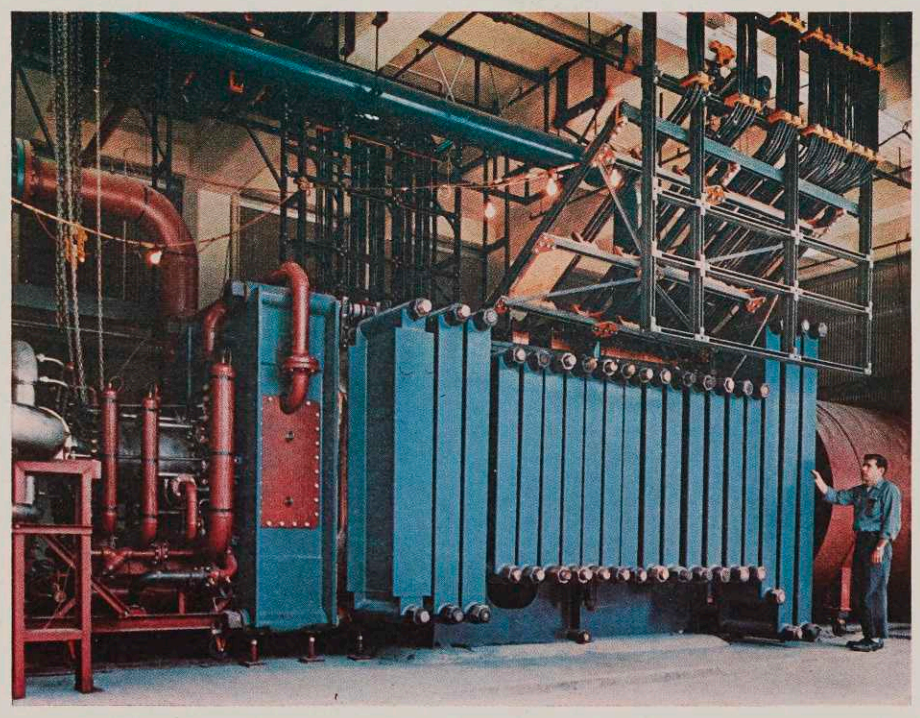
by Lawrence Lessing

As the pall of power dimouts and pollution creeps over the U.S., warnings are increasingly sounded, particularly by the utilities, that we must either do with less power or put up with more pollution. Some of the gloomier environmentalists go so far as to propose that the U.S. resign itself from here on to a lower standard of living. And the present "energy crisis" in fossil-fuel supplies, examined in the preceding article, may bring some taste of that. But these pessimistic views assume that basic developments in electric power are at an end. They ignore a great body of advanced, but largely neglected, technology that promises much more efficient ways of generating and transmitting electricity than those used at present, with much less pollution and defacement of nature.

Three major new power developments have come into view over the past decade, in science's almost prescient, self-correcting way. One of these—called magnetohydrodynamics—is a method of generating electricity directly from a supersonic flow of hot ionized gases; this has already been demonstrated on a practical scale. Another development, still in the conceptual state but based on known and tested technology, is a method of gathering solar power in space. And finally, entering into these and other advanced methods of handling power, there is the revolutionary development known as superconductivity, the carrying of electric current without resistance or loss. These developments form a complex, synergistic mix that could begin to raise electric power to an entirely new level of efficiency.

Efficiency is the key. The higher the efficiency of an energy system, the more usable power is produced per unit of fuel, and the less pollution and waste. Conventional steam power plants, after nearly a century of refinement, barely reach an efficiency of 40 percent; the rest of the energy from burning coal, gas, or oil goes off in waste heat, smoke, and such partial-combustion products, or pollutants, as oxides of nitrogen and sulphur. The steam-generating process, which currently accounts for over three-fourths of the nation's power, is essentially a ponderous three-stage mechanical system. Water is heated to high-pressure steam in a furnace boiler; the steam then spins a huge turbine, which in turn drives a big rotary motor generator, whirling a copper-wire armature through a magnetic field to produce electric current. Energy is lost at each stage, and more is lost in transmission lines. The whole system still reflects nineteenth-century attitudes that the earth's resources are so limitless that we can afford, as the shortest route to the greatest profit, to waste most of them.

Even more inefficient than conventional steam are the nuclear power plants. Contrary to popular impression,



ELECTRIC CURRENT FROM A HOT STREAM OF GAS

Production of electric power by means of "magnetohydrodynamics"—directly from a supersonic flow of ionized gases—was first demonstrated on a small scale in 1959 by Avco Everett Research Laboratory. By 1965, Avco had built the experimental Mark V generator (left), the first to put out useful amounts of power. Now Avco proposes construction of a full-scale prototype plant, which could burn coal, oil, or natural gas. The flow diagram (right) illustrates the principle of operation. The fuel, along with a "seeding" of potassium crystals to raise conductivity, is burned in the long, rocket-like chamber at 4,000° to 5,000° Fahrenheit, sending a high-velocity stream of conductive gases down the tube, which is ringed by a strong superconducting magnet. In its magnetic field a series of electrodes draws off current from the gases. Part of the hot exhaust gases are fed back to the burner, and part to an air turbine to get out still more power. An electrostatic precipitator then recovers the potassium "seed" from the stream for re-use, at the same time removing all particulate waste, while a chemical unit recovers usable nitric and sulphuric acid. The exhaust goes up the stack as clean gases, carbon dioxide and nitrogen.

they do not get electricity directly from the atom, but link a nuclear reactor to the old steam turbine. The reactor merely replaces the fossil-fuel furnace in heating the boiler. Efficiency reaches only about 30 percent, for only a small part of the nuclear heat is converted to electricity. The bulk of the heat, some 50 percent greater per unit of power than that from fossil-fuel plants, goes to waste in cooling water. While nuclear fuel eliminates nearly all air pollution, except for a minuscule amount of radioactive gases, the heated water, discharged into rivers, lakes, or oceans, raises the threat of thermal pollution and carries with it some additional radioactivity. By the year 2000, at the present rate of power growth, about a third of the average daily runoff of fresh water in the U.S. will be required to cool power plants. The excess heat raises the water temperatures around the discharge by ten to thirty degrees, with potentially disastrous effects on aquatic life.

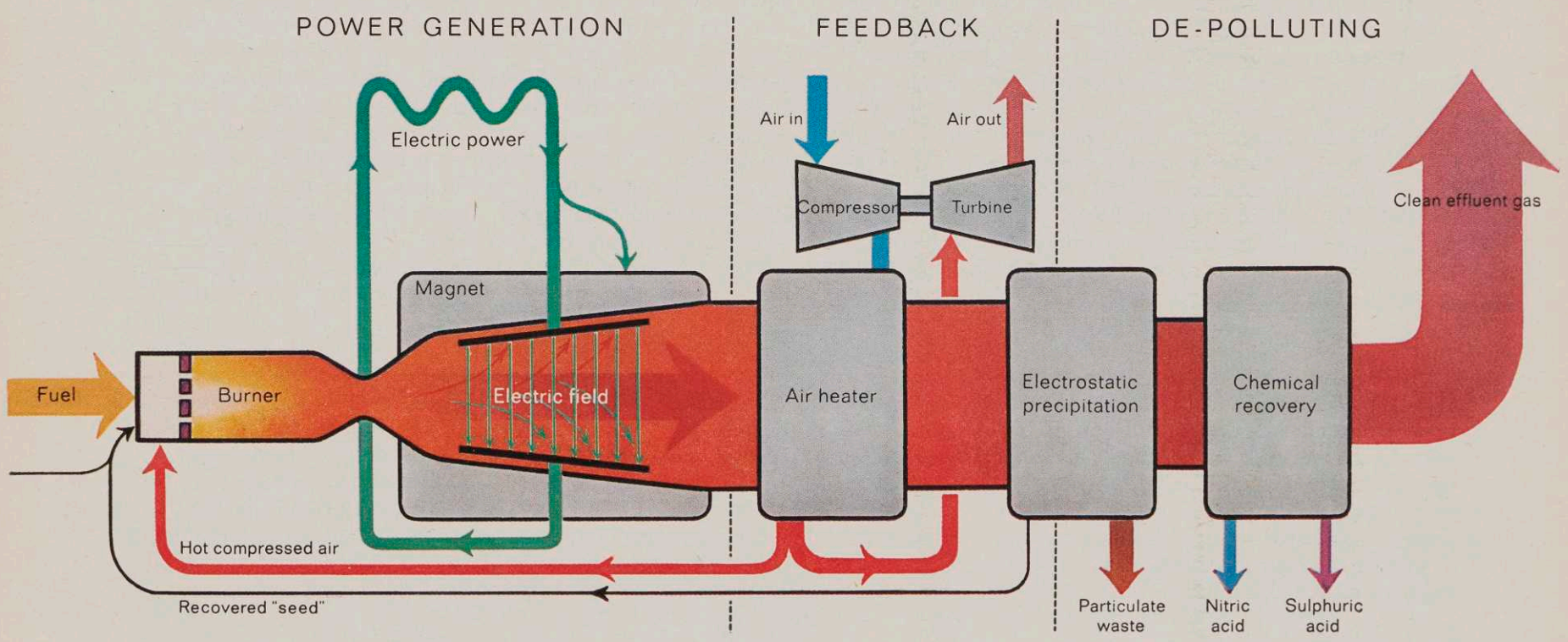
These are the dimensions of the current dilemma. Since U.S. power capacity is projected to double again by 1980 to more than 600 million kilowatts, the next decade is crucial. Even with the most energetic measures to reduce the more noxious pollutants from present systems—patchwork at best—over-all pollution will continue to rise with this massive increase in capacity. Only by developing radical, more efficient means of generating and transmitting electricity can the power industry begin to cut pollution at the source. Unfortunately, the most promising alternatives so far have had only meager support from either the industry or the government. And in the present deep recession in science and technology, largely induced by federal budget cuts and tight-money policy, most of the work has been at a standstill for over two years. None of these alternatives offer any instant solutions, for much hard development still lies ahead, but they need vigorous support now to meet the goals of 1980.

A way to overcome resistance

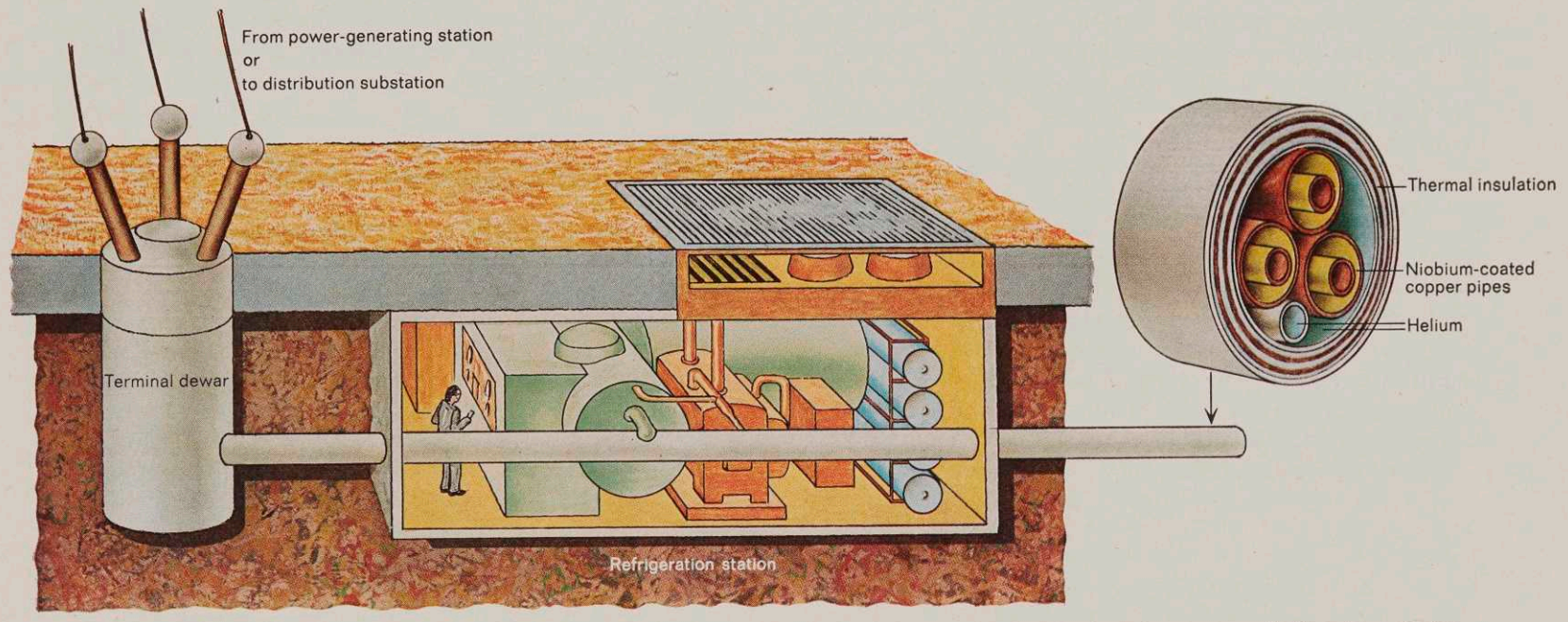
The most basic of the forward-looking developments, running like a thematic thread through all of them, is superconductivity. In 1911 the Dutch Nobel Prize physicist Heike Kamerlingh Onnes discovered that at temperatures near absolute zero (minus 460° Fahrenheit) certain metals suddenly lose all resistance to an electric current and become perfect conductors. That is, they carry current without any heat or other energy losses. Ordinary copper conductors, operating at normal temperatures in a power system, may run up cumulative current losses of 20 percent or more. Since conductors are the heart and arterial system of all electric equipment, this basic discovery of a means to carry power without energy loss early raised visions of revolutionary lightweight, highly efficient electromagnets, generators, motors, transformers, circuits, and transmission lines.

For more than forty years, however, superconductivity remained a laboratory wonder. All the elemental metals that were investigated and found to be superconducting, such as mercury, lead, and tin, carried so little current that they had no practical use. As increased current induced a higher magnetic field around the conductors, superconductivity was extinguished and the metals reverted to their normal conductive state. In 1953-54, however, physicist Bernd Teo Matthias, leading a research group at Bell Laboratories, discovered two bimetallic compounds that could withstand very high magnetic fields and therefore carry high superconductive currents. Both were compounds of the element niobium (also called columbium). One of them, niobium-tin, became superconductive at eighteen degrees above absolute zero, the highest transition temperature of any superconductor up to then. But it took nearly another decade to solve some of the basic technical problems posed by these complex new materials.

To reach the extremely low operating temperatures required, even by niobium-tin, it was necessary to bathe the superconductors in liquid helium, the coldest of liquefied gases at minus 452° Fahrenheit. This was a strange, forbidding region, not yet adapted to industrial uses. Moreover, the new superconductors themselves were strange, brittle materials, difficult to fabricate. It took seven years to develop methods of forming niobium-tin wire, and longer to discover that the materials operated best in or on a copper matrix, which served as a support and as a heat sink and shunt in any disruption of the superconducting



TRANSMITTING POWER WITHOUT LOSS



This is Union Carbide's conception of a superconducting transmission line for conveying huge amounts of power with virtually no loss. Current would be carried by a thin film of ultrapure niobium, electroplated on three copper pipes, and cooled to minus 452° Fahrenheit in liquid helium. The helium would be recycled from refrigerating stations spaced about five miles apart. At each end, apparatus enclosed in big dewars, or thermos bottles, would adjust temperatures—cooling cables that bring power from the generating station and warming up conductors that lead to distribution lines.

current. Efforts to get the materials into working circuits and machines encountered further problems. Researchers found that the superconductors carried only direct current without loss; when carrying alternating current, they ran losses nearly as high as in conventional copper. After the first burst of enthusiasm, many laboratories dropped out. Gradually, however, the problems gave way.

The first major use of superconductivity, employing one of its more magical features, was in electromagnets. Ordinary magnets of this kind are made of copper coils helically wound around an iron core, and require a constant and sometimes enormous input of direct current to maintain their magnetism. An electromagnet with superconductive coils, however, needs only one large injection of current, which then circulates in the coils almost endlessly without loss, so long as the coils remain supercooled. (Measurements on one coil indicate that the original current might run down in about 20,000 years.) Such powerful, economical magnets had an immediate appeal in high-energy physics and other areas of research, and a small industry sprang up to supply magnets or materials.

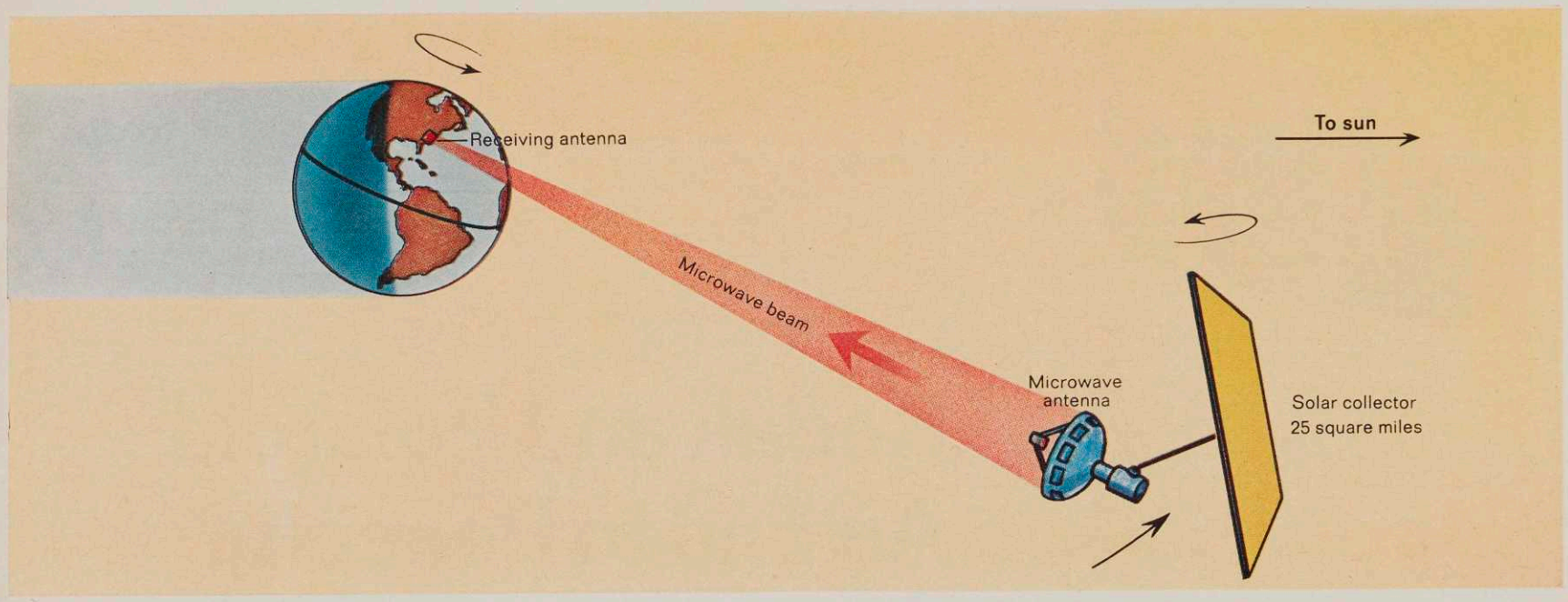
The biggest superconducting research magnet built thus far is a cylindrical giant, seventeen feet in diameter, which went into operation last year in the Argonne National Laboratory near Chicago. It is wound with some twenty-five miles of niobium-titanium copper strip, supplied by Norton Co., and generates a powerful magnetic field around a bubble chamber. A conventional magnet of the same capacity would have required 10 megawatts of power, enough to supply a good-size town, plus thousands of gallons of cooling water per day. The Argonne magnet requires only 300 kilowatts, most of it to run its helium refrigerator, at a saving in power costs of $350,000 to $400,000 a year—which gives some idea of the scale of superconductor economy.

Electromagnets are not confined to esoteric uses in laboratories; they are basic to all power production. Potentially, superconducting magnets could markedly raise the efficiency of generators, transformers, and motors, while greatly reducing their bulk and cost. In addition, as will be seen later, they are indispensable for developing new and cleaner forms of power generation, more efficient nuclear systems, and ultimately thermonuclear power. Yet the U.S. has done relatively little research and development in these industrial directions. Honors for the first industrial-scale development go to Britain, where this year International Research & Development Co., Ltd., installed in a power plant a 3,250-horsepower superconducting DC motor to pump water; it is the forerunner of lighter, more advanced designs for other heavy industrial uses. James Watt's famous steam engine, which powered the first industrial revolution, began with the same sort of task, pumping water from mines.

A refrigerated magnet

A more immediate and greater role for superconductivity, many believe, lies in power transmission. Big losses of current are sustained in the distribution of power from central stations; superconductive lines could cut these losses, making more power available without added generating capacity and its accompanying pollution. The U.S., moreover, has done more basic work on superconducting cables than on generators or motors, largely through the efforts of one company, Union Carbide Corp.

GENERATING POWER WITHOUT FUEL



This idea for getting nonpolluting solar power from space was worked out by Dr. Peter Glaser, head of engineering sciences at Arthur D. Little, Inc. Glaser put together electronic and space technology already in existence. The collector, five miles wide on each side, is an array of solar cells in stationary synchronous orbit. The cells convert sunlight to electricity, which is transmitted by superconducting cable to a microwave converter. An antenna beams the microwave energy to a receiving grid on earth, where it is converted to usable power, enough for a city the size of New York.

Carbide had a basic interest in superconductivity from the start of Matthias' work with niobium. Its mining and metals division is the country's largest producer of niobium, a lustrous gray metal, long used as an alloy in stainless and tool steels. The Linde division is the leader in liquefied gases of all kinds and in cryogenic techniques. In the great acceleration of research on cryogenic liquids for fueling rockets and supporting space vehicles, Linde developed superinsulating materials to contain the liquid gases at their frigid temperatures almost indefinitely, with only slight losses. Such extremely low-temperature fluids as liquid helium and hydrogen became industrial materials, shipped by tank car, and handled with no more difficulty than other materials. Carbide therefore had no inhibitions about considering the use of liquid helium to supercool miles of superconducting cable.

The big problem was that in the U.S. nearly all electric power is transmitted as alternating current, which none of the superconductors then known could carry without excessive loss. Outside the U.S., high-voltage DC power transmission has had a wide resurgence in the past decade (see "DC Power's Big Comeback," FORTUNE, September, 1965). It can carry bulk power more economically than AC over long distances, underground, or underwater, and link big power grids more securely. So far, however, the only DC transmission line in the U.S. is the Pacific Intertie, which shuttles power between Oregon and southern California. In other areas, utilities say, conversion of DC to AC for local distribution would be too costly, though economical solid-state converters are available. A superconducting DC line would offer the ultimate in transmission without loss, but utilities show little interest.

To make superconductive power transmission feasible in the U.S., Carbide scientists began a search in the early Sixties for a superconductor that could handle AC. By 1967 they discovered that a thin film of ultrapure niobium, electroplated on a copper backing by a special process, carried AC with extremely low losses. Moreover, this film could carry some twenty-five times more current than the largest copper cable. So promising was the discovery that the Edison Electric Institute commissioned Carbide's Linde division to make a study. This culminated early last year in the successful demonstration of an experimental twenty-foot-long, supercooled cable. Potentially one full-scale, 345-kilovolt superconducting line, twenty inches in diameter, could carry more power than is now used in all of New York City. It would take twenty-two conventional cables, ten inches in diameter, to carry the same amount of power.

Underground advantages

Projecting such a development into a transmission line, however, is a complex technical exercise. The calculations have to weigh savings in current against capital costs. Superconductors entail the added expense of refrigeration, and moreover must run underground for the most efficient operation. At present power loads, niobium cable could not possibly compete in cost, at least at the start, with conventional overhead bare-copper transmission lines, which at high voltages minimize loss of current. But underground, niobium could show immediate advantages over conventional underground cable, which costs about ten times more per mile than overhead lines, and is limited to lower voltages with much higher current loss. Losses

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Diagrams by Max Gschwind

Kodak and Polaroid: An End to Peaceful Coexistence

Both companies are threatening to assault each other's market strongholds. It could be a war everybody wins.

by Philip Siekman

Confronting each other at the top of these pages are the only still cameras manufactured in any quantity in the U.S. On the left is the latest version of Eastman Kodak's easy-loading Instamatic, a product line so successful that one must look back to Singer's foot-powered sewing machine or Hoover's vacuum cleaner for a comparable example. On the right is the Colorpack II Polaroid Land camera. Some 70 percent of the still cameras bought in the U.S. are either Instamatics or Polaroids, ample measure of the domination their makers hold over the $2-billion amateur-photography business.

Up to this point the relationship between Kodak and Polaroid has been an impressive demonstration of peaceful coexistence. Almost as though they were in different industries, the two companies have commanded separate monopolies; neither has intruded to any great extent on the other's terrain. Polaroid has waxed strong doing its thing, one-step or instant photography, without sign of a serious competitor. Kodak has prospered doing practically everything else in photography; it towers so impressively over the core of its business, conventional amateur cameras and film, that it is difficult to understand why anybody else bothers.

This pacific duopoly was, in large part, dictated by necessity. Kodak could not find a way around Polaroid's high, broad patent wall. Polaroid could not make a camera that was foolproof enough, portable enough, or cheap enough to compete on even terms with Kodak's easy-loading Instamatics. Nor did either company have much cause to take on the other in battle. During the Sixties both grew rapidly, mutually benefiting from the increase in disposable income, in leisure time, in travel, and, above all, in that favorite photographic subject, babies. Polaroid had about all the growth it could handle, yet its business still looked too small to Kodak, which is physically and psychologically committed to volume production.

Now, however, the Kodak-Polaroid arrangement verges on dissolution. These two powerful, skillful companies are turning—slowly and reluctantly to be sure—to face each other across the broad expanse of the business. Polaroid has reached such size that continued substantial growth probably can be obtained only by penetrating deep into the mass, "Get the baby in the bathtub, Harry," market that is Kodak's prime territory. Polaroid has made forays into Kodak's heartland, the market for simple cameras selling for $20 or less. And in three new factories within an hour's drive of its headquarters in Cambridge, Massachusetts, it is moving with a sense of urgency and in an atmosphere of secrecy toward production of a totally new camera and film that it describes in terms Kodak has to consider ominous.

Meanwhile, back in Rochester, Kodak is gathering its forces for defense and counterinvasion. It has finally—belatedly, some would say—decided that in-camera processing not only is here to stay, but promises to be a big enough market to warrant serious attention. For about a year Kodak has been making confident promises to develop and market an alternative to the Polaroid system at some unannounced point in the near future.

A contest of equals

Kodak's size and reputation are so great that many investors apparently assume the tide of battle must eventually swing against its smaller rival. Although Kodak had neither product nor timetable, its announcement last December of an interest in instant photography helped

NEW WAYS TO MORE POWER WITH LESS POLLUTION *continued from page 81*

in underground copper cable run about twenty times higher than in superconducting niobium. At higher voltages, conventional cable requires water, oil, or other forms of cooling to reduce excessive losses. Some electrical manufacturers are pushing development of an ultrapure copper cable cooled by liquid nitrogen; though not superconducting, it would increase current tenfold. But pure niobium more than doubles this, at only somewhat higher cost.

The economics of superconductivity, in transmission lines as well as in generators and other equipment, will not really be known until larger-scale developments are worked out. Carbide last year proposed, at the Edison Institute's request, an $8-million program to build a short three-phase superconducting line for field tests. But money to meet more immediate utility needs has been so tight that so far no funds have been forthcoming. Since the project will require two to three years of research and development, and some ten years to build the line and establish its reliability to the utilities' satisfaction, delays now could put off completion of the test until the mid-1980's or later. Meanwhile, as power loads continue to climb, as more new power plants are forced to locate farther away from center cities to reduce urban pollution, as more and longer transmission lines to bring the power in are forced underground by aesthetic as well as practical land-use considerations, the need for superconductive power-carrying capacity will become urgent.

Space-age power

In much the same stage of development is magnetohydrodynamics, or MHD (see diagram, page 79). The basic principle goes back to 1831 and Michael Faraday's historic discovery that the movement of a conductor in a magnetic field induces a current in the conductor. But MHD became feasible only with the intensive development of gas dynamics and high-temperature materials in rocket and aerospace technology. In place of the copper-wire armatures in rotary generators, MHD substitutes a high-velocity stream of hot, conductive gases in a long, rocket-like tube, surrounded by electromagnets. Current is continuously drawn off by electrodes along the length of the tube. MHD reduces the three stages of the steam-generating cycle to a single continuous process, requiring no turbines or other moving parts. Operating at 4,000° to 5,000° Fahrenheit, well above steam temperatures, it has a potential efficiency of close to 60 percent.

MHD, like superconductivity, stirred great initial enthusiasm a decade ago. But the first crude apparatus produced disappointingly low power, and as the problems of development stretched out, interest waned. Both General Electric and Westinghouse did some early work on it, but, as monopolists in the production of heavy steam-turbine generators, they displayed no great fervor and soon dropped out. The only developer to stick stubbornly with MHD through the decade was Avco Corp., largely through the initiative of its research director, Dr. Arthur R. Kantrowitz, an authority on high-temperature gas dynamics. In 1959 Avco demonstrated the first small MHD generator, delivering 10 kilowatts. Step by step, to reach higher outputs, the rugged components were developed to contain MHD's blasting hot temperatures. By 1965, in a joint $10-million development program with a utility group led by American Electric Power, Avco had solved most of the basic problems, and with Defense Department support had built a pilot generator, the Mark V. It achieved for short spans an electrical output of 32 megawatts (32 million watts), the highest up to then.

Mark V was designed for only short-term operation, sufficient to prove its ability to reach the megawatt range. Smaller generators had been operated for hundreds of hours in the kilowatt range to prove long-term reliability. The next step was to build an experimental MHD base-load plant, closer in scale to commercial operation, combining both high and continuous output. All the components were in hand, save one. Mark V was forced to operate with conventional electromagnets, and sustaining their magnetism consumed some 8 megawatts of the MHD power produced. For economic, full-scale power generation, an MHD base plant would need superconducting magnets. Foreseeing this, the Kantrowitz team dug into superconductivity and came up with some basic developments. It pioneered the use of a copper matrix to develop a strong niobium-zirconium strip. And, concurrent with the Mark V development, it built an experimental superconducting magnet, five feet long and twelve inches in diameter, the largest up to then, which demonstrated the feasibility of large superconducting magnets for MHD.

In 1966, therefore, Avco proposed to build a 30-megawatt MHD prototype base-load plant. The utility group agreed to raise some $13 million for it, providing the federal government put up a matching sum. But federal funds were denied, and the utilities withdrew. Avco doggedly continued its MHD work in other directions. That same year, as an outgrowth of its Mark V generator, the company installed at the Air Force's Arnold Engineering Development Center a similar but advanced MHD unit to supply short bursts of peak power to operate a hypersonic wind tunnel. The practical success of this unit moved a group of New England utilities and Edison Electric Institute to join with Avco last year in a program to develop an MHD generator with a longer operating span to meet emergency or peaking demands in power systems. The MHD unit has the advantage of high capacity, at about half the capital cost of a gas-turbine standby system. But progress toward an experimental MHD plant for primary power generation—which might now be operating and ready for commercial development—has been virtually halted since 1965.

Meanwhile, progress in MHD has been moving much faster in other countries, particularly West Germany, Japan, and the Soviet Union. Indeed, next year the Russians, whose engineers were attentive participants in all the early MHD symposia, will take the lead by bringing onstream the world's first large-scale MHD prototype plant, now nearly completed.

A flaming cut at pollution

Only in the last few months has MHD surfaced again in the U.S. on the rising tide of concern over power and pollution. An obscure ripple had appeared more than a year ago when a special panel of the President's Office of Science and Technology delivered a report entitled "MHD For Central Station Power Generation: A Plan For Action." It called for a "modest R. and D. effort of several million dollars" to determine whether a large prototype plant should be built, and about $4 million in annual funds to continue research. But the panel had been convened by the previous Administration, and its report, couched in terms not likely to penetrate the average density of the political mind in Washington, was ignored.

Nevertheless, implicit in MHD from the start was a generating system, the only substantial one on the horizon, that promised greatly reduced pollution from fossil fuels.

continued page 132

NEW WAYS TO MORE POWER WITH LESS POLLUTION *continued*

Because of its very high and concentrated operating temperatures, MHD promotes more complete combustion of hydrocarbons, producing about one-third less effluent from its stack than a conventional power plant of the same capacity. Because the MHD process requires the "seeding" of its gas stream with potassium crystals to enhance conductivity, and this "seed" must be economically recovered at the outlet for re-use, it has a built-in recovery system that can also be designed to remove nearly all particulate matter, as well as nitrogen and sulphur pollutants. Because MHD needs no cooling water to condense steam, it discharges no thermal pollution into bodies of water but dissipates its waste heat into the air. And since MHD produces more power per pound of fuel than steam generators, it could show a substantial saving in fuel. The Office of Science and Technology study estimated that development of MHD could effect a fuel saving at present coal prices of some $11 billion between 1985 and the year 2000, thus cutting costs as well as pollution.

These advantages were reviewed with some bite late last year when Arthur Kantrowitz appeared before a Senate subcommittee hearing on emerging power techniques. The sensible course of development as he saw it, since five years had been lost on the larger project, was to press on with construction of an MHD plant of the intermittent type for emergency and peak-power use, which would meet an immediate economic need, lay the foundation for a viable MHD industry, and provide additional technology for a full-scale MHD power plant. One of the major missing links is a more efficient method than is now available for recycling MHD's hot exhaust gases back into the system to get out the ultimate amount of power. The first MHD plants are therefore likely to be hybrids. The Soviet MHD unit is coupled at the exhaust end with a steam turbine to wring additional power out of the still-hot gases and reach a total of 75 megawatts. Such a hybrid will use less than half the cooling water of a conventional steam plant of equal capacity, and could have other nonpolluting features. Alternatively, MHD can be coupled to an air or a gas turbine, which would reduce water needs to virtually zero. Later, as more efficient means of recycling are found, MHD would reach peak efficiency on its own.

A forerunner of thermonuclear power

Despite these prospects, all that came out of that Senate subcommittee hearing was a $600,000 appropriation from the Department of Interior, promoted by western Senators, to investigate the burning of low-grade western coal for MHD power. This is hardly enough to get such a study off the ground. To bring MHD to its present stage, Avco has obtained contracts for $13 million, and has spent some $4 million in risk money of its own. Avco's work has shown that the use of powdered coal as a fuel is feasible, but presents such difficult problems of corrosion, erosion, and ash deposit that the better strategy would be to move first on cleaner, more easily handled oil or natural gas. But there is no over-all U.S. energy policy or strategy for following up such promising developments as superconductivity and MHD.

Yet MHD's significance goes well beyond getting more power with less pollution out of conventional fuels. The MHD principle also applies to the development of more efficient nuclear power plants. This application involves a different type of system, called closed-cycle MHD, on which various laboratories are working. Instead of getting power from a stream of combustion gases that pass through the apparatus and out the stack, closed-cycle MHD employs a high-velocity stream of liquid metals or helium gas endlessly circulating in a closed coil of pipes or tubes, heated by a nuclear source. Electric current is drawn off in a high magnetic field, as in open-cycle MHD. So far these closed systems are being applied only to small nuclear power sources for military and space uses. But they can be scaled up, once more advanced high-temperature or gas-cooled reactors are developed, to replace the inefficient steam turbine in converting nuclear heat to electricity; this would eliminate the great burden of waterborne thermal pollution. When and if sustained thermonuclear power is achieved, it will be by a further extension of MHD. For MHD is the intermediate step toward a thermonuclear generator, in which an ultrahigh-temperature stream of hydrogen gas in an ultrastrong superconductive magnetic field will be fused into helium to produce electric current.

There is no lack of imaginative developments to solve the twin problems of power and pollution, given the will to pursue them. One of the most provocative is a scheme presented two years ago by Dr. Peter E. Glaser, head of engineering sciences at Arthur D. Little, Inc., for wresting electric power directly from the sun. He proposed development of a large space platform, composed of a mosaic of solar cells, that would convert sunlight to electric power (see diagram page 81). A flexible superconducting cable, two miles long, would convey the power to a satellite station, where it would be converted to microwave energy for transmission to earth. There it would be reconverted to usable power. All the working elements for such a system are here or close at hand.

Glaser calculates, in a recently refined systems study, that a thin, five-mile-square array of solar cells in stationary orbit some 22,300 miles above the equator could transmit enough power (10,000 megawatts) to supply New York City. The receiving antenna would have to be six miles in diameter, but it would consist of a flat, open mesh of wires, under which cows could graze, for its power density would be only one-tenth that of sunlight reaching the earth. All together, Glaser's calculations indicate, power could be delivered to earth at a capital cost of about $500 per kilowatt at the start, compared to $140 to $280 a kilowatt for steam power, about the same for MHD, and $200 to $400 for present nuclear plants. But "fuel" would be free and pollution nil.

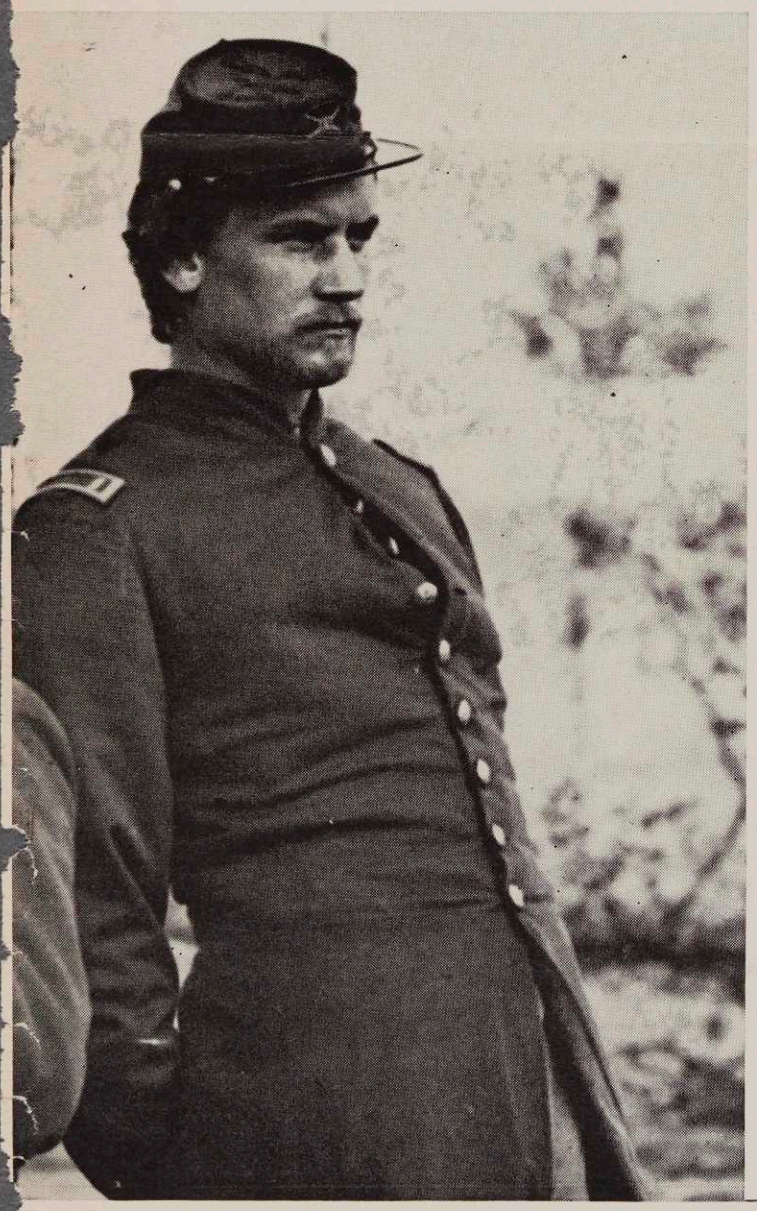
This cost estimate is contingent on NASA's launching a space station and space shuttle service, which would reduce the cost of lifting bodies into orbit to $50 per pound. It also assumes development of techniques for fabricating large structures in space, on which the Soviets have made a start but the U.S. has not. The space program has now been so deeply cut, however, and has fallen so far out of favor with Congress, the Administration, and a distracted public, that it would be unrealistic to foresee construction of an experimental solar-power station much before 1985–90. A common plaint against the space program is that it has had few, if any, industrial spinoffs. But it already has greatly contributed to all these advanced power techniques, as well as to other forward technologies; the hitch is that they are not being industriously pursued and used.

The developed-country problem

It may well be asked why anything so far out as solar power from space is worth considering, since more advanced nuclear plants are coming along and the Atomic Energy Commission predicts that they will be providing half the total electric power by the end of the century. But projected energy needs in this period are immense, both for the U.S. and for the rest of the world if it is to reach any measure of equality with the U.S. Most authorities agree that the

continued page 136

been a time didn't have problems?



Little more than a hundred years ago, this country was torn apart by a war that turned fathers against sons, brothers against brothers. Yet we endured. Forty years ago, a depression shattered the security of millions of citizens. Yet we endured. Today we're facing some of the most serious problems in our history. But perhaps the most serious problem of all is a loss of faith in our ability to endure.

In times like these, newspapers have an even greater responsibility to the people. We, at Knight Newspapers, are very aware of that responsibility as we meet the day-to-day challenge of reporting news fairly, fully and honestly. We know that we have a duty to inform our readers . . . not to overwhelm them. To give them all the news . . . and to give it in its proper perspective. That's why we look for—and foster—this sense of responsibility in our newspapers. And why we provide an atmosphere of innovation, creativity and professionalism to help them effectively inform the communities they serve.

Life has never been simple in this country. It never will be. Each new generation will face a new set of problems. But as long as we sustain faith in ourselves as a nation, we will not only endure . . . we will prevail.

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NEW WAYS TO MORE POWER WITH LESS POLLUTION *continued*

world will need to develop every available source of power, especially nonpolluting ones. This includes not only solar power, but also geothermal power (see "Power from the Earth's Own Heat," FORTUNE, June, 1969), generating electricity from hot water and natural steam trapped in the earth's crust.

To develop all the cleaner alternatives would take a sizable amount of money, but nothing like the more than $2 billion in federal funds spent so far to bring nuclear power to commercial status. It has been estimated that an investment of at least $500 billion will be required by the year 2000, in both conventional and nuclear power, to meet U.S. energy demands. With the preservation of clean air and water becoming a part of capital costs, the increasing added expense of antipollution devices, cooling towers, and the like should broaden the incentives for developing more direct alternatives. For, while conventional steam power is almost at the end of its development, the newer systems, such as MHD, are only at the beginning of theirs, in a position to make wide strides toward cleaner, more economical power systems.

So far the total amount of money spent on the new developments has been minuscule, considering the size of the problem and of the industry involved. It is noteworthy that the recent innovations were made not by the electrical industry proper, but by aerospace, chemical, and electronic interlopers. The electric-utility industry itself spends less than one-quarter of 1 percent of its operating revenues on research and development. And most of this, except for some token grants to advanced research projects, goes merely to improvements in present systems.

The government's support is little better than the industry's. Research spending in fiscal 1970 amounted to about $350 million, of which some 85 percent went directly to nuclear energy and the rest was thinly scattered elsewhere. Glenn Seaborg, Chairman of the Atomic Energy Commission, has said that someday using the heat of nuclear fission with MHD may produce spectacular results. More recently, before an international meeting of scientists, he unfolded a dazzling vision of a worldwide grid of electric-power generation and distribution via satellites, microwaves, laser beams, and superconducting transmission lines. But neither the AEC nor any other government agency is doing much to promote these promising developments, and the support of advanced research falls between the stools.

The problem of pressing new and beneficial technologies in a highly developed nation such as the U.S. is becoming more obdurate than any of the problems facing underdeveloped countries. The immense investment in the internal-combustion engine precludes any intensive development of the fuel cell or other electrical alternatives for a truly nonpolluting automobile. The dead capital weight of obsolete railroad and mass-transit systems, sucked dry, blocks the concerted development of advanced high-speed electric ground transportation systems, already appearing elsewhere in the world. And the U.S. electrical industry, which might be contributing to solutions in these areas, is showing some of the same capital inertia. The country that built the world's first central power station is now in danger of losing its leadership in the new level of technologies the times require. Snug in the complacency that U.S. technology leads all the world, the country has not kept its eye on the major index of modern industrial civilization—energy. END

AIR MAIL

JW7 10/19/70

(Provisional letter paper)

THE CLUB OF ROME

Rome, October 9, 1970
DAP/amp

Mr. Ralph P. Davidson
Associate Publisher
Time Inc.
Rockefeller Center
New York, N. Y. 10020, USA.

Dear Mr. Davidson:

I was very glad to meet you again the other day in Paris and I hope that by now you are well and back in New York.

As I mentioned during our conversation, The Club of Rome is trying to give an answer to many of the open questions which come to the mind of modern man when he sees the precarious state of his environment, society and perspectives. I will not give you at this moment more details about this truly multi-national, transcultural and interdisciplinary group of people, but I am of course at your disposal if you might be interested in knowing more. An idea of the kind of background thinking which supports their purpose may be given by the two articles in the Italian magazine 'Successo' I wrote recently, as per copies herewith.

As I also mentioned, The Club of Rome has just started 'Phase One' of a Project called 'The Predicament of Mankind'. Of its two main objectives, namely

(a) Acquire and diffuse a real in-depth understanding of the present critical state of human affairs and of the narrowing and uncertain perspectives and options which are likely for the future if present trends are not corrected.

(b) Recognize and propose new policy guidelines and patterns of actioncapable of redressing the situation and keeping it under control,

Phase One tackles only the first one, using a 'Systems Dynamics' methodology developed and tested by Prof. Jay W. Forrester of MIT and the best information as may be obtained from international agencies. To this effect, a pilot simulation model of the world with five main variables--population, capital investment, food production, natural resources, and pollution--and a number of ancillary variables--as many as the information support allows--has been prepared by

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Professor Forrester and now work is on for The Club of Rome at MIT, under the direction of Professor Dennis L. Meadows, to bring the model to a more advanced stage. You may be interested in glancing at the flow diagram of the pilot model ('World2') and a computer run made on a certain set of assumptions (see annexes). But if you are interested in knowing more about this unique effort to understand the interplay and gross impact of the multiple problems and situations which make the world so unstable and difficult, you have but to ask Professor Forrester or Professor Meadows, who will cordially invite you to have a look at what they have done and are doing at MIT in this connection.

Looking forward to seeing you in the near future, I am, with best personal regards,

Sincerely yours,

Aurelio Peccei

Enclosures

cc: Prof. Jay W. Forrester ✓
Prof. Dennis L. Meadows

GLOBAL PROBLEMS PUT TO COMPUTER

Group at M.I.T. Is Asked to Identify Critical Factors

By WALTER SULLIVAN
Special to The New York Times

ROME, Oct. 4—An extraordinary organization, known as the Club of Rome but with worldwide connections, is operating on the premise that the world's problems have become too complex and interrelated for resolution by the human mind.

It has therefore commissioned a group at the Massachusetts Institute of Technology, headed by a leading authority on systems analysis, to seek to program the world's problems and their interactions into a computer.

The members of the club—about 50 scientists, economists, management and system's-analysis specialists, educators and business leaders—do not expect this experiment, known as "World 2," to solve those problems. But they feel that only through the development of such techniques can the world ultimately be saved from the growing menaces of technology.

According to Aurelio Peccei, the Italian business leader and management specialist who is the central figure of the group, the goal of the computer experiments is not to predict the future but to identify what factors in the world situation are critical in determining the long-term evolution of civilization.

Mr. Peccei, who has long been on the management committee of the Fiat corporation, cited as an example a test run made when the computer program was still in a rudimentary stage. It showed, he said, that capital investment in industry is the controlling factor.

If the analysis reaches a stage where it is possible to identify the crucial factors and the effect on the future of various courses of action this information would then be made available to world leaders to help them in their decision-making, Mr. Peccei added.

Despite its name, the Club of Rome, which was organized in 1960, rarely meets there. Rather its sessions have been in Moscow, Tokyo and other centers. While Soviet specialists have sat in on some of the meetings and shown an interest in the project, they are not officially members of the club.

The members of the club's executive committee include Hugo Theimann, head of the Battelle Institute in Geneva, where the club is incorporated; Alexander King, scientific director of the Organization for Economic Cooperation and Development; Edward Pestel, head of teh Technical University in nover, West Germany, and Saburo Okita, who heads an economic research institute in Japan.

In its early stages the project was supported by the Agnelli Foundation in Italy. At the start of this year Mr. Peccei said $1-million was needed to carry on the work and he now reports that enough is in hand, thanks to the Volkswagen Foundation, a less grandiose counterpart of the Ford Foundation, to complete World 2 by next June.

Feresster in Charge

The computer study at M.I.T. is under the direction of Jay W. Forrester, professor of management, who has sought to use computer methods to attack the extremely complex problems faced by cities and large corporations.

"As our business organization and social systems have grown," he wrote recently, "they have become too complex for human judgment and intuition."

The thesis is that modern technology has suddenly made the world a single, extremely complex system with all its elements interdependent. No problem within that system, be it political economic or technological, can be solved, it is held by analyzing that problem alone.

At this point in history, Mr. Peccei said, "every nation and people has therefore acquired a vested interest in the solution of the principal problems of the others, lest, their degeneration contaminate the world system, and their own life. Some problems are of such complexity, he added that "no nation or conventional group of nations, however powerful, can singlehandedly resolve them."

If, however, the many problems of the world and their elements can be xpressed numerically and their interactions described by mathematical equations, then a computer can tackle them.

This, in essence, is what the M.I.T. group has been asked to do. World 2 is an elaboration of an earlier, skeletal effort known as World I, Plans for an even more ambitious attemp next year, to be called World 3, are to be discussed at a meeting of the club in Ottawa in April.

As described by Mr. Peccei in a recent interview, World 2 represents the state of the planet in terms of primary variables and 30 or moore subsidiary variables.

The five prime variables are world population, capital investment in industry, capital investment in food production, the world inventory of natural resources and the level of mans interference with nature, notably by pollution.

The interactions and feedback influences of these variables on one another are described in some 40 equations.

"The human mind," said Mr. Peccei, "can comprehend only two or three variables."

(Provisional letter paper)

THE CLUB OF ROME

Rome, October 17, 1970
DAP/amp

cc. IWF
JAS
GSB
JC

Prof. Dr. Ing. Eduard Pestel
Rector,
Technische Universität Hannover
Appelstrasse 24 B
3 Hannover, Germany.

Dear Eduard:

Thank you for calling me back today. We are nearing the VW moment of truth, and this is a very important moment not only for CoR but also for the ideals it stands for, because if we look around the situation is steadily worsening in many parts of the world--in Latin America, in the Middle East, in the Soviet Union, in East-West relations, and probably also in our Western countries or at least in our cities, in our universities, and in the environment on which our whole life depends. And, on the other side, the more we search the less we detect any effort in the world to clarify the nature of the very serious predicament in which mankind finds itself, and to understand its morphology and dynamics in order to organize a starting base for action. Therefore, having given to this matter a great deal of meditation, I am more convinced than ever that Phase One of our Project is in effect the only true effort currently on or envisaged as a first step in the right direction. I would like the VW responsible people, and the Curators who will take a decision November 4 and 5, to know that on them hangs a decision not for just another project, but for a project of vital importance. I know that it is up to Dr. Gambke, Dr. Zarnitz and to you to inform the Curators beyond what the mere Project papers circulated in advance can do. This time the CoR has limited its request of funds to what is a bare minimum--and a low amount at that--, has defined concretely the boundaries of the work, has the support of a well-tested methodology and software, and is using young German talents in its work team. Therefore, the VW expectations and conditions, I believe, have been rightly understood and met.

Moreover, as you know, the CoR is having a good deal of moral and technological support from international agencies. M. Philippe de Seynes, the UN under Secretary General who heads

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the Economic and Social Council (ECOSOC) and who is therefore responsible for the two major UN programs for this decade--the international cooperation in the ecology field, embodied mainly by the Conference on 'Man and his Environment', to be held in Stockholm in 1972 (and preceded by the Prague Conference here-below) and the 'Second Development Decade', which comes on the wake of the First Decade frustrations--is encouraging us all along the line, and is prepared to give us all support, provided that we are in business, namely that we carry out our Project. However, this support has already been materialized by a number of conferences with UN key officials and the supply of all the information they had available as appropriate inputs into our 'World3' simulation model. As I have also written you, the Economic Commission for Europe (ECE), whose membership includes all European countries (East and West) plus the USSR and USA, namely all industrialized countries, save Japan and Canada, has given its full approval to our approach and will support our effort. The two key officials so far involved are its Executive Secretary, Mr. Yanez Stanovnik, and the official responsible for the Prague Conference of 1971, Mr. Amasa S. Bishop. Not only we will have advice and data from them. But they also offered to organize a meeting with the group of Senior Governmental Advisors on Environment which will gather in Geneva from November 30 to December 3, 1970, and among which are some of the highest officials responsible for environmental problems in the member countries, the scope of the meeting being that we illustrate and discuss with them our Project. The meeting will be held at the UN Headquarters in Geneva and will likely lead to a presentation of our conclusions (our main conclusions)at the 'ECE Conference on Environmental Problems' which will be held in Prague in 1971.

We have also discussed the Project with Mr. Addeke H. Boerma, the Director General of the Food and Agriculture Organization of the United Nations (FAO) who was very much interested, also because what we do could give flesh and muscle to the 'Indicative World Plan for Agricultural Development' (IWP), which is an important element in the long-term orientation of FAO's work. But there is a wide recognition that IWP and practically all other UN activities lack the system approach and the overall vision and framework which are necessary to make them significant; and therefore a linkage of some sort with a project like ours--there is no other similar project afoot, and therefore it <u>has to be</u> ours--is highly welcome.

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It is up to us, then, to pursue these contacts with FAO. We have also taken contact with Professor Adriano Buzzati-Traverso, Deputy Director General of UNESCO, and responsible for its scientific branch, who is prepared to call a meeting of scientists at UNESCO to discuss the problems that we may have in carrying out our Project. Also this avenue is open for us to use it, if we want.

And, last not least, the Organization for Economic Cooperation and Development (OECD) has repeatedly confirmed its interest in our Project, expressing also the wish of a mutual cooperation. It has on a study of the problems of modern society, which probably will be carried out mainly under economic optics, namely to consider the diseconomies (environmental and other) of economic growth. And therefore, also in this case, our wider context may broaden the background of its study. Not only Alex King is OECD's Director General for Scientific Affairs and therefore a natural link with the CoR--although he is one of our members and in our Executive Committee in a personal capacity only--but the Secretary General, Dr. Emile van Lennep, and his Deputy for these matters, M. Eldin, have had meetings with us and discussed in detail what we are doing and in which way we can be of mutual assistance. I am sure that Dr. van Lennep will be more than glad to give any support OECD can offer to a privately sponsored but public-minded effort as ours.

I have recited here things that you already know. I have only to add that I am sure that other international institutions, like the World Health Organization (WHO) and the International Bank for Reconstruction and Development (IBRD), are ready to back us if we ask them. We have not moved ahead with them, in order to wait for the official VW decision. But many of these international organisms know that the development of our plans is now pending on this decision: if it were less than we expect--and need--some other precious time would be lost in a moment when world conditions suggest that the question of time is of essence.

I will not repeat now in detail the contacts with other organizations, not of international character, that we have or plan to have in the course of Phase One to check with them our bearings and possibly receive any suggestions they would like to make on our work. You know that we have had many contacts with Soviet personalities and that Mr. Jermen M. Gvishiani, Vice Chairman of the State Committee of the USSR Council of Ministers for Science and Technology, participated in our meeting last December when the CoR was invited

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to Vienna by the then Chancellor Josef Klaus. We have on hand an invitation by Mr. Gvishiani to go again to Moscow in the near future--a follow up to the visit we made there last year--to discuss with his Committee and some Institutes depending from the Academy of Sciences the new shape of our Project. I think that we must accept his invitation, and that 3 or 4 of us ought to go to Moscow sometimes after the VW decision, in order to have high level discussions and renew our proposal that there be Soviet participation in the CoR and in our work groups. Again, we must say that our Project in its new form is more along the lines of Soviet thinking, and therefore that it will be easier for the people there who are sympathetic with the CoR to overcome the difficulties of more conservative people to go along with an innovative effort as ours.

In other countries we have, as you know, contacts which however will become particularly meaningful when our Project will be on its stride. I will mention here that we have always kept open a very good communication line with first class people in Canada, and particularly Ottawa. I have received recently communication from our colleague Pierre Gendron that during a meeting with key personalities in the Canadian capital it was decided to invite the CoR to have its next year meeting in Ottawa and that a grant of some $30,000 has been approved to cover our expenses. This does not foreclose the financial support we have asked our Canadian friends for the CoR's general activities. And moreover it is rather important because it is a token of recognition of an important and not so deeply committed nation as Canada, which comes after similar gestures by Austria and Switzerland. And I wish to inform you that I have received a letter dated September 25 from Dr. Saburo Okita telling me that in a meeting (after Prof. Oshima's recent return to Japan) they agreed to go ahead "in cooperating with the CoR by raising the funds and also by organizing a small group of experts working on 'The Predicament' and related studies". I am sending you copy of the letter with this same mail. Alex King, who has just returned from Japan, has given me confirmation of this.

I will not go into details about contacts in other countries, limiting myself to mention that Belgium, Holland and Sweden are probably those next in line in Europe for some action when we will have defined our programs. Louis Camu and Jacques Spaey in the first one, Frits Böttcher in the second (where Prince Bernard of The Netherlands knows very well and is very sympathetic with the CoR) and Arne Tiselius and others in the third have given word that

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they will be active. In the United States there is a continuous intellectual response from so many quarters that the major difficulty is to keep contact with them--a response which has to be converted into financial backing as well. You or I must probably start again by talking to Det Bronk. And a new field of expansion is represented by Latin America, Africa and Asia. In Latin America there is much expectation and interest about the CoR, and I believe that Dr. Victor Urquidi, the President of the well-reputed Colegio de Mexico, can be our spearhead. He is deeply interested, intellectually first-class, and well convinced that innovation along our lines is needed and urgent. For Black Africa, Professor Adeoye Lambo has promised to give us inroads into the subcultures in which that Continent is divided. As to Asia, we will have to define our line of action. We must be sure that there is a tremendous potential of support from all the three great developing regions, and we must prepare ourselves to dedicate much time to visit them and involve some of their leading personalities in our effort. If you and the other Colleagues of the Executive Committee will approve, I am prepared to devote some time to these contacts.

Probably you want me now to recapitulate the present status of the CoR funding at the moment when we are asking VW to complete its grant in order to allow us to carry out Phase One of our Project. I have to say that we are profoundly grateful to VW for the consideration that it gives to our effort. But I would like to add also that--while I consider essential at this stage that Phase One of our Project be financed totally by VW--we want and hope to succeed in establishing an international base for our funding. To Japan and Canada, as you know, we asked $100,000. Italy has already provided another $100,000, of which about 75,000 are still available after covering various CoR expenses so far. All these funds are private and they must come from irreproachable sources. And they should be destinated (a) to cover the general CoR expenses--other than those of Phase One--for instance during one or two years, and (b) to contribute to funding Phase Two when we will have decided what Phase Two will be and which financial support it needs (a decision this to be taken, e. g., at the beginning of next year, and possibly in consultation with VW). Moreover, the Battelle Memorial Institute has in principle decided to give a grant to Battelle-Geneva, which may be used to select and coach people during Phase One, but with a view to shape up Phase Two and use them during that second step of our Project. Hugo Thiemann may give you more details, if you want them. The cost of the Rome Secretariat has been charged

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so far to the firms I work with in Italy and also for the future I hope will not be debited to the CoR.

We can thus prepare in the next few months an estimate of the financial support needed, say, for 1971-72, having reasonable grounds for not being too concerned--assuming always that the pivotal decision of VW to take up the cost of Phase One is positively reached at the beginning of November. In more general terms, I think that our main sources of finance will have to be foundations, but that we must address them on the basis of well-defined projects (as now Phase One, later Phase Two, and so on), and, in particular as to the big US foundations, that our approach must be started ex novo because of the reasons we know.

This is where we stand at this crucial moment. I will leave tomorrow and plan to stay the whole of next week in the United States and then ten days between Buenos Aires and Rio, coming back November 4. But I am totally at your disposal and ready to come back a few days earlier from the trip if you think I could be of some help November 2 or 3 in Hannover. And in the meantime I can be reached through my Secretary in Rome.

Please convey my best regards to Dr. Gambke and Dr. Zarnitz. All my best to you and Anneliese.

Cordially,

Aurelio Peccei

cc: Alex
Hugo
Dennis

Please note that our new address is:

00147 Rome, Via Giorgione 163.

Our new telephone number is 5107, while telex and cable addresses remain unchanged.

NATIONS UNIES | ОБЪЕДИНЕННЫЕ НАЦИИ | UNITED NATIONS

COMMISSION ÉCONOMIQUE POUR L'EUROPE | ЭКОНОМИЧЕСКАЯ КОМИССИЯ ДЛЯ ЕВРОПЫ | ECONOMIC COMMISSION FOR EUROPE

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(à rappeler dans la réponse)

Palais des Nations
CH-1211 GENÈVE 10

cc JWF
GSB
JAS

1 October 1970

Dear Dr. Tieman,

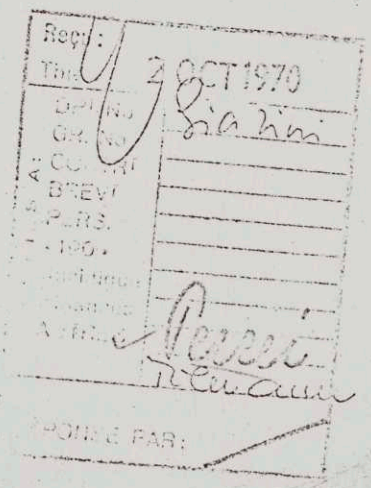
I am returning with many thanks the documents by Professor Forester which you kindly loaned me several weeks ago, and hope that the delay in their return has not inconvenienced you.

I have gone through them rather carefully and have, needless to say, found them exceedingly interesting. Indeed, I have written to Dr. Meadows, requesting copies of these and other relevant documents for my retention, particularly since (in a recent letter) he has expressed an interest in my participation in the work which is under way at MIT in elaborating the "World Dynamics Model". While the project is a very difficult one - and indeed it is not clear to me at this stage that the input equations can be sufficiently accurately formulated to permit the development of meaningful conclusions - it is certainly worth the effort and I am glad to participate in whatever small way I can.

With cordial regards,

Amasa S. Bishop
Director
Environment and Housing Division
Economic Commission for Europe

Dr. Tieman
Battelle Memorial Institute
7 route Drize
CAROUGE - GENEVA



MASSACHUSETTS INSTITUTE OF TECHNOLOGY

10/1/70 19

Memo to Prof. Forester Room Ext.

There are transcriptions with editing of 2 speeches before the Club of Rome.

from N Roche Room Ext.

MURAN BOSTON

Club of Rome

Introductory Remarks

Jay W. Forrester
July 20, 1970

This meeting has been called on very short notice, as most of you know. We are gathered here as a result of a meeting of the Club of Rome in Berne, Switzerland, on June 29-30, 1970. At this meeting, it seemed evident that there was a need for a methodology for the Club of Rome's study on the dynamics of social systems; that is, the study of the future world trends in respect to population, pollution, capital investment, food, and other broad problems of growing population. It was clear that the lack of this methodology was going to stand in the way of the progress of the study.

As a result of that discussion, I suggested that the Executive Committee come to M.I.T. for two weeks to see what we have been doing here over the past fifteen years in the field of dynamic modeling. I felt this would be a worthwhile answer to the questions that were bothering the group. As a result of that invitation, we are meeting here today.

We have had only two weeks to notify people, and to put together a program. There may be holes in that program, and if we have overlooked important problems, we ask your indulgence. We have not had time to pay attention to everything we would have liked to.

I would like to outline the structure and reasons for the kind of program that we would like to present. Roughly, the days have been divided so that there are lectures in the morning, and workshops in the afternoon. The workshops are in many ways the most important part

of this two week period. For the structure of the program we have drawn on the experiences of our two-week summer session programs, which are designed to give insights into Industrial Dynamics to members of industry, government, and other universities.

We have found that the workshops are most effective in these sessions. Industrial Dynamics is not a spectator sport; it is not learned by listening to lectures, by watching other people work, or by reading the literature. These activities show results; they do not give the experience of dealing with a major system, and of exploring one's own interests in order to discover how the policies of a system affect behavior. In the workshops, we hope you will begin to understand feedback mechanisms in complex social systems.

Although we have carried over the structure of the summer sessions, we have altered their substance. During the summer, we used material on the dynamics of commodity markets, in order to instruct people in the behavior of systems. We wished to show the interaction between the individual's perception of the system and the computer model. We felt this material was not suitable to the purpose of the Club of Rome and so sought material that was more relevant.

Beginning July 1 on the airplane from Paris, I tried to devise a substitute system with which this group could work. I will discuss it more thoroughly on Tuesday. It is a workshop exercise now, a global view of the interactions of the major aspects of civilization. It is not a final model in which we would stand behind each individual assumption, but it deals with issues of interest, and provides a point from which your own thinking can start. The system deals

with the interactions of population, capital investment, pollution, agriculture, and natural resources.

This morning's program will begin with a presentation by Dennis Meadows of some of the basic concepts of system structure. This talk will prepare you for this afternoon's presentation by Gerald Barney of a model representation of Malthus' work on population. After this, we will start the workshops, dividing into four groups, each with 5 to 6 Club members and 2 staff members. The staff will demonstrate how to put this simple model on the time-sharing computer system; they will allow you to work with it and to modify the statements and policies in it. This will give you a feeling in one afternoon of the process of the entire model from the verbal description of the system, to some computer work.

Tomorrow afternoon we will take the same steps with the World Model. Because this is a more complex system, it will be drawn out over a longer period of time. Throughout the program I have allowed short sessions in which I will make points about the nature of systems, of modeling, and of system structure. The exact nature of these sessions depends on what people need and want as the Conference progresses.

Tuesday, we begin the first of a series of lectures on various social systems, that we are now working on, or that we have worked on in the past. Some of this work is just preliminary; some is fully developed. At 11:00 a.m. Jørgen Randers will tell you of some work he has started on the disposal of solid waste. I hope you will leave

us with the impression that we are talking about a fundamental body of knowledge, a basic approach which underlies most human endeavor, and most fields of knowledge. Wherever you find processes and activities changing through time, you also find that the approach we are talking about for complex systems can be used to throw light on the nature of the process. This includes study of the fundamental structure and processes of history, as well as questions of internal medicine.

Tuesday evening, Raymond Bauer will speak to us at a dinner at the Faculty Club. He is a Professor at the Harvard Business School, and was a Senior Consultant to the Goals for America Program, a project connected with the White House Staff. Yesterday, newspapers reported that this study has just been made available. I thought this would be interesting because that study arose several times in conversation during the meeting in Berne.

Wednesday morning, Richard Foster will discuss glucose-insulin control in the body, an example of the breadth of the approach we are taking in complex systems. At 11:00 a.m. on Wednesday, John Collins will open the discussion on urban affairs and cities, which I will continue the next day. Workshop sessions on Wednesday will be devoted to World Dynamics.

Thursday, I will discuss the Urban Dynamics work, explained in my book Urban Dynamics. I will review the contents of the book, as well as the questions that arise from it. Discussion will continue until it is no longer profitable. Friday, I will again talk about systems.

Following that, Gilbert Levin, a staff member of the Albert Einstein Memorial Hospital in New York, and Edward Roberts, a member of our staff here, will tell you of some work they have been doing on the dynamics of drug addiction and the social dynamics of drug addiction and the community. Levin will give his background as member of a hospital, and Roberts will explain the model itself.

After lunch, we will have a full-group workshop session in order to discuss questions on the World Model that have come up in the smaller sessions. We will carry on that discussion as long as it is profitable. Finally, this week, I would like to invite you to a picnic at my house in Concord on Sunday.

Monday, Meadows will open with a short discussion of systems and modeling. Then I will take the two major morning sessions with a study that I did several years ago on the dynamics of corporate growth. Although this is not the central theme of our interest here, there are aspects which do not appear very strongly in the other studies we have done. It extends all the way from the personalities of the founders of the company, to the consequences of the growth of a new technically based company over fifteen years. I think you will find it interesting.

Monday evening, President Howard Johnson of M.I.T. will have a reception for us at the president's house at 5:30 p.m. There will be dinner afterward at the Faculty Club, where we hope to have as guests other members of the M.I.T. administration.

Beginning Monday, some of the afternoons of next week will be open so that individuals will be able to arrange their own time. The Executive Committee of the Club of Rome would like to work on project plans for the future, so we are setting aside some blocks of time for them. Other people will be able to continue the workshops, to read and to study.

On Tuesday, Meadows will speak on Commodity Markets. He has just finished a book on this subject, which will be published later this year. He will also talk about its extensions into international commodity control. At 9:30 on Wednesday, Edward Roberts will talk about a social system involving community health care, a study carried out with the Harvard Medical School. It has interesting examples of the counter-intuitive nature of complex systems, and raises some issues quite different from those that are normally raised in connection with government services in the community. Gerald Barney will then continue his earlier talk with a more complete discussion of the dynamics of land use and food production. On Thursday, we have an open subject to be chosen according to what is interesting or necessary to cover at that time. Walter Schroeder will then tell you about the additional material we are preparing to follow up the Urban Dynamics book.

Thursday afternoon, we have a program that is subject to change or cancellation if it does not seem appropriate. In the meeting at Berne there were many discussions of social trends, the stresses between classes, the gaps between generations, and some of the pressures that are developing in corporations. We have prepared a group of readings

on these subjects: a book by Edward Hagen, a book by Douglas MacGregor, and a paper of mine on new corporate design. These works discuss authoritarian hierarchies and democratic organizations in social systems.

Thomas Kuhn's book entitled The Structure of Scientific Revolutions is not quite in the same category, but is relevant for what it says about how a new approach to systems might be related to current and historical approaches to systems. I read this book with a great deal of interest because it seems to me it says much about the problems which we have in introducing a new approach to complex systems to a scientific world which on the whole is unequipped to receive it. It is a very valuable book, although it is not directly related to the other three.

Friday is a wind-up session; we will continue to discuss the characteristics of complex systems. Meadows will talk about implementation of policy changes in systems; there will a general discussion in the afternoon and further work of the Executive Committee. This may run into Saturday. The group as a whole will be finished by Friday afternoon, and may take evening planes.

Are there any questions about this program? If any of you have suggestions about the structure of the program, please let me know. The program is not frozen, and we would like to be as flexible as we can.

I would like to turn the meeting to Aurelio Peccei who will tell you about the Club of Rome and the reasons we are gathered here.

rec'd. 10/13/70

(Provisional letter paper)

THE CLUB OF ROME

October 9, 1970
DAP/amp

Professor Dennis L. Meadows
Massachusetts Institute of Technology
50 Memorial Drive
Cambridge, Mass. 02139, USA.

Dear Dennis:

As a follow up to my letter of September 30, I wish to inform you that on my way to Detroit I will change planes in Boston Sunday October 18. I will be arriving at Logan with TWA 811 flight, according to schedule at 1:10 p.m., and will leave by TWA 753 flight at 2:45 p.m. for Detroit.

It might be good to see or phone each other in order to check on the programs we will do together after my visit to Detroit and Montreal. If you choose to come to Logan, I will be of course delighted. But it will be Sunday, and you might wish to rest or do something else, so that, if I will not see you, I will phone you home or look for a message of yours with indications to phone you somewhere else, if you are at all reachable.

We have had some good news recently, both from Japan and the Battelle Memorial Institute. And I would like to talk to you before you send your report on Phase Zero to Eduard. Thus, if we miss each other Sunday in Boston, I will phone you sometimes from Detroit, where I will be staying at the Sheraton Cadillac Hotel.

Sincerely,

Aurelio Peccei

cc. JWF ✓
JAS
GSB
JC

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(à rappeler dans la réponse)

Palais des Nations
CH-1211 GENÈVE 10

29 September 1970

Dear Dr. Meadows,

I must apologize for the delay in writing to you following our meeting at the Batelle Institute several weeks ago. On the Monday after that meeting, Dr. Peccei and Dr. Tieman visited Mr. Stanovnik, and I had the opportunity of further discussions with them then. At that time I also provided to Dr. Peccei copies of the several articles in which both you and he had expressed interest:

1) A paper, entitled "On Solving the Population Crisis", together with a covering note, providing some background information;

2) A copy of an article from "SCIENCE" (13 February 1970), entitled "Japan : A Crowded Nation wants to boost its Birth Rate";

3) An article, entitled "The Status and Outlook of the World Programme on Controlled Fusion Research. This is a paper which I presented before the National Academy of Sciences about a year and a half ago.

ooo I am enclosing copies of the first two documents. With regard to the vvv third, I am enclosing a more technical version of the article given to Dr. Peccei, since I believe you may already be more familiar with the field than he is. This invited paper, presented last November before the Plasma Physics Division of the American Physical Society, includes many of the very fascinating developments which occurred in this field during the latter part of the year. *

ooo I am also enclosing, at your request, a copy of the Draft Programme of Action by the ECE in the Field of Environment (Working Paper No.5). This document, together with five others which have been prepared by the Secretariat, will serve as the basis discussion at the meeting of Senior Governmental Advisers in November/December of this year.

Dr. Dennis L. Meadows
Massachusetts Institute of Technology
Alfred P. Sloan School of Management
50 Memorial Drive
Cambridge
Massachusetts, 02139
U.S.A.

* You may be particularly interested in the environmental advantages which would accrue from the successful development of controlled fusion.

With regard to your kind invitation to visit MIT for two days after the November meeting, I very much appreciate your offer and accept with pleasure. I do not know if you have any specific date in mind, but would hope that this matter could be left a little bit flexible for the moment, particularly in view of the fact that I have several other commitments during the early part of December. You will be interested to know that Mr. M. Strong, the newly appointed Secretary-General of the Stockholm Conference, is now in Geneva and I am scheduled to meet with him tomorrow on a number of topics relating to that Conference.

Finally, I would greatly appreciate it if you could send me, at your earliest convenience, copies of the more important documents relating to the work which the Club of Rome has under way at MIT. Dr. Tieman has kindly loaned to me a set of Dr. Forester's papers on "A World Dynamics Model". They are, however, is only copies and he needs to have them returned to him in the next several days. Needless to say, I found them exceedingly interesting and would welcome a chance to study them in greater detail in advance of my coming to MIT.

With best wishes for success in your work, and cordial regards,

Sincerely yours,

Amasa Bishop

Amasa S. Bishop
Director
Environment and Housing Division
Economic Commission of Europe

cc. JWF
JAS

JWF 10/9/70

DEPARTMENT OF ELECTRICAL ENGINEERING

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

CAMBRIDGE, MASSACHUSETTS 02139

7 October 1970

Room 4-234

Dr. Amasa S. Bishop, Director
Environment and Housing Division
Economic Commission of Europe
Palais des Nations
CH-1211
GENEVE 10

Dear Dr. Bishop:

I was delighted a few days ago to learn of your present whereabouts and activities from Dennis Meadows of M.I.T. I have been very much in touch with Drs. Meadows, Forrester and Peccei concerning the Club Of Rome Project. I attended the two-week session in Cambridge in July. I think the program is an extremely important one, and I am very optimistic that Professors Forrester and Meadows's methodology will permit us to get a handle on the problem in ways that will give society data on the trade-offs in ways that are so urgently needed.

I will keep in touch with Meadows and try and meet up with you when you come to M.I.T. in November or December. I hope to be in Europe sometime during the Spring and would want to touch base with you again at that time.

I am delighted that you are giving this problem such conscientious attention.

Sincerely yours,

Gordon S. Brown
Dugald C. Jackson Professor
of Engineering

GSB:fkj

cc: Professor J. W. Forrester
Professor D. L. Meadows

Save for chronology book.

Not used in this form in W. D.

~~Furthermore, the principal financing for the project was being delayed until a suitable methodology could be identified.~~

~~At that point~~ I suggested ~~to the group~~ that ~~we believe~~ we believe the "Industrial Dynamics" approach developed at the M.I.T. Sloan School of Management since 1956 ~~is~~ is the methodology for which they ~~are~~ were searching. We ~~have been applying~~ applied this approach to social systems first in the context of corporate management and more recently in a broadening circle of applications ranging from internal medicine to the life cycle of cities. I invited the Executive Committee of the Club of Rome to visit ~~us at~~ M.I.T. for two weeks to ~~learn what we are doing~~ review the Industrial Dynamics programs, and to judge for themselves the applicability ~~of our approach~~ to ~~social systems~~ their project on world evolution. After a two hour lecture and discussion of our work, the Executive Committee and several other members accepted the invitation ~~on June 29~~ to come to M.I.T. three weeks later for a symposium ~~of~~ of two weeks duration ~~to be held~~ to start on July 20.

This ~~memorandum~~ book has the further purpose of revealing ~~exhibiting~~ the detailed steps and mistakes along the road to formulating ~~in starting~~ a dynamic model of a social system. ~~formulation~~. Customarily, ~~the~~ any professional literature reports only final results and perfected theories. The student reader is ~~often~~ left with the impression that the ~~perfected and polished~~ polished final result emerged in the first effort. Some ~~of the~~ scientific literature of the 1800's is especially interesting, ~~and revealing~~, even today, because it is more a ~~journal and~~ diary of an avenue of investigation and less a presentation of final results. The nature of blind alleys, the reasons for taking wrong approaches, and the methods of finding one's way back to a productive investigation can be helpful to the beginner. This ~~document~~ book is set down hoping that it will serve a useful educational purpose for the serious beginner in modeling the dynamic behavior of social systems.

We believe
~~It has been our feeling that~~ one does not gain an adequate appreciation of ~~our~~ the Industrial Dynamics approach to feedback system structuring and computer simulation ~~approach~~ unless he actively participates in the process. ~~During the last several~~ For many years we have conducted a two-week ~~special~~ summer-session program in Industrial Dynamics and have made afternoon workshop sessions a part of that experience. The participants in the summer session programs often ~~have~~ developed a simple model of a ~~2-loop~~ two-loop commodity market and ~~have~~ examined the dynamics of commodity behavior. This has been an effective teaching tool. However, ~~it~~ commodity markets did not seem close enough to the interests of the Club of Rome members to be the best vehicle for the proposed conference.

This ~~memorandum~~ book describes a model of world behavior which was developed during the ~~two~~ three weeks between the meetings ~~in~~ at Bern and ~~at~~ M.I.T. The first step in developing the model consisted of ~~about 1~~ one hour on the airplane from Paris ~~back~~ to Boston which resulted in the general flow diagram in Figure 1-1 that ~~ing~~ suggested the principal system levels and some of the interconnections between them. The sketched system ~~It~~ involved population with birth and death rates, capital investment with generation and discard, natural resources and their depletion, pollution with ~~its~~ generation and absorption, and the fraction of capital investment devoted to food production. This sketch was done on July 1.

I returned to the subject on Saturday, July 4 and that day worked through the full formulation of the World1 Model to the point of generating the first complete flow diagram, a complete and operable set of equations, the drafting of the table functions, inserting the model into the computer, and obtaining the first two computer runs to be described later.

→ a computer console in my study at home, connected to the M.I.T. time-sharing computer systems expedited the pace.

10 insert.

(A)

It was created ~~for one~~ as a point of departure for the ~~afternoon~~ afternoon laboratory groups wherein the participants, in small groups, would have an opportunity to experiment with a system model using a time-sharing computer system. By so doing they could experience the system design process of changing social policies to observe resulting modification of dynamic behavior.

(TP)

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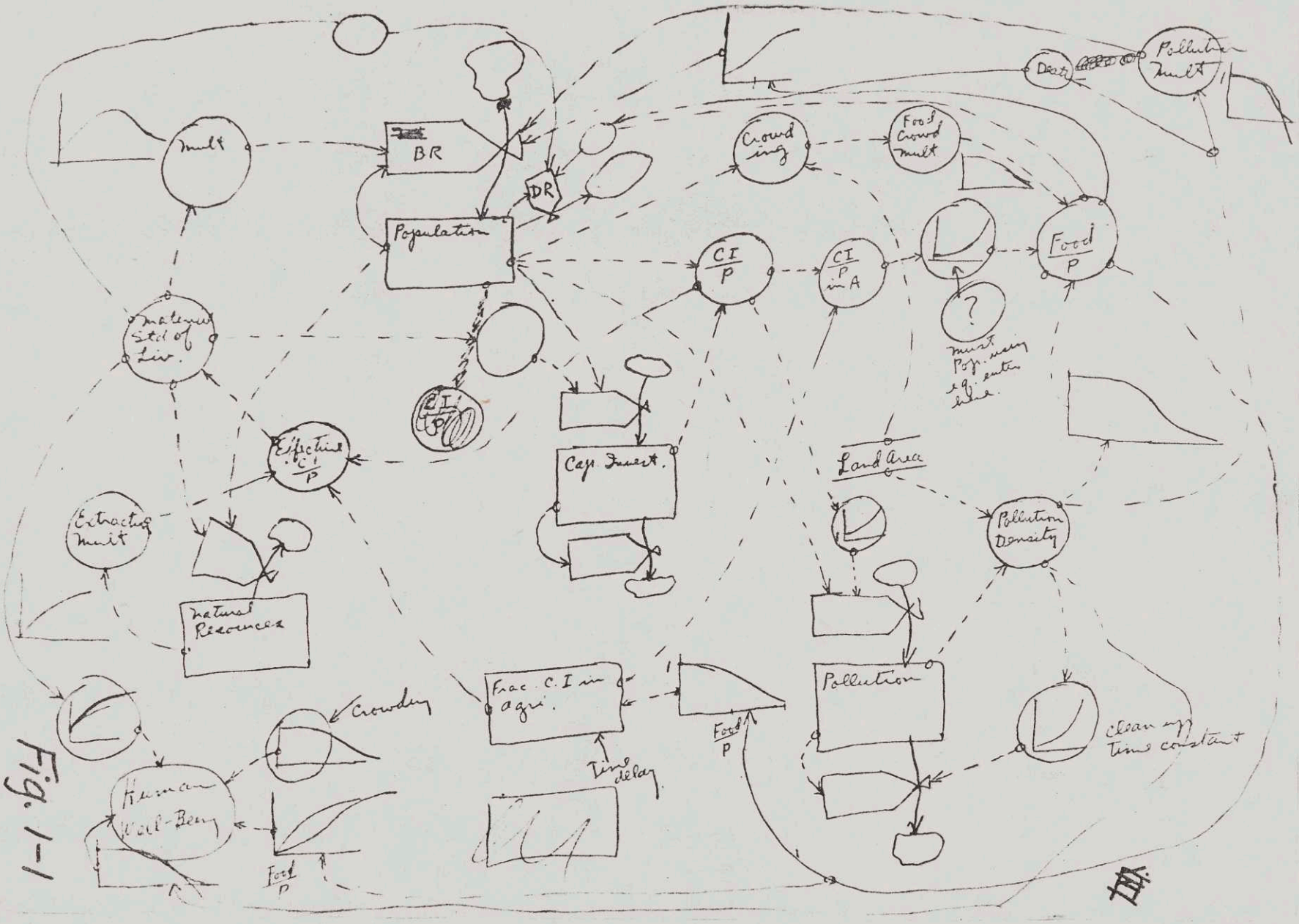
Mult
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DR
Population
Crowding
Food Crowd Mult
Death
Pollution Mult
CI/P
CI/P in A
Food/P
Material Std of Liv.
Effective CI/P
Extracting Mult
Natural Resources
Cap. Invest.
Land Area
Pollution Density
Pollution
Frac. C.I in agri.
Time delay
Food/P
Crowding
Human Well-Being
Food/P
clean up Time constant

Fig. 1-1

In the following week the World1 Model was investigated and ideas generated for its improvement. On Saturday, July 11 this model was evolved into the World1A version, then into World1B, and finally into the World2 Model, which ~~is~~ was the form ~~being~~ frozen ~~as the starting point of the workshop~~ for the workshop sessions for the Club of Rome Conference on July 20-31. ~~It is expected that~~ The workshop groups ~~will~~ started with the World2 version and explored the process of system restructuring, system extension, and investigation of how the parameters and policies affect system behavior.

D-1360

DESCRIPTION OF WORLD2 MODEL RUNS

CHAPTER 6

by
Jay W. Forrester
Professor of Management
Sloan School of Management
Massachusetts Institute of
Technology

Cambridge, Mass.

August 10, 1970

D-1360

DESCRIPTION OF WORLD2 MODEL RUNS

CHAPTER 6

WORLD2-STD.S

This is the standard computer run from the WORLD2 model. The "S" suffix indicates that the plot card has been changed to give predetermined plotting scales and is done so that the curves can be more easily compared. The standard computer run shows a peak in population at about year 2030 and gradual decline thereafter. The population decline is occurring because of the depressing effect of declining natural resources.

It is interesting to note that quality of life reaches its highest point at 1970. Can this be reasonable considering today's strong worldwide feeling of distress and disenchantment? Perhaps so. A sense of well-being may be related more to "progress" and to improvements since the recallable past than to the absolute level of quality of life. A feeling of malaise could therefore occur at the peak of the quality of life curve because little improvement has been observed in the preceding two decades.

In this standard run, pollution peaks in year 2050 at about 4.5 times the pollution intensity of 1970. This is not a high enough value for pollution to enter importantly into the overall dynamic behavior.

WORLD2-6S

This computer run is again the standard model but with a compressed time scale showing a period from 1900 to 2300. The natural resource consumption continues to depress the effectiveness of capital and causes a gradually declining material standard of living. This increases the death rate and brings most characteristics of the system in 2300 back to about the values of year 1900.

WORLD2-5S

In this computer run we explore the effect of reducing the birth rate normal coefficient BRN1 from 0.045 to 0.035 at the year 1970. There is a slowing of the population growth from 1970 until 1990, and then we see that population curves upward again. Peak population in the year 2040 is only slightly less than in the standard run. Around the year 2000, both food ratio and the material standard of living are slightly higher than in the standard run. Quality of life reaches a peak at the year 2000 and then declines. The rising food ratio and material standard of living appear to account for the resumption in population growth which begins to move upward again after 1990.

WORLD2-4S

In this computer run the capital investment generation coefficient CIGC1 has been increased from its original value of 1 to a value of 1.2 in 1970 This means that, all other things being equal, the capital investment generation is increased 20% above its previous value. In this computer run the pollution scale has been changed and runs from 0 to 80 instead of the previous range of 0 to 8. The increased rate of capital investment pushes up the material standard of living, causes the food ratio to rise slightly above that in the standard computer run and causes the population to reach a slightly higher peak in the year 2020. The most conspicuous change, however, is the slight increase in capital investment which causes rising pollution generation and results in overloading the pollution absorption capability of the system. As the total pollution in the system rises, the pollution absorption time from Equation 34 increases and slows down the pollution clean-up processes. Pollution rises precipitously between years 2020 and 2050. This depresses the food ratio, and greatly influences the quality of life from pollution. The effects of pollution and reduced food act to reduce the birth rate and increase the death rate in sufficient degree to cause a collapse of world population from a peak in year 2020 to a minimum of less than one-fourth as much in the year 2070.

In effect this is a dynamic model equivalent of the ecological crisis which is often discussed in the public press. It might occur through ocean pollution which could affect water evaporation, weather, and photosynthesis.

This computer run raises a question about industrialization and its future trends. The world environment may not be able to cope with the pollution which would be generated by the present world population if all of that population reached a level of industrialization comparable to that in Europe and North America.

Should there be a pollution crisis which cuts severely into food production, as well as directly affecting birth and death rates, one can speculate on which societies will be most affected. Is it not possible that the industrialized nations with their large cities and their high degree of inter-connectedness may be the most vulnerable victims of their own industrialization. In other words, if a population decrease should occur, it might strike unevenly the various world populations and might touch less severely on those societies which have not reached a high degree of industrialization.

WORLD2-21S

In this computer run we retain the increased capital investment accumulation from Run 4S. In addition in 1970, the birth rate normal coefficient BRN1 is reduced from 0.045 to 0.025. This is a severe reduction in normal birth rate, and leads to almost constant population between 1970 and 1990. Thereafter, population turns up again slightly.

But we see that even this substantial reduction in birth rate does not forestall the polluation crisis which was seen in Run 4S. Capital accumulation in the year 2020 is about the same as in Run 4S. Pollution is here again plotted on a scale of 0 to 80. Pollution generation is also about the same as in Run 4S.

With respect to future problems of environmental pollution, we begin to suspect that industrialization is more fundamental than population. A highly industrialized society creates many times the pollution per capita of a non-industrialized society. Furthermore, industrialization tends to push up population and population density. Industrialization here includes hospitals, medical care, and all other aspects of society which sustain large population densities.

This computer run raises questions about population control as a fundamental process for insuring a future world equilibrium. If reduced birth rate could be inaugurated under present world conditions, the resulting increase in industrialization per capita, food per capita, and quality of life, would in turn reduce the apparent pressure for controlling population, and would put upward pressure on birth rates once more. So, a control of birth rate tends to defeat itself by reducing the pressures which make birth control seem to be necessary.

But even more important, should population actually be stabilized, a rising industrialization might itself be sufficient to bring the environmental forces to a crisis overload.

WORLD2-12S

In this run the natural resource usage rate NRUN1 has been reduced, other things being equal, to 25% of its previous value in the year 1970. This is equivalent to assuming that recycling of waste and new technological advances will reduce the seriousness of declining natural resources. This computer run should be compared with the standard run and also with Run 4S. We see that declining natural resources no longer depress population. Instead, population and capital investment continue to rise until the environmental crisis arising from pollution again reasserts itself. The pollution scale here is again 0 to 80. Results are very similar to Run 4S.

WORLD2-27S

Here we combine the conditions of Runs 12S and 4S. This means that capital investment is increased 20% and natural resource usage is reduced to one quarter in the year 1970. The effect is to precipitate the environmental crisis about twenty years earlier than in Run 4S. We see that any combination which allows population and capital investment to increase without first being checked by falling natural resources or by crowding will lead into system collapse through rising pollution.

WORLD2-22S

In this run we examine a reduction in pollution generation rate along with the conditions of Run 27S. Here in 1970, three changes have been made. Capital investment generation is increased 20% and natural resource usage is reduced to one quarter of its previous rate as in Run 27S. In addition, pollution generation POLN1 has been reduced from 1 to 0.5. Compared with Run 27S, we see that the reduced pollution generation allows population to rise longer before the collapse occurs. With a smaller rate of pollution generation, other things being equal, population and capital investment continue to rise until environmental overloading again occurs. Here, the peak population occurs about thirty years later than in Run 27S.

In 1970, the usage rate of natural resources was substantially reduced and we see that the natural resource curve levels slightly at that time. However, as population and capital investment both continue to rise, the natural resource usage rate is pushed upward again by sheer magnitude of consumption rate and, by the year 2100, the natural resource level has fallen lower than in the standard computer run. Again, we see the self-defeating effect of many policy changes in complex systems. A reduced natural resource usage rate allows population and capital investment to rise far enough to compensate for the reduced consumption, other things being equal. In other words, other things are not equal. The changed propensity to consume raises the consuming population and related industrialization.

Assembly Instructions: These pages to be interleaved with the corresponding WORLD2 computer runs.

World Model: Definition of Terms

WORLD DEF 07/19 1429.8

*	DEFINITIONS FOR WORLD DYNAMICS MODEL
BR	BIRTH RATE (PEOPLE/YEAR)
BRCM	BIRTH-RATE-FROM-CROWDING MULTIPLIER (DIMENSIONLESS)
BRCMT	BIRTH-RATE-FROM-CROWDING-MULTIPLIER TABLE
BRFM	BIRTH-RATE-FROM-FOOD MULTIPLIER (DIMENSIONLESS)
BRFMT	BIRTH-RATE-FROM-FOOD-MULTIPLIER TABLE
BRMM	BIRTH-RATE-FROM-MATERIAL MULTIPLIER (DIMENSIONLESS)
BRMMT	BIRTH-RATE-FROM-MATERIAL-MULTIPLIER TABLE
BRMS	BIRTH-RATE-FROM-MATERIAL SENSITIVITY (DIMENSIONLESS)
BRN	BIRTH RATE NORMAL (FRACTION/YEAR)
BRN1	BIRTH RATE NORMAL NO. 1 (FRACTION/YEAR)
BRPM	BIRTH-RATE-FROM-POLLUTION MULTIPLIER (DIMENSIONLESS)
BRPMT	BIRTH-RATE-FROM-POLLUTION-MULTIPLIER TABLE
CFIFR	CAPITAL FRACTION INDICATED BY FOOD RATIO (DIMENSIONLESS)
CFIFRT	CAPITAL-FRACTION-INDICATED-BY-FOOD-RATIO TABLE
CI	CAPITAL INVESTMENT (CAPITAL UNITS)
CIAF	CAPITAL-INVESTMENT-IN-AGRICULTURE FRACTION (DIMENSIONLESS)
CIAFI	CAPITAL-INVESTMENT-IN-AGRICULTURE FRACTION, INITIAL (DIMENSIONLESS
CIAFN	CAPITAL-INVESTMENT-IN-AGRICULTURE FRACTION NORMAL (DIMENSIONLESS)
CIAFT	CAPITAL-INVESTMENT-IN-AGRICULTURE-FRACTION ADJUSTMENT TIME (YEARS)
CID	CAPITAL-INVESTMENT DISCARD (CAPITAL UNITS/YEAR)
CIDN	CAPITAL-INVESTMENT DISCARD NORMAL (FRACTION/YEAR)
CIDN1	CAPITAL-INVESTMENT DISCARD NORMAL NO. 1 (FRACTION/YEAR)
CIG	CAPITAL-INVESTMENT GENERATION (CAPITAL UNITS/YEAR)
CIGC	CAPITAL-INVESTMENT-GENERATION COEFFICIENT (DIMENSIONLESS)
CIGC1	CAPITAL-INVESTMENT-GENERATION COEFFICIENT NO. 1 (DIMENSIONLESS)
CII	CAPITAL INVESTMENT, INITIAL (CAPITAL UNITS)
CIPC	CAPITAL INVESTMENT PER CAPITA (CAPITAL UNITS/PERSON/YEAR)
CIPCT	CAPITAL-INVESTMENT-PER-CAPITA TABLE
CIQR	CAPITAL-INVESTMENT-FROM-QUALITY RATIO (DIMENSIONLESS)
CIQRT	CAPITAL-INVESTMENT-FROM-QUALITY-RATIO TABLE
CIR	CAPITAL-INVESTMENT RATIO (CAPITAL UNITS/PERSON)
CIRA	CAPITAL INVESTMENT RATIO IN AGRICULTURE (CAPITAL UNITS/PERSON)
CR	CROWDING RATIO (DIMENSIONLESS)
DR	DEATH RATE (PEOPLE/YEAR)
DRCM	DEATH-RATE-FROM-CROWDING MULTIPLIER (DIMENSIONLESS)
DRCMT	DEATH-RATE-FROM-CROWDING-MULTIPLIER TABLE
DRFM	DEATH-RATE-FROM-FOOD MULTIPLIER (DIMENSIONLESS)
DRFMT	DEATH-RATE-FROM-FOOD-MULTIPLIER TABLE
DRMM	DEATH-RATE-FROM-MATERIAL MULTIPLIER (DIMENSIONLESS)
DRMMT	DEATH-RATE-FROM-MATERIAL-MULTIPLIER TABLE
DRMS	DEATH-RATE-FROM-MATERIAL SENSITIVITY (DIMENSIONLESS)
DRN	DEATH RATE NORMAL (FRACTION/YEAR)
DRN1	DEATH RATE NORMAL NO. 1 (FRACTION/YEAR)
DRPM	DEATH-RATE-FROM-POLLUTION MULTIPLIER (DIMENSIONLESS)
DRPMT	DEATH-RATE-FROM-POLLUTION-MULTIPLIER TABLE
ECIR	EFFECTIVE-CAPITAL-INVESTMENT RATIO (CAPITAL UNITS/PERSON)
FCM	FOOD-CROWDING MULTIPLIER (DIMENSIONLESS)
FCMT	FOOD-CROWDING-MULTIPLIER TABLE
FPCI	FOOD POTENTIAL FROM CAPITAL INVESTMENT (DIMENSIONLESS)
FPCIT	FOOD-POTENTIAL-FROM-CAPITAL-INVESTMENT TABLE
FPM	FOOD-FROM-POLLUTION MULTIPLIER (DIMENSIONLESS)
FPMT	FOOD-FROM-POLLUTION-MULTIPLIER TABLE
FR	FOOD RATIO (DIMENSIONLESS)
LA	LAND AREA (SQUARE KILOMETERS)
MSL	MATERIAL STANDARD OF LIVING (DIMENSIONLESS)
MSLN	MATERIAL STANDARD OF LIVING NORMAL (CAPITAL UNITS/PERSON)
NR	NATURAL RESOURCES (NATURAL RESOURCE UNITS)
NREM	NATURAL-RESOURCE-EXTRACTION MULTIPLIER (DIMENSIONLESS)
NREMT	NATURAL-RESOURCE-EXTRACTION-MULTIPLIER TABLE
NRFR	NATURAL-RESOURCE FRACTION REMAINING (DIMENSIONLESS)
NRI	NATURAL RESOURCES, INITIAL (NATURAL RESOURCE UNITS)
NRMM	NATURAL-RESOURCE-FROM-MATERIAL MULTIPLIER (DIMENSIONLESS)
NRMMT	NATURAL-RESOURCE-FROM-MATERIAL-MULTIPLIER TABLE

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NRUN      NATURAL-RESOURCE USAGE NORMAL (NATURAL RESOURCE UNITS/PERSON/YEAR)
NRUN1     NATURAL-RESOURCE USAGE NORMAL NO. 1 (NATURAL RESOURCE UNITS/PERSON/
NRUR      NATURAL-RESOURCE-USAGE RATE (NATURAL RESOURCE UNITS/YEAR)     YEAR)
P         POPULATION (PEOPLE)
PDN       POPULATION DENSITY NORMAL (PEOPLE/SQUARE KILOMETER)
PI        POPULATION, INITIAL (PEOPLE)
POL       POLLUTION (POLLUTION UNITS)
POLA      POLLUTION ABSORPTION (POLLUTION UNITS/YEAR)
POLAT     POLLUTION-ABSORPTION TIME (YEARS)
POLATT    POLLUTION-ABSORPTION-TIME TABLE
POLCM     POLLUTION-FROM-CAPITAL MULTIPLIER (DIMENSIONLESS)
POLCMT    POLLUTION-FROM-CAPITAL-MULTIPLIER TABLE
POLG      POLLUTION GENERATION (POLLUTION UNITS/YEAR)
POLI      POLLUTION, INITIAL (POLLUTION UNITS)
POLN      POLLUTION NORMAL (POLLUTION UNITS/PERSON/YEAR)
POLN1     POLLUTION NORMAL NO. 1 (POLLUTION UNITS/PERSON/YEAR)
POLR      POLLUTION RATIO (DIMENSIONLESS)
POLS      POLLUTION STANDARD (POLLUTION UNITS)
QLC       QUALTIY OF LIFE FROM CROWDING (DIMENSIONLESS)
QLCT      QUALITY-OF-LIFE-FROM-CROWDING TABLE
QLF       QUALITY OF LIFE FROM FOOD (DIMENSIONLESS)
QLFT      QUALITY-OF-LIFE-FROM-FOOD TABLE
QL        QUALITY OF LIFE (SATISFACTION UNITS)
QLM       QUALITY OF LIFE FROM MATERIAL (DIMENSIONLESS)
QLMT      QUALITY-OF-LIFE-FROM-MATERIAL TABLE
QLP       QUALITY OF LIFE FROM POLLUTION (DIMENSIONLESS)
QLPT      QUALITY-OF-LIFE-FROM-POLLUTION TABLE
QLS       QUALITY-OF-LIFE STANDARD (SATISFACTION UNITS)
SWT1      SWITCH TIME NO. 1 FOR BRN (YEARS)
SWT2SWITCH TIME NO. 2 FOR NRUN (YEARS)
SWT3      SWITCH TIME NO. 3 FOR DRN (YEARS)
SWT4      SWITCH TIME NO. 4 FOR CIGC (YEARS)
SWT5      SWITCH TIME NO. 5 FOR CIDN (YEARS)
SWT6      SWITCH TIME NO. 6 FOR POLN (YEARS)
R 3.933+1.616
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Suggests not World Dynamics.

Too broad. Not World

2nd book. (Meadows)

Dynamics of Global Equilibrium.

JWF

(Provisional letter paper)

THE CLUB OF ROME

Rome, September 16, 1970
DAP/amp

NOTE FOR EXCOM MEMBERS:

Dr. Alexander King
Dr. Saburo Okita
Prof. Eduard Pestel
Dr. Hugo Thiemann

'The Predicament of Mankind' Phase One: 'Dynamics of Present World Situation'.

I am giving you herewith some progress informations on our Project, complementing those you already know directly or, in the case of Okita, through Oshima.

1. Meadows has prepared a Draft of the MIT assignment from CoR, and on the basis of this Pestel has submitted to VW a request for funds in CoR's name. A translation into English of this submission will be made available to ExCom members by Thiemann. Pestel has already discussed it with the VW Secretariat with very favorable reactions and will see to it that all necessary information and clarifications are given to the VW reviewers, and then the VW Curators, so that the objective of having Phase One totally supported by VW may be attained. The Curators' meeting is scheduled for November 5, 1970.

2. In the meantime, Meadows will prepare the final text of the Prospectus for the Phase One research to be committed to MIT by CoR based on the VW funding. This document will be complemented by a letter containing the budget and payment conditions as agreed between CoR and MIT, and will embody also results from the preparatory work carried out up to the end of October (Phase Zero), including a preliminary description of 'World3' model. Once approved, the Prospectus may be used also outside the ExCom.

3. It is felt that, by the time the Phase One Prospectus is available for distribution (namely the beginning of November), also a CoR Basic Document should be ready. On the one hand it should constitute a substitution or complement of the old 'green pages' (Ozbekhan's document). On the other hand it should correlate

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Secretariat:
• Rome: Via Pastrengo 16, 00185 Rome - phone: 480041 - telex: Tecnital 61497 - cables: Romclub
Offices:

Phase One and its Prospectus both with Phase Two of the Project to be carried out in Geneva, and the other general activities considered by the CoR. Peccei will prepare a draft of this document to be circulated among ExCom members for observations, modifications and, finally, approval.

4. Peccei-Meadows have met with UN Under-Secretary General de Seynes on August 27 in New York to illustrate Phase One and asked for renewed moral and technical support for the CoR effort. The meeting was very successful, and M. de Seynes gave us very useful advice and indications as to whom to contact within the UN family. Meadows has already made contact with ECOSOC in New York and will keep it up in order to insure that the data input into our Project will be, as far as possible in accord with UN standards and tradition. Contacts with other UN agencies will be taken as indicated by de Seynes. Such projects as the 'UN Second Development Decade' to be launched during this year's XXV General Assembly, the 'UN Conference on Man and his Environment' (Stockholm, 1972) and the 'ECE Conference on Environment Problems' (Prague, 1971) will represent a very good information source on the substantive problems presently facing mankind, and therefore strict contact will be maintained with the functionaries responsible for their preparation or implementation.

5. For these reasons contact was established with the Economic Commission for Europe (ECE), whose members are all European countries (East and West) plus USSR and USA, namely all industrialized countries, save Japan and Canada. Therefore, ECE holds key positions and is very influential. Phase One was illustrated by Thiemann-Peccei-Meadows to Mr. Amasa S. Bishop, the official responsible for Prague 1971, and then to Mr. Janez Stanovnik, ECE Executive Secretary. Both were extremely interested and offered all possible support to our Project. Not only will contacts be kept up, but ECE offered to make known the objectives, program and status of Phase One during the meeting of Senior Governmental Advisers on Environment to be held in Geneva November 30 to December 3, 1970 which some of the highest officials responsible for environment problems (e.g. Christian Herter Jr. for the US) will attend. An informal meeting at the ECE Headquarters in Geneva willbe arranged during that period for our Project to be presented and discussed.

For your information, I am sending you under separate cover three documents on the official meeting mentioned hereabove,

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namely a circular letter by Stanovnik to the member States, a report on the preparatory meeting of March 20, 1970 (showing the nature and importance of the studies member countries will prepare) and a preliminary (confidential) ECE internal document on its program of action concerning environment.

7. Thiemann has offered to examine in depth the question of the particularly qualified personnel to be selected (within a wide range of disciplines and nationalities) and engaged during Phase One with a view to helping (a) to design Phase Two and (b) then carry it out. It is felt that only by linking the mono-methodology Phase One with the subsequent, and more diversified and sophisticated Phase Two(and possibly other phases), and a continuity in the personnel employed, can our Project maintain full thrust and the high intellectual and philosophical levels we all want. Therefore, Thiemann will ask all ExCom members, and others, all possible aid in his endeavor. He is also asking the Battelle Memorial Institute to grant funds for this specific purpose. And he will inform us in due course.

8. Clearly, as mentioned, the CoR activity--even during the first period--will not be only that of the Project's Phase One study and research. Contacts, missions, conferences and publications will be increasingly necessary, and on demand. Preparation and earmarking of personnel for the purpose, as under 7, and perhaps others, must also be foreseen. All these activities will require funds other than those expected from the VW Foundation to cover the cost of Phase One. This is a matter for the ExCom to consider.

Aurelio Peccei

cc: Prof. Dennis Meadows ✓
Prof. Keichi Oshima

Enclosures: under separate cover

Principles of Complex Systems

September 29, 1970
Dennis Meadows

Analysis of Capital Formation in World 2

Take World2 exactly as defined in the Documentor memo D-1354, but Assume:

- CIAF is constant at .3
- Pollution is constant at 0
- Land area is infinite
- Population is constant at 1.65E9
- Capital investment is initially at 4E8

(1) Making a linear approximation to the table function CIPCT derive an algebraic expression for CIG in terms of CI.

(2) What would be the behavior of CI under these conditions?

(3) Now recognize that CIPC has a maximum value of .15. What will be the behavior of CI?

(4) Using a linear approximation to CIPCT over the range $4 < MSL < 5$, show that the delay constant associated with CI's behavior is about 68 years. How long will CI thus take to essentially reach equilibrium. Why was that particular range of MSL selected?

(5) Using the same approximation to CIPCT as in (4) derive a general expression relating the equilibrium value of CI (designated CI_e) to CIAF. What is thus the general effect of increasing CIAF on CI_e? What effect does the level of population have on the rate of capital formation when CIAF is held constant? What do these results imply about the process of capital investment?

(6) Assume CIQRT is constant at 1, CI is constant at 1E10 and then change the first assumption to let CIAF vary as in W2. Approximate all table functions by linear equations over their full range to find an algebraic expression for the equilibrium value of CIAF. Although CIQR", FPM, and FCM are all equal to 1 by assumption represent them explicitly in the expression.

(7) What will happen to CIAF as FPM and FCM decrease from 1?

(8) What is the real world counterpart of CIQFT

(9) Does the delay constant found in (4) depend upon the ratio of population to capital investment when CIAF is constant? What is the direction of the relationship? If CIAF were permitted to vary what would be its influence on the delay constant? Using the preceding conclusion plus the dependence of CIAF on population, what is the influence of population size on the adjustment constant of (time constant) of capital investment?

→ from (6)

CLUB of ROME

Conference on World Dynamic Systems

Tentative Roster of Participants

July 16, 1970

Dr. Jeremy Bray, M.P.	House of Commons	London, England
Prof. Gordon S. Brown	Prof. Electrical Engineering, MIT	Cambridge, Massachusetts
Mr. Alexander N. Christakis	Consultant to Club of Rome Project	Washington, D. C.
Prof. John F. Collins	Visiting Prof. of Management, Pol. Science & Civil Eng., MIT	Cambridge, Massachusetts
Prof. Richard M. Douglas	Chairman Dept. of Humanities, MIT	Cambridge, Massachusetts
Prof. Jay W. Forrester	Prof. of Management, MIT	Cambridge, Massachusetts
Mr. Raymond Gastil	Batelle Seattle Research Center	Seattle, Washington
Dr. William Gouse	Office of Science and Technology	Washington, D. C.
Mr. Robert Greenleaf		Cambridge, Massachusetts
Mr. Kaya	Representing Dr. Saburo Okita	Tokyo, Japan
Prof. Dr. Gert von Kortzfleisch	Prof. of Business University Mannheim	Mannheim, Germany

Mr. Robert Maes	President of Independence Foundation	Philadelphia, Pennsylvania
Prof. Dennis Meadows	Assistant Professor of Management, MIT	Cambridge, Massachusetts
Mr. Meyer	Assistant to Prof. Dr. Ing. Pestel	Hannover, Germany
Prof. Hasan Ozbekhan	Club of Rome, Project Director	Los Angeles, California
Dr. Aurelio Peccei	Managing Director, Italconsult	Rome, Italy
Prof. Dr. Ing. Eduard Pestel	Rector, Institut fur Mechanik, Technische Universitat Hannover	Hannover, Germany
Mr. Ronald L. Ritchie	Vice-President, Imperial Oil Ltd.	Toronto, Ontario
Dr. Hugo Thiemann	Directeur General, Institut Battelle	Geneva, Switzerland
Prof. David White	Prof. Electrical Engineering, MIT	Cambridge, Massachusetts
Mr. Erich Zahn	Assistant to Prof. Dr. Kortzfleisch	Mannheim, Germany

Copies meadows seeger collins Brown to each one 9/29/70

JWF 9/24/70

LETTER TO THE VW FOUNDATION

Subject: New formulation of the application of the Club of Rome from May 22, 1970

Dear Secretary General:

According to the decision of the board of curators of June 26, 1970, I now submit in the name of the Club of Rome the new formulation of its application for a single grant for the performance of the project "Predicament of Mankind" (Appendix 1). You will see from this application that the amount of money of the application has been diminished to nearly 1/4 of the original one. This results from the fact that the methodology of System Dynamics, developed at M.I.T. in Cambridge, Massachusetts, can be applied to this research project.

As you already know, a part of the amount of money of DM 200,000, which was granted from the board of curators, was used for the performance of a symposium, the results of which made it possible for us to submit this new application just today. The rest of the money will be used -- according to Appendix 2 -- to prepare our plans within a "pilot project" so that after acceptance of the herewith filed application the work can start on November 15 and should be finished 9 and 1/2 months later.

It is our intention that a further study of subsystems and special problems to give politically relevant decision aids should follow the global project. For those further studies an international financing is intended. Furthermore, these studies will be made at Geneva. It is the opinion of all participants that, because of the world's political situation, the U.S.A. does not seem to be the right place for such a project.

But the project submitted today must be carried out at M.I.T., because only there are the scientists available who have already mastered the proposed methodology and who are capable of teaching younger scientists. In this connection I should like to mention that two young German scientists, Dr. Erich Zahn and Peter Milling from the institute of Professor v. Kortzfleisch of Mannheim are now fully involved in the performance of the pilot project.

With this application I send you a short report about the symposium together with the extraordinarily voluminous appendices which were made available as copies to the participants of the symposium from M.I.T.

I hope that our application finds a more positive response this time.

Sincerely yours,

Eduard Pestel

Enclosures:

JAY 7/31/70

Massachusetts Institute of Technology
Alfred P. Sloan School of Management
50 Memorial Drive
Cambridge, Massachusetts, 02139

July 31, 1970

Dr. Aurelio Peccei
Managing Director
Italconsult
Via Pastrengo 16
Rome, Italy

Dear Aurelio,

Enclosed are the two proposals for short term activities which we discussed before your departure. The first, dated July 29, covers only the direct costs of the conference itself plus the expected secretarial follow-up work. The second proposal, dated July 30, covers the interim period from the beginning of August to November 15, when final word on further funding by the Volkswagen Foundation should be available.

These proposals summarize our discussions through noon of July 30. Eduard had a chance to read them and sign just before he left Boston. In order to start things moving at M.I.T., I have taken his acceptance as "official". We both felt, however, that you should also have an opportunity to sign and to comment. (These proposals, however, are largely for administrative purposes; they do not attempt to describe in detail the work to be done.)

For the M.I.T. administration, we will need either the signed originals of the proposals, or a letter from the club establishing the grants. If the Volkswagen Foundation attaches any terms and conditions to its grant - terms which we should observe here at M.I.T. - I would appreciate your sending me a copy.

Also enclosed are the indexes of our conference books, so you may distribute them to other club members.

Also, we are almost ready to mail a complete set of the material to your son.

If there are any follow-up items which I have neglected in the rush, please let me know. Thank you.

Sincerely,

John A. Seeger
Administrative Officer
Urban Dynamics Group

JAS:nrk
cc: Jay W. Forrester
Dennis L. Meadows
Eduard Pestel

JWF 9/22/70

OFFICE OF THE PRESIDENT

CAMBRIDGE, MASSACHUSETTS 02139

September 18, 1970

Professor Jay W. Forrester
E52-454C
M. I. T.

Dear Jay:

I appreciate very much your kind note, and I was delighted to see that the Club of Rome meeting went well. I will be interested to hear about the progress of the project.

Yours sincerely,

Constantine B. Simonides
Vice President and Assistant
to the President

CBS:lj

SLOAN SCHOOL OF MANAGEMENT
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

INTER-OFFICE CORRESPONDENCE

JWF 9/21/70

FOLLOW-UP	
FILE	

TO Jay W. Forrester DATE 9/19/70

FROM John A. Seeger JAS (cc DLM)

SUBJECT Proposal by Club of Rome to VW Foundation

My comment on VW attitude toward overhead was apparently a false alarm. Dennis and I today went over the budget as Pestel proposed it to the VW Foundation; there are modifications, but no distortions of content.

Pestel reworked the personnel section to include employee benefits in with salaries. He added together the salary increments for you and Dennis, and showed the total opposite Dennis's name, representing Dennis as "100%". As this is a true representation of effort (if not of payroll distributions) it appears reasonable to me.

Pestel retained the line item for "indirect costs", dropping only the reference to percentages levied against direct salaries and wages. He combined computer costs into indirect costs. And he added $13,000 to the proposed travel budget, anticipating payment by the project of some travel for Club of Rome Executive Committee members.

Dennis is now working on final proposal (very similar to the preliminary proposal) which we shall transmit to Aurelio through the Division of Sponsored Research official channels.

JWF 9/21/70

ALBERT EINSTEIN COLLEGE OF MEDICINE
OF YESHIVA UNIVERSITY

DEPARTMENT OF PSYCHIATRY

Reply to:
SOUND VIEW - THROGS NECK
COMMUNITY MENTAL HEALTH CENTER
2527 GLEBE AVENUE
BRONX, N.Y. 10461

September 14, 1970

Professor Jay W. Forrester
Sloan School of Management
M.I.T.
Cambridge, Massachusetts

Dear Jay:

Thanks for your kind note. It was a pleasure to participate in your bold and promising venture with the club of Rome.

No commitment was made for an honorarium by Jack. Mel Roman and I both submitted a statement of travel expenses to the conference administrator, which has not yet been paid, but is a matter of no concern.

Best Regards,

Gilbert Levin, Ph.D.

GL/ip

JWF

September 18, 1970

Dr. Amasa S. Bishop
Director
Division of Environment and Housing
Economic Commission of Europe
Palais Des Nations
Geneva, Switzerland

Dear Dr. Bishop:

Though we regreted the interruption of your sailing last Saturday, I believe the meeting was very useful. The Club of Rome executive committee, Aurelio Peccei is unofficial chairman, considers the ECE work to be extremely important in its potential for extensive East-West cooperation. Hopefully your conference can catalyze the formation of more extensive efforts, for the Club of Rome program is based on the assumption that such collaboration is both feasible and absolutely necessary.

Phase I of the Club of Rome program involves the design of that model we discussed briefly last Saturdy. Assumptions about the relation of environmental quality to population growth, food production and economic development are critical determinants of behavior in the model. It would thus be extremely valuable to our group if we could spend one or two days with you going over the assumptions incorporated in the model. We must assess both the structure of the relationships and the value of parameters within that structure.

Would it be possible for you to visit M.I.T. for two days shortly after your November conference? We would, of course, pay all expenses and provide a consulting fee. I would attempt to bring here at the same time the man who will become Assistant Secretary General in charge of the Stockhom conference over Mussard. It would provide you with an opportunity to examine our work and our methods in detail.

You mentioned a recent article analyzing the Japan population study. If you can give me the specific reference, I'll send Aurelio Peccei the copy he requested. I look forward to studying your draft proposal for a future ECE program on the environment.

Cordially,

Dennis L. Meadows

DLM:jm

JWF

Massachusetts Institute of Technology
Alfred P. Sloan School of Management
50 Memorial Drive
Cambridge, Massachusetts, 02139

MEMORANDUM

TO: Aurelio Peccei

FROM: John A. Seeger

DATE: September 4, 1970

SUBJECT: Administrative Detail: money

Under the two research projects already established here for the Club of Rome -- the Conference and the first phase of the World Model work -- we expect to spend approximately $40,000 by mid-November.

MIT requests that all outside-sponsored projects arrange their finances so that funding comes in advance of expenditures. We have stretched that policy in the past two months with the cooperation of the Institute administration. Now it is time for us to catch up.

On your return to Rome could you arrange to send a check or bank draft -- whatever is most convenient for you? It should be made payable to Massachusetts Institute of Technology and mailed to:

Mr. Fred Watriss, Assistant Treasurer
Massachusetts Institute of Technology
77 Massachusetts Avenue
Cambridge, Massachusetts 02139 USA

It would be helpful if the check were accompanied by a note identifying the payment as funding for Account No. 72589 ($10,000), and Account No. 72508 ($40,000). A copy of this memo would serve the purpose.

Thank you very much.

cc. Jay W. Forrester
Dennis L. Meadows
Frank McGrory