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Carbon Dioxide, Climate and Society

J. Williams*

The fate of CO_2 produced by combustion of fossil fuels, its possible impact on climate and the implications for energy strategies were discussed at a workshop,** organized by IIASA and cosponsored by several other international organizations,*** in February this year.

Observations made in Hawaii and at the South Pole since 1958 and at other places for shorter periods have shown that the concentration of CO_2 in the atmosphere is increasing by about 1 part per million by volume (ppmv) per year. It is accepted that part of this increase is due to the combustion of fossil fuels, although it is possible that destruction of the biosphere is also adding CO_2. Concern over the increasing atmospheric CO_2 concentration arises because, while the gas is transparent to incoming short-wave radiation, it absorbs long-wave radiation coming from the earth's surface.

Consequently, an increase in the atmospheric CO_2 concentration leads to increased absorption and re-radiation of long-wave radiation: part of the re-radiation is back to the earth's surface, giving an increase of temperature there.

With this in mind, the main questions that were considered at the IIASA workshop were: How much of the CO_2 from combustion of fossil fuels will remain in the atmosphere? Are there other significant man-made sources of CO_2? What will be the climatic impacts of an increased atmospheric CO_2 concentration? Do the answers to the above questions imply an immediate curtailment of the use of fossil fuels or affect other energy policy decisions?

The sources and sinks of carbon dioxide

Three working groups met in order to address these questions. The first working group considered the question of the sources and sinks of CO_2 and the possibilities of predicting future levels of atmospheric CO_2 concentration given a knowledge of the fossil fuel input. CO_2 circulated between the atmosphere, oceans and biosphere and models are required to represent the exchanges of CO_2 between these reservoirs.

It turns out that our confidence in existing models of the carbon cycle is considerably less now than it was ten years ago. But nevertheless, the working group concluded that reasonable predictions of the level of atmospheric CO_2 concentration can be made for a period of 20-30 years using the existing models. The major uncertainty in these predictions is not in the role of the oceans but in the magnitude and

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**The proceedings of the workshop, containing all papers submitted and working group reports, are in preparation and will be published this year.

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direction of the net fluxes between the biosphere and atmosphere. The working group considered data indicating the apparent insignificance of forest fires and a number of changing land-use practices as sources of CO_2, but found further support for the idea that tropical forest clearing is a significant source of CO_2. However, it was felt that if there has indeed been a net global deforestation this has in part been compensated by regrowth patterns in areas cut over past decades.

What climate can we expect?

The second working group addressed the impact of increasing atmospheric CO_2 concentrations on climate and environment. A large part of the discussion centered on the use of models of the climate system to study the effect of doubling the CO_2 concentration. A variety of one-dimensional, globally averaged models have been used and the group considered that this kind of calculation has been refined to the point where, accepting a 25% uncertainty, a doubling of CO_2 concentration gives a 2-3°C surface temperature increase, depending on how clouds are treated in the models. However, these figures are calculated under carefully specified constraints on the behavior of the rest of the climate system. The group therefore also considered the use of expensive (time and money consuming) general circulation models, which simulate the three-dimensional atmospheric circulation and consider more of the feedbacks in the climate system. These models still have shortcomings, since, for example, they do not consider the coupling of the atmospheric and oceanic circulation. But, as the group pointed out, statements about global average temperature trends are of little value to planners and policy makers, who need to know what the regional changes in seasonal temperature and rainfall are going to be.

At the moment the complex models are not sufficiently developed to reliably answer these questions, but it can be stated that some of the regional changes will be both positive and negative with regard to temperature and precipitation. Model results already suggest that there will be more rainfall, because the warmer atmosphere causes more evaporation from the oceans, and this increase will show up in areas affected by monsoonal circulations and some mid-latitude regions. But, there will probably be places where rainfall decreases because of altered large-scale circulation patterns. Since our present socio-economic system is tuned to present climatic conditions, large-scale climatic changes, especially those affecting the production of food, can be expected to have many repercussions.

What does this mean for energy strategies?

The third working group considered the implications for energy policy decision-making of the CO_2-climate questions. It was judged that mankind needs and can afford a time window of between 5 and 10 years for vigorous research and planning: this would serve to reduce the uncertainties found in almost every aspect of the CO_2 issue and thus sufficiently justify a major change to energy policies that can be more responsive to the CO_2 problem than is continued reliance on abundant and inexpensive fossil fuels.

The group discussion centered on the question: What are the tolerable rates of burning fossil fuel? It is clear that to maintain a rate of fossil fuel use at or below a certain 'tolerable' level, while maintaining hope within the impoverished masses of the world, will require extremely careful planning and the ability to deploy inexhaustible energy sources effectively. The aspirations and energy requirements of the developing world will play a major role in determining the rates of fossil fuel use on a global scale.

In considering the above question the working group derived five policy statements, which together reflect the importance of flexibility in determination of energy policies.

1. Quantitative estimates of the rates of increase of atmospheric CO_2 concentration and other molecules that absorb long-wave radiation and of the resulting global and regional climatic changes are not only uncertain now but are likely to remain so for most of the next decade. It is therefore premature to implement at this time policy measures that require reduction in the use of coal and other fossil fuels. Present knowledge is sufficient to require detailed study of alternative energy supply systems but does not yet warrant a policy of curtailment of fossil fuel use.

2. On the other hand, policies which emphasize the use of coal, because of its great abundance, in preference to non-CO_2-producing energy supply systems are equally unjustified. Such policy decisions can become difficult and very costly to reverse. Emphasis on coal at the expense of either hard or soft solar, nuclear (including the breeder), nuclear and/or solar-methanol systems appears to be unreasonable in view of the possible CO_2 consequences. The maintenance of great flexibility in energy supply policies at this time is necessary.

3. Environmental impact assessments of escalating energy use must be performed with greater depth than in the past and on a scale commensurate with the potential importance of the problem.

4. It would be highly desirable to devise energy supply systems that allow ready environmental amelioration. This concept requires that energy systems are non-polluting (or very nearly so) or that undesirable effects are easily mitigated (at acceptable cost and energy expenditure).

   Non-polluting systems include (1) a solar or hydro electric hydrogen economy, (2) the IIASA 35 TW scenario fueled largely by synthetic methanol manufactured at large energy parks with nuclear or hard solar energy supply, or (3) a very highly decentralized solar energy supply system, which, however, is unlikely to provide sufficient energy to maintain the global economy at a satisfactory level.

   Systems that allow easy mitigation include those employing short-time recycling of carbon through the atmosphere. Biomass as fuel with prompt and rapid regrowth is one example. Stripping CO_2 from exhaust stack systems and even from the atmosphere itself is technically feasible and the manufacture of synthetic methane or methanol (as in the IIASA scenario) from the carbon thus obtained would be an effective "short recycling time system". It is also possible to "store" CO_2 in the living biomass by planting more trees, or in the deep oceans by locating and using areas of sinking ocean waters or in old oil and gas wells. These techniques may prove costly in either money or time, but quantitative tradeoffs may prove either favorable or necessary. Another possibility is in the area of climate modification or control, e.g. controlled modification of the albedo.

5. No less important than effort to maintain an appropriate energy supply are those to reduce energy demands. With carefully developed procedures, energy demands can be reduced on a global scale without causing unacceptable changes in the global economic well-being.

HAM: The Hungarian Agricultural Model

C. Csáki*

Because food production is one of the most decentralized activities of mankind, the focal point in Food and Agriculture Program's (FAP) research at IIASA is the modeling of various national food and agricultural systems.** To study the world's food and agricultural problems, consistent national agricultural policy models will be constructed and linked at IIASA. The international and East-West characteristics of IIASA offer a good opportunity for the appropriate modeling of market as well as centrally planned economies.

The first result of IIASA's modeling work on the agriculture of CMEA*** member countries is the development of a national policy model for the Hungarian food and agricultural sector.

1. IIASA's approach

In the CMEA member countries, agricultural policy and policy goals are determined by the fact that they are integral parts of the central plans for the whole national economy. The basic figures of production and consumption are fixed by the national plan and realized by coordinated systems of sectoral (industry, agriculture, etc.), regional, local (country, city, etc.), and enterprise plans.

In the planning of a country's economic development, meeting a constantly growing demand by a balanced growth of production is considered as a basic requirement. Therefore the government's agricultural aims are the following:

- satisfactory growth of food production and increased efficiency and productivity in agriculture by:

  concentration and specialization of agricultural production through the organization of large-scale state and cooperative farms and agro-industrial combines, and modernization of the whole of food production or its branches by introducing industrialized production methods and techniques;

- a certain degree of self-sufficiency of the country in agricultural products;

- optimization of foreign exchange earnings from agriculture;

- the improvement of living and working conditions of the population; and

- a stress on development of food processing industries to increase the share of processed foodstuffs produced for consumption and export.

Only a few of these policy objectives are emphasized in any country at a given period of time, and by no means the same ones.

Although the methods for realization of these policy objectives are by both direct and indirect means in each country, their role is different. With respect to modeling agriculture we can draw two basic conclusions:

First, in the centrally planned economies the whole agricultural system is controlled by the national plan and the market has only a partial role determined directly and indirectly by targets for production and consumption. Therefore, we need a different model structure from those developed for the conditions in market economies.

Second, though the major agricultural policy goals are similar, there is no unified agricultural policy of CMEA countries as in the countries of the European Community (EC). Therefore, a country by country approach seems necessary in modeling this area.

Using the experiences gained from former agricultural modeling work in socialist countries and the results of FAP methodological research on the general structure and linkage of national food and agriculture models, we would like to develop a relatively new model structure for centrally planned food and agriculture systems.

This structure:

- should incorporate the basic features of the CMEA member countries' economy,

- should be consistent and comparable with other parts of IIASA's Food and Agricultural model system,

- should be detailed enough to be used as an experimental tool for investigations connected with the development of food and agriculture, and

- would hopefully contribute to the further development of techniques applied in the planning and management of food and agriculture.

As the first step in the realization of IIASA's objectives in the modeling of centrally planned agricultural systems, the structure and the first version of the Hungarian Agricultural Model (HAM) has been developed as a prototype for the CMEA countries. This work is a joint undertaking of IIASA and three institutions in Hungary,* which is coordinated and supervised by a special committee under the Hungarian Committee for IIASA. We hope the experiences gained with this model can be used for further work in this area. Work has already begun on modeling the Bulgarian and Czechoslovakian food and agriculture systems.

2. Some features of Hungarian agriculture

Agriculture plays a traditionally important role within the Hungarian national economy. Although the share of agriculture in the production of national income has considerably decreased, agriculture still remains a very important national economic sector. An area of more than 6.7 million hectares of land, over 70% of the total territory, was under cultivation in Hungary in 1974. Arable lands represent 53.5% of national territory, which is one of the highest ratios known in the world.

In 1974, some 16.2% of the Hungarian national income was produced by, and 20.4% of the working population of 10.5 million employed in, agriculture.

The per capita value of agricultural production is higher in Hungary than in other centrally planned countries and in certain respects it exceeds the levels reached by countries of the EC. In 1975, the per capita annual meat production in Hungary was 140 kg while the average for the EC countries was only 71 kg, and for the USA 109 kg. In 1975, Hungary produced 25.9% of the total corn production of the CMEA countries. In addition, to satisfying to a high degree the food demands of the population (in 1975, 3242 cal and 100 g protein consumed daily), the Hungarian agricultural sec-

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**General outline of IIASA's Food and Agricultural Program was described in OPTIONS 78/1.

***Council for Mutual Economic Assistance.

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tor is also a considerable and regular supplier of products for export.

In 1974, agricultural products and foodstuffs represented about 23% of total Hungarian export. For several years now, Hungary's foreign trade turnover figures for agricultural products have shown a significantly positive balance with both socialist and non-socialist countries.

In the last few years, Hungarian agriculture developed relatively rapidly. The annual rate of development was 2.8% between 1966 and 1970 and 4.8% between 1971 and 1975. In recent years, progress was accomplished by increasing the yields of cereal fodder, mainly wheat and maize, and by poultry and pig breeding. Relatively large scale farms are characteristic of Hungarian agriculture.

The major agricultural policy goals are fixed by the five-year and long-range plans of agricultural development. Under the present (fifth) five-year plan (1976-80) the development of animal husbandry, in particular cattle and pig production, and the food processing industry as well as the increase of foreign exchange earnings from the export of foodstuffs are emphasized. These targets are realized through the implementation of indirect economic means. The cooperative and state farms and other enterprises have a relatively wide economic independence.

3. Basic characteristics of HAM

In Hungary and in other centrally planned countries of Europe several models have been developed to describe the agricultural economy. In most cases the modeling of agriculture has been connected with the elaboration of the national five-year and long-range (15-20 year) plans. The models generally cover the agricultural production sector, but one can find models including the food processing sphere, too. The remaining part of the national economy is taken exogenously. In a few cases the agricultural model was connected with an aggregated model of the whole national economy (two-level planning). A static deterministic and normative approach is common (mostly linear programming), supplying results for the end year of the time period. Econometric methods and simulation techniques have been used in only a few cases at the macro-level in agriculture, and until now no detailed macromodel of Hungarian agriculture has been completed using the latter methods.

Unlike the normative agriculture models that have been developed, HAM has a descriptive character. It reflects the present operation of the Hungarian food production system and, therefore, the present decision-making practices and economic management of the government are described. At the same time, various normative elements, such as government decisions and published plan targets influencing the projected operation of the system, are also considered.

The main objective of this modeling effort is not straightforward optimization, but to make a tool that offers opportunities for a better understanding of the dynamic behavior of the Hungarian agricultural system and the interactions of its elements, so that the model can also be used for mid- and long-range projections.

In HAM we try to endogenize a large part of the economic environment and the most important factors of food production. Hungarian food and agriculture is modeled as a disaggregated part of an economic system closed at the national as well as at the international level. Therefore, unlike former Hungarian agricultural models, HAM has the following features:

- the food consumption sphere is incorporated;
- the nonfood production sectors of the economy are represented by assuming that they produce only one aggregated commodity;
- the economic, technical, biological, and human aspects of food production are covered;
- both the production of agricultural raw materials and food processing are modeled;
- under "other" agricultural production and food processing, all products not individually represented are aggregated, and
- financial equilibrium is maintained.

HAM is, in fact, a system of interconnected models. Two spheres are differentiated within the system.

The economic management and planning submodel describes the decision making and control of the socialist state. The submodel of the real sphere covers the whole national economy, including the disaggregated food production sector. The major blocks of the latter submodel are related to production, consumption, and trade, as well as to updating available resource and model parameters. (HAM consists of five major blocks.)

The overall methodology used by the model is a simulation technique. For the description of subsystems, suitable techniques, e.g. linear programming and econometric methods, are employed. The model is dynamic, with a one year time increment. Subperiods within the year are not considered. The time horizon of the analysis is 15-20 years. Random effects of weather and animal disease conditions can also be considered.

Long-range government objectives such as the growth of the whole economy, the growth rate of food production, meeting the increasing consumer demand, a given relation of consumption to accumulation, and a given positive balance of payments in food and agriculture are considered as they are determined by the long-range development plan of the national economy. HAM is focused on the development of food and agriculture (production structure, investments) and its interaction with the rest of the economy.

4. Possible usage of HAM

HAM can obviously be considered an element of the FAP agricultural model system being developed and as such it will be linked with other national models and used for global investigations. Furthermore, HAM might be used as an experimental tool for investigations connected with the development of Hungarian food and agriculture in the following way:

- Based on the model, the realization of major policy goals and plan targets and their main alternatives can be investigated. For example, the key factors and bottlenecks of realization, the considerations for a faster growth, the expected labor outflow from agriculture, and the feasibility of the goals may be analyzed.
- Linking with other national models, HAM is suitable for studying the adjustments and reactions of the Hungarian food and agriculture system to a changing international market. For example, export and import structure, the desired level of specialization or self-sufficiency, and the reaction of the domestic to the world market may be investigated.
- Finally, HAM is designed to be useful for the further development of the Hungarian economic management system, since the model can analyze the efficiency of policy instruments, the impacts of the new instruments, and the areas of additional control requirements.

5. First version of HAM and further work

The elaboration of a detailed national agricultural policy model requires in-

tensive economic analysis as well as complex and relatively large scale data collection modeling, and computer programming work. Therefore this kind of venture is generally realized in several stages. In developing HAM, it took a few months to complete the general structure of the model. Now, after one year of work the first version of HAM (Ham 1) based on real data is operational on both IIASA and Hungarian computers.

HAM 1 describes the Hungarian food and agricultural sector in a rather aggregated way (in the model 9 food and agricultural commodities and 1 commodity expressing the rest of the economy are considered) and it has all of the basic features described above.

During the last two months several runs of HAM 1 have been executed (each for a time period of 15 years):

- to investigate how the model reflects reality;
- to analyze how appropriate the applied methodological solutions are;
- to study the reactions of the system (Hungarian food and agriculture) as reflected by HAM 1 to changing external conditions (e.g. changing world market prices);
- to calculate the impacts of changes within the system (e.g. modification of some of the policy instruments or decision-making rules) on the performance of the whole system.

The results of our first calculations are rather promising. The methodological investigations included

- testing the operation of the whole model system,
- investigating alternative methodological solutions for some of the model modules (e.g. instead of linear programming, using non-linear optimization in the consumption and trade block), and
- performing sensitivity analysis of the crucial model parameters.

They have supported the appropriateness of our approach and led us to several conclusions that are important for the further refinement of the model.

Based on the experiments with HAM 1, a presentation of the results in Hungary in the second half of April 1978, a model presentation at IIASA and probably also in the Soviet Union, further development of HAM will take place later this year. The final model version (HAM 2) with more disaggregate commodity coverage (about 25 food and agricultural commodities) is expected to be completed by the end of 1978.

Models and Computing

Wm. Orchard-Hays*

Mathematical models are an important part of a system analyst's tool kit. There are several purposes to which models may be put, but perhaps the four primary advantages are:

1. They demand clarity of concepts and often result in new theoretical insights, not always limited to technical ones.
2. They usually permit simulation of aspects of reality that cannot be studied empirically (for example, the possible effects of an economic policy).
3. They sometimes permit relatively rapid simulations of long time spans. (In one case, 150 years were simulated in 150 minutes.)
4. Some models simply automate involved calculations, with less chance of error and with more comprehensive results than could be achieved otherwise.

Many models encompass all these advantages, but all models are abstractions. It must be possible to extract from the real world those features that are important to the study at hand without seriously violating "reality". This is often no simple task.

Though computing is only one aspect of mathematical models--and even today some models are mainly for theoretical studies--applied systems analysis most often requires computerized models. Indeed, the complexity and use of today's models are almost completely dependent on computerization. The world of computing has mushroomed in a quarter century not only in technical wizardry and economic importance, but in concepts as well. Language has not always kept pace, not to speak of clarity of understanding by the many professions that utilize this new power. Words have been abused and lost their former precision of meaning. Terms such as "file", "data processing", and even "computation" which at one time seemed fairly precise, can now mean almost anything in detail. The word "model" has been similarly abused and there is prevalent some confusion about the nature and purpose of models as now realizable with the aid of computers.

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Developing a model

One can recognize seven distinct stages in the development and use of a model or system of models:

A. Conceptualization. It is obvious that someone must conceive of a model before it can be created, but conceptualization includes, beyond just an idea, a theoretically sound approach to modeling the real situation under study, replete with some form of equations and a scheme of symbolism that represents concise, even if abstract, concepts. It must also include competent judgment as to the feasibility of the work it suggests. This first stage may require a stroke of genius, together with boldness, or it may fall out rather naturally from prior experience, but it is the sine qua non of the model.

B. Detailed structuring. The concepts must be fleshed out with detailed study of the various factors to be taken into account, the results to be found, the consistency of various assumptions, and the inevitable simplifying approximations, the computability and trade-offs between increased effort and increased benefits, and the availability of appropriate data. Detailed structuring may never be fully satisfactory and refinements often continue throughout the life of a model. Furthermore, this stage refines and modifies the original conceptualization.

C. Numerical implementation. The detailed structure of a model is mathematical in form but the model does not exist in any realistic sense until meaningful numbers are available for coefficients, parameters, and control variables. This can involve a vast effort requiring statisticians, technical experts, preliminary data processing, and judgment. Even then, initial values will often be only first approximations or best estimates. Data refinements will almost certainly continue, may require changes in the structure of the model, and may even challenge the feasibility of the original concept.

D. Computer implementation. This stage, though embodying the work of the first three stages, is different in nature. It is an exercise in computer programming and system design, requiring different skills and interests. The efficiency and usability of the computerized embodiment of the model are important and require specialized expertise of their own kind, just as the other stages do.

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Again, this stage may require modification or adjustment in the results of the prior stages. It may be found excessively expensive to carry out the required calculations, though much of this kind of difficulty should have been foreseen. A more serious problem may be inconsistency in data and instability in computational algorithms which, however, may not become apparent until later stages.

E. Running test cases. When the computer programs are ready and have had preliminary testing, and initial data are at hand, computer runs are made. It is not to be expected that first runs will be satisfactory. Typically, three kinds of problems arise:

a) The programs, though nominally checked out, do not properly handle unforeseen circumstances. Correcting this is simply a process of continuing refinement and must be counted on. It may, however, disclose flaws or omissions in the work of stage B, requiring a certain amount of "going back to the drawing board".

b) The data may be found inconsistent in some sense, even though not technically wrong. This can require tedious calibration of the data or a side study by data experts.

c) The algorithms may prove unexpectedly slow or unstable on actual data. This can be very serious requiring work by methodology experts. In the worst case, it could render the whole effort impractical without a new approach.

F. Production runs. Assuming one gets through stage E satisfactorily, a new capability has been created that can now be exploited, namely production runs of various cases. What models really provide is artificial experience. However, one cannot run an infinite number of cases and so considerable judgment and skill are required to use the model effectively. The presentation of results often requires further sophisticated processing also. It is not easy to interpret reams of paper output.

G. Review and evaluation. The development of some modern modeling techniques was largely carried out for, and with, rather deterministic models. The approximate validity of results could be determined with a quick perusal by the responsible manager. This is not the kind of model with which we are most concerned. As models are applied to more futuristic problems, or those with less rigorously defined ranges of variation and well-established norms, the results of a run must be subjected to critical review and interpretation. This requires a broad scope of knowledge and judgment.

The language problem

Thus, one can see that the creation of an elaborate modeling capability may be a long, tedious, and expensive process. Present-day computers and software make possible the creation and use of extensive models which incorporate intricate mazes of information, rules, representations, and relationships. This very power in itself creates difficulties; one is the intrinsic meaninglessness of representations. For example, the greek letter pi has nothing whatever to do with the ratio of the circumference of a circle to its diameter. It is only because that letter (i.e. graphic) has been used universally for a long time to denote the ratio, that we feel the graphic itself is meaningful. Even before computers, special jargons--as in a trade or profession--were regarded as "gobbledy-gook" by the uninitiated. With modern computing practice, each user-analyst can create his own jargon, which even he may not fully remember a year later. Furthermore, there are nearly always at least two systems of symbology involved in a computerized model. The first is more or less conventional mathematical notation with perhaps a few additional acronyms. The second is the rather stiff symbology of some computer programming language. One tends to feel that translation of the first to the second should be relatively simple--hardly worthy of the efforts of the senior analyst. This viewpoint overlooks two facts.

First, mathematical notation is nonprocedural. It represents relationships, not actions. This is why the statement of an algorithm is sometimes awkward or, if specialized notation (which exists) is used, it is so cryptic as to be almost unreadable. But a model implies actions, namely computations and other data manipulations carried out procedurally. Specifying relationships is only part of the job; the procedure is also an inherent part of the model. Indeed, there is a hierachy of procedures. Thus, programming is an important part of a model, not merely a practical necessity to make the computer work.

Second, even a perfect description of a model does not cause anything to happen unless there exists a working processor that "understands" the symbology. It is this fact--and misconception of its nature--that has the most profound implications. It is entirely possible for a person to be capable of quite an acceptable job of programming and checking out a complicated computer program without ever really understanding the nature of the mental, physical, and mechanical actions carried out. For example, we commonly refer to a procedure having been implemented, to a program being available, to a library of subroutines, etc. But if one asks for a precise answer as to where and in what form a program exists, it turns out to be all but impossible to give an answer. This is not due merely to the proliferation of computers, programs, manuals, etc., which may require a kind of specialized librarian's knowledge. The various forms in which a program exists recede into more and more transient states until finally, during execution, a program can hardly be said to have an identifiable existence at all. It is all mixed up with many other programs under execution. Its execution is controlled by still other programs of which the application programmer is largely or wholly unaware. The levels and degrees of abstraction are so extensive as to almost defy description. However, there are people, obviously, who understand them. (Even "printing out" a program requires much sophisticated equipment, the program is not just "there" in such a form.)

Implementing a model

Thus, computer implementation itself involves several stages or steps. First, there is a transformation of mental concepts to a written form. Second, there is a transformation of cause-and-effect relationships into a procedural program. Concurrently or additionally, there is another transformation into an implemented programming language. Once this step is reached, the vast resources of modern computing technology essentially take over. But computing technology cannot push much further back. Somewhere in these first steps, a mechanically unbridgeable gulf is crossed by human mental activity. However, even though this cannot be automated, it can be somewhat standardized, in much the same way as principles of algebra, geometry, and analysis have been standardized. There is nevertheless an additional difficulty: there are no universal principles, basic theories, and scarcely any provable theorems--at least not at the present. Hence, one must take a definitional approach and introduce specific conventions. Many scientists find this distasteful, since it seems to force the problem into a preconceived form. Still, it is a practical necessity for much work simply due to the extremely high cost of development of elaborate systems of programs.

One kind of modeling widely used is called optimization, particularly those techniques from the field of mathematical programming. This area is an outgrowth of the technique called

linear programming developed right after World War II. Computerization is a necessity for this type of model and its various extensions and descendants, due to the enormous amount of arithmetic. However, arithmetic is really only a part of the problem. Computer software for this area has been more highly developed over a longer period of time (now exceeding a quarter century) than for any other modeling technique, and current systems of programs are so elaborate as to require experts in their use, not to speak of model formulation for a particular investigation. Indeed, this software now often includes facilities to help in the formulation itself, and particularly in what are called model generation and reporting.

IIASA's facilities

Software of such scope requires a powerful computer, even though preliminary and auxiliary work may be done on more modest equipment. This is one of the special considerations at IIASA. First of all, IIASA is not a large institution by comparison with national research centers or large universities. IIASA does maintain an in-house computer facility and, within our budgetary limitations, a very fine one, but modest in size. Second, IIASA staff--by intent and for our major purposes--includes researchers from many different countries with greatly differing capabilities and styles of computer usage. Furthermore, the staff has a higher turnover--for positive reasons--than most other institutes of a similar kind. Finally, telecommunication facilities are generally less advanced in Europe than in the USA and, between East and West, only in a preliminary stage. (IIASA itself is providing leadership in the latter development.) Consequently, it sometimes takes extraordinary efforts to obtain the use of the necessary computing capability for important IIASA studies.

When one speaks of computing capability, one usually means more than the raw computing power of the hardware and basic software provided by a manufacturer. Elaborate systems of programs for important applications areas have been developed, but these may be specialized to particular makes and models of equipment and the proper combination may not be readily available. Beyond this, each center needs to build up its own style, experience, and know-how that can be applied with a minimum of effort to new tasks. This is one of the greatest difficulties for IIASA, for reasons that should be apparent from the preceding discussion.

The CNUCE - connection

IIASA's National Member Organization in Italy is Consiglio Nazionale Ricerche (CNR) and one of its subsidiary institutes is CNUCE, located in Pisa. CNUCE operates a larger computer center which provides fully adequate hardware and much software suitable for advanced modeling techniques and other purposes. They are also very active in telecommunications networking. This combination of circumstances makes use of the CNUCE facilities especially advantageous and appropriate for IIASA, utilizing a dedicated telephone line and terminal equipment. Such an arrangement has been in practical, everyday use since the Spring of 1977. Although the volume of work is much less than on IIASA's in-house facilities, it provides a valuable additional capability at a reasonable cost.

One special software system installed in Pisa is for mathematical programming work of a developmental nature and includes extensive provisions for model generation and reporting. It is also usable for general computational work in an interactive mode and it is the only system of this type so designed. It was developed in the USA at the National Bureau of Economic Research under a federal grant by this writer before he joined IIASA, and he has further enhanced it during the past year and a half. Models of considerable complexity and size have been implemented and used with this system, with remarkable ease and flexibility. The telecommunications facilities include links between IIASA's in-house computer, a network-node minicomputer also at IIASA, and two large computing systems in Pisa. (Other large computers and even networks are accessible also.) In the Energy Program's system of models, some are implemented in Pisa, some locally, and supportive work is done in both places and elsewhere, as most appropriate. Both data and programs are often transmitted between the various processors. There are still limitations on practical speed and volume of transmission but, with assistance from both IIASA's Network Project and our Computer Services department, a remarkably versatile combination of facilities is already in being.

It is expected that such capabilities will continue to improve and expand. The major difficulty now is not so much technical as educational. The complexity and sophistication of the various systems is often more than can be comprehended by staff members, in a reasonable time, to the degree necessary to take full advantage of what is available. There is likewise the ancillary problem of documenting work that has been done so that it can be used or at least referenced in the future, often by new researchers. These problems have not yet been satisfactorily solved and will require a determined effort in the immediate future.

News from IIASA

IFAC moves to Laxenburg

The "International Federation of Automatic Control " (IFAC) has moved its international Secretariat from Helsinki, Finland, to Laxenburg near Vienna, thus making one of the important international scientific bodies a neighbor of IIASA. IFAC was founded in September 1957 and has, at present, 38 national member organizations.

The moving of the IFAC secretariat to Laxenburg follows an offer by the Austrian government, which on April 21 signed a contract with IFAC concerning its new offices. The address of the new IFAC-secretariat: Schlossplatz 12, A-2361 Laxenburg.

Prof. Howard Raiffa, first director of IIASA, and Ralph Keeney, member of IIASA's System and Decision Sciences group from June 1974 until July 1976, jointly received the 1976 Lanchester Prize of the Operations Research Society of America for their book: "Decisions with Multiple Objectives: Preference and Value Trade-Offs". The Prize citation states that "this book makes a major step forward in both theory and application of decision theory...There can be no doubt that this book is a major contribution to the advancement of the state of the art of operations research. "The Prize was presented to Ralph Keeney by the Chairman of the Lanchester Prize Committee, Ralph Disney, at a meeting in Atlanta, Georgia (USA) in late 1977.

The Sixth IIASA Network Meeting was held in Sophia, Bulgaria, on March 28-30, 1978. There were approximately 80 participants from the several institutes that are affiliated with the IIASANET project. The meeting consisted of demonstrations of access via dialed and leased lines to data bases at the European Space Agency in Frascati, the International Atomic Energy Agency in Vienna, and the Computing Research Center in Bratislava. Since Bulgaria has no public international direct dial access, the direct dial service provided by the Bulgarian PTT for the experiments was of special interest. The papers presented gave details of the present state and plans for national networks together with several proposals for the future configuration of the IIASANET. These proposals included both terrestrial and satellite segments.

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