The Biosphere and Humanity

Paper Presented on IIASA's 20th Anniversary

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CP-94-4
April 1994

Cover design by Martin Schobel

Printed by Novographic, Vienna, Austria

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Foreword

IIASA celebrated its twentieth anniversary on May 12–13 with its fourth general conference, *IIASA '92: An International Conference on the Challenges to Systems Analysis in the Nineties and Beyond.* The conference focused on the relations between environment and development and on studies that integrate the methods and findings of several disciplines. The role of systems analysis, a method especially suited to taking account of the linkages between phenomena and of the hierarchical organization of the natural and social world, was also assessed, taking account of the implications this has for IIASA's research approach and activities.

This paper is one of six IIASA Collaborative Papers published as part of the report on the conference, an earlier instalment of which was *Science and Sustainability*, published in 1992.

In his paper Dr. Chadwick provides a summary of the principal global models to attract attention over the last few years. What may be called the "global modeling movement" reached its peak in the 1970s – ten are listed in Chadwick's summary – and then declined down to two in the 1980s, but apparently the movement has by no means lost its force in the 1990s.

To this reader the interest of the models is in the varied and often mutually contradicting results that they produced, all working from similar data and using computer programs with about the same features. Thus the World 2 model, attributed to Jay Forrester, and World 3, developed by Meadows *et al.*, both showed that the world has already, or on present trends will soon, pass its sustainable limit and then collapse. The Bariloche model, originating in Argentina that has had financial difficulties, considers that if the developed countries can pass down two percent of GNP as aid all will be well – the environmental problem is less urgent than the financial. The Japanese model, FUGI, would attain harmonious growth by shifting investment to developing countries, provided there is coordination among the investing countries.

Dr. Chadwick's group is preparing its own model, POLESTAR, that should be released soon. Much of the paper is concerned with the new model, that will have some novel and potentially valuable features. What are the criteria of success of a model? In the past the main criterion has been to arouse the interest of a wide public. POLESTAR seeks to meet more exacting requirements than this. We will have to wait for the results before its success can be judged. Meanwhile the reader will be interested in the plan on which it is being created.

Committee for IIASA '92
Nathan Keyfitz (Chair)*

*Members of the Committee for IIASA '92 were: Nathan Keyfitz (Chair), Peter E. de Jánosi, Alexander Kurzhanski, Arkadii Maltsev, Nebojša Nakićenović, Roderick Shaw, Claudia Heilig-Staindl, Evelyn Farkas

The Biosphere and Humanity

Michael J. Chadwick

Abstract

Methods of investigating the possibility of meeting the needs and aspirations of a world with 10 billion people are considered, following a brief review of a selection of "global models" previously employed. It is suggested that past modeling work supports the view that geographical variations in resource use and supply must be incorporated into a search for an "optimistic scenario" rather than dealing in global mean values. This is essential, as it is evident that supply inequalities rather than overall physical limitations of supply are the reason for any inability to meet the needs of an increasing World population. A transparent, relatively simple and iterative modeling procedure (POLESTAR) that is of use in investigating sustainable development pathways is briefly outlined.

1 Introduction

Over 35 years ago Thomas (1956), in *Man's Role in Changing the Face of the Earth*, addressed some of the major issues relating to the Biosphere and Humanity. This work emphasized that, as well as Man changing the biosphere, the biosphere also determines, and has determined, much of Man's behavior and responses to external influences. A chapter entitled *Humanity and Nature* in the IIASA report to UNCED (Shaw *et al.*, 1992) addresses the same subject

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and the whole of the UNCED process, and AGENDA 21, in particular, points out the relationships between environmental problems and the economic framework in which development issues must be undertaken. Environment, development, and hence economic and social systems interact. As MacNeill *et al.*, (1991) stress, environmental and economic systems are interdependent.

2 Global Models

One way of exploring the interdependence of elements of the global system has been to adopt a systems approach and use models to investigate characteristics of the system. Over the last 20 years considerable effort has gone into such activities. Indeed, a symposium on global modeling was held early in the life of IIASA, in 1978 (Meadows *et al.*, 1982), when many of the models to which I refer here were presented and evaluated. The assessment made here is approached rather differently. *Table 1* attempts to summarize 12 "models" in terms of their main purpose, *Table 2*, their structure, and *Table 3*, their results and main conclusions. Many of the outcomes and conclusions of the models could be anticipated but, nevertheless, a composite message would require inclusion of the following factors:

1. While some models emphasized the physical limits of the global system, particularly environmental sinks, where social and political features were included these modified this conclusion. Taking the models together, the overriding effect of economic, political, institutional and social determinants were stressed.
2. Regional differences and interactions were of crucial importance.
3. To envisage a global situation where conflicts were minimized and equity increased, rather major economic changes seemed to be necessary: high aid requirements, changes in investment patterns, stabilization of world prices and ability to respond adequately to high degrees of uncertainty.
4. Although it would be an oversimplification to suggest this as the sole outcome, it is nevertheless possible to recognize an overall *pessimism* resulting from model investigations.

Table 1. Global models.

Model	Year	Key references	Purpose
1. World2	1971	Forrester (1971)	Investigate the behavior of the World System as current growth trends are continued.
2. World3	1972	Meadows *et al.* (1972) Meadows *et al.* (1974)	Investigate limits of the World System; identify dominant elements influencing long-term behavior.
3. Mesarovic–Pestel	1974	Mesarovic & Pestel (1974)	Test economic and policy options for a regionalized world.
4. Bariloche	1974	Herrera *et al.* (1976)	Investigate socio-political obstacles to the attainment of an "ideal society".
5. FUGI	1974	Kaya *et al.* (1980)	Use of scenarios to identify policies relating to harmonious growth between industrialized and developing nations.
6. MOIRA	1975	Linnemann *et al.* (1979)	Examination of the world food situation in terms of limitations.
7. SARUM	1976	SARU (1977)	Detection of areas and extent of stress in global system development.
8. UN World Model	1977	Leontief *et al.* (1977) Petri (1977)	Develop framework for global projections in which economic interdependence features.
9. Global 2000	1977–1979	CEQ (1980)	Determination of the effect of continuation of present policies on population resources and the environment.
10. Marchetti	1978	Marchetti (1978)	Investigate the consequences of a 1000 billion world.
11. Surprising Futures	1986	Svedin & Aniansson (1987)	Investigation of the role of surprise in societal development.
12. Basic Linked System	1988	Fischer *et al.* (1988)	Exploration of simultaneous changes in several policies of different governments.

Table 2. Global models: time-span, method of investigation, structure and manipulative potential.

Model	Time span	Methodology	Structure	Manipulation
1. World2	1900–2100	Systems dynamics with feedback loops between sectors.	Population, capital, agriculture, pollution and natural resources. No social factors or geographical disaggregation.	Standard run; adjust parameter values and run simulations.
2. World3	1900–2100	Systems dynamics with feedback loops between sectors incorporating time delays.	Population, capital, agriculture, pollution and natural resources; few social factors included but partial disaggregation of population, capital and agriculture.	Standard run; alteration of technologies and social policies; sensitivity analysis.
3. Mesarovic–Pestel	1975–2025	Multilevel hierarchical systems.	Individuals, groups, demo-economic, technology, ecology and geophysics; ten geographic regions.	Use of scenarios to test policies.
4. Bariloche	1960–2060	Optimization procedures.	Nutrition, education, housing, capital goods and consumer goods in four geographical regions.	Standard run; alteration of socio-economic policies.
5. FUGI	1970–1985	Input–output model with links between modules, sectors and regions.	Global input–output, global macro-economic and metal resources components with 15 geographical regions in the first two.	Alteration of assumptions of relative economic growth in industrial and developing countries.
6. MOIRA	1975–2010	Optimization procedures.	Main agricultural sub-sectors in 106 nations.	Standard run for one year on agricultural policies; sensitivity analysis.

7.	SARUM	50 years	System dynamics, input–output, econometrics and a multilevel approach with links between variables, sectors and regions.	Economic sub-sectors (13) and 15 regions.	Commodity price variations investigated.
8.	UN World Model	1970, 1980 1990, 2000	Input–output model.	15 regions each with 45 sectors including economic and pollution features; sectors are linked.	Scenarios based on GDP growth rates investigated.
9.	Global 2000	1975–2000	Forecasting by projections.	Forecasts link projections in one field (such as GNP, climate) to resource and environmental projections.	Projections using tools of government (such as policy assumptions).
10.	Marchetti	Unlimited	Forecasting.	No model structure – global scenarios.	Population, primary resource and environmental effects.
11.	Surprising Futures	1975–2075	Imaging.	No model structure but population, agriculture and energy use considered.	Standard run and others incorporating "surprises".
12.	Basic Linked System	1990–2000	Simulation model with linear and non-linear programs.	Country dimension to food production, consumption and trade.	Effects of policies on domestic food situation.

Table 3. Global models: some results and conclusions.

Model	Result	Conclusions
1. World2	Physical limits resulting in collapse of system.	Current trends will lead to collapse of the system; equilibrium attained by imposing limits.
2. World3	Overshooting and collapse evident but technical progress and social change factors modify the result.	Measures required if equilibrium is to be imposed.
3. Mesarovic-Pestel	Economic gaps between regions are reduced with the early application of development aid.	International cooperation and coordination required at the level of a "New World Order".
4. Bariloche	Two percent of industrialized countries GNP must be allocated to developing countries.	Need for new aid policies.
5. FUGI	Harmonious growth obtained by shifting investment to developing countries.	Need international cooperation and coordination of investment.
6. MOIRA	Stabilization of world food prices causes increases in food production in developing countries.	Physically sufficient food can be produced; distribution inequities only overcome by political change.
7. SARUM	Price changes are crucial to bring about production development.	Economic and policy factors are paramount.
8. UN World Model	Political, social and institutional, not physical limits determine economic growth.	Imposition of many existing technologies leads to unmanageable levels of pollution. Policy and technical change required.
9. Global 2000	Population growth, resource availability and environmental loading are the major determinants of the future quality of life.	Policies to deal with population, resources and the environment require new initiatives.
10. Marchetti	Technological responses can handle population growth requirements.	1000 billion population need not exhaust primary resources or overload the environment.
11. Surprising Futures	Inclusion of surprises in the scenario determines the outcome in a major way.	Society needs to be better prepared for the occurrence of major uncertainties.
12. Basic Linked System	Increased food supplies are absorbed into the system as producers, consumers, traders and governments adapt their behavior.	Negligible improvement in consumption by poor countries.

The general pessimism resulting from consideration of the results of global models could, in part, be countered by critiques of the models (Cole *et al.*, 1973), particularly in relation to the inclusion of the social, economic and political features thought necessary, and from the point of view of the degree of linkage and feedback that should be included in the model structure. Deficiencies in both aspects were identified, and this raises the question of how "literally" the models should be taken. Modelers did not intend the models to be taken literally, and serious students of the results did not interpret them in this way. But in the discussion of the results and conclusions, this consideration became hazy.

Models, or inter-linked accounting frameworks, are useful, nonetheless, as tools for exploring options for the future. But they are probably most useful for exploring the necessity for policy shifts if they are *simple*, *transparent*, and *iterative*. The Stockholm Environment Institute has been developing a model (POLESTAR) that can be *metaphorical* rather than prescriptive, can be used to assess the feasibility of developments in certain generic directions, and might be used to guide thinking as the possibilities of meeting needs and aspirations of an increasing population in the coming decades are responded to.

3 Polestar

A major purpose of POLESTAR is to find out whether it is possible to recognize, and begin to detail, an *optimistic* (certainly a *possibilistic*) scenario for a 10 billion world, between 2030 and 2050. It attempts to set bounds on our human activity if there is to be a sustainable level of resource use, a sustainable economic system and an environmentally viable supply system.

Stated simply, the issue posed for exploration by POLESTAR is, can a world of 10 billion people achieve their development needs and aspirations in a way that is equitable and sustainable? The question is posed, as it is posited that if present levels of industrial production and consumption are expanded to accommodate this population, the material flows and environmental loads would need to increase by factors of between 10 and 20. Are there limits to economic growth or are innovative technologies, new institutions and existence quality expectations able to change sufficiently to enable reasonable aspirations to be met? Is it possible to do this and maintain and expand conditions of equity, sustainability, democracy, economic viability and resource sustainability? If the objectives broadly outlined are to be within striking distance, then are there guidelines and is there a generic direction in which we should proceed?

3.1 Model structure

The model incorporates up to ten regions. There are a number of modules: demographics, life styles, agriculture and fisheries, households, transport, industry and services, forestry, mining, energy systems, water systems, waste management, and natural resources. Relationships within the socio-ecological system employed in the model are between society, environment and the economy, environmental services, impacts, labor and institutions, other goods and services, and natural resources. The socio-ecological system is applied at the regional level and there is inter-regional linkage to establish the overall global pathways.

The inter-regional relationships allow overall current accounts to be assembled and with the development of scenarios, these can be translated into scenario accounts. Two or more of these can be evaluated, due to the transparency of the structure, and compared.

The type of computational flows required for the linkages between some modules are shown in *Figure 1*.

4 Limitation Versus Distribution

The fact that 80 percent of the population of the world is inadequately provided for should not be taken to indicate that an overall supply limitation exists for meeting the needs and aspirations of 4 billion people. The richest 20 percent of the world's population receive 150 times the income of the poorest 20 percent (UNDP, 1992). Economic and social inequalities – distributional inequity –

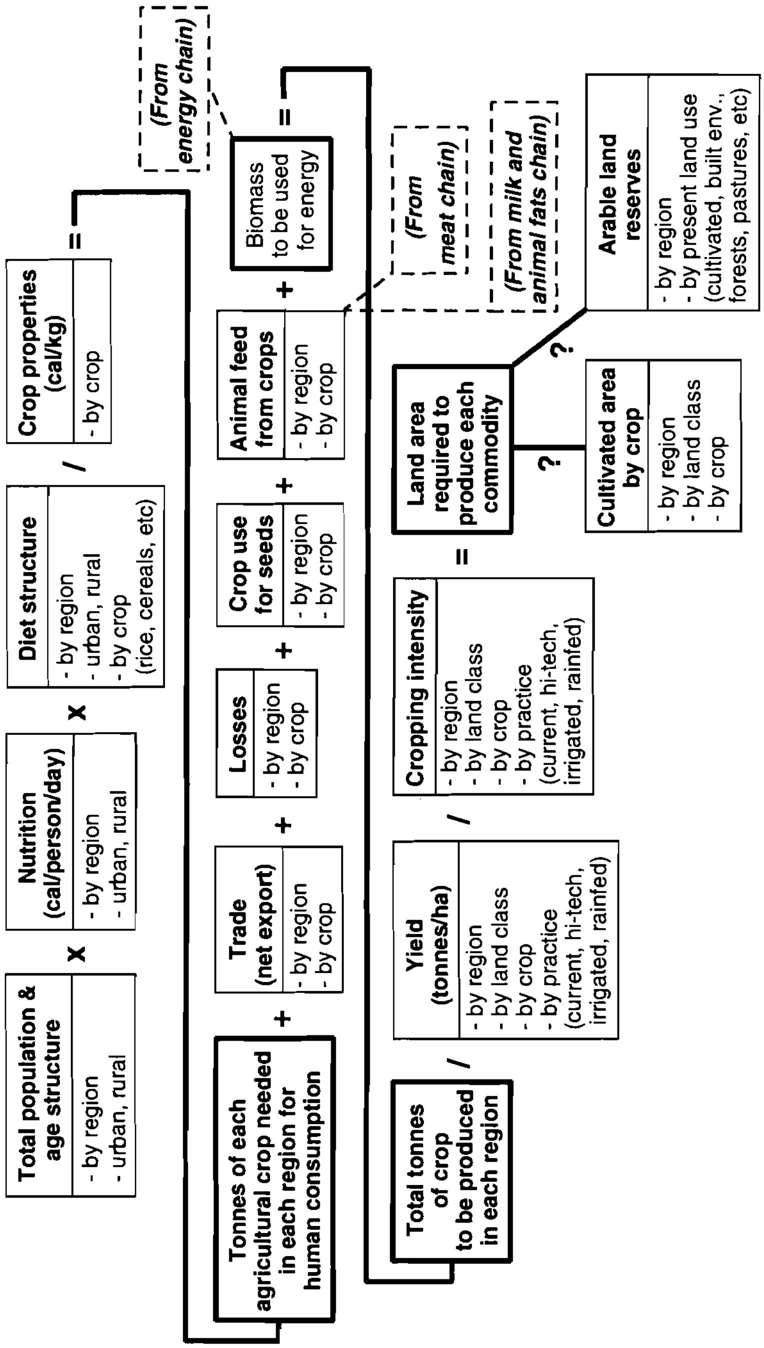

Figure 1. Computational flows and interlinkages for various modules of Polestar.

are the root cause of impoverishment, not overall supply limitation. It is for this reason that social and economic features must form part of the modeling procedures and opportunity be given to reflect regional variations in consumption and supply.

Much exposure has been given to the collapse of centrally planned economics. A crisis in one economic system and the "triumph" of another has been discerned: but it would be ironic, indeed, if the "crisis of socialism" was merely evidence of the "tip of the iceberg", if it is but the first sign of a general crisis for the global economic system as a whole – due to our unwillingness or inability to deal with social and economic issues grounded in the inequitable distribution surrounding resource demand, supply and use. If an economic system poses a threat to multinational corporations, business and banking, when it experiences a setback much is made of it, particularly in the media, and reduced commitment and plummeting confidence hastens the demise of the system. However, there has been less made of any failure in the free market system. Its daily failures to provide for the poor and underprivileged, that have little influence, are not made manifest with such enthusiasm; but there is plenty of evidence for its inadequacy.

There are net flows of resources from developing to industrialized countries. The gap between rich and poor has doubled in the last 30 years; in spite of advice to free-up and restructure developing country economies, protectionist measures by developed countries deny access to their markets for labor and goods. Within developing countries income disparities increase. In developed countries in Europe while unemployment rose, real hourly wage rates fell by 9.7 percent between 1980 and 1990; 25 million inhabitants in the USA bought food with food stamps in 1990 compared with less than 5 million in 1980. Financial institutions in the developed world have suffered from unparalleled corruption. Growth in industrialized countries is generally less than half of what was attained 30 years ago. Migration pressures multiply along with security risks, violence and drug trafficking. It could be said, and has been said, that unrestrained free market policies do not produce economic growth and internationally competitive economies. They do incur hideous social cost and growing environmental degradation. Equity could well be the key to sustainability and any model that seeks to investigate long-term aspects of this needs to take distributional variability into account as a driving condition.

5 Conclusions

The 1972 Stockholm Conference embedded environmental concerns in the international agenda. It encouraged a commitment to effective environmental action. But the target is constantly moving. The prospect of a 10 billion world requires an investigation of the demand dimension, the supply implications and a charting of the way in which it is necessary to divert the expectations of the "rich" to accommodate the aspirations of the "poor". A concerted effort to chart such a path should be a disciplined, imaginative task undertaken with a high level of commitment. A "Blueprint for Sufficiency" should be a major endeavor for the sustainable development community. The report by Shaw *et al.* (1992) has charted the bounds and indicated the systems analysis task. POLESTAR is exploring the pathways of sustainable development further.

Acknowledgements

The author thanks Dr. Ted Munn for his comments, and Dr. Paul Raskin and his colleagues at SEI-B in Boston, USA, for readily making available material from the SEI POLESTAR project. He is also pleased to acknowledge the contributions of Mr. Gerald Leach (SEI), Dr. R. Shaw (SEI), and of Barbara Massingham, previously at SEIY in York, UK. The POLESTAR project at SEI was originated by Professor G.T. Goodman in 1988–89.

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Discussion

Robert E. Munn

1 Introduction

As Professor Michael Chadwick emphasizes, "Biosphere and Humanity" is an enormous subject encompassing most of the natural and social sciences. So Chadwick's opening comment: "to address such a topic, one has to take a systems approach" is indeed correct. I welcome his historical review of global models, and I am glad to learn of the development of POLESTAR, which is based on some of the emerging ideas on sustainability.

To begin, I cannot miss the opportunity to raise a point in connection with the POLESTAR scenario of a 10 billion world. An IIASA Research Report by Cesare Marchetti published in 1978 assumed a 1 trillion world (!) and examined the consequences. Wolf Häfele says in his forward to that report (Marchetti, 1978):

> As there is much debate on whether the carrying capacity of the earth is 4.8 or 20 billion people, it is a drastic undertaking of the author to ask for a carrying capacity of 1000 billion people.

Despite this skepticism, the paper was published, much to the credit of Wolf Häfele. Marchetti's conclusion was that "from a technological point of view, a trillion people can live beautifully on Earth, for an unlimited time, without exhausting any primary resource and without overloading the environment". Amongst other things, Marchetti envisaged that two-thirds of the world's population would live on floating towns - and this scenario appears in a paper that was published a decade before scientists began worrying about sea-level rise. What a wonderful solution for coastal cities!

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2 Surprising Futures

William Clark used the term *not-impossible* scenarios, reflecting the view that the future will contain discontinuities and surprises. The conditions leading to a discontinuity can sometimes be determined retrospectively, but the triggering event(s) is usually very much of a surprise. For example, the fall of the Austro-Hungarian Empire was due to a buildup of socio-economic pressures over the second half of the 19th century; the trigger was the assassination of Franz-Ferdinand in Sarajevo. In the 1986 Malmö (Sweden) Workshop on Surprising Futures co-sponsored by IIASA (Svedin and Aniansson, 1987), one of the not-impossible scenarios envisaged that the USSR would cease to be a European power by the year 2017. This report was not exactly greeted with enthusiasm by IIASA senior management, but it illustrates the value of exploring a range of futures.

I believe that IIASA should strengthen its studies on discontinuities and surprises. Some of Holling's ideas of the 1970s still have worth, and they are becoming enriched with recent ideas drawn from chaos theory, sustainable development, and ecosystem integrity. Marchetti's scenario is an example of the kind of not-impossible futures that ought to be included in these studies.

3 Why do People Build Global Models? Does Anyone Use Them?

"Big" socioeconomic/environmental models are built for a number of reasons:

- to aid in understanding complex phenomena;
- to permit scientists from different disciplines to communicate with each other;
- to answer "what-if" questions (policy analyses);
- to design monitoring systems;
- to identify knowledge gaps and research priorities;
- for educational purposes.

Many "big" models do not have a long shelf life, and seem to have had very little impact on anyone beyond the modelers themselves. This is particularly true of models with socioeconomic components. What regional land-use models have actually been used for long-range planning? However, a few models have been spectacularly successful, particularly in terms of their impact on public policy.

3.1 The Limits-to-Growth Scenarios

The Limits-to-Growth scenarios changed public attitudes from a consumer society to a conserver society. In this connection, it is interesting to note that the follow-up models listed in *Table 2* of Chadwick's paper contributed little to public policy. What was so special about the Meadows 1972 model?

3.2 The Nuclear Winter Scenarios

The nuclear winter scenarios (SCOPE, 1985) had a major impact on public opinion. Realization that nuclear war could have serious climatic impacts on countries of the non-combatants in the southern hemisphere was a major factor in United Nations debates on disarmament and on the subsequent test ban treaties negotiated between the United States and the Soviet Union.

3.3 Greenhouse Gas Climate Warming Scenarios

It is quite incredible that First Ministers began to take climate warming seriously in the late 1980s, based on model predictions alone. In the rather similar case of stratospheric ozone depletion, the beautiful colored photographs showing the growth of the ozone "hole" in the last decade were quite enough to convince policy people that action had to be taken. But observational evidence for climate warming was not available when IPCC was established, and the modest global warming that had occurred was certainly within the range of natural variability.

Why did these simulation models have such a major impact? One of the reasons, I believe, is that science writers as well as scientists were involved, and the media, for whatever reasons, found the issues highly newsworthy. In the nuclear winter case, the leading Soviet simulation modeler of nuclear winter scenarios disappeared in Spain – what science fiction writer could top that? More fundamentally, however, the scientists involved in these three examples were literate and persuasive. One could not fail to be moved by Dennis Meadows, Sir Frederick Warner, Bert Bolin, Steve Schneider, and many others.

4 Model Performance Testing

One final point to be mentioned is the need to improve our ways of assessing model performance. Simulation modelers provide maximum likelihood estimates for given input variables. Through sensitivity analyses, they decide what variables and processes to include and what not to include in their models. But for a very complex system such as a climate or a socioeconomic system, modelers do not provide estimates of the 95% confidence limits of their outputs. Yet in these days when the precautionary principle is so widely discussed, confidence limits are extremely important for policy analysis.

5 What Should IIASA Do?

In the context of simulation models of the biosphere and humanity, IIASA should:

1. Continue its studies on the management of surprises.
2. Undertake studies whose objectives would be to improve methods of establishing confidence limits for the outputs of large global models.
3. Produce not only technical peer-reviewed books and journals but also "popular" versions of those studies that are relevant in the policy field. Here I note with pleasure the appearance

of two such paperbacks: by Martin Parry (1990) and by Sten Nilsson (Nilsson and Pitt, 1991).

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Rapporteur's Report

Markus Amann

The discussion focused on two major issues:

- What are the criteria for a *good* "Biosphere and Humanity" model? How to evaluate the success of a model?
- What innovative elements will be necessary for any new successful model?

Professor Ted Munn identified the "Limits-to-Growth" scenarios, the "Nuclear Winter" calculations and the "Greenhouse Gas Climate Warming" models as spectacularly successful. These models had major impacts on global society by changing public attitudes from a consumer to a conserver society (the Limits to Growth model), by raising the awareness of the climatic impacts of nuclear warfare (the Nuclear Winter calculations) and by getting the greenhouse gas problem accepted, solely based on scenario calculations without observational evidence.

According to Munn the major reasons for the success of these modeling exercises were the facts that the issues were highly newsworthy and, perhaps more important, the scientists involved were literate and persuasive.

Implicitly, the criteria used to measure the success of a model have been assumed to be the influence model calculations have on public opinion and policymakers. However, these criteria are normally not the criteria for evaluating scientific success, such as correct simulation, internal consistency, innovative methodologies, etc. One participant even expressed the opinion that some of the "spectacular models" might have been successful in terms of policy

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impacts, but a step back in science. Many of these models have been developed with a bias to illustrate the importance of specific aspects. Munn repeated his conviction that, in view of the current threats to the global biosphere, the major criteria for evaluating "global" models can only be their policy impact. There is no time left for academic discussions.

Professor Schwefel expressed doubts about whether the creation of pessimism in the future development options of the globe, mainly among young people, could be considered as a "success" of models. He suggested that the modeling community should focus more on improved goals (or objective functions in the modeling language) for global development.

There was general agreement that, without taking into account the following aspects, no model on the biosphere will be successful in the future:

- analyzing the reactions of systems to surprising discontinuities;
- exploring the confidence limits of the model results and identifying the most relevant model inputs;
- taking into account social factors, such as distributional variabilities, as important driving forces;
- and creating popular documentation on the findings of model applications.