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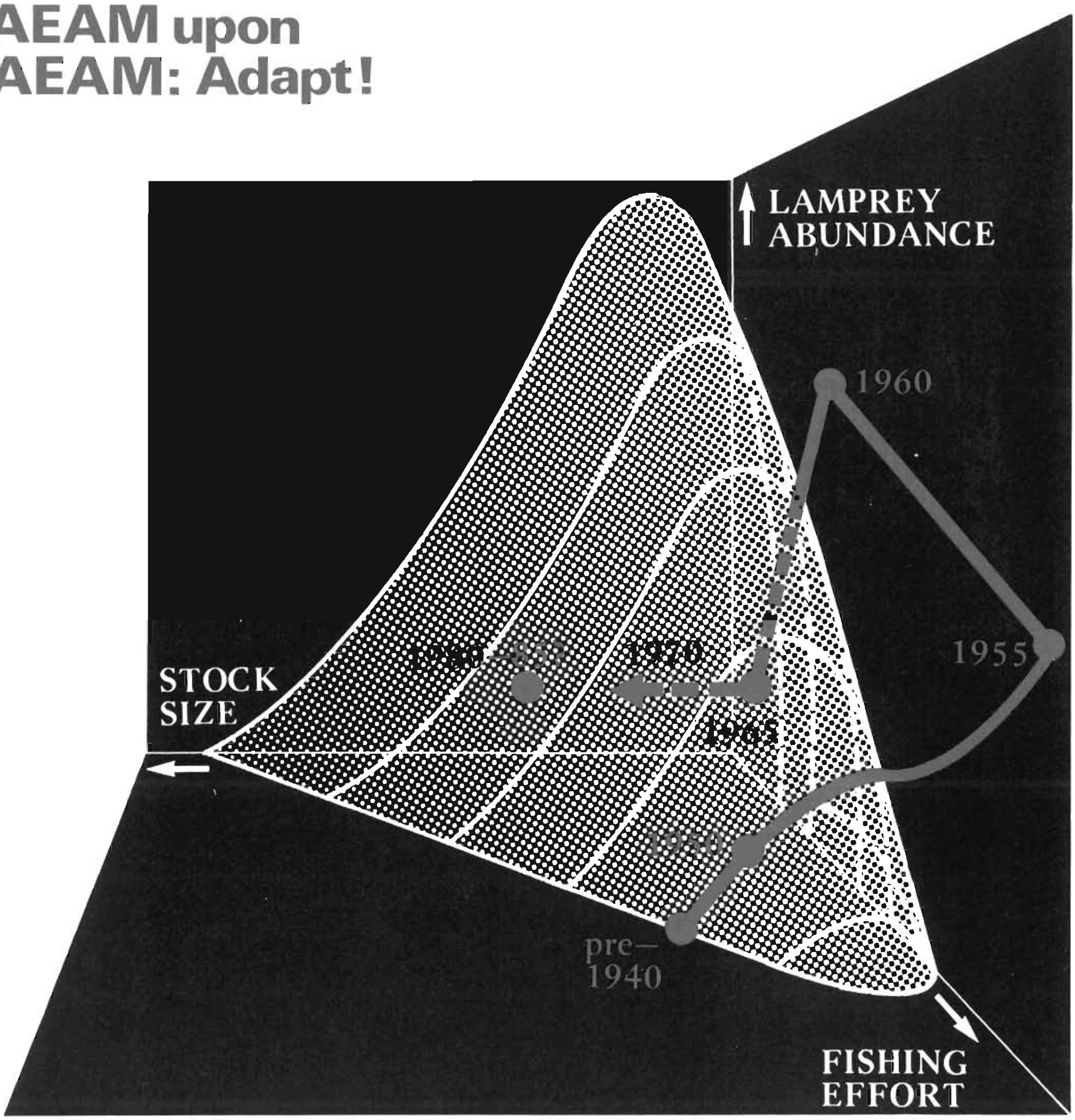
OPTIONS

AEAM upon AEAM: Adapt!



Ecologists and managers met in January to assess Adaptive Environmental Assessment and Management. **Carl Posey** reports.

The group assembled under the winter rain and slate skies of Vancouver Island, Canada, reminds one of physicians, patients, relations, and hospital administrators gathered in a quiet place to assess a controversial treatment — controversial because of its internal contradictions. It has been used to treat everything and nothing, and carries a high risk of failure; but when it works, it works superbly well. While it can produce economies, it is expensive. The cure it offers forces drastic changes upon the patient, changes that may seem worse than the illness being treated. It can take years to tell whether a cure is possible, or even whether there has been one. It combines such extreme technology as organ transplants with faith healing. And, one suspects, it embodies a fundamental misunderstanding of hospitals.

But this is not really a medical meeting. The treatment is called Adaptive Environmental Assessment and Management – AEAM – and it treats human understanding of complex, interacting systems. The traditional objective of systems analysis has been to sketch out optimized alternatives, typically leading to such benefits as maximum efficiency. At the same time students of the craft have noted that, in foreshadowing this optimum future, in seeking equilibrium in the best of its myriad forms, conventional techniques can also create systems that are rigid, unyielding, and fragile in the face of inevitable change.

The difference AEAM offers is that it retains, with the quantifying techniques, the human ability to adapt to surprise – it accommodates the unexpected. Mathematical representations are a means of forcing people to think about a problem in quantifying terms; but the quantified result is the beginning of the process, not an end. For AEAM to work, humans must come back into the picture, apply the simulation, the model, extend its ability to represent reality, and help the rigid mathematical world bend with the rising winds of change. Thus, AEAM proceeds as a kind of flexing between people and numbers and machines, between humans interacting verbally (and viscerally) to define and quantify the elements of a problem, and machines capable of driving these numerical simulations through time, to show how various policy choices produce various futures, good and bad.

Beyond GIRLS

"It all started with GIRLS, the Gulf Islands Recreational Land Simulator," says Professor C.S. Holling, now the Director of IIASA, and formerly director of the Institute of Animal Resource Ecology at the University of British Columbia (UBC), Canada. "We used that to introduce methods of bridging gaps between disciplines. Then we began training people at Environment Canada, in a series of resource management workshops. But in the early 1970s we decided to concentrate on two prototypical case studies and carry them through to implementation."

The two selected were the salmon study then under way with the Canadian Department of Fisheries and Oceans, and another on the budworm problem in northeastern Canada. These detailed case studies were carried out by Professors Holling and Carl Walters with colleagues at IIASA, who received a grant from the United Nations Environmental Programme – aid that did much to add the EA to the AEAM acronym.

In 1979, alumni of IIASA and the UBC unit opened Environmental and Social Systems Analysts Ltd. (ESSA) of Vancouver, an entrepreneurial incarnation of the, until then, purely scholarly AEAM process. The Parksville meeting was organized by ESSA's Dr. Pille Bunnell and her colleagues, and is being moderated by Michael Staley, one of ESSA's senior people and an AEAM pioneer. The questions treated during the three days on Vancouver Island are important to all the participants. For the people at ESSA, however, there is an extra dimension: they must ask this group of believers and infidels, practitioners and practiced-upon, whether their special kind of work is worth doing.

Dr. John Wiebe of Environment Canada, the hosts of the meeting, expresses his motives for sponsorship:

AEAM & IIASA

IIASA formally began its research in 1973, producing over the ensuing nine years such major works as *Energy in a Finite World*, but also attempting a number of more modest endeavors, some of which have had international impact in areas of scholarship and decision. The work on AEAM is one of those. In 1974, a small Canadian team came to Laxenburg to extend and amplify potentially promising work on resources and environmental management. For two years, elements of that group worked at IIASA, which helped accelerate and focus their efforts, and broadened its ecological and modeling base to connect with developments in decision theory and optimization. At the same time, through the Institute's involvement, the effort became more international in nature. A team was mobilized from Venezuela, Argentina, Austria, the Soviet Union, and the United Kingdom, to produce *Adaptive Environmental Assessment and Management*, the seminal work on this kind of adaptive process, published in 1978. When members of that team returned to their home countries, another cycle of exploration, testing, and application took place in which opportunities and problems were identified in this second generation of research. Now, elements of that original group are returning to IIASA for a third phase of development and extension, in which their efforts will intersect with IIASA studies in water resource management, risk analysis, and interactive methods. This intersection is expected to provide a background of intensive analytical and practical experience, that reflects the growing emphasis at IIASA on institutional behavior in complex decision environments.

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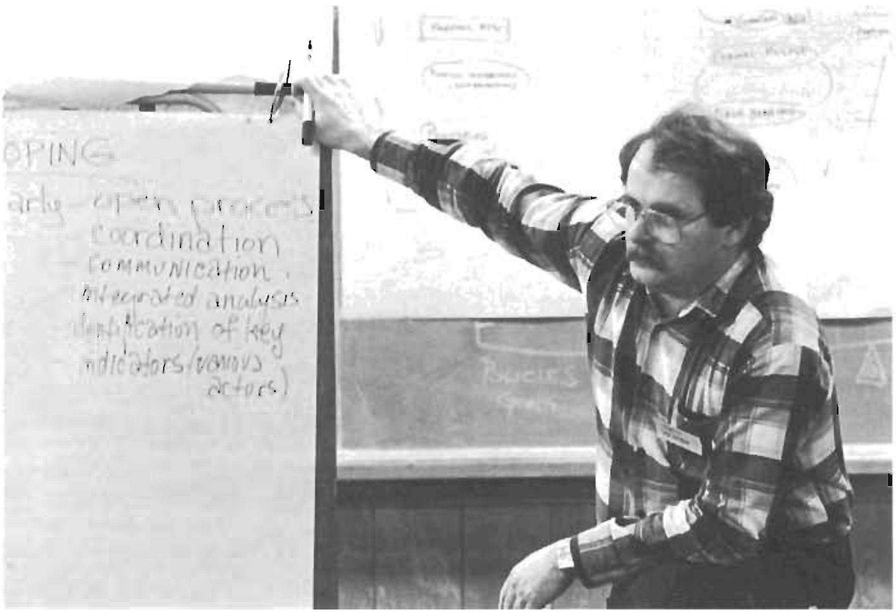
"We wanted to see whether AEAM had really progressed beyond conventional systems used to solve environmental and resource problems. This seemed a good time to take a closer look at the concepts behind it, the ways the process has been used, the views of clients. We wanted also to look at its applications. For example, it isn't much used in the environmental assessment field. Why not?"

There is an early sense that despite the "environmental assessment" in the name, this is not the best test of AEAM. By the time the workshop has ended part of the consensus (with some small amount of opposition) will be that perhaps the middle EA should drop out, leaving a process called Adaptive Management.



John Wiebe

The Workshop

"Workshop" is a fundamental concept. The AEAM process begins with a workshop, where, in an environment removed from the invisible but unyielding bulkheads of internal organization, key "players" can meet, talk, focus their ideas, translate them into numerical terms, develop a simple model, and use it to explore various courses of future action. At something like $50 000 a workshop, this can also be the most expensive part of the process, especially when salaries and other "hidden" costs are included.

The concept is so deeply embedded in AEAM that one hears "workshop" being substituted for the process – it holds the same kind of association with AEAM, and engenders the same kind of misconceptions, as "modeling" does in systems analysis. When one thinks of AEAM, one thinks of workshops.

Typically, a "practitioner" or "facilitator" – or a team – leads the AEAM workshop, which represents an intensely productive beginning to the process. This key figure has an extremely difficult role to play, for he or she must guide the workshop without manipulating it, and integrate the evolving ideas that the meetings yield.

The benefit of this relationship is that, if you have the right practitioners, you can have a richly productive workshop, and raise the chances for successful application of what has been learned. But the reverse is also true: mediocre facilitators almost guarantee failure. Thus, one sees this cornerstone of AEAM, this operative (if misapplied) synonym for the process, as being completely dependent for its success upon the leader's unblemished desire to come to something close to truth by the workshop's end.

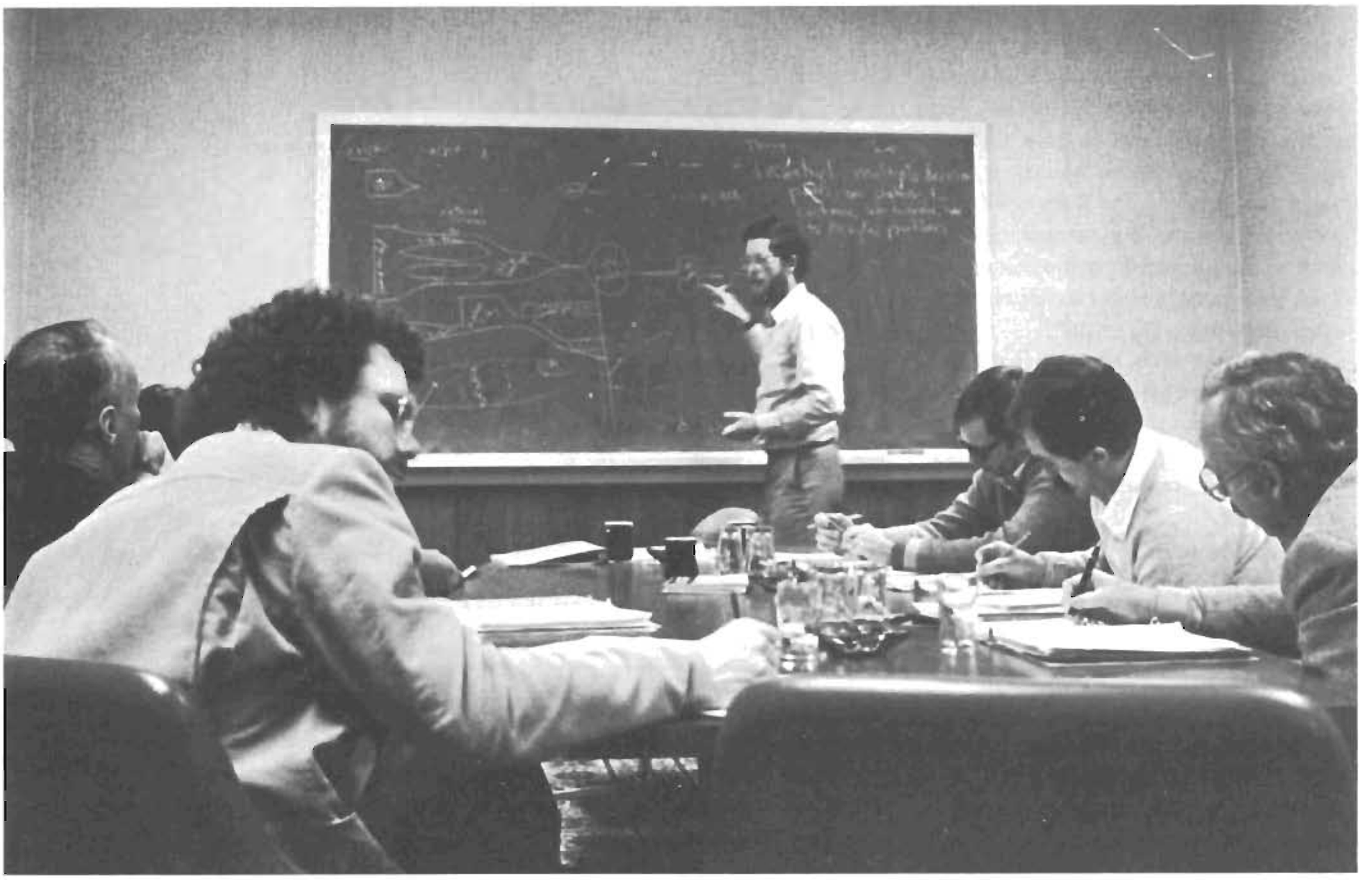
A five-day workshop is an enormous commitment of time as well as money. The period is spent in day-and-night sessions, in which the players – policy makers, people with vested interests, and others – and the practitioners are reduced to a baseline point of view. This reductive process is naturally fatiguing, as is the reciprocal process of quantifying and modeling policies and plans.

But the most negative aspect of AEAM "workshopping" derives from its most positive one. By removing people from their normal, but change-resisting, setting for a working week, and by relaxing their proprietary perspectives, one also removes some of the protective shield that forms between employees and organizations. When the workshop is over, when five days of a neutral and productive point of view have ended, they usually must return to the constraints of living and working within their organization, which has not changed. AEAM believers they may be, but they often find themselves pilgrims in a strange land after all. The shock of this return can destroy the person's ability to implement the new understanding developed at the workshop, for, almost by definition, if AEAM does not lead to change, it fails.

And there are problems with credibility after the workshop. As one participant puts it, "People use all their political capital to have the first workshop, but they don't have at that point anything solid enough to go in afterward for more funding." Throughout the Parksville meeting, one hears that lament again and again, and senses that there are a lot of silent believers locked away in the immutable institutions of the world.

This shock of withdrawal among AEAM workshop players is endemic in a process that depends upon real objectivity for any real success – that, in fact, forces such objectivity upon those with strong biases. Such objectivity is now possible because AEAM is still so new that the conduct of it is a form of serious research, which draws in good and sincere people with a real interest in using the process to solve problems. But there is always the specter of vested interest, one, the people in Parksville conclude, that will become more pervasive as AEAM enters wider use.

The Parksville meeting to assess AEAM is itself cast in the form of a workshop, a three-day session in which the plenary opening and closing are



Carl Walters (center)

punctuated by intermittent meetings of four smaller, more specialized groups. No models are under construction, so the discussions lack the constraints and focus that such quantifying efforts introduce; however, everyone is an old hand, and perhaps such boundaries are unnecessary here. One senses great willingness to come to a kind of truth about AEAM, about the workshop phenomenon embedded in the larger concept. But one senses also that, as the group disperses, the participants will return to their home organizations and find everything as it was. Those who believed in the process will believe in it still, and those who have resisted it will continue their resistance. Nothing will have changed, except that the main practitioners of the technique, the art, of AEAM will understand better how old and potential clients feel about their work. *That* is worth the price of admission.

The Model

While the mathematical models developed early in the process are in some respects mere subsystems of the workshops, they also have a life of their own — a life that, like almost everything else in the process, sparks internal controversy. The various opinions expressed at Parksville spring from certain properties of AEAM, but also from certain characteristics of the real world of politicians and institutions.

There is, for example, some disagreement among practitioners and among clients about what the model is supposed to do. To many, its only real utility is to provide a constraining numerical presence at the workshop stage, after which it can be — should be — discarded. The emergent consensus is that the model represents a first step toward applying the adaptive process to solving problems, and that many other steps — perhaps the proverbial thousand miles of steps — must follow if there is to be any long-term success.

Again, there is disagreement as to whether the model should be predictive or merely diagnostic. Some practitioners argue that the model, while essential, should be anything but predictive. This view, for example, came from Dr. Alan Birdsall, a vice-president of LGL Ltd., a Canadian research company taking part in the Outer Continental Shelf Environmental Assessment Program of the US government. There, so little was known of the ecological forces along the Arctic seacoast that the model rested on only scattered data; of course, no prediction was possible.

Not everyone at Parksville thinks the model is absolutely essential to the AEAM process. Some see it as a way of forcing people to identify their preconceptions, and to disaggregate vested interests, which, reduced to technical details, become transparent. To them, the model is useful, but not essential.

Another view, in which models are seen as indispensable *because* they are predictive, is expressed by Dr. Michael Zagata, a former Audubon Society ecologist who now leads the ecological sciences program of Tenneco, one of the petroleum giants. "This predictive element is a crucial difference between AEAM and some of the other interactive processes," he says, "— that and the ability it gives us to look at the impact of adjusting roles. Everyone can see how things change, or don't change, when you alter a variable."

There is, besides, a rising chorus of voices favoring a predictive capability and, moreover, favoring development of the models beyond the rudimentary form they have by the end of a workshop. This, nearly everyone agrees, has been one of the self-destructive forces attendant upon AEAM, this tendency to stop with whatever emerges from a workshop, to attempt to employ an unfinished model in the complicated real world. Better, these voices say, to spend another hundred days of research, and adjust the model to the point where it can be used effectively in the context of the particular problem and institutional setting.

That setting presents another frictional point in the process. Although the model designs begin as graphs and diagrams, they must finally be translated into mathematical equations – a translation that can be an incomprehensible, even frightening, intellectual experience for many people. And it is virtually out of character for the politician, the quintessential maker of policy, to be expert in mathematics. Thus, the group at Parksville repeats this familiar problem: to implement what has been learned from modeling, one must explain the new knowledge and the predictions in nonmathematical terms.

This question of how much methodology is too much is persistent here, as it is in any gathering of people attempting to apply the techniques of systems analysis to nonmechanical, often abstract, problems. No one here believes AEAM or any other analytical process should be expressed to policy makers in methodological terms, at least not yet, but it is also clear that the process under discussion has appeared a little before its time. John Wiebe makes the point: "My kids are growing up unafraid of computers. They use a personal computer at home, and so the idea of a model will become more, not less, commonplace with time. . . . Methodology is one of the few ways we have of coping with the problems of the kind of development we're going to see. We're being hit by horizontal problems when we have vertical institutions. . . ."

Innocence and Institutions

These "vertical institutions" provide one of the consistently troubling threads running through the three days at Parksville. In the Holling overview that opens the meeting, one hears the problem summarized this way: "The key issue is not policy advice in the narrow sense, but access to a much more creative range of options for policy makers. The feeling is stronger now than it has been because problems arise with a speed, and at a scale, that exceeds the adaptability of conventional systems.

"AEAM is one way to stimulate and generate a much more creative range of options than is available otherwise – to generate *strategic* options . . . dealing not with equilibrium systems, but with multiequilibria, where situations jump from one equilibrium to another, making it possible to absorb and benefit from unexpected events.

"If policy makers were not so desperately concerned with such limited options, it would mean that we're giving them what they urgently need. But because they are concerned, we know the institutional framework and our process are incompatible. We have been profoundly naive about institutional behavior."

This naiveté, the participants generally agree, has helped cripple the ability of AEAM "converts" within institutions to effect beneficial changes indicated by the process. But its persistence in AEAM is also connected to the axiomatic relationship between models and the real world: models are always simpler. One senses that the archetypal institution being approached has little to do with the reality of government agencies and other client organizations. In this simplified view, information flows from scientists upward through research managers to the directors in a process that is, at first appearance, linear, but that is not linear in practice because of a "coalition of resistance to change between middle managers and field workers." In this model, the whole institutional structure works against change, and the AEAM practitioner feels the problem can only be solved by educating scientists who will eventually percolate upward through this change-resisting system. And, some fear, the selection process within such systems may itself be change-resisting, effectively filtering out scientists who are receptive to change.

But there is also vocal resistance to this simple model. A rough consensus develops that such models remove the human element, which *is* the adaptive element in an institution. This opinion, many feel, connects back to the initial idea that, in developing the AEAM process, there has been a naive view of institutions.

Given the almost infinite variability of institutions, what is the cure? One advanced at Parksville is that the AEAM practitioner must "understand the anatomy, psychology, and behavior of client institutions, and their decision-making processes." The problem-solving approach would be made at high management levels, and a strong effort would be made to identify decision makers, opinion shapers, agents of change, as well as to involve other parts of the organization – to "give them a share." The difficulties of an outsider's understanding *any* institution that well are obvious, and lead to another question: should the AEAM process be introduced from outside the institution, or should there be a cadre within?

While there is general agreement that one applies AEAM techniques more successfully by coming into an institution from outside, the fact is that the single substantial grafting of AEAM has been into the US Fish and Wildlife Service, which operates an Adaptive Environmental Assessment unit in Fort Collins, Colorado. This five-person team, led by R.A. "Ike" Ellison, runs six to eight projects, ranging from synthesis to management to revised design, but has not found an environmental assessment project. It was initiated, according to former USFWS director Dr. Spencer Smith, as a means to train "managers to be managers, and teach them there are adaptive processes around that they can use."

A salmon fishery enhancement unit developed within the Canadian fisheries service simultaneously with the UBC's adaptive assessment efforts to improve the management of the west coast salmon resource, and provides an interesting prototype. Al Wood, who directs regional planning for Canada's Department of Fisheries and Oceans — and who constitutes the AEAM believer resident in the fisheries agency — describes the differences:

"Our enhancement program started from zero, rather than being in place in the bureaucracy before. This made it easy to shape in the beginning, although it gets less easy to change as it hardens. We find the program has brought research and operations people together, and possibly forced research to become better directed. I think some of the researchers occasionally view our team as competition, and we see some dogmatism in specialities — some people want to be innovative in every field but their own."

Still, in the AEAM experience to date, institutions represent virtually blank walls. The workshops work, the models predict, the participants enthuse, but, more often than not, the institutions remain rigidly in place. Perhaps the most important product of the three days on Vancouver Island will turn out to be a clearer recognition that AEAM, if it is to deliver what it seems to promise, must equip itself with the institutional equivalent of the facts of life.

Major Applications of AEAM

	1973
Environment Canada	Eastern spruce budworm research and management policy planning: Fredericton, New Brunswick
	1974
Austrian Man and Biosphere Program, UNESCO, and IIASA	Environmental and social consequences of development in the Alpine village of Obergurgl, Tyrol
Canadian Department of Fisheries and Oceans	Management of west coast salmon: Vancouver, British Columbia
	1976
Arctic Project Office, US National Oceanic and Atmospheric Administration (NOAA)	Ecological processes of Barrier Islands lagoon, Alaska
	1978
US Fish and Wildlife Service (USFWS)	Management of wildlife: C.M. Russell Refuge, Montana
Environment Canada	Effects of oil pipeline on caribou herd: North Slope, Alaska, USA and North Yukon, Canada
US Geological Survey and USFWS	Truckee–Carson river quality assessment: Reno, Nevada
	1979
British Columbia Council of Forest Industries	The assimilative capacity of aquatic environments for pulp mill effluent: Vancouver
Alberta Oil Sands Environmental Research Program	An adaptive environmental assessment approach to the effects of development of the Alberta oil sands: Fort McMurray, Alberta
California Water Policy Center (USFWS)	Sacramento–San Joaquin water management system
	1980
US Forest Service	Western spruce budworm research planning: Portland, Oregon
Mekong Secretariat, UN Bangkok, and Ford Foundation	Application of AEAM to the Nam Pong environmental management research project: Bangkok
British Columbia Hydro and Power Authority	Mackenzie Delta modeling for environmental studies of the Liard River hydroelectric development: Northwest Territories
NOAA and Bureau of Land Management — Outer Continental Shelf Environmental Assessment Program (OCSEAP)	Research planning related to effects of petroleum development in the Bering Sea (crab populations)
Ontario Ministry of Municipal Affairs and Housing	Integration of the lakeshore capacity study: Toronto
National Power Plant Team (USFWS)	Acid precipitation — research needs: Ann Arbor, Michigan
Cooperative Agreement between Assistant Secretary for Fish, Wildlife, and Parks and Governor's Office, North Dakota	Wetland preservation and protection: Bismarck, North Dakota
	1981
Wyoming Game and Fish Department	Resource development and management: Jackson Hole, Wyoming
Petro Canada	Development and application of a site selection methodology for a liquefied natural gas facility on the coast of British Columbia: Calgary, Alberta
Environment Canada	Beaufort Sea hydrocarbon development — scenario evaluation
Great Lakes Fisheries Commission	Training in adaptive environmental assessment and management: Sault Sainte Marie, Ontario
Biological Services Program (USFWS)	Development of the Beluga coal resource: Cook Inlet, Alaska
US Environmental Protection Agency (USEPA)	Potential impacts of drilling muds and cuttings on the Gulf of Mexico marine environment: Pensacola, Florida
US Bureau of Land Management	Saval Ranch Project — research planning and management of alternative cattle-grazing schemes: Elko, Nevada
USEPA	Environmental effects of developments in Mobile Bay, Alabama
British Columbia Ministries of Forests and Environment	Research planning for the integrated wildlife-intensive forestry research program: Victoria, British Columbia
Ontario Ministry of Natural Resources	Application of AEAM to fisheries management and acid rain research in the Algonquin assessment unit: Toronto
	1982
Canadian Department of Fisheries and Oceans	Research needs and data base management for acid rain studies in Eastern Canada: Toronto
US Forest Service	Development of an integrated management model of forest, fisheries, and wildlife resources in southeast Alaska: Juneau, Alaska

The Experience

To date, more than sixty AEAM projects have been conducted or are in progress. The results of these vary widely, and they tend to satisfy different criteria for success (the identification of which is a persistent but unresolved theme of the Parksville meeting). Several representative projects are described at Parksville:

Obergurgl: The Obergurgl project is a jewel in the AEAM crown, for it demonstrates better than any other how well the process works, when it works. It also demonstrates the importance of having "a wise man" on the scene, in this case Dr. Walter Moser, an ecologist now with the University of Alberta in Edmonton, Canada, but formerly head of the Alpine Research Institute, which

The people of Obergurgl, following an AEAM study, decided to control further development. Among the steps taken were: establishing much of the valley as nature protection areas; improving the existing tourist accommodation and the introduction of zoning regulations that restricted new construction; subsidizing the farmers with payments from the tourist companies; and the repair of damage caused during the construction of ski runs and ski lifts by replanting and reseeding.

In January 1982, IIASA's Public Relations Officer, Peter Schlifke, visited Obergurgl to ask what effects the model has had on life there. He reports that prosperity continues, since prices were raised without protest as the tourist facilities were improved; farmers still receive subsidies; there is almost no waiting time at any ski lift even when hotels are full; and one new hotel is being built.

When asked about the impact of the model, the hotel owners replied enthusiastically that it had been very good. The farmers tended to play down the role of the model: "We always knew that things could not just go on as they did in the fifties and sixties and that things would have to slow down. Science did not bring us as many advantages as some people think it did."

1970

1900 Courtesy of Dr. Moser

1982

But the farmers acknowledge the role of tourism in their lives: "While my father used the money he made by selling milk and cattle to support his family, I have to use the money I make from tourism to support my thirteen cows," declared Mr. Hermann Scheiber, Chairman of the Agricultural Board and an instructor at one of the three ski schools. "And I am afraid that my son will think twice before he takes over the farm."

The village priest noted that the younger people were leaving Obergurgl, a tendency that the model had predicted. Dr. Horbata explained that it was not for economic reasons but partly "because of the new opportunities they get through better education."

The younger generation was also discussed by a farmer's wife: "We have five children and I made sure that none of them learned a profession that is linked to tourism. After all, if one learns to be a cook, for example, then he'll soon want his own hotel – but there is no more land to build on. Although my children may be working for the tourist business here, they will always have another leg to stand on."

The general impression is that the people of Obergurgl are content with their decision to forego quick and easy profits from tourism in favor of a more stable future by controlling growth.

has a station above the village of Obergurgl in Tyrol, Austria. "Looking down at this little village," he reports, "I became concerned about how the people and the town would do – how they would go from the natural ecosystem to a man-made one. . . ." The study, begun in 1971, had by decade's end produced a heightened awareness among towns-people of the destructive aspects of continued growth of tourist facilities, and led to protection of the area from further development.

While the project soon produced results – decisions on zoning and farmer subsidies were made a year after the basic model was constructed – it also shows that the role of AEAM is easily forgotten. Many villagers think they would have come to the same realization anyway. After 1975 there was no construction in the village until 1981, when work on a new hotel was started.

Salmon enhancement: Conducted by the UBC team, this is actually many studies, part of a continuing program begun in early 1973 to look at Skeena River salmon. The first phase involved an effort to demonstrate the utility of the AEAM process to government and policy people, in about five workshops. The second phase focused on research policy analysis, and aspects of salmon management from population dynamics to the enhancement of stocks. The third phase consisted of training Canadian fisheries people (like Al Wood), followed by a series of workshops in which the early models were run by commercial fishermen, to give them an idea of how one arrived at the salmon management scenarios used by the Canadian government to regulate their fishery. The project is regarded as a successful, if unfinished, application of AEAM, according to UBC's Carl Walters.

Beaufort Sea lagoon: In this study of ecological processes in Simpson Lagoon, on the Beaufort Seacoast west of Prudhoe Bay, Alaska, AEAM proved extremely useful in shaping a research program and adjusting the conventional wisdom about Arctic ecosystems. According to Alan Birdsall, whose company coordinated the lagoon project, a series of workshops let them refine fieldwork and helped shift the scale of the study until the correct one was found. "We found it difficult to transfer research results to guidelines and regulations that often have little to do with these results," he reports. "We also had some trouble explaining to clients and to university researchers on the project what we did in workshops.

"But AEAM did get us better science. It integrated science into the company, influenced investigators, made them grow. The reviews of the project were quite positive, especially for its adaptive approach and for having an effect upon environmental stipulations." But he also notes that AEAM is a "fragile process," and it is easy to remove its internal parts until it ceases to function.

Liard River: Proposals to dam the Liard River in British Columbia struck a deep chord in the Canadian people, for whom the Mackenzie River Delta, where much of the dam's impact would be felt, is hallowed wilderness. "So far," explains Robert Everitt of ESSA, "this is a textbook case of AEAM. We had a knowledgeable client in BC Hydro, and there were no false expectations."

The object here was to use the model (which was mainly concerned with biophysical processes) to identify gaps in data and understanding, communicate study objectives, and coordinate various consultants working on the project. At present, an effort is being made to integrate two years of fieldwork on socioeconomic and wildlife components into the program, and extend the model more toward ecological impact assessment.

Dr. Stanley Hirst, who runs the environmental program at BC Hydro, provides a client's view of the project. "BC Hydro is commissioned to turn out kilowatts. Our environmental work is just a means to that end. Our knowledge of the Liard River system was appallingly bad. In the case of the Mackenzie Delta, the dam project is in northern British Columbia but the power goes to Vancouver, and the people downriver, in another province, get nothing but the impact. Thus far, that doesn't seem too great, as there isn't much difference between the natural river and the regulated one. Now we are asking ourselves, can the ecosystem stand the stability of the regulated system?"

As to the role of AEAM in all of this, Dr. Hirst notes that, initially, there was not much consistency or interaction in project management. "We are now involving the project engineers on the environmental assessment side, because decision making on the project starts at relatively low levels. And we have tried to use workshops as our major method of communication.

"Although we have some misgivings about cost, I think the outcome has given us something we would not otherwise have got. We've been able to standardize – before, it was difficult to get the investigators to measure the right things. The ability to test various scenarios has been a strong benefit, but we intend to use the technique for research planning, not for environmental impact assessment."

What about the EA?

This "not for environmental impact assessment" echoes throughout the three days of discussion. There are dissenters, however. Alan Birdsall, while

finding the process deficient as an environmental assessment device, thinks the ability of AEAM to eliminate "unlikely or extraneous" concerns can be quite valuable in the assessment procedure. John Wiebe believes AEAM "*can* be applied to the environmental impact assessment process. The idea would be a continuous planning process. ... In the post-approval phase, I see some really innovative AEAM applications," he says. "It could be very useful in developing biological and socioeconomic monitoring programs for unregulated issues, and it might be used to rationalize various conflicting demands."

Perhaps AEAM belongs more at the regulatory end of the impact assessment process. Tom Duke, a senior scientist with the US Environmental Protection Agency's laboratory at Gulf Breeze, Florida, "has not given up" on AEAM as an environmental assessment tool, citing his own positive experience with the Fish and Wildlife Unit in more realistically simulating the effects of drilling fluids on the marine environment. Still, he also looks toward a role for the process that has less to do with assessment than with formulating regulatory policy. "AEAM could have merit in shaping the regulatory process," he says, "especially as we come into what I see as a period of *negotiated* environmental settlements, something that satisfies both attorneys and engineers."

Tenneco's Mike Zagata also views AEAM as most valuable at the regulatory end of the environmental assessment process, mainly as a way of generalizing experience. "So far, we've done everything on a case-by-case basis," he explains, "a very expensive, time-consuming process. It would be much better if we could arrive at something more generic, so that each instance doesn't have to be studied in depth. I think AEAM can be extremely valuable in helping us arrive at the kind of repeatable results we need to develop generic permits.

"It would be good to get a cooperating company to try it up front in the environmental assessment process, and then, later, compare the costs of carrying out scenarios prepared through AEAM and through alternative methods ... run an entire pilot project." Later, he adds, "You need someone willing to try a new approach when the one they have satisfies their recognized needs. You know, if you've never had a refrigerator, you don't miss one."

Then Where, and When?

But where does the AEAM process find its best applications? The following views of how AEAM should work in various phases of environmental assessment and management developed during the workshop:

- *In research planning*, the AEAM process is good for planning, bad for impact assessment, but excellent at defining and evaluating the problems and detailed design of research programs. It can also be effective in putting a research program back on the right track. It helps determine what is salient, identifies gaps in data that are hard to see, organizes information, and provides a common understanding of the system being studied.

- *In policy and planning*, AEAM works to the degree that it facilitates analyses of options for decision makers. Here, the AEAM process is most appropriate where the situation is most ambiguous, helping with the search for clarification and offering promise as a means of collaborative conflict resolution, mainly at the beginning and end of the environmental impact assessment; it is less effective at the intermediate stage of the assessment.

- *As an integrator or synthesizer* of research results, the AEAM process works only at the beginning, and doesn't work at all at the end. It is a valuable definer of actions and key indicators, and is an excellent guide to gathering information. But the client must be committed early in the process to implementing the beneficial results of the work. The time scale of the AEAM-induced change is widely variable, ranging from a few months for coordinating research to something like five years for effecting major policy changes.

- *In shaping resource management policy*, AEAM provides an adaptive management technique, formed by trial and learning and made interactive through workshops and other procedures. It is most effective as part of the policy-formulating process, in process design, in the generation of alternatives, and in evaluations; but the practitioner must point out to the client where the process is not appropriate. AEAM seems not to handle the general public very well (perhaps because the process can require some proficiency in mathematics), but can be effectively used in a variety of institutional arrangements, ranging from legislatures to small-organization consortia.

At the end of the workshop, the chorus of voices is not quite harmonious. One hears that the concept of AEAM is too much the offspring of the small teams at UBC, IIASA, and ESSA, and the US Fish and Wildlife Service. One hears a need to generate more reliable, positive results. One hears AEAM is the best process around, for the price.

In three days, in this small coastal town on Vancouver Island, they do not get much beyond a rough and sometimes puzzled consensus, one that says yes, let's keep trying with it, but says this with a kind of fatigued enthusiasm. At the same time, they have a much improved comprehension of the strengths and weaknesses of this kind of medicine, and will be closer to knowing how to adapt its use to the right kind of patient, with the right illness, in the right hospital. And they will still be sufficiently bemused to say, as John Wiebe does, "There has to be a lot more conceptual work ... one still can't quite grab it. ..."

No doubt when AEAM becomes easily seen, when one can "grab it," it will be time for something else.

Carl Posey directs the Office of Communications, IIASA.

Gaming

Ingolf Stahl and **Isak Assa** talk with **Roberta Yared** about new uses of operational gaming as a promising method in systems analysis.

The adequate modeling of human behavior is a widely recognized problem in systems analysis. Gaming is a method for capturing the "human factor" in a more satisfactory way.

Operational games involve two or more people "acting out" decision making concerning practical problems. Gaming is also known as "multiperson interactive simulation." The participants in a game interact, as the decision of any one "player" influences the decisions of the other players.

Dr. Ingolf Ståhl, a Swedish economist at IIASA, declares that "gaming, as a people-oriented approach, is very much needed as a part of systems analysis to complement modeling, for the benefit of those making policies and of those providing the analyses upon which decisions are based. One way for analysts to include currently unquantifiable human qualities is gaming."

Modern computer science and programming techniques allow the construction of large models of interacting systems in a fairly short time at moderate cost. Simulation models, in particular, have become more intricate in the attempt to depict real life more closely, and they must incorporate assumptions about human behavior to be of value. This usually means the designer's own "mental models" of how people act or should act. If these are incorrect, the simulation model runs the risk of being invalid. Professor Martin Shubik summed up the situation well at an IIASA workshop: "As the computer is unable to walk around and look at the world, it is not able to correct modeling errors."

"Often the only feasible way of putting the behavioral assumptions of a simulation model to a test is gaming," Dr. Ståhl explains. "Gaming becomes the acid test, giving a red or green light to a model to be used in reality. It tests the validity of the model and can lead to alternative assumptions."

"And," Dr. Ståhl says with a smile, "while the cost of using an inappropriate model can be very high, gaming is inexpensive."

No one loses in this type of gaming. Nor does anyone really win – although Dr. Ståhl has been known to present bottles of wine to participants. What the players, the modelers, the game theoreticians, and everyone else involved in a game "win" is knowledge.

Gaming as an educational tool was eagerly adopted by the business world for managerial training in the 1950s as the use of computers became more widespread. Game playing has replaced thesis writing for an advanced degree in business management in many institutions. Planning methods, forecasting, and production and inventory control are examples of what is taught well, and easily, through gaming.

Gaming also gives decision makers and planners an opportunity for a "dry run" or dress rehearsal: whether they are assigned a role (be a manager, be a government) or just follow their usual professional duties, people go through the decision-making process (play), receiving feedback from the other players. The negotiations and arguments of the other participants provide a good cross section of what any decision maker would have to take into account, but are not restricted to the imagination, judgment, or intuition of any one individual. These are usually just the political, cultural, institutional, and social considerations that are difficult to capture in a mathematical model. Gaming thus forces players to clarify their thoughts and perceptions.

Dr. Ståhl talks about a game developed for the top management of the Conrail Corporation in the United States. They wanted it to demonstrate the economic and political implications of various strategies, since they were convinced of the need for less governmental regulation of the rail industry. The Conrail officials told the model designers, led by Richard D. Duke, that they felt the most valuable aspect was the time spent in defining, and redefining, information until all agreed that the model was an accurate representation of their rail system. When the designers first sought data on the system and its parts, the managers did not agree at all about how the corporation actually operated or about the elements affecting its performance. Each official had concentrated only on his portion of responsibility. The need for precise communication with the model designers also led the Conrail managers to find that there were opportunities to improve profits within the system that none of them had seen before and that did not require further regulatory reform.

Eastern European countries have long used managerial games, and use them for practical planning purposes on a wider scale than the west. Dr. Isak Assa, Associate Professor at the Institute for Social Management in Sofia, Bulgaria, has been developing such games for his Institute and for the Annual Gaming Seminar of the Council for Mutual Economic Assistance (CMEA) since 1974. Now at IIASA, he talks of the exciting possibilities of gaming: "combining the heuristic capabilities of man with the computing capabilities of the machine."

Dr. Assa notes that his Institute began using games to introduce mathematical methods, computer use, and changes in the economic mechanisms "since you cannot lecture to ministers and high officials as if they were still students, and because we wanted them to enjoy the process, which they did." He tells of using a game to teach managers to handle the expanded responsibilities they faced following the Bulgarian economic reforms.

There is a computer bank of games approved and accepted by all the CMEA countries at Friedrich Schiller University, Jena, German Democratic Republic. These games model specific decision problems in an enterprise or organization, as well as the planning chain going from a ministry to an industry as a whole and then to individual plants.

The first game developed at IIASA, devoted to sharing natural resources, was designed by Dr. Valery Sokolov and Professor Igor Zimin in 1975. A group has been concentrating on operational gaming since 1980 under Dr. Ståhl,

Associate Professor of Managerial Economics at the Stockholm School of Economics. Research at IIASA concentrates on gaming as an aid to policy formation and implementation; testing model validity; examining whether some game theories hold true in reality; and comparing the behavior of people from differing cultures and economic systems.

Dr. Ståhl stresses that the work at IIASA "is on concrete problems with natural resources and the environment, particularly the social reactions to possible climate changes due to carbon dioxide emissions from the burning of fossil fuels such as coal, and the question of cost allocation in projects dealing with water resources development and management. A cost allocation game developed by a group of scientists from the USA, Japan, and Sweden has been played in Bulgaria, Italy, Poland, and Sweden by planners, scientists, and students, as well as by various groups of scientists at IIASA."

The game derives from a situation in Skåne, the southernmost part of Sweden, where administrators, planners, engineers, and economists had been studying the long-term supply of water to the region's communes – the Swedish administrative units, which include urban and adjacent rural areas. Water demand can usually be satisfied more cheaply if communities join together to build a large water plant than if each community builds its own separate facility. Water engineers and mathematicians at IIASA worked out the costs involved for plants constructed by each commune and for plants built by all the possible groupings among the communes. The lowest cost for each commune was found when all the communes combined in a "grand coalition" to build one plant serving the whole region.

The problem lies in dividing the costs of construction fairly among those jointly building such a facility. The conclusion from the IIASA work was that no single "correct" answer to cost allocation problems exists; nevertheless, some concepts seem to be more reasonable than others in encouraging the parties to cooperate.

Seven different methods to establish suitable cost allocation procedures were analyzed, including some used in practice and newer ones derived from mathematical game theory. Three principles of particular importance to fair division in such situations were identified:

> *Individual rationality:* no party should pay more in the grand coalition than it would pay if building on its own

Group rationality: the members of a group in the grand coalition should not pay more than they would if this smaller group built a separate joint facility.

Cost overrun: no party should pay less if there is a cost overrun.

These principles set up normative guidelines for cost allocation and narrow the range of possible solutions; they are not intended to predict behavior in any strict sense.

However, there was interest in discovering to what extent officials responsible for water and regional planning might act in accordance with these theories. Dr. Ståhl devised a cost allocation game, which was first played in 1979 with six planners responsible for water management in Sweden. Each player received the list of costs covering all possible coalitions of communes, and the players drew from a lottery to determine which communes each would represent. Dr. Ståhl told the players that they would either have to pay the sum necessary for a commune to build alone, or, "by acting skillfully both during the formation of coalitions and during the allocation of the total costs within a coalition, get away with a lower payment."

The results, according to Dr. Ståhl, indicated that none of the solution concepts tested is a perfect predictor in all situations, though some appear more adequate than others. He says, "We wanted to find out what results would be produced by planners and other kinds of players in various countries, particularly those with different economic systems. This would help us examine whether there are inherent distinctions between countries regarding fundamental economic behavior of decision makers, for example in attitudes toward maximizing savings, or in the degree of risk avoidance, or in the tendency to cooperate."

The same game on cost allocation in Skåne was then played in Poland, Bulgaria, and Italy, countries where water management was being studied in regional development planning work under way at IIASA. The players were managers from the Wroclaw Water Works in Poland; engineers from the Vodproekt Institute in Bulgaria; and

Ingolf Ståhl

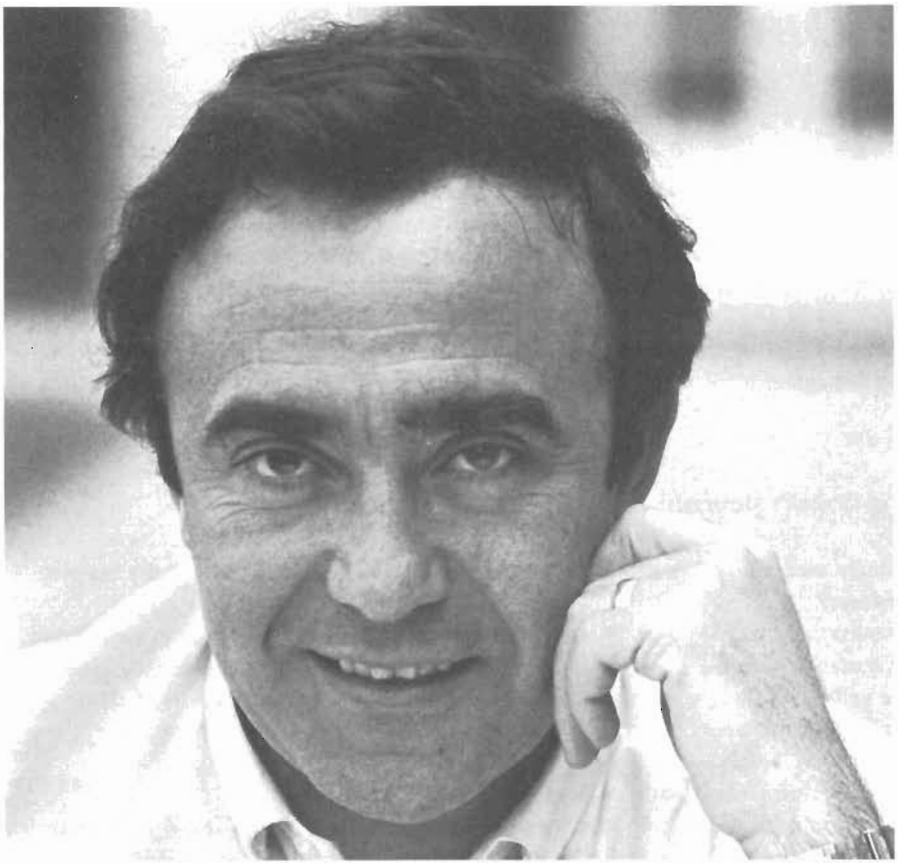
regional planners from IRPET, the Institute for Regional Economic Planning of Tuscany, in Florence, as well as doctoral candidates and scientists in these countries.

The professionals in all of the countries came up with nearly the same cost divisions. The graduate students ended with cost allocations that differed from those of the professionals and, indeed, from those of the other student players. Dr. Ståhl admits that "the professionals' response was not the one the game theoreticians and mathematicians had selected as the most equitable – the most fair."

Asked to explain the differences between the students and the professionals, Dr. Ståhl points out that "the professionals have thought about, if not participated in, similar problems of cost allocation. They are more likely to have a clear conception of what kinds of goals and principles apply in such situations." Another distinction between the two kinds of players was that "the students were somewhat less prone to defend the interests of 'their' commune than the planners." Dr. Ståhl also reports that the professionals spent their time "more efficiently, trying to form coalitions and discussing general principles, while the students spent more of their time calculating specific cost divisions."

Dr. Ståhl says that the difference between the outcomes of the games played and the model developed by the mathematicians arose because "the model was static, the people were dynamic. We improved the model through gaming so that it now includes the fact that grand coalitions are formed step by step. People fear the breaking up of negotiations under the uncertainty of ever reaching a final solution," explains Dr. Ståhl. "They play it safe, making smaller, two- or three-party coalitions at first, then larger ones, until they reach the grand coalition that leads to the biggest total cost savings for the parties involved."

This step-by-step procedure was followed by the players in all four countries. The biggest difference was the amount of talking involved. "The Italians had two to three times more verbal exchanges than the Swedes, with the



Isak Assa

Poles and Bulgarians in between," Dr. Ståhl remarks, "yet they all reached the same conclusion."

"It was exciting to find," says Dr. Ståhl, "that there were very small variations in the outcomes of the games in the different countries. The differences between professional planners and students within a country were larger than international differences between planners. This similarity in behavior among the planners in all of the four countries," he points out, "is an encouraging indication that planning models developed in one country can be successfully used in other countries."

Another result of the gaming project at IIASA is the first joint meeting of the CMEA Annual Gaming Seminar and the International Simulation and Gaming Association (ISAGA), the main western organization. This will come about through the efforts of Isak Assa and Ingolf Ståhl, and will take place in June 1983 in Sofia during conferences organized by Bulgaria's National Committee for Applied Systems Analysis and Management, an IIASA member organization. Dr. Ståhl hopes this meeting will be "the beginning of further fruitful collaboration in the field of solving conflicts with the aid of gaming."

History of Gaming

The oldest – and most persistent – use of gaming is military. Most of the board games we play today for amusement are held to have originated with primitive man sketching attacks and defenses on the ground before him, perhaps with stones marking the positions of himself and his enemy. These earth tracings could be used to give orders, to work out contingency plans, to instruct future warriors by showing what had occurred previously. Eventually these drawings were formalized with set rules into true games.

Prehistoric game boards, with warriors represented by small pieces of many kinds of materials, have been discovered by archeologists in (to date) China, Persia, India, Greece, and Egypt. Sun Ssu, writing of military strategy in China in the 5th century BC, discusses elements of what is now codified in game theory and concepts of operational gaming. Chess might be seen as a crude model of warfare in Persia in the first millennium BC. Chess-like games were used in military training in Europe during the Middle Ages.

War games *per se* are said to have been officially invented by a Prussian lieutenant named von Reisswitz in 1811. He used a map rather than a board for greater realism and had referees for the games, as well as a book of rules. He called his creation *Kriegsspiel* – War Game. It was being used to evaluate strategy and weapons – rifles versus muskets – by the 1866 Austro-Prussian War. War games, now computerized, continue as a regular feature in most military establishments today.

It was primarily the development of computers, able to make complicated calculations and deal with large masses of data, that led to gaming for non-military purposes. Game theory, the mathematical branch dealing with conflict resolution, was developed by John von Neumann in the late 1920s. He and Oskar Morgenstern published *Theory of Games and Economic Behavior* in 1944 and this inspired social scientists to take up gaming and use it in systems analysis.

Since the end of the Second World War the gaming literature has developed very rapidly and ventured into such different fields as business, ecology, energy, futures research, health care, regional and central government planning, and international negotiations. The future of gaming lies with civilian applications.

Groping in the Dark

Groping in the Dark: The First Decade of Global Modelling by Donella Meadows, John Richardson, and Gerhart Bruckmann (John Wiley and Sons Ltd., Chichester, UK, © 1982 IIASA): this is an unusual book that appraises the state of the art of social-system modeling. The book includes descriptions and critiques of seven major global models, responses to a questionnaire sent to all members of the global modeling community, and the discussions at the Sixth IIASA Symposium on Global Modeling.

Presented here in abridged form are those issues of theory and method on which the modelers could only agree to disagree, as well as those upon which they did agree.

Let all the flowers flourish: Areas of Disagreement

1. Should models be built to answer a single well-defined question or should they be built to represent many aspects of a system and serve many different purposes?

♦ Making general-purpose models results in large numbers of virtually incomprehensible equations that, for all of their complexity and detail, are still unsatisfactory representations of reality. They only give the appearance of answering questions; the answers are bogus.

♦ Making single-purpose models just results in simplistic answers that are often totally wrong because they ignore the crucial complexities of the total system.

Underneath these arguments there is a basic difference about the purpose of modelling:

♦ The purpose of modelling is to make the incomprehensible clear by exhibiting its essence. A system cannot be bounded and its essence cannot be discussed without reference to a particular problem or question.

♦ The purpose of modelling is to use the computer to deal with complexities that the mind cannot understand. The more you can put into a model, the more likely it is to give the proper answer to any one question and to all questions.

At issue are not only the purposes of modelling, but also the nature of the world being modelled and our ability to know it.

♦ The world is made up of deep causal structures that produce the surface behaviour that we observe as strings of separate events. By asking clear questions about behaviour, observing carefully, and using systems theory, we can discover the basic structures. Similar structures produce similar behaviour in widely different systems (the same structure underlies the oscillating, goal-seeking behaviour of economic markets and blood-sugar regulation). We can never know the full details of the world or answer all questions about it — no computer could hold so much information, even if we could assemble it. But we can learn general behavioural tendencies and probable policy responses.

♦ The world is made up of sets of distinct systems boundable by similarities in surface characteristics (national economies, ecosystems, populations, the transportation system). As we learn, we can produce more complete representations of these systems, which will be useful for more purposes. We can never be confident of underlying causal structures, because they are unseen and unseeable and cannot be compared directly against observable events. But we can replicate past series of events, and thereby predict future ones.

Since the two approaches are bound to produce totally different kinds of information (although neither kind is recognized as reliable information by the other side), it is probably to the benefit of the human race to have the argument go on, as long as it remains civil.

2. Should models be made in direct response to pressing issues of public policy or should the goal be general improvement in understanding?

♦ It is simply irresponsible to go sounding off to the policy world on the basis of uncertain, untested models that have not been subjected to the scrutiny of the scientific community. Theory, testing, discussion, and improved understanding should precede policy application.

♦ Decisions are being made daily on the basis of mental models that are even worse than our own — admittedly bad — computer models. It is irresponsible not to present new insights to the world, even if the insights are not complete.

Perhaps it is not humanly possible for applied and basic scientists in any field to learn to appreciate each other, but it would be nice if they did, because they are both necessary and depend on each other in many vital ways.

3. Should models be normative or descriptive?

The discussion rose above the methodological differences between optimizers and simulators, and it was recognized that every model of every type has both normative and descriptive aspects.

Why modellers seem to prefer one style of presentation over the other is probably a matter of genes, glands, and life experiences. It is very useful to have both types of modellers around.

4. How far into the future can one see with a model?

♦ Not very far at all, and our confidence in what we see goes down rapidly as we look forward in time. Probably five, ten, at most fifteen to twenty, years is the upper limit for any sensible modelling study.

♦ For physical capital, population, resource, technology, and environmental questions, fifty to a hundred years is reasonable – and, in fact, necessary, because decisions taken now have impacts that will last that long.

For precise point predictions of rapidly moving entities, one cannot be very certain very far into the future. For general time trends or policy responses of quantities that move slowly, something useful (but not a point prediction) can be said about what will happen over the very long run.

5. What is the best method to use for global modelling?

Methods shape both the inputs and the outputs of the models. Indeed, the method used is one of the best predictors of model structure and model results. Some process carried out by modellers, users, or both, is needed to assess the applicability of a chosen method to a given problem and to sort out the differing results arising from different methods. There are beginning attempts to do this – but untangling method from model from results is long, hard work.

6. Should models be large or small?

♦ Big models get out of hand. They cannot be explained or documented. They cost a fortune to run. They require data that cannot be found. They are black boxes full of undetectable errors. One should make small, transparent models and complicate with the greatest reluctance.

♦ Small models simply do not capture the real world. They are not credible to policy makers who know how complicated the world really is. The bigger the model the more comprehensive and reliable it is.

'Some people love simple models. Others love complicated models.' Each group should probably go on making the best models it can, big and small, seeing as far as possible into the black boxes, and accounting as much as possible for omissions in earlier work. For any problem or system being modelled there is probably a balance point where the degree of detail and inclusiveness is just enough and not too much. Finding this point is the continuing challenge.

7. Should the procedure for developing the model be top down or bottom up?

♦ One should start with a rough working sketch of the *entire structure* one is trying to represent. This way the big interactions and the interfaces among subsectors will be clear and nothing important will be omitted. Then one can elaborate, add detail, estimate parameters, and polish the model until time or money runs out.

♦ One should begin with complete models of all the *separate subsectors*. They should be carefully estimated, tested, elaborated, and explored, so that one understands and has confidence in each part of the model before they are fitted together. Each sectoral model can then be of use even before the pieces are combined.

We can think of only a few suggestions that might help clear up this controversy:

- No modeller or modelling institution favouring either side should impose its preference on anyone else.
- Everyone who feels strongly in favour of one procedure should try the other at least once, just to see what happens.
- Someone should try a project that uses both strategies simultaneously.

8. What should be done when data about a crucial system relation are not available?

♦ Guess.

♦ Leave it out.

There are excellent arguments to back up both of these positions. However, within each basic position there is also a balance-point problem that faces each modeller anew in every modelling effort. Data are somehow never sufficient for what any modeller really would like to do.

What we can do is be more understanding, humble, and tolerant of each other's struggles at the edge of the unknown. Even experiments that fail teach all of us something.

9. How should actors, technology, prices, population, etc. be represented?

Actors

♦ Aggregate them by function. Represent their actual decisions exactly as they make them, including their goals

♦ Don't aggregate them at all. Represent what you know to be the net result of their decisions (usually an optimiand dissatisfactions. Only national governments are important actors.

zation of something). There are important actors on every level, from individuals to multinational organizations.

Technology

♦ It's unpredictable. Assume it is constant. It is a general, increasing tendency of an economy to use its resources more and more productively. It is the most important determinant of the future.

♦ It's unpredictable. Assume it makes any problem easier to solve exponentially over time. It is very specific to certain sectors and problems, it progresses in spurts, it costs money, takes time, and produces bad side effects. It is really pretty irrelevant to the future.

Prices

♦ Any model that doesn't include them is just plain stupid. Prices are vital to the efficient distribution of scarce goods; they are the signals of scarcity.

♦ Prices are only information links regulating flows of real stuff. All you need to model is the real stuff, not the prices; they disguise real scarcity.

Population

♦ Birth rates are unpredictable; keep population exogenous, preferably using uncontroversial official UN extrapolations. Avoid antinatalist formulations; emphasize that if you take care of development, population will take care of itself.

♦ Emphasize the endogenous influences on birth rate. The main role of population in the global system is to drain economic output away from investment and into consumption.

Surely there can be no one 'right' way to represent any of these factors. The choice depends on the system, the problem, the method, the data, and the ideology and values of the modeller.

10. How should a model be tested?

There is hardly any subject within the field of social-system modelling that generates so little understanding and so much intolerance. Perhaps the most important statements to listen to are the modellers talking about the testing they have done on their own models by their own standards, why these tests were or were not satisfying, and what they see as obstacles to proper testing as they define it.

11. What is the appropriate audience for global modelling? When and how should results be communicated to this audience?

♦ The audience is the scientific community. The results should be presented in full technical detail for evaluation before any decision can be made about policy application. Results should be evaluated by scientific standards.

♦ The audience is the current corporate and/or national leaders. They should be involved in the modelling process as directly as possible, preferably in private briefings and on-line interaction with the model.

♦ The audience is the general public. The other two audiences suggested here should be avoided because they will contaminate the model with establishment biases and pressures. Results should be represented soon, loudly, and clearly.

Whatever the audience, communicating results is another area of recurring anguish for modellers. A statistics professor we know has mounted on his door a sign that says, 'Be maximally noncommittal, but consistent with all you know.' This counsel of caution is a lot easier to recite than to follow, even for one's own modelling project.

This is the way modelling should be: Areas of Agreement

1. It is better to state your biases, insofar as you are able, than to pretend you do not have any.

There was total agreement at the Conference that no one making a global model (or any other kind of model, for that matter) can possibly be free from biases induced by cultural and ideological backgrounds, academic training, and methodological preferences. One can never be fully aware of all one's biases. But one can be aware that one is unaware.

2. Computer models of social systems should not be expected to produce precise predictions.

At present we are far from being able to predict social-system behaviour, except perhaps for carefully selected systems in the very short term. Effort spent on attempts at precise prediction is almost surely wasted, and results that purport to be such predictions are certainly misleading.

3. Inexact, qualitative understanding can be derived from computer models and can be very useful.

If your doctor tells you that you will have a heart attack if you do not stop smoking, this advice is helpful, even if it does not tell you exactly *when* a heart attack will occur or how bad it will be.

4. Methods should be selected to fit problems (or systems); problems (or systems) should not be distorted to fit methods.

Each modelling technique was evolved originally to answer a particular type of question or study a particular kind of system. Problem definition should precede method selection.

5. The most important forces shaping the future are social and political, and these forces are the least well represented in the models so far.

Why do 'soft' variables get left out? The commonest explanation is that there are not sufficient theories and/or data to include sociopolitical variables. The most poignant explanation that surfaced at the Conference was, 'We thought that, if we put that stuff in, all you guys would laugh at us!' Neither of these is really a good reason.

6. In long-term global models, environmental and resource considerations have been too much ignored.

The problem here can hardly be lack of theories or data, since the field of ecology is at least as well developed as that of economics. But somehow there has been little communication between the ecologists and the global modellers so far.

7. Models should be tested much more thoroughly for agreement with the real world, for sensitivity to uncertainties, and over the full range of possible policies.

The one test that every model passed, agreement with historical data, was not viewed as very impressive by anyone. Interesting suggestions for better testing included these:

- Give the model to an independent or opposing group for testing.
- Be sure that all policy tests are symmetrical (if you test for lower trade barriers, also test for higher ones).
- At the beginning of the project, appoint someone who cannot be fired to be the resident critic and model tester.
- Throughout the project keep a notebook in which all doubts, uncertainties, guesses, and alternative formulations are entered. Refer back to this notebook and test each uncertainty for its effect on the model results.
- Be sure the model sponsor appreciates the importance of testing and budgets sufficiently for it.

8. A substantial fraction of modelling resources should go to documentation.

9. Part of the model documentation should be so technically complete that any other modelling group could run and explore the model and duplicate all published results.

10. Part of the documentation should be so clear and free from jargon that a non-technical audience could understand all the model's assumptions and how these assumptions led to the model's conclusions.

The state of documentation in the field of social-system modelling in general is atrocious. No field that is supposed to be scientific can possibly progress if its practitioners cannot build on or criticize each other's work. Problems can be avoided if documentation is an ongoing, constantly updated activity, instead of one nobody thinks about until the fun is over.

11. Modellers should identify their data sources clearly and share their data as much as possible.

12. Users, if there are any clearly identifiable ones, should be involved in the modelling process as directly and frequently as possible.

There are two reasons for this. First, the interested attention of a user is likely to keep the model true to its purpose and reflective of real-world conditions and constraints. Second, a user who has helped shape a model and who understands it is likely to implement its results.

13. It is necessary to have an international clearinghouse for presenting, storing, comparing, criticizing, and publishing global models.

IIASA has played this role admirably in the past, and should continue to do so in the future.

14. There should be many more global models.

Global problems require global models.

Computer models do not make the job of decision making any easier. They make it harder.
They enforce rigorous thinking and expose fallacies in mental models we have always been proud of.
We think the work is worth it.

News from the Institute

Profile: IIASA Deputy Director, Dr. Vitali Kaftanov

"The work done at IIASA is more and more necessary in today's world with its many problems," states Dr. Vitali Kaftanov, former Head of Laboratory at the Institute of Theoretical and Experimental Physics, Moscow. "What is the most important is the quality of the work and the quality of the people." This is why he says he is "very excited" about joining IIASA as the new second Deputy Director. His connection with IIASA actually started before the Institute existed, as he helped draft the IIASA Charter. Council Chairman Academician Jermen Gvishiani asked for his assistance on managerial questions because of Dr. Kaftanov's experience at CERN, the European Center for Nuclear Research.

Studying high-energy neutrino interactions, Dr. Kaftanov was one of the first Soviet nuclear scientists to work at an international organization. He was in Switzerland with CERN from 1963 to 1965, and then from 1966 to 1968. Returning to Moscow, where he was born and educated, Dr. Kaftanov worked with teams from the USA and Europe on what was then the world's largest 70-GEV proton accelerator at Serpukhov. In 1972 he became head of the Soviet team for a joint USA-USSR neutrino experiment at the Fermi National Accelerator Laboratory in Batavia, Illinois. From 1976 to 1982 he again led the Soviet group at CERN, working with its new synchrotron.

"It is a big change for me," says Dr. Kaftanov, "moving from fundamental research in physics to the applied work done at IIASA, but I have worked with the Moscow Energy Group on nuclear power plants, and I am optimistic, in terms of the work, the mathematics, and the human relations."

Workshop: Spatial Choice Models in Housing, Transportation, and Land-Use Analysis

A common thread to all problems considered in human geography is understanding and predicting how people choose from spatially distributed alternatives. The existence of the spatial dimension introduces peculiar features, if not in the choice process itself, at least in the overall patterns resulting from it. Uneven geographic structures of settlements and activities emerge, individual choices mutually affect each other, and shortages, competition, and congestion arise.

IIASA held an international workshop on spatial choice models from 29 March to 1 April 1982, at which scholars had the opportunity to present recent advances in the field and confront different approaches for future research. Their involvement went beyond any prior expectation, showing the vitality of what might superficially look like an arid technical problem and monitoring the ebullient state of the research in progress.

A subtitle for the workshop was "Towards a Unifying Effort." If one considers this goal too literally, one concludes the meeting was a failure. Not surprisingly, this failure to reach a narrow goal turned out to be a success in showing the way to wider, much more interesting goals. As a matter of fact, the meeting showed clearly that scientists working on spatial choice models do not want to be unified. They prefer to fight what some participants called "religious wars."

The "micro–macro" dilemma had the largest share of controversy, although in an unexpected way. The technical problems of modeling the interactions between individual (disaggregate) behavior and mass (aggregate) behavior were mostly left aside, and discussion tended to cluster around the philosophical side of the matter. Convincing theoretical support favored macrolevel regularities as a starting point for understanding a system, while equally persuasive theoretical support was given to the need to know more about individual choice behavior in order to evaluate policies and analyze considerations of well-being. Both sound knowledge and sound welfare criteria are needed in urban and regional planning, and a reconciliation of the two now conflicting views would be most welcome.

The problem of equilibrium versus disequilibrium, or rather the use of the word "equilibrium" itself, was also much debated. People seem to be so obsessed about criticizing or defending the word that an assessment of the usefulness or limitations of the concept can hardly be made. This is a general systems-theoretical issue as there is an increasing awareness, among scientists and practitioners, of the existence of structural instability and changes, random fluctuations, and self-organizing features in geographic systems. The impact and effectiveness of the conceptual tools developed to cope with this issue have still to be assessed.

The third big "controversy" might be called the fight between the "economists" and the "chaotics." In spite of the emotional undertones, a step toward integrating spatial economic theory and the newly developed approaches to self-organizing systems has been undertaken. Although the right balance between the two has yet to be found – and perhaps there is no general rule to follow – the danger of taking just one of the extremes has been clearly pointed out. Everyone agreed on the limitations of a purely neoclassical economic approach to modeling spatial systems. On the other hand, the dangers of straightforward extensions to the social sciences of approaches developed in physical and biological sciences were also stressed. This is not to say that one cannot learn from the other. Interdisciplinarity makes science go on, and analogy is its main tool.

Most papers at the workshop on theory and applications of spatial choice models were of high quality, thus creating a usable product and a starting point for future work. The issues of dynamic modeling, welfare theory, and evaluation must be addressed to reach the ambitious but realistic research goal of building a dynamic framework to analyze the effects of different policies in a settlement system across various scales of time and space. *Dr. Giorgio Leonardi*
Workshop Chairman

IIASA Anniversary Stamp

The Austrian Post Office will offer a new stamp issue on October 4, 1982 to commemorate, and coincide with, the tenth anniversary of IIASA.

The stamp features Schloss Laxenburg which houses the Institute, a former hunting lodge and summer residence of the Habsburg emperors. In various shades of brown, the 3 schilling stamp was designed by Prof. Otto Zeiler, the leading Austrian stamp designer, and etched by Maria Laurent.

NMOs

The National Committee for Applied Systems Analysis and Management, People's Republic of Bulgaria, is organizing a chain of conferences devoted to systems analysis to be held during June, 1983 in Sofia.

There will be an international conference on decision making, emphasizing multi-party decision making and risk analysis, with the participation of IIASA scientists. The events will also include the first joint session of the Annual Gaming Seminar of the Council for Mutual Economic Assistance and ISAGA, the International Simulation and Gaming Association.

Further information is available from the Chairman of the organizing committee for the conference: Dr. Ognyan Panov, Institute for Social Management, Pionerski Pat No. 21, Sofia 1635, Bulgaria.

Visitors

Professor Nathan Keyfitz spent a month at IIASA after his stay in the People's Republic of China as part of a distinguished scholar exchange program. He lectured on the social, political, and economic issues revolving around the effective population growth control policy there. He is Andelot Professor of Demography and Sociology at Harvard University, Lazarus Professor of Sociology at Ohio State University, and a member of the US National Academy of Sciences.

Professor Bela Csikos-Nagy lectured on "Searching for a New Economic Growth Path in Hungary." He reviewed economic, organizational, and monetary options concerning the problems generated by the stagnation of economic growth. Professor Csikos-Nagy is the President of the Hungarian Economic Association and of the National Price Office, and teaches at the Karl Marx University of Economics in Budapest.

IIASA's **Annual Report 1981** has been published; free single copies are available on request.

New Titles

Groping in the Dark: The First Decade of Global Modelling. D. Meadows, J. Richardson, and G. Bruckmann, Editors. 311 + xxvii pp.

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

IIASA Collaborative Proceedings Series

CP-82-S2 Risk: A Seminar Series. H. Kunreuther, Editor.

Research Reports

RR-82-6 DRAM: A Model of Health Care Resource Allocation in Czechoslovakia. P. Aspden, L. Mayhew, and M. Rusnak. Reprinted from *OMEGA: The International Journal of Management Science.*

RR-82-7 Operational Estimation and Prediction of Nitrification Dynamics in the Activated Sludge Process. M.B. Beck. Reprinted from *Water Research.*

RR-82-8 Systems Engineering and Microelectronics in Water Quality Management. M.B. Beck. Reprinted from *Microelectronics in the Water Industry* (F. Fallside, Editor), supplement to *Journal of the Institution of Water Engineers and Scientists.*

RR-82-9 A Practical Numerical Algorithm to Compute Steady-State Ground Level Concentration by a *K*-model. E. Runca. Reprinted from *Atmospheric Environment.*

Single copies of journal reprints are available free of charge. All other publications can be ordered from the Distribution Section, Office of Communications, 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 Committee for Systems Analysis; **Union of Soviet Socialist Republics** — The Academy of Sciences of the Union of Soviet Socialist Republics; **United Kingdom** — The Royal Society of London; **United States of America** — The National Academy of Sciences.

Director's Corner:
One Very Human Microcosm

IIASA has focused largely on issues at national and global scales. Sometimes lost in this perspective, however, is the personal element so critical for the resolution of any real problem, regardless of scale. The key role of singular individuals is well illustrated in the Obergurgl story, a small but illuminating chapter from IIASA's first decade of experience. I recently had the opportunity to bring myself up to date with this continuing story, and to understand better how IIASA has been used as part of a solution in one very human microcosm of today's world.

Obergurgl is 1930 meters above sea level in the Austrian Tyrol and has a population of 310. About ten percent of its narrow valley is usable land; the rest angles into mountains. The villagers have the adaptive reflexes of mountain people everywhere: their environment is an unforgiving one; they live more or less upon its terms.

Over the centuries, the villagers have experienced unexpected events, opportunities, and pressures. Their climate has shifted. Their economic setting has been transformed. Their society has changed. In 1850, when the population soared and taxed available resources, marriage was forbidden. Theirs is a history of change – and adaptation.

The postwar explosion of tourism challenged the village with new pressures. The people of Obergurgl adapted once more, this time entrepreneurially. They built hotels, cleared ski runs, added lifts, and grasped the new and financially rewarding opportunities. But it is in the nature of things that one day's solution is another's problem; and so it has been in Obergurgl.

For it was not very long before the younger villagers, spurred by the sudden wealth of their elders, developed expectations of wealth for themselves: one worked hard until one was about thirty to accumulate sufficient capital to build a hotel of one's own. For a time, hotels and related facilities proliferated rapidly. By 1972, visitors could choose from scores of places to stay, and be towed skiward on more than a dozen lifts.

But in the early 1970s, the pervasive and growing concern over environmental quality began to touch the collective consciousness of Obergurgl. It began with a deep sense of unease, with the fear that the very characteristics that had attracted tourists to the village were being destroyed by such energetic development. And the problems were deeper than just those of environmental degradation. Economic guarantees eroded. Hotels were proposed in areas that were economically infeasible. And, as the rising expectations of one generation began to be thwarted, conflicts developed between young and old. Fathers had to tell their sons, "We've reached our limits, there is no more for you."

At the same time, the valley's farmers, who for generations had squeezed subsistence from the hard flanks of the mountain, became increasingly conscious that they were not sharing in this new wealth.

Thus, Obergurgl became a microcosm of the larger world, in which tensions arise from converging resource limitations, rapid economic development, and social and demographic conflicts. The entrepreneurial adaptation of the villagers had become a trap, a predictable trajectory toward something they did not want.

Now the key individual, Dr. Walter Moser, enters the picture. At the time, he ran a University of Innsbruck botanical research station overlooking the village. He saw its problems and where the present currents must carry the village and its enterprising people. And so he moved to change the balance of forces at work there.

He did *not* enter searching for solutions. He made no pretense there was any panacea in their simply returning to the past. Nor did he want to freeze this Alpine world in a pastoral museum, a single frame of time. He wanted instead to help the people of Obergurgl pause so that the strong adaptive capacities they had used for centuries could re-emerge. He perceived clearly that ten or twenty years away there would be a new burst of demand, of technology, of opportunity that would spawn still another class of problems. To create this pause for reflection, Moser used science, he used systems analysis, he used IIASA and the interactive approaches we've developed. But the basis of everything he did was interaction with the individuals, interaction in *Heurigen*, offices, and homes: gentle efforts to have the villagers agree to a demonstration of the model they developed with IIASA. At the heart of all he did was the encouragement of interaction among the people with the problem. And it worked.

It worked not because of the model or even the very careful way in which the villagers were involved. It was rather the immense investment of that one individual in communicating, interacting, establishing the necessary conditions for communication, in order to highlight conflicts and to defuse them.

What have been the positive consequences of these efforts? The wealthy people of the village subsidized farmers so that they could still farm, not as an act of charity, but as a newly focused perception of the essential, honorable role the farmers have in the life and success of the village. Another fund was established to support the University of Innsbruck's continuing research on the problems.

And then, we have the Obergurgl experience percolating out to other villages, so that the lessons have been applied in village after village in the Alps, and continue to be applied at second-, third-, and fourth-order levels.

Obergurgl is good news. It shows that new combinations are possible, that trajectories toward a life no one really wants are not irreversible. It shows it is possible to pause before some point of no return is reached, long enough to have our adaptive reflexes shape a response to change. From Obergurgl, from this Alpine microcosm, we know it works within a world of villages. Perhaps it could work in a world of collectives.

But, one wonders less optimistically, how can it be made to work in a world of nations? The question is worth asking.

C.S. Holling