

Shell Photo Service, UK



Risk Analysis

Does risk analysis help citizens and officials to decide how safe is safe enough? How should we deal with new technologies whose benefits must be balanced against possible catastrophes? The IIASA Risk Group offers some suggestions following a study of siting liquefied gas facilities in the Federal Republic of Germany, the Netherlands, the United Kingdom, and the United States.

Risk analysis has become as controversial as the new technologies it seeks to assess. It grew, particularly in the 1970s, to provide scientific expertise required by government officials, companies, and the public, faced with having to make decisions concerning the use of new techniques, new energy sources, and new types of installations. These promise many benefits while also being potentially devastating. Analysts were called upon to present impartial facts, particularly about the disputed safety factor, so that decisions could be made – and be seen to be made – rationally and justifiably. Risk analysts have developed techniques, models, and methods (such as event-tree analysis tracing the logical consequences of malfunctioning equipment) to find the probability of an accident occurring,

and the probable loss of life if an accident did happen. But precisely because these are new technologies, there are no historical data from which to quantify risk.

Since risk analysis is a new field with few guidelines and no set formulas for how to go about it, analysts often did not agree on their assessments of the many uncertainties. Their work was used by various conflicting parties in a debate to support claims of safety or refute others' claims. The analyses did not – could not – deliver a flat answer to settle the question.

The scholars involved in the IIASA study, including the risk analysts, agree that this is as it should be. Conflicts about the distribution of benefits and risk among people cannot be “solved” by objective scientific facts. It is a polit-

LEG facility being built at Mossmorran

CONTENTS

1983/2

-
- 1 Risk Analysis**
Experts in a political context: decision making on whether new technologies are “safe”
-
- 6 The Long-Wave Debate**
Gerhart Bruckmann presents the various economic theories that may explain the current recession
-
- 10 Victor Weisskopf: Science, Technology, and Society**
A Distinguished Lecture at IIASA
-
- 14 News from the Institute**
Book review; meetings; new titles
-
- 16 Director's Corner**
C.S. Holling: Myths

ical and cultural problem to create a consensus on "how safe is safe enough?", to balance risks against benefits, to resolve conflicting values and viewpoints. Analysts can identify, assess, and evaluate risks to aid people making a decision on whether the risk involved is acceptable. "We do have some suggestions for improving the process, drawn from our examination of the use of risk analysis in political decision making on the siting of liquefied energy gas (LEG) facilities in the Federal Republic of Germany, the Netherlands, the United Kingdom, and the United States," says Howard Kunreuther, Professor of Decision Sciences at the Wharton School, University of Pennsylvania, who headed the IIASA study. "We found it quite fascinating to investigate the political decision process and the existing institutional arrangements in four different countries as each had to make decisions on the same new technology, where there is a low probability of a large-scale catastrophic accident. This is the first study to really look at a cross-cultural comparison of decision processes for this kind of decision."

The Problem

The long-range transport and storage of natural gas was made practical by technical advances in liquefaction, while the oil embargo and the quadrupling of oil prices in the 1970s made natural gas even more attractive as an energy source. The gas is chilled until it becomes liquid: natural gas (primarily methane) liquefies at -161.5°C (-260°F) with about one six-hun-

The Netherlands – from Rotterdam to Eemshaven

(*Michiel Schwarz: Imperial College of Science and Technology, London, UK*)

1974 – National government policy paper states need to import LNG to conserve Dutch natural gas resources; Ministry for Social Affairs commissions report (March) on safety aspects from state-supported TNO-Netherlands Organization for Applied Natural Science Research (issued in 1976).

1975 – Monopoly NV Nederlandse Gasunie (50 percent state-owned, 25 percent Shell Nederland BV, 25 percent Esso Holland) begins talks with Rotterdam authorities for facilities near their LNG plant (operational May 1977); government sets up technical study group STUNET (supports Rotterdam).

February 1977 – Gasunie formally applies for terminal approval; government sets up ICONA – interministerial committee for North Sea affairs – to advise cabinet (supports Rotterdam).

June 1977 – Gasunie signs contract to import LNG from Algeria, must name site by October 1978.

December 1977 – Opposition in Rotterdam district and province leads Gasunie to begin talks with Groningen authorities for site at previously rejected Eemshaven; Groningen commissions study from TNO.

March 1978 – Preliminary cabinet decision supports Rotterdam.

July 1978 – Rotterdam authorities notify cabinet that they disagree on siting.

August 1978 – Cabinet approves site at Eemshaven.

October 1978 – Parliamentary vote of approval.

April 1980 – Algeria announces it wishes to renegotiate contracts; no construction.

Wilhelmshaven, Federal Republic of Germany

(*Hermann Atz: IIASA*)

1972 – Deutsche Flüssigerdgas Terminal Gesellschaft (DFTG) formed by Ruhrgas AG and Gelsenberg AG for Algerian LNG imports; talks with Lower Saxony Ministry of Economic Affairs and Transportation and local authorities for facilities at Wilhelmshaven.

July 1976 – "Settlement contract" for Wilhelmshaven site despite local opposition; land sale to DFTG by Ministry approved by Lower Saxony parliament.

June 1977 – Contract signed with Algeria, must name site by October 1978.

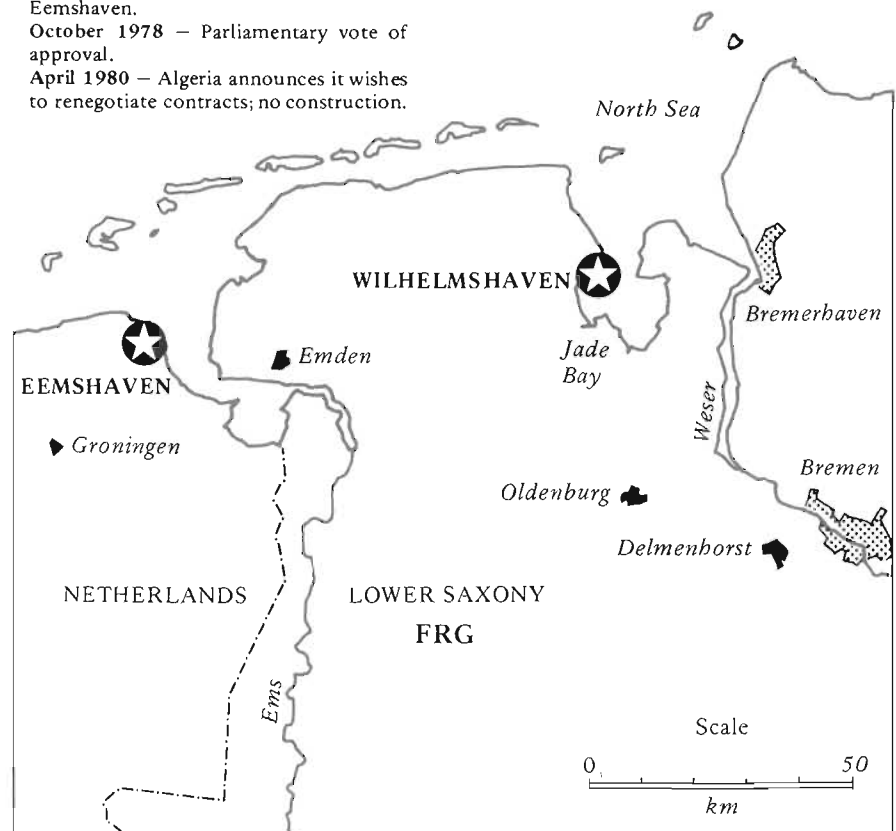
1977–1978 – Certified experts (such as W. Brötz and O. Krappinger), state institutes, and consultants commissioned for safety reports (*Gutachten*) by DFTG, objectors, and licensing agencies.

September 1977 – DFTG applies for construction licenses: three public meetings held mid-1978. Federal Water and Shipping Board North-West requests Minister of Transport to make decision because of concern over shipping hazards.

September 1978 – Citizens' groups appeal to administrative law court; Lower Saxony commits itself to 80 percent subsidies for tourist facilities in the area.

March–July 1979 – Recommended changes in channel secure federal then district approval.

April 1980 – Algeria announces it wishes to renegotiate contracts; no construction.



OPTIONS

ISSN 0252-9572

is produced quarterly by the Office of Communications, IIASA. Material from *Options* may be freely used and reproduced with acknowledgment to the International Institute for Applied Systems Analysis. Please send tear sheets of any printed reference to the Office of Communications, IIASA, A-2361 Laxenburg, Austria. Telephone 02236 71521; telex 079137.

Editor: Roberta Yared
 Managing Editor: Derek Delves
 Designer: Martin Schobel
 Photographer: Franz-Karl Nebuda
 Printed in Austria

dredth of its volume as a gas. A tank of liquefied natural gas (kept at -162°C and slightly above atmospheric pressure) therefore contains 600 times as much energy as a tank of the same size holding natural gas.

LEG vaporizes upon contact with the normal atmosphere into a highly flammable cloud that increases in size as it is moved by the wind. If such a vapor cloud is ignited, it creates a fireball.

A "spill" of LEG could occur anywhere along the chain of men and equipment that liquefy the gas in fractionation plants in a producing country, load and ship LEG in specially constructed tankers, unload and store it at an importing terminal, regasify it as needed, and distribute it to consumers by pipeline, truck, or rail.

A storage tank ruptured in 1944 at the first liquefied natural gas (LNG) facility, in Cleveland, Ohio, USA. The vapor cloud ignited, resulting in 120 deaths, 300 injuries, and some US\$7 million in property damage. This set the industry back for two decades, but in the mid-1960s engineers and technicians were confident that the problems had been solved and pronounced that LEG was safe. Commercial development resumed. In the late 1970s there were also deaths by incineration in the areas surrounding liquefying plants in Saudi Arabia and Qatar, truck tankers in Mexico and Spain, and an empty storage tank in Staten Island, New York, USA.

The public is now more aware of technological accidents and their aftermaths. We know about radioactive leaks from nuclear plants, oil spills and oil rig explosions, uncontrollable satellites, collisions between airplanes, and so on, so there is a sense of "it could happen here." A 1982 study by the Clark University Hazard Assessment Group states that 17–31 percent of US deaths can be attributed to technology.

Dr. Werner Salz of the Ministry for Research and Technology in the Federal Republic of Germany notes other developments in society: "There has been a diminished confidence in experts' statements on risk and a realization that many of the events which are being examined are not subject to detailed scientific analysis. There has also

been an increasing recognition that distinctions must be made between analyses of the risk associated with an event and people's values and preferences. Another important development is the concern by the public that they participate more fully in the decision process on these issues."

The Participants and the Process

Though the decision process for siting an LEG facility begins with a consideration of natural gas as an energy source, the formal political procedures started when energy companies requested permission from the government authorities to build LEG facilities, stating that the facilities were safe. It was presented as a decision for or against a specific facility at a specific site, usually chosen by the company. All the national governments involved supported the use of LEG on energy policy and economic development grounds. Under existing laws in the four countries, national, provincial, and local (district, municipal, village) authorities had to grant approval and open public hearings were held. Outside expert advice on safety factors was sought in each country, besides that of the companies' engineers and professionals in various ministries and regulatory bodies. Opposition in each case came from residents, including some other industries, close to the proposed sites on safety grounds: with the exception of the Sierra Club in the USA (opposed to any site) and the Scottish branch of the Conservation Society in the UK, no national public interest groups were involved in the siting debates on LEG, as they usually are in the more emotional debates on nuclear plant siting. In three of the cases, the final decision – approval – was made by the national government: the Dutch cabinet with a parliamentary vote, the Minister of Transport in the FRG, and the UK Secretary of State for Scotland. In America, the state of California passed an LNG Terminal Siting Act in 1977. There are no national laws so far specifically referring to siting large-scale energy facilities in any of the four countries, and the decision process was, and is, based on regulations and practices

concerning land use and the siting and construction of any industrial facility.

Because of the variety of concerns and the number of parties involved, each case study followed a multi-attribute, multi-party framework, which traces the process through separate and sequential political "rounds". Each round concerns the formulation and resolution of one subproblem with different parties involved in different rounds, each party with its own valid organizational and personal interests and beliefs. "Agenda setting and question formulation is critical," declares Professor Kunreuther. "Because of time and cost considerations, a decision on one level in one round is often binding in that it cannot easily be reopened for political discussion." Dr. Joanne Linnerooth of the IIASA Risk Group notes that when citizens' groups questioned the need for LEG, they were generally told that, according to procedure, this was not a topic that could be addressed at the local level. "In addition, the order in which subproblems are considered may affect the final outcome. A sequential decision process precludes the use of a comprehensive analysis of the entire LEG question in which the costs and benefits of various options could be assessed."

The importance of the timing of a risk assessment in relation to the timing of site selection is also emphasized by those who compared the various risk assessments for the IIASA study. Dr. Christoph Mandl, former Chairman of the Department of Mathematical Methods and Computer Sciences at the Institute of Advanced Studies, Vienna, Austria and Dr. John Lathrop, who joined IIASA as a decision analyst from the Lawrence Livermore Laboratory of the University of California, USA and is now with Woodward-Clyde Consultants in California note: "Once a site is selected, given the political realities of the situation, the question of the overall acceptability of the risk is more or less settled. If a risk assessment is applied at the design level, it may consider various modifications to reduce the risk in the most cost-effective way. However, given its scope and charter, the assessment is highly unlikely to find that the site cannot be made acceptably safe with current technology and so

should be abandoned. On the other hand, if a risk assessment is applied at the site selection level, it would at least be feasible to rule that none of the sites in the current choice set is acceptable."

The Risk Analyses

There were no fewer than fifteen studies of the risks from the proposed LEG facilities in the four countries. They were commissioned by various parties at different stages of the decision processes, sometimes to examine only a particular question, such as shipping hazards. In the Netherlands one major analysis was made and used by all parties: the Ministry of Social Affairs requested a study from a state-supported applied research institute. In the other countries there was a mixture of analyses, including those prepared by private consulting firms in the UK and USA, and by professionals certified as experts by their technical organizations in the FRG.

Dr. Mandl emphasizes that "there is still disagreement between analysts concerning definitions of risk, how to quantify the risks, which models to use, what to include and what to exclude. This is true of risk assessment in general and LEG facility siting in particular: because there are no historical data on accidents at LEG facilities, the frequency of such accidents as well as their consequences cannot be readily estimated. Empirical data are lacking so probabilities have to be judgmental."

This "honest disagreement" led to widely varying estimates in the analyses, even when they addressed the same question for the same site in the same terms — which was rarely the case.

How to Improve the Process

Some IIASA scholars argue for more complete review procedures or for formal rules of evidence on analysis submitted in hearing procedures. The IIASA Risk Group proposes guidelines for risk assessments to make evaluation easier for people participating in these procedures. They suggest that the definition of risk used should be stated, and why it was chosen explained. Ac-

knowledging that not every possible hazardous event can be included, they stress that events not considered, at least those that are known, should be clearly pointed out. When estimating probabilities, they recommend that judgmental probabilities should be generated by a number of experts providing estimates. Consequences of an accident should be expressed in terms familiar to decision makers, such as the number of fatalities or the financial losses. Possible effects on neighboring facilities should also be included (for instance, when an LEG terminal is close to a chemical plant). The parts of the systems presenting the greatest risk should be identified, so that design features can be modified if necessary. The possible range of uncertainty of the risk estimate should be shown through sensitivity analysis of the judgmental probabilities. The assumptions on which the analysis is based should be clearly stated, with their implications presented to aid comparison with other assessments. They strongly feel the estimation of the risk and the benefits of alternatives should be included. "As we see it, the ideal result of a risk assessment report is the quantification of the risk in comparison with risks from other sources, the risks between alternatives, such as site A *versus* site B, or site A *versus* no site." They also state that "there is no scientific way to decide whether a certain risk level is acceptable to society or not. Therefore risk assessment reports should avoid making statements on this question." Risk analysis is a part of the decision process, and its value lies in making informed debate by all concerned parties possible. "The debate could focus on the alternatives themselves rather than the particular assessment or presentation promoted by an interested party," says Professor Kunreuther.

He notes that analysts not only clarify the potential effects, but by eliciting the preferences of the conflicting parties can also point out where negotiation and bargaining would be possible. Analysts may also be useful in developing guidelines for selecting sites and formulating options for sharing the potential gains and losses of those affected, such as compensation or insurance schemes.



California, USA

(John Latbrop, Joanne Linnerooth)

September 1974 — Western LNG Terminal Company (subsidiary of Pacific Lighting Corp. and Pacific Gas and Electric Co., with El Paso Natural Gas Co.) files applications with the Federal Power Commission to import natural gas from Alaska and Indonesia at three sites in California: Los Angeles, Oxnard, and Point Conception. Western commissions risk assessments of each site from consulting firm Science Applications, Inc.; Oxnard commissions risk assessment from consulting firm Socio-Economic Systems, Inc.; Federal Power Commission and California Coastal Commission make own studies. **1976** — Lobbying begins for state legislation as federal, state, and local authorities cannot agree on site or risks.

September 1977 — California LNG Siting Act requires remote site with decision power given to California Public Utilities Commission (CPUC).

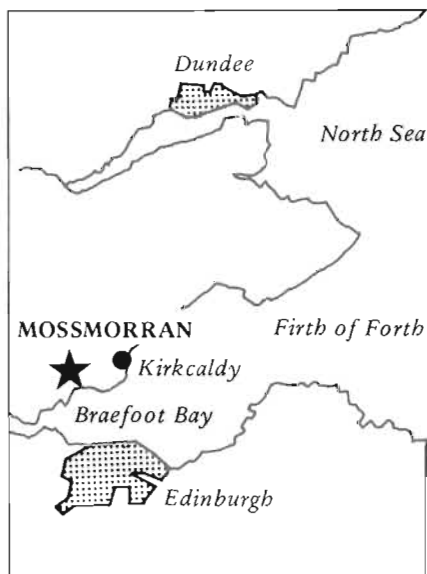
October 1977 — Western re-applies for Point Conception site, with new study by Arthur D. Little, Inc.

July 1978 — Point Conception conditionally approved by CPUC.

October 1979 — Point Conception conditionally approved by Federal Energy Regulatory Commission (reorganized Federal Power Commission).

April 1981 — Petition by residents' groups to Federal Court of Appeals because of earthquake risk; federal and state studies later declare site seismically safe.

1982 — Western announces it will not build terminal in near future as California no longer needs to import natural gas.



Mossmorran—Braefoot Bay, Scotland, UK
(Sally Macgill: Leeds University, UK)

1976 – Shell UK Expro and Esso Chemical Co. Ltd. begin talks in July with Fife local authorities for facilities using British North Sea natural gas, after abandoning similar plans at Peterhead; contested by residents' associations.
 January 1977 – Fife authorities commission hazard and environmental impact report from consulting firm Cremer and Warner (completed May 1977 and circulated).
 January–February 1977 – Shell and Esso formally submit planning applications; Joint Action Group formed in opposition.
 May 1977 – District and regional councils approve applications in principle;

public inquiry announced by Secretary of State for Scotland, postponed after protests about one week's notice given.
 June 27–July 21, 1977 – Public inquiry held in Dunfermline.
 November 1977 – Summary of inquiry submitted to Secretary of State.
 January 1978 – Action Group queries danger of radio-spark ignition of methane, not raised at inquiry: Secretary of State requests further reports on this issue.
 January 1979 – Action Group publishes assessment of marine hazards by consultants Burgoyne and Partners, and Professor D.J. Rasbash (volunteer).
 August 1979 – Secretary of State for Scotland approves applications in principle.
 October 1979 – Action Group lodges court appeal against validity of decision.
 February 1980 – Court of Sessions rejects appeal.
 March 1980 – Construction begins.

Professor Howard Raiffa of the J.F. Kennedy School of Government at Harvard University, USA, and IIASA's first Director, also sees analysts as mediators: "I happen to believe that we do a miserable job in conflict resolution and I believe that analysis could be instrumental in arriving at better resolutions; better in the sense of making all parties happier. As a rule of thumb, the more dimensions of conflict there are, and the more widely different the points of view, the more these differences can be exploited in obtaining compromises. One role of analysis is to achieve a means of compromise."

"With the three studies on Point Conception in California, there is a difference of four orders of magnitude in the risk of ten or more fatalities and about a factor of ten difference in both societal and individual risk," Dr. Lathrop found. "None of the studies mentioned sabotage as a cause of accidents and none of the studies discussed other costs and benefits that could be just as important for evaluation, such as unemployment and health effects when energy supplies are interrupted or property losses due to accidents. The studies disagreed substantially on the events considered as causing spills, their probabilities, and their consequences."

A problem faced by citizens' groups in all siting questions is funding their own analyses. Different countries have tackled the problem in various ways. For example, the Berger Commission in Canada provided government funds

to several groups to enable them to prepare their case regarding a proposed pipeline in the Mackenzie Valley. Another solution is the free Science Shops in the Netherlands, where university faculty members volunteer their expertise to groups involved in negotiations.

A complaint made by some government officials in IIASA seminars on Risk Analysis was that risk analysts tend to present an overconfident picture of the accuracy of their estimates by the way in which they choose data, discuss their assumptions, and present the results. The format chosen for presenting results can have a pronounced effect on the perceived magnitude of the risk. One of the California studies included a "worst case scenario" – without an accompanying probability estimate of its occurrence – in which up to 70,000 people were likely to be killed, accompanied by a map so that residents could determine whether the vapor cloud would cover their homes. The strong public reaction to this scenario was a factor leading to the California LNG Terminal Siting Act, which required a remote site for an LNG terminal by giving maximum allowable population density figures at stated distances from a facility.

"While policy makers would prefer more precise estimates of risk, our present state of knowledge simply does not warrant such statements. There is no 'magic number'. The uncertainties should be clearly communicated in risk assessment reports," says Dr. Lathrop.

Despite the problems, "the fact remains that risk analysis is an 'art' that is a more desirable means of assessing risk than any other alternative," Dr. Mandl declares. Dr. Linnerooth agrees that technical risk analyses may shed some light on the ways in which a technical system can go wrong, but is less optimistic about the usefulness of risk analyses as a basis for political debate. "The problem of reaching a consensus between conflicting interests in society, such as those over the location of a new technology, may not be solved, or even helped, by expert calculations of the safety risks. Risk may only be a symbol for the fears and anxieties that the public may have concerning the technology. These fears are not adequately captured by the 'body count' figures found in most risk analyses. The analyses are simply addressing the wrong problem."

This more constructive role for analysis seems attractive to all those concerned with decisions relating to new technologies – the responsible authorities, the energy industry, the analysts, and the rest of us as we weigh risks and benefits.

Roberta Yared

Kunreuther, H. and J. Linnerooth, with J. Lathrop, H. Atz, S. Macgill, C. Mandl, M. Schwarz, and M. Thompson, **Risk Analysis and Decision Processes** will be published shortly by Springer-Verlag. Other publications on risk analysis and IIASA's LEG facility siting study are available from the Institute.

The Long-Wave Debate

In its last issue, *Options* brought a contribution by Cesare Marchetti, "Recession: Ten More Years To Go?" The vivid interest and the surprisingly large echo that this article met induced *Options* to invite Gerhart Bruckmann to analyze the state of the art in the renewed activities on long-wave theory in a wider context.

The longer the recession lasts, the more economists have begun to wonder about its nature. After 1945, industrialized countries all the world over experienced three decades of steady growth; no wonder economic theory concentrated on "equilibrium growth" on the one side, on short-term business cycles (*Konjunkturzyklen*), of a duration of four to five years each, on the other side. "Recession" assumed the meaning of (a couple of years of) below-average growth, but alas! there always was growth, and to utter a phrase like "Limits to Growth" was blunt heresy. Parallel to this, governmental economic activity increased substantially, giving rise to a noticeable yet spurious correlation between the amount of government intervention and GNP: the more government, the more affluent we became.

We are not yet fully aware of the extent to which this thirty year experience has come to dominate our thinking. We continue to speak of a "prolonged recession", as if the next (short-term!) upswing were just lurking around the corner, and we look at government to finally *do* something about it.

A few months ago, an Austrian economist remarked: "The valley seems to be a low plain." If the distance between successive valleys is more than four to five years, there may be quite a way to go before we reach the next peak, and if governments continue to provide us with mountain climbing equipment to get us more quickly ahead through the Great Plains (as they did, more or less successfully, in all previous valleys) it will be as costly as it will be futile.

There is something peculiar about the toolchest of economics, as compared to the toolchest of other sciences (let's say, engineering or physiology). In economics, it is much more difficult to locate the right tool, and there is much more disagreement among the

mechanics as to which tool to use. But the toolchest as such is much larger: it is crammed with tools that seem obsolete but may, all of a sudden, prove useful again, if (a) found and (b) properly adapted. The longer the recession lasted, the more economists remembered the work done by an earlier generation on the theory of long waves — took it out from the chest where it lay, badly neglected, found it fascinating, and began to adapt it, not so much in the light of changed circumstances as on the basis of all the wealth of economic data and knowledge accumulated meanwhile.

The pioneers of the older generation had been Parvus, Van Gelderen, Pareto, De Wolff, and finally Kondratieff, who was the first to attempt to base long-wave theory upon empirical data, and whose name is, ever since, associated with any analysis of economic movements with a life-span of forty to sixty years (Kondratieff cycles). Kondratieff concluded that such long-term cycles are characteristic of the whole of the capitalist economies, as a result of differing phases of capital accumulation.

The work of this first generation culminated in the writings of the Austrian economist Joseph Schumpeter, mainly in his book *Business Cycles* (1939). Schumpeter conceived the notion that the irregular *clustering of innovations* was the main cause of a regular succession of four phases — prosperity, recession, depression, and recovery. In a historical perspective, four such full cycles can be identified: the first one characterized by the steam engine, the second by the railroad, the third by the chemical industry and electricity, and the fourth by the automobile.

The year in which Schumpeter's book appeared was all but favorable to his ideas. Overshadowed first by the political developments of World War II, then by reconstruction and steady growth, his ideas fell into obsolescence. Long-wave theory became a Sleeping

Beauty, waiting for a prince to kiss it awake. The prince's kiss had its prophets — amongst them Colin Clark and Ernest Mandel; irritatingly enough, however, most voices to announce "Limits to Growth" — well before the so-called oil crisis — came from outside the economists' guild.

Whatever really happened in 1973, it certainly revolutionized economic thinking, shattering, in various respects, the dearly beloved paradigm of equilibrium growth. In particular, several leading scientists began, more or less independently, to resume work on long waves. No one prince cut his way all alone through the thorn bushes — the thorn bushes themselves were erased by a fire blast. Apparently the area around the haunted castle still remained unattractive — so far, only very few noblemen found the journey worthwhile. Most of their names can be found in the special issue the journal *Futures* devoted to "Technical Innovation and Long Waves in World Economic Development" (August 1981). In that issue, Jos Delbeke gives a classification scheme of the new approaches to the phenomenon of long waves, according to what the respective authors see as the main causes: innovation, capital, labor, and raw materials. Let us follow Delbeke.

Innovation

In direct continuation of Schumpeter's reasonings, Gerhard Mensch and Alfred Kleinknecht regard technological innovation as the primary driving force of economic development. In a thorough historical analysis, Mensch gave Schumpeter's theory an empirical base. According to Mensch, around the years 1825, 1886, and 1935 new clusters of basic innovations occurred, generating completely new sectors. Competition, rationalization, and concentration raise the capacity of the new



Gerhart Bruckmann is Professor of Statistics at the University of Vienna, Austria, President of the Austrian Futures Research Society, and a member of the Club of Rome. Since 1973 he has been responsible for the IIASA conference series on Global Modeling. He is currently engaged in preparing an international workshop on long waves.

industrial sectors. However, at a certain point the capacity becomes too great for the domestic market, so the export market becomes vital. Since foreign industrial countries have also gone through this same process, competition grows among a diminishing number of large concerns on the world market. Aware of the growing saturation, these concerns invest less money in the industrial sectors and more on the international money and capital markets. In the next stage, the monopolies try to sell their surplus in the less developed countries with the help of massive credits. Ultimately, these countries reach their credit limits, and the saturation of demand is complete.

During this critical period, which begins with recession and lasts until the end of the depression, the economy has no fundamental solution other than the creation of basic innovations and new sectors: only "innovations will overcome depression." Mensch calls the situation in which society is forced to innovate the "technological stalemate" — a period of reorientation, in which economic policy cannot offer fundamental solutions to the crisis, at least in the short run. All governments can

do is to create a favorable climate for innovation.

Kleinknecht defends both the empirical data base and the conclusions of Gerhard Mensch; furthermore, he claims that what seems to be a contradiction between his view and that of other authors can also be seen as different yet compatible views of the same phenomenon.

Capital

Delbeke lists two approaches which consider varying intensity in capital goods production as the most important characteristic of the long wave: the approaches used by Mandel and by Forrester.

Ernest Mandel defines the industrial cycle as the successive acceleration and deceleration of capital accumulation. When the acceleration of capital accumulation reaches a certain point during the upswing, it becomes impossible to invest the total mass of accumulated capital at an adequate rate of profit. This is overaccumulation, and it must be understood as a relative phenomenon: there is simply too much capital available to attain the expected social average rate of profit. Consequently, the average rate of profit of the total accumulated mass of capital declines. Conversely, in the crisis and depression phase, capital is devalorized. Underinvestment now occurs: less capital is invested than would be expected at a given level of surplus-value production and at the given (rising) average rate of profit. This periodic devalorization and underinvestment has the function of again raising the average rate of profit of the entire mass of accumulated capital, which in turn allows the intensification of production and capital accumulation.

Jay Forrester has developed a new method of analyzing growth dynamics in which the capital goods sector plays the crucial role. Forrester's theory is based on two important pillars that create endogenous fluctuations. The first is a multiplier accelerator mechanism that transmits the fluctuations in investment to the rest of the economy and works on the long term. The second is rational behavior along a capital-stock

adjustment model, which causes alternating phases of capital hunger and capital saturation. The economic agents continually exaggerate: they expand the capacity of the capital sector too much in the upswing to catch up with demand, and they let the capital stock collapse to a level below the long-term average in the downswing. The entrepreneur is rational *ex ante* but not *ex post* because of perception delays.

It may be surprising that Forrester views innovation not as a cause but as a consequence of the long wave. The Forrester system dynamics model generates long-wave behavior even without technological change. According to Forrester, each phase of the Kondratieff cycle offers a different climate for innovation; hence what can be observed as "clusters" or "bunches" of innovations in the sense of Schumpeter or Mensch is not an exogenous input, but rather a result of the model. In a system dynamics model, however, every major variable is at the same time the cause *and* the consequence of the system's behavior. In particular, it would be presumptuous to claim, as some authors do, that in Forrester's theory innovation plays no major role: within the system, it certainly has a definite impact upon all other economic variables.

Labor

In all long-wave theories discussed so far, labor was either ignored or played only an insignificant role. Yet unemployment is of the utmost social and political concern, much more so than innovation or investment. The book published by Christopher Freeman together with his associates John Clark and Luc Soete *Unemployment and Technical Innovation* therefore represents a cornerstone in long-wave research.

In their thorough analysis, they arrive at the following conclusions: "During the upswing, after decades of preliminary scientific and technical work, major new technologies generate both new investment and new employment on a large scale, thus becoming substantial new branches of activity.... The main employment effect during

the upswing is a steep increase in employment....

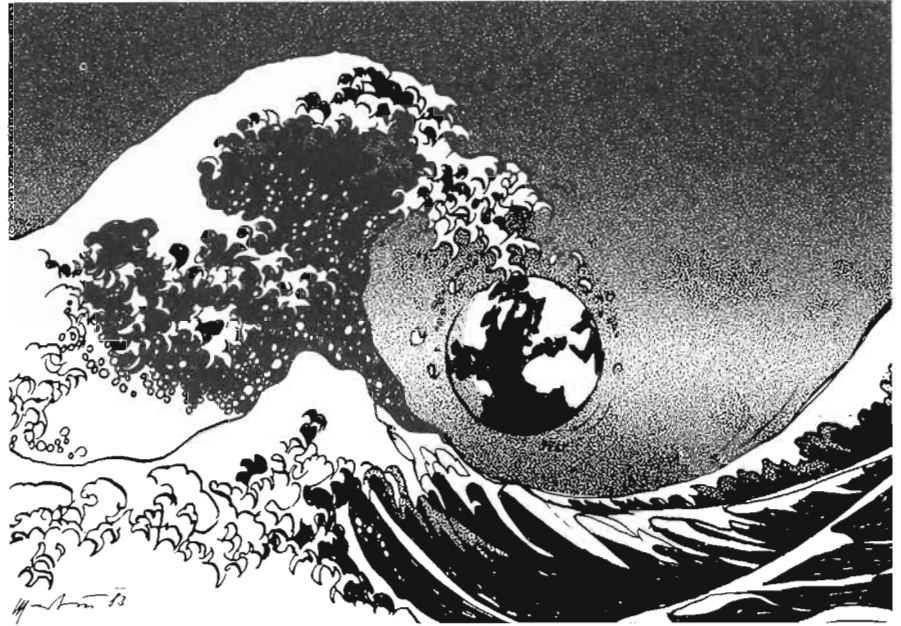
"After about a quarter of a century, the new branches of industry are firmly established, and their role as generators of additional new employment diminishes and eventually disappears. During the downswing, competitive pressure within industry becomes stronger, capital intensity grows, and investment continues, but labor-saving and material-saving technical changes become increasingly important.

"The loss of impetus for the growth of employment in the new industries is reinforced by the acceleration of labor-displacing technical changes, and by economies of scale which arise from the success of the new technology itself. This process is the most intense during the Kondratieff downswing."

The open debate between Freeman and his associates on one side and Mensch and Kleinknecht on the other side focused not so much on the importance of innovations as such, as on the social and economic factors that influence the timing of such "clusters" of innovations and their reciprocal influence on the behavior of the economy. According to Freeman, the key aspect of the long wave lies in the investment behavior. In his view, capital intensity grows in the downswing; in Forrester's approach it declines. Both Freeman and Forrester, however, emphasize the increasing unemployment of production factors in industry during the downswing — labor for Freeman, capital for Mandel and Forrester.

Raw Materials

W.W. Rostow, more than the other authors considered here, emphasizes the dynamics of growth in a world perspective. He sharply distinguishes and relates three distinct phenomena: the forces set in motion by a leading sector in growth, by changes in the profitability of producing foodstuffs and raw materials, and by large waves of international or domestic migration. In his view, the second factor is particularly important because it generates a price revolution, i.e. a short period of a sharp rise in the relative prices of food and raw materials at the expense of



the prices of industrial goods. If the producers of the former are the less developed countries and of the latter the developed countries, then a price revolution means a period of deteriorating terms of trade for the developed countries.

As Delbeke points out, Rostow's theory does not correspond with the actual post-war situation, but it definitely throws light upon the present price revolution. The new shortages of primary goods and especially energy fit well into the adjustment theory and are likely to create new leading sectors on the input side of the economy: new energy sources (nuclear, solar, wind), new raw material sources (ocean reclamation), new foodstuffs industries (bio and genetic industries), environment industries, and so on.

Delbeke's classification scheme definitely proves useful as a first guideline; but, as he points out himself, no such scheme is capable of paying full tribute to the thoughts developed by the different authors. The headings chosen should clearly not be mistaken for monocausality. In particular, both Forrester and Freeman apply a systems approach: Forrester by means of the system dynamics methodology, Freeman by applying what he calls "reasoned history": the attempt "to interpret the statistical evidence of changes in the international economy over a long period in the light of a discussion of the incidence of major technical and

organizational innovations and their assimilation in the economies of the industrialized countries."

As the different publications appeared and the various theories became known, emphasis shifted toward multi-causality as a more adequate approach to the complex phenomenon of the long wave. In particular, Van Duijn set out to integrate several theories. He constructs his synthesis by combining the innovation theory of Schumpeter and Mensch, the hypothesis about the life-cycle of industry along an S-curve, and Forrester's multiplier accelerator mechanism of investment, which intensifies the growth and saturation of basic innovations. The role of time lags is considered essential for the particular behavior and length of the long wave.

Policy Implications

Long-wave theory is developing rapidly; several important books are to appear within the next few months. In this rapid development, however, some basic questions have been bypassed — the most basic question of all being whether the long wave exists at all, whether it is a reality or just a myth. Different authors distill, from the same set of empirical data, different theories. On one extreme, there are distinguished scholars who claim that what is regarded as a long wave cannot be signif-

icantly differentiated from white noise. On the other extreme, Cesare Marchetti is convinced that the long wave is a precisely predictable cycle, a law of "anthropological significance". In the last issue of *Options*, Marchetti stated: "The distance between their center points — when half of the innovations in the waves have been made — is precisely fifty-four years." Marchetti, like Freeman and Mensch, focuses his analysis on innovation; starting from a different angle, he explains the innovation cycle as a result of mechanisms of market saturation.

Between these two extreme views, the nonexistence of the long wave and the long wave as an anthropological law, there lie all the other theories. The question which of these views is correct goes far beyond esoteric theoretical interest — it is of the utmost policy relevance. If the distance from centerpoint to centerpoint is exactly fifty-four years, are not any measures to get more quickly out of a depression *a priori* doomed to fail? Marchetti bluntly states: "The curve will not start rising again until the 1990s." And if the long wave is a myth, what other explanation of the present world economic situation can be given? Obviously, understanding what is happening now is a prerequisite for any policy recommendations.

Hence, the most important task for the coming years will be to put the disconnected pieces of the puzzle together, to attempt to arrive at some more integrated theory which may have to incorporate additional aspects hitherto neglected. Even more important, however, will be a more thorough analysis of the impact of institutional and social changes; several authors claim that "innovation", in the decades to come, will have to be perceived not only in the traditional sense as product or process innovation, but increasingly as institutional innovation, both on an entrepreneurial and on a political level.

This is the point where another question, concerning long-wave theory as a whole, comes up. As Delbeke says: "Perhaps the most fundamental problem is the question of whether our industrial society is itself behaving along a life-cycle of economic development. Should this be the case, we are the wit-

nesses of the transition from a growth economy to an equilibrium economy." It may well be that future historians will divide the economic history of man into three major periods: the pre-industrial period, the industrialization era (characterized by four Kondratieff cycles), and the post-industrial period which began in the last quarter of the twentieth century. The beginning of this new macro-phase would, in retrospect, be characterized by man's hitting against ecological limits and, having reached certain saturation levels in the industrialized countries, by a shift in demand from material goods to immaterial goods. Or, as Forrester put it: "A balance between human population and environment may now be the most fundamental requirement for political and social innovation for its own sake." Investigation of this alternative view is not in contradiction to previous research on long waves; it only requires a widening of the context.

In summary: the state of the art seems as fascinating as it seems messy. But oddly enough, as different and even contradictory as the various theories may look, there is far less divergence between the sets of policy recommendations to be drawn from them. No matter whether innovation is a cause or a consequence of cyclic behavior, *all* scientists working in this field will agree that one of the foremost tasks of government will lie, in the years ahead of us, in enhancing a climate favorable for innovation, and if innovation is understood to include institutional and social changes, even those who do not believe in a fifth Kondratieff cycle will go along. So, when Freeman calls for "an active public policy, which has a dimension largely lacking either in present day monetary constraints or post-Keynesian demand-stimulating policies," he finds himself in line with Marchetti who proposes to help entrepreneurs "by putting at their disposal, for nominal fees, the research capabilities of the state." And, when Marchetti bluntly states: "Reaganomics, Thatcherism, Mitterandism, etc. are bound to break their promises, together with the monetarists, nervously turning disconnected knobs," he finds himself in agreement with both Freeman and Rostow.

And all this in turn is again not in contradiction to Forrester when he says "We are entering a time when creative management, more than creative technology, can make the difference between corporate death and survival.... In the next few years, political innovation will be needed; it will be tried, and we should see that it is guided constructively...."

And this is what makes additional research in long waves particularly promising. Optimistically, from this research could emerge, before too long, a somewhat consistent set of policy instruments. If more time elapses in which the traditional instruments continue to fail, the threshold may be reached from whence onward this (yet to be developed) set of policy instruments will be believed and implemented. Pessimistically, further research could at least lead to better understanding of the economic phenomena of our time.

IIASA's Role in Long-Wave Research

In its new research plan, IIASA has now institutionalized its "clearing-house activities" under the leadership of Tibor Vasko. Some of these activities represent a spillover from earlier IIASA research; some, however, are activities in a newly emerging field, such as the revived interest in long waves. Much as it did ten years ago with regard to global modeling, IIASA intends to provide a forum function, bringing together the leading scientists in the field. As a first step, in conjunction with the Municipality of Florence, a top-level workshop on "Long Waves, Depression, and Innovation: Implications for National and Regional Economic Policy" will be held in Florence, Italy, from 26 to 28 October 1983. This workshop will bring together, for the first time, the leading scientists working in this field, with the explicit double goal of advancing theoretical insights into the *problématique* and of examining policy implications on the national and the regional level. Furthermore, this workshop may be expected to form the starting point for whatever international scientific cooperation might emerge.

Victor Weisskopf: Science, Technology, and Society

Science and technology have characterized the civilization of our society for a very long time, perhaps about 300 years; of course, this is not long compared to the history of mankind. They have developed mostly in Europe, later in the United States also, and have spread over the whole world. It certainly has done much good: it improved our living standards, eliminated epidemics such as the plague and other fatal diseases, increased the average age by almost a factor of two, created great cultural achievements of lasting significance in science and art. But the value of that civilization has been called into doubt. That has happened before, but never to the extent that it has in the last twenty years. One can almost speak about a crisis of this civilization.

The question arises whether this crisis is a symptom of aging, presaging the end of Western civilization either through annihilation by nuclear war or through internal disintegration, or whether it is in some way a manifestation of "growing pains". After the storm and stress of adolescence, in which a great deal was done without a thought to possible consequences, it could represent a transition to thoughtful maturity.

A few words are in order about the history of science and technology. Technology is much older than science. We find technology already in the Greco-Roman period, and in the early Chinese periods. At that time, of course, it was mostly concentrated upon toolmaking, the plough, the waterwheel, and shipbuilding. Most of the work was done by hand; it was a slave labor society. Only in the early Middle Ages did technology become more important due to the growth of cities, and the need to supply them with food, clothing, and other necessities. Traffic and transportation and toolmaking had to be improved.

Technology is definitely older than science for the simple reason that science needed instruments. Galileo needed a telescope and even before Galileo, Copernicus and Tycho Brahe needed

their instruments to measure the stars and their movements. So science in some ways is a consequence of technology. The close link between the two that we observe today is a later product. One of the first examples in which science preceded technology was the electromotor. In the years 1834 to 1835 M. Faraday, F. Neumann, and W. Weber discovered the laws of electricity and magnetism; not until twenty years later did Werner von Siemens construct the first electric motor and the dynamo. One always says that things go faster today. That isn't true. The time interval between the discovery of the neutron and the first nuclear reactor is also about twenty years. Two factors come

We must learn to understand that the world cannot be comprehended by looking at it only in one way.

in here which roughly balance one another: the problems became more difficult, but there are more scientists around. Of course, there are examples where the transition is faster or slower, but it is doubtful that there is a definite acceleration.

The developments of science that have led to technical applications have never been carried out with the intention of application. When H. Hertz discovered electromagnetic radiation, he didn't think of radio; when Rutherford discovered radioactivity he didn't think of cancer research; Chadwick, who discovered the neutron, didn't think of nuclear reactors nor of the nuclear bomb.

Today we have a very close symbiotic relation between technology and science. Technology needs science for further development of its methods and science needs technology for the construction of instruments. The connection between science and technology shows up clearly when one considers

how scientific and technical leadership go hand in hand. One is impossible without the other.

In the nineteenth century one of the most important scientific discoveries was the existence of atoms and molecules. It led to the chemical industry. The discovery of the laws of thermodynamics and the recognition that heat is random molecular motion went together with the development of the steam engine and other heat engines. The third most important discovery during the nineteenth century was the connection between electricity, magnetism, and light, which led to the electrical industry, to electric lighting, motors, electrical communication, and so on. In the twentieth century the development took on a much wider scope. The internal structure of the atom was revealed through quantum mechanics, and the atom turned out to be essentially an electric phenomenon. At the beginning it was a very esoteric science dealing with abstract concepts. But pretty soon it turned out to be of extreme practical value. It has become the basis of materials science and engendered electronics, transistors, semiconductors, computers, and a vast expansion of the chemical industry. All this was based upon our quantum mechanical knowledge of the atom and the molecules.

Later on, around 1930, science penetrated into the center of the atom, the atomic nucleus. This was a step into a new realm of nature. Nuclear processes do not occur on the earth's surface. The energy exchanges are too small to bring about nuclear reactions. The only exceptions are the natural radioactive substances, but they are remnants of the time when earthly matter was ejected into space by a supernova explosion. They are the last embers of that cosmic fire.

Nevertheless, nuclear processes are very essential for what happens on earth. They take place in the centers of stars and supply the energy for radiation. Solar energy is of nuclear origin. In this sense, the transition from atomic to nuclear physics can be called a "leap into the cosmos".

These extraterrestrial processes can be engendered on earth by nuclear technology in the form of nuclear power,

or in the applications of artificial radioactivity in medicine and in materials science. Unfortunately, nuclear processes have military applications. By making use of nuclear energy, we can extract several million times more energy from the atom than by chemical means. The arm of technology became a million times stronger, for beneficial and for destructive purposes.

The development of science and technology in the last century grew steadily in speed and in scope. It is an exponential increase exerting its influence on every part of the social fabric of our society, on our way of life, our way of thinking, and our philosophic outlook. Everything is shaken to the core. What are the effects of this development? First, the technological society has produced a social regrouping: the artisan was replaced by the workers. Second, agricultural work that was done before by 80 percent of the population, is now done by 7 percent. A great movement from country to city took place. An explosive growth of the cities has occurred in the last hundred years. Third, communication, transportation, and information have vastly increased. People traveled by horse-drawn carriages from ancient days until the

nineteenth century. Today we have automobiles, trains, and airplanes, shortening travel time by a factor of more than a hundred.

The fourth item is population growth. The development of medicine, "death control", has increased the average age; epidemics have been eliminated. In my own lifetime the population of our planet grew from 1.8 to over five billions. The fifth point refers to the increasing technological possibilities. With the present technical means, adequate housing and food could be provided for everybody on earth, all kinds of strenuous labor could be abolished, the comfort of living could be improved for everybody. It could; but these possibilities have not been realized, except in a few developed countries.

There is one important common feature in all technological achievements: they are what one may call "double negatives". Life is made easier, obstacles are torn down, burdens are eliminated, something negative has been negated.

This tremendous upsurge had a big effect on thinking and philosophy; an impressive example is the spirit of enlightenment 200 years ago. Previous

Nuclear bombs are not weapons of war: they are means of national and international suicide.

golden ages were either in the past or in heaven, but in the age of enlightenment people thought that this golden age would be here on earth in the near future. Science and technology would abolish need, so moral progress would take place because the absence of need would lead to the absence of evil as a consequence.

How did it really go? Some parts of the dream came true, but the vast and rapid progress and change in both social and philosophical thinking have created, and are still creating, serious problems. Some of these problems have been solved; at this time it is important to stress this fact. Many are not yet solved, however.

Let me start with the positive side of the balance sheet of human development in the scientific-industrial age. In the middle of the nineteenth century



and before, at the beginning of the industrial society, workers were ruthlessly exploited, there was child labor, a twelve-hour working day, and so forth. Today we have social legislation, trade unions, workers' rights, medical care, old-age care, all developed to varying degrees. This must be considered as moral progress in a certain sense.

The situation in the Third World, however, is considerably worse. The benefits of the industrial system are on a lower level and they are not shared among the different strata of the population. Although it is true that there are fewer countries under the domination of developed nations, power has been transferred from foreign to indigenous "exploiters" without any major increase in the general welfare. These countries must, in a few decades, catch up with what has taken the Western world a century or more to achieve; this cannot be done without some crises and disasters.

We come now to the unsolved problems; the negative side of the balance. What is involved here is pollution: material and spiritual pollution. Let us begin with material pollution.

The expansion of technology over the surface of the globe has produced effects on nature which can no longer be neglected. Earlier, the regions and areas where technology changed nature for the worse or for the better were small compared with the regions that remained entirely unaffected. Today, the entire surface of the earth is involved. We constantly increase the content of carbon dioxide in the air, we reduce the forest areas, we pollute the rivers and the oceans, we use up the raw materials; lately it is being maintained that the use of nuclear power stations could produce global damage.

Most probably all these questions, nowadays in the foreground of discussion, can be technically solved. It will not be easy and it will increase the cost of industrial production, but this is nothing new. Social progress also increased the costs of industrial production, and rightly so. For the costs should correspond not only to what is needed to produce the goods, but also to what is needed to correct possible damage caused, be it to nature or to the social sphere. It involves a certain

adaptation of technical development that no longer can be exclusively directed toward innovations and new inventions; it must also be oriented toward avoiding undesirable consequences.

These problems are solvable, but only under certain conditions. One of these conditions is a stable population. We need birth control in order to offset the death control that was introduced by medical advances, in order to re-establish the order of nature as it was. Another condition is a reasonably stable political situation without irrational outbursts and conflicts nurtured by emotions and fanaticism.

But the first and foremost condition is the avoidance of nuclear war. The danger of a nuclear holocaust is the prime example of a spiritual pollution of our thinking. It is the most threatening, the most deadly, of all pollution; much more deadly than material pollution. Tensions between nations are unavoidable. They have always been there, and all too often these tensions have led to war; but previously there were winners and losers, and the losers could limp away. The damage was repairable. Of course, the dead could not be resuscitated, but life could be resumed. Today it is different; there is no recovery even if only a few percent of those nuclear bombs that are deployed today are used. The damage would be irreparable. It would be a catastrophe of unfathomable severity, millions of people dead, damage to the environment, to the soil, radioactivity spread over the planet's surface, rescue operations impossible, hospitals and cities destroyed. The worst possible reactor accident shrinks to total insignificance compared even to the application of one single bomb. We don't even know how terrible it is. The unknown effects probably dwarf the predictable ones; the survivors would envy the dead. The penetration of science into the innermost nucleus of the atom has revealed a new kind of force which is now abused for nuclear weapons. The arm of technology has been multiplied by several million. Woe be to mankind, if this arm is ever used for destruction.

Nuclear bombs are not weapons of war: they are means of national and international suicide. Every thinking person knows this, but the nuclear arms



Victor F. Weisskopf: Professor Emeritus of Physics, Massachusetts Institute of Technology, USA; former Director General of the European Organization for Nuclear Research (CERN); past president of the American Academy of Arts and Sciences; member of the US National Academy of Sciences.

race goes on anyway. Why? The only purpose one can think of for nuclear weapons is deterrence, the prevention of a nuclear war; but for this you only need a few hundred weapons. What we witness here is a triumph of insanity in a civilization that calls itself rational, the apotheosis of madness. If we survive at all, our age will be looked upon as an age of a mental epidemic.

The nuclear weapons race shows a lack of moral revulsion against unlimited violence, against indiscriminate killing of innocent victims, old people, women and children. This moral deficiency was already apparent in World War II, when the saturation bombing of cities was met with collective indifference. This atrophy of moral resistance grew with the passing of time to such an extent that we are ready to accept the nuclear arms race and live with it. There is a qualitative race and

*We are psychologically,
if not economically,
deprived.*

a quantitative one. The qualitative race consists of the invention of new kinds of these terrible weapons; the United States is leading in this race. The quantitative race consists of increasing the numbers and weight of these bombs; the Soviet Union is leading in that race. Can these races ever be stopped?

What we need is a new attitude towards the rule of force. There is no issue at stake which could conceivably justify the resort to nuclear weaponry. Political differences must be tolerated. Today, in the nuclear age, it is impossible to change a political system of another nuclear power by force. People and governments are not yet aware of this. We must find a way for nations to coexist, which is not based upon the threat of mutual annihilation.

There are other forms of spiritual pollution. The scientific industrial age has brought us enormous gains. Science and technology have given us the means to remove hunger, to remove want, to remove illness, to remove oppressive manual work. These are all examples of abolishing a negative. We are back at the double negative. Humanity can be freed of its burdens. Freed for what? What does one do if one doesn't need to fight for one's existence any more? Then one is thrown back upon himself, one must find something, one must find a meaning of life. Work today, except for a selected few, is very mechanical. The result of the work is not the individual achievement of the working person, but of the engineers who have developed the machines. The worker has very little influence on his work or on the enterprise of which he is a part. What has become then of human dignity, of individual sense and purpose? In earlier centuries this individual sense and purpose was given by religion, but the role of religion has weakened nowadays. Goethe said, "He who has art and science also has religion." This is valid today, if one understands by religion a deep commitment to a great cause beyond one's personal interest, whose values are never questioned. The scientific community has a little of that; not all scientists, but some of them. It comes from the greatness of the scientific ideas that have evolved, such as the origin of the universe, the development of stars, the formation

of elements, the fundamental and the molecular basis of life. We begin to understand what makes the universe tick. This is an inspiration for a true scientist; it fans his enthusiasm and his commitment. For the nonscientist, however, it does not have much significance. He only knows that there are laws of nature, and therefore the Bible stories can no longer be true; the significance of science for him is only derived from the practical application of physics, or chemistry, or biology. The scientists are guilty for this situation because they do not try sufficiently hard to tell the public about the greatness and the wonder of nature as discovered by science.

Let us look at art. Previously, art was in the service of religion and as

*The danger of a nuclear
holocaust is the prime example
of a spiritual pollution of
our thinking.*

such it was generally comprehended and acknowledged. Where religion lost some of its influence, art has acquired a certain independence. It still expressed the great ideas of the time, but it was accessible only to the upper stratum. Contemporary art seems to be even worse. It also expresses the ideas of our time, but it puts the emphasis on the negative aspects.

True enough, contemporary art is full of new ideas and original creativity, but it does not yet come close enough to the positive ideas of our culture and to mankind's need for sense and purpose. Today's art lacks the elements that were so prominent in earlier art, namely beauty and hope.

For most people, however, neither art nor science means very much. When the most important material needs are provided for, as they are in the developed countries, what is then the content of life? We are psychologically, if not economically, deprived. What is sorely lacking is a fulfilling, creative content of life for the population at large.

Let us return to our original ques-

tion. Does the present crisis represent the end of the scientific—technical culture, or is it merely a transitional crisis from a relentless drive to a more mature and calmer period? I cannot answer this question, but I know that the optimistic answer rests on two basic conditions. The first is the abolition of the nuclear war danger; this Damocles' sword hanging over mankind must be removed. The second is the provision of a creative and purposeful content of life for the majority, and not only for a few.

The first task is extremely hard; the second may be even harder. We need a new step of humanization of the industrial society, which should provide a sense of responsibility and participation for most people. We need creative outlets for human activities accessible to all. Not enough efforts are devoted to this goal. We must be careful, however, to avoid the grave danger of attempting to reach this goal by fanatic ideologies. There exists a human urge for one simple all-embracing answer to our problems. This leads to violence, hatred, and oppression, as we have seen in so many recent examples of fanaticism. In this respect, the present lack of an inspiring ideology may even be a positive element. It gives us the freedom of choice. It is certainly a great asset to the creative minority. Can it be transformed into an asset for the majority? It may be possible, if our system of education is improved and its philosophy directed towards an understanding of "complementary" approaches to the problems of life. We must learn to understand that the world cannot be comprehended by looking at it only in one way. We need the scientific, the emotional, the artistic, and perhaps also the religious approach to the totality of human experience. They often are seemingly contradictory, since they illuminate our perceptions from very different sides. All approaches are needed to cope with the predicaments of our existence and to arrive at a life worth living. As long as a growing number of people realize the need for new ways of thinking and acting in order to solve the two great problems of our day — the avoidance of nuclear war and the creation of a meaningful life for all — there is still hope for hope.

News from the Institute

Book Review

Nuclear Technologies in a Sustainable Energy System. Selected Papers from an IIASA Workshop. Günter Bauer and Alan McDonald, Editors. New York and Berlin: Springer-Verlag. 329 pp.

"If we continue with the present crippling of nuclear power, we shall be driven very quickly into the domain of low-grade fossil fuels. I think none of us has really understood what it will mean for whole regions to be destroyed or moved." These are the terms in which Professor Wolf Häfele, former leader of IIASA's Energy Systems Program and now Director General of the Nuclear Research Center at Jülich in the Federal Republic of Germany, sees the debate about nuclear power. This volume contains twenty-one selected papers based on presentations made at a Workshop held at IIASA in May 1981 under the title "A Perspective on Adaptive Nuclear Evolutions: Towards a World of Neutron Abundance." New concepts such as *in situ* spent fuel rejuvenation and parent-satellite systems, as well as emerging technologies such as fusion-fission hybrids, synthetic fuel producers, fusion reactors, and spallation breeders are explained and analyzed.

Safety and environmental considerations and concerns about proliferation have guided research on nuclear technologies in recent years. Nobel laureate Professor Hans Bethe stresses that the first priority in nuclear power development should be to "close the fuel cycle" — that is, to attain a complete intrinsic recycling capability for heavy elements.

The scientists discussed ways in which fission reactors, fusion reactors, and accelerators might be combined in synergetic systems. One new concept considered is that of a nuclear energy system comprising numerous small, specialized "satellite" reactors providing heat or electricity for localized or regional purposes with fuel supplied by a "parent" nuclear facility. Nuclear "minireactors" could meet specialized energy needs and are particularly well suited for remote locations. Small reactors are presently in routine service in

submarines and surface ships. Additionally, Sweden operated a small Agesta plant in a Stockholm suburb for ten years, and Canada has been using several very small, simple, and safe SLOW-POKE reactors for teaching, research, and experimental industrial processes. Manufacturers in the United Kingdom, France, the FRG, and the USA are tentatively offering smaller reactors, but no firm orders have yet been placed. The USSR and India have wider experience of operating smaller units.

Other papers look at alternative methods for reprocessing spent fuel in the light of proliferation issues and the public acceptability of the radioactive waste disposal process. Current work and outstanding problems in plasma physics and fusion reactor technology are described; several scientists expressed optimism about the fusion breeder as a long-term option, supplying fissile fuel to twenty or more fission reactors. The potential of fusion reactors to supply heat for producing hydrogen by electrolysis or "synfuels" from gaseous and solid fossil fuels is examined. Dense plasma focus devices are suggested as a possible source of neutrons for a hybrid fusion-fission system. Accelerator breeders, in which protons would be accelerated to high energies to produce neutrons in spallation reactions, are considered for producing fissile fuel and for transmuting waste fission products.

Professor Freeman Dyson gives a historical perspective on the subject of the Workshop under the title "Quick is Beautiful", arguing for faster responses to changing energy needs by the mass production of simpler and smaller reactors. A summary of the Workshop's panel discussion, an overview that touches on technical, social, and economic considerations, is also presented.

Derek Delves

Meetings

An Adaptation and Optimization course given at IIASA covered the state of the art in mathematical techniques combining elements of prediction, optimization, adaptation, and uncertainty.

External lecturers were Professor Karl-Johan Åstroem of the Lund Institute of Technology, Sweden; Professor Herbert Robbins of Columbia University, USA; and Academician Yakov Tsyypkin of the Institute of Control Problems, USSR.

After an Adaptive Health Care Modeling Workshop held in Bratislava, Czechoslovakia, the Slovak Ministry of Health will continue work with IIASA along the lines set out during the sessions for management of public health services.

IIASA, with the Swedish Council for Planning and Coordination of Research and the University of Umeå, conducted an adaptive environmental assessment workshop on subarctic land use, concerned with the joint management of reindeer herding, forestry, and general economic development.

A seminar on global and national energy issues was held in Berlin, GDR, jointly sponsored by IIASA and the Academy of Sciences of the German Democratic Republic.

Methods for assessing the regional socioeconomic and environmental effects of large-scale energy projects were discussed at a workshop at IIASA, with reference to experiences in Canada, Sweden, the USA, and the USSR. A book on this subject is being prepared.

Amsterdam, Budapest, Dortmund, Leeds, Melbourne, Turin, and Vienna were reference studies at a task force meeting at IIASA on the nested dynamics of metropolitan processes and policies: structural change in metropolitan regions.

Organizational structures in innovation management in the electrotechnology industry were analyzed at an IIASA task force meeting of senior managers and researchers from Austria, Bulgaria, Czechoslovakia, Finland, Japan, Sweden, the USSR, and Yugoslavia. The meeting was held in Prague, Czechoslovakia, with the cooperation of the enterprise ČKD, the Institute of Management, and the Committee for IIASA of the Czechoslovak Socialist Republic.



Visiting Finnish Minister of Education and Science Kaarina Suonio (right) with Institute Director C.S. Holling.

New Titles

Nuclear Technologies in a Sustainable Energy System. Selected Papers from an IIASA Workshop. G.S. Bauer and A. McDonald, Editors. 329 pp. (See review on facing page.)

Uncertainty and Forecasting of Water Quality. M.B. Beck and G. van Straten, Editors. 386 pp.

Available from Springer-Verlag, Tiergartenstrasse 17, D-6900 Heidelberg, Federal Republic of Germany, or Springer-Verlag New York Inc., 175 Fifth Avenue, New York, NY 10010, USA.

Modeling Growing Economies in Equilibrium and Disequilibrium. A.C. Kelley, W.C. Sanderson, and J.G. Williamson, Editors. 375 pp.

Available from Duke University Press, 6697 College Station, Durham, North Carolina 27706, USA.

International Series on Applied Systems Analysis

Volume 11 **National Perspectives on Management of Energy/Environment Systems.** W.K. Foell and L.A. Hervey, Editors. 357 pp.

Volume 12 **Mathematical Modeling of Water Quality: Streams, Lakes, and Reservoirs.** G.T. Orlob, Editor. 538 pp.

Available from John Wiley and Sons Ltd., Baffins Lane, Chichester, West Sussex PO19 1UD, UK, or John Wiley and Sons Inc., 605 Third Avenue, New York, NY 10016, USA.

IIASA Collaborative Proceedings Series

CP-83-S1 Environmental Management of Agricultural Watersheds. A Selection of Papers Presented at a Conference held in Smolenice, Czechoslovakia. G. Golubev, Editor.

Status Report

SR-83-1 The Human Settlements and Services Area. A. Rogers.

Research Reports

RR-83-1 The Deviant Dynamics of Death in Heterogeneous Populations. J.W. Vaupel and A.I. Yashin.

RR-83-2 The Strategy for Organized Technology in the Light of Hard-, Soft-, and Orgware Interaction. G.M. Dobrov. Reprinted from *Long Range Planning*.

RR-83-3 Topological Methods for Social and Behavioral Systems. J.L. Casti. Reprinted from *International Journal of General Systems*.

RR-83-4 Modelling the US Federal Spending Process: Overview and Implications. M.A.H. Dempster and A. Wildavsky. Reprinted from R.C.O. Matthews and G.B. Stafford, Editors, *The Grants Economy and Collective Consumption*. London: Macmillan.

RR-83-5 Can Knowledge Improve Forecasts? N. Keyfitz. Reprinted from *Population and Development Review*.

RR-83-6 Integrated Computer Systems in the Pulp and Paper Industry. P. Uronen.

RR-83-7 Mathematical Modelling at IIASA. R.E. Levien, A.P. Wierzbicki, and W.B. Arthur. Reprinted from *Mathematical Modelling*.

RR-83-8 Patterns for Family Migration: Two Methodological Approaches. L.J. Castro and A. Rogers. Reprinted from *Environment and Planning A*.

RR-83-9 Fueling Europe in the Future. The Long-Term Energy Problem in the EC Countries: Alternative R&D Strategies. W. Sassin, A. Hölzl, H.-H. Rogner, and L. Schratzenholzer.

RR-83-10 Forest Monitoring and Harvesting Policies. J.L. Casti. Reprinted from *Applied Mathematics and Computation*.

RR-83-11 Water and Fire: Water Needs of Future Coal Development in the Soviet Union and the United States. J. Alcamo.

RR-83-12 The Migration Component in Subnational Population Projections. A. Rogers. Reprinted from **National Migration Surveys, Survey Manual X: Guidelines for Analysis**. United Nations Economic and Social Commission for Asia and the Pacific, Bangkok, 1982.

RR-83-13 The Expected Value of Perfect Information in the Optimal Evolution of Stochastic Systems. M.A.H. Dempster. Reprinted from *Stochastic Differential Systems*.

All IIASA publications can be ordered from the Publications Department, IIASA.

National Member Organizations

Austria – The Austrian Academy of Sciences; Bulgaria – The National Committee for Applied Systems Analysis and Management; Canada – The Canadian Committee for IIASA; Czechoslovakia – The Committee for IIASA of the Czechoslovak Socialist Republic; Finland – The Finnish Committee for IIASA; France – The French Association for the Development of Systems Analysis; German Democratic Republic – The Academy of Sciences of the German Democratic Republic; Federal Republic of Germany – The Max Planck Society for the Advancement of Sciences; Hungary – The Hungarian Committee for Applied Systems Analysis; Italy – The National Research Council; Japan – The Japan Committee for IIASA; Netherlands – The Foundation IIASA–Netherlands; Poland – The Polish Academy of Sciences; Sweden – The Swedish Council for Planning and Coordination of Research; Union of Soviet Socialist Republics – The Academy of Sciences of the Union of Soviet Socialist Republics; United States of America – The American Academy of Arts and Sciences.

Director's Corner: *Myths*



When the first pictures of Earth from space were obtained, they seemed to many to be a reconfirmation of the minuteness of man and of the fragility of the planet. But an advertisement by the investment division of a major bank captioned one of the pictures with "Businessmen, attack this planet!" What was a delicate jewel in one conception became a digestible morsel in another.

Reality is not perceived; it is conceived. Conceptions derive from the myths we hold. They give some intelligibility to the world around us so that we dare act despite a lack of detailed knowledge, and despite the difficulty of predicting the future with any certainty. Representing the results of tested experience, myths give guidance to action, determining the way we define problems, collect information, and attempt solutions. They provide a sense of certitude that, if widely shared, can move societies or institutions to a common purpose. Many of the remarkable economic developments since World War II were driven by a set of myths that, in many ways, allowed collaboration between groups both within and between nations.

Myths can be as all-encompassing as a belief in a guiding essence — of man, nature, society — or as narrow as the belief that free market play will resolve all inequities. Myths are not wrong. They are partial truths. As a consequence, they hold the seeds of their own modification within themselves.

The very certitude they provide that allows action generates the information that exposes their incompleteness. Paradoxes and inconsistencies develop. The world begins to be viewed as complex when before it was seen as simple and easily comprehensible. Boldness of innovation is displaced by caution. Collaboration is displaced by polarization.

The clash between environmental values and economic needs provides one example. So long as there are shared myths — common beliefs — those clashes can be resolved. Industrial development around Lake Baikal in the Soviet Union has been modified to the benefit of both social development and environmental quality. Phosphate intrusions into the Great Lakes of North America have been dramatically reduced and the lake conditions improved without harming industrial growth.

But now the problems seem to have taken on a different dimension. In part, that is because the scale has changed. What was once local and contained has become international. National economies have become intertwined. At the same time, economic growth has slowed and additional environmental issues have emerged that ignore borders. The established and presumed impacts of acid rain on lakes and forests, for example, continues to be an issue between countries and groups in Europe, Japan, and North America. Decision on joint action is difficult, since the sources and their consequences are not clear and unambiguous. How much more difficult is the response to possible global climatic change induced by increasing concentrations of gases caused by the burning of fossil fuels.

The scale of such issues and their inherently uncertain nature presents a dilemma. Predicted outcomes of current crises are often untestable. We are forced to develop, at best, a rigorous chain of detailed logic in which the parts are subject to disproof, in the traditions of experimental science, but the whole is not. The difficulty is that one chain of logic can be as convincing as another, even though the consequences of each might be totally different. Their acceptance is determined by whether the arguments are believable and whether the conclusions reinforce one's myth.

In the face of increasing unease regarding past patterns of development and present problems, few myths today find common public acceptance. Their incompleteness is all too evident because of the very success of modern societies. Until new myths emerge to give fresh clarity, we are left with extreme and often sectarian views. That leads to polarization, such as that between advocates of continued economic growth and those of no-growth. One seeks certitude by stopping the destruction and misuse of resources and environmental systems. The other seeks certitude in continued growth in which the uncertainties are identified, reduced, and controlled through the application of improved knowledge and predictions. Both assume that there is a route that will lead to a future free of shocks and surprises.

There is clearly the need both for regulations and for better development designs. There are profound hazards from erosion of biotic resources, from pollution, and from toxic substances in the environment that require regulating. And who would argue that ignorance of, and passivity toward, the future is to be preferred to effective prediction and design? But any decisions, in the past as in the future, will always be made in the face of considerable uncertainty and incomplete knowledge. The scale of the present issues and the polarizations between groups means, however, that analysis of specifics and a search for details is not enough.

Some larger understanding of natural and historical patterns is a minimum need in order to provide context. William H. McNeill, the historian, recently developed that argument in exploring "The Care and Repair of Public Myth" (*Foreign Affairs*, 1982, Vol. 61, No. 1, pp. 1–13). His appeal to academic historians was to step back from detail and search for larger generalizations. If that is an appropriate appeal to the historian, it is equally so to all of our traditional areas of scholarship. Above all, it is a challenge to the most applied facets of systems analysis. When myths are wanting, the search should not be for solutions but for the relevant questions.

C.S. Holling