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COMPUTER CULTURE
The Scientific, Intellectual, and Social Impact of the Computer

ANNALS OF THE NEW YORK ACADEMY OF SCIENCES
Volume 426

COMPUTER CULTURE
The Scientific, Intellectual, and Social Impact of the Computer

Edited by Heinz R. Pagels

The New York Academy of Sciences
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COMPUTER CULTURE[a]

The Scientific, Intellectual, and Social Impact of the Computer

Editor and Conference Organizer

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Computer-Assisted Negotiations

A Case History from the Law of the Sea Negotiations and Speculation Regarding Future Uses

Moderator: DONALD B. STRAUS
Panel Members: T. T. B. KOH, J. D. NYHART, ELLIOT L. RICHARDSON, AND JAMES K. SEBENIUS

D. B. STRAUS (*Research Institute, American Arbitration Association, New York, N.Y.*): What we're trying to do here is a little different from what has been done before at this conference. Our session has been orchestrated, and we're trying to present a cohesive story.

In previous sessions, we've examined what computers do. Some people have wondered whether or not computers think and, if so, how they do it. There have been forecasts of new levels of artificial intelligence, and there've been talks about computer graphics, about the limits to computation, and about human and psychological factors in computer use.

Here we're going to shift our perspective from the world of artificial intelligence to a real-world case history in which a computer model helped negotiators do a better job of understanding a complex issue and reach some strategies for solving it.

In other words we're moving from the world of artificial intelligence (AI) to intelligence amplification (IA), reversing both the initials and our perspective.

Specifically what we want to do is to share with you some ideas backed by a limited and single experience of how computers may add to the negotiating process more than just their acknowledged ability to handle huge numbers and large quantities of information.

When disputing parties are willing to develop and examine together on computer model the issues that are the subject of their negotiations, there is often movement from adversarial to collaborative attitudes. There can even be new insights and mutual appreciation of each other's goals and values. Additional opportunities for mutually acceptable solutions will be revealed.

As this conference has already demonstrated, the recent technical and hardware developments of computers have been spectacular. The human, or software, developments have lagged behind, especially as they concern the joint use of computers for multiparty deliberations and negotiations.

We on this panel see a need for greater awareness of the potential

contribution to international negotiations and a corresponding need for more attention directed to this application of computers, and to more real experience, such as that in the case we will shortly be examining.

Our session is divided into four segments. The first segment will be about the development of the Massachusetts Institute of Technology Deep Ocean Mining Model and its subsequent use in the law of the sea negotiations. In the second segment, we will critique the MIT model and its use in the law of the sea; in the third, very brief segment, there will be a listing of international negotiations where computer assistance might have been used in the past or might be used in the future. And lastly there will be a panel discussion among our speakers on the potential roles of computer-assisted negotiations, or CAN as we have called it, why it is needed, its opportunities, and its limitations. Each speaker will participate in each segment, and as we go along we'll get increasingly less formal.

I wish to remind you at the outset that this is a session on the use of computer-assisted negotiations, not on the law of the sea as a substantive matter itself. The law of the sea (LOS) has been selected as a convenient case history to sharpen our focus. The speakers will not address the important political and substantive issues of the LOS, nor will we entertain questions or discussions on these important and timely questions. We do this, not to restrict free speech, but rather to enhance our free exchange of ideas on this very important topic—the use of computers in negotiations. We do this in the context of the overall theme of this conference—the scientific, intellectual, and social impact of the computer.

Now our first speaker in the first segment, which is on the development and use of the MIT Deep Ocean Mining Model in the law of the sea negotiations, will be Professor Nyhart.

J. D. NYHART (*Alfred P. Sloan School of Management, Massachusetts Institute of Technology, Cambridge, Mass.*): In the fall of 1974, the MIT Department of Ocean Engineering and the Harvard Law School jointly offered an experimental seminar in legal and engineering aspects of ocean uses. The idea was to match a half-class of MIT engineers with a half-class of Harvard law students. The students so mixed were to undertake examination of several projects in order first to analyze both the legal and technical problems involved and then together to create a synthetic problem-solving effort and come up with a joint analysis reflecting both legal and technical training. I was one of the MIT faculty involved. One of the groups was assigned the problem of answering the question, Should the "Mithar Mining Co." invest in deep ocean mining?

Now since the 1860s, it has been known that in parts of the ocean bed, within the first few inches of its surface, are lumps about the size of a fist or a small potato. These "nodules" are created matter that contain in certain parts of the globe what is thought to be commercial quantities of copper, nickel, cobalt, and manganese. Although they were discovered first in the 1860s, it wasn't until the late 1960s that it was thought possible

to gather up these nodules and process them in an economically viable way.

No one has yet launched such a mining operation, and today it is generally assumed that the cost would be about $1¼ billion.

The curiosity of one of the MIT students working on the novel project was aroused. Lance Antrim decided to investigate the economic feasibility further, as the topic for his thesis in environmental engineering at the institute. I was his thesis supervisor. Such were the rather humble origins of what was to become known as the MIT Deep Ocean Mining Model.

Basically, the model was and is an engineering costing and sizing effort coupled with a comparatively simple discounted cash flow model. Assumptions are made initially about the desired throughput of three million tons of nodules per year, the location of a United States west coast processing plant, and the location of the mining area southeast of Hawaii. Following these assumptions, the engineering aspects of the study include sizing and cost estimations for the mining collector, the pipestring to carry the nodules from the ocean floor to the ocean mining vessel, the ore ships to transport the nodules to port, the processing plant on shore, and the slurry pipelines for taking the nodules to the processing plants and the waste from the processing plant to tailing ponds to be stored. Unit by unit the equipment believed necessary for these operations was identified and described, and its capital and operating costs estimated.

The model's output summarized both operational and capital costs. It also provided three measures of economic turn on the investment over a 25-year period: the net present value at a range of discount rates, the internal rate of return, and the payback period in terms of years. I should mention that today discounted cash flow programs for a variety of uses are readily available. They are off-the-shelf software. At the time the model was constructed, such programs were far less common. Antrim was soon joined by another graduate student, Arthur Capstaff, who concentrated on the task of putting together such a program.

In good MIT fashion, Lance Antrim and I cast about for money to support his graduate education, while work on his thesis went ahead. A good portion of the costing effort was in hand by the time the new Office of Ocean Minerals of the National Oceanographic and Atmospheric Administration in the Department of Commerce undertook its support. Later, support from NOAA was to be added to by the U.S. Department of State and the Treasury. The Office of Ocean Minerals was looking forward to the day when the federal government would be regulating the mining of the deep seabed by United States consortia. The NOAA administrator's motivation in supporting the development of the model was to provide a creditable and feasible counterpoint in regulatory efforts when dealing with the otherwise superior data base presented by potential regulatees. NOAA wanted to know, as best it could, what the economic impact of different technical options were in the untried and unperfected technology of deep ocean mining. It knew that it would probably have to draw up initial regulations before the technology was

tested on the abyssal plains of the ocean. Neither the sponsors nor those of us at MIT envisioned the use of the model we are discussing today, that is, its use in the law of the sea negotiations to assist in the development of acceptable formulas for revenue sharing.

One of the goals in constructing the model was to make it a relatively easy task to introduce new values for its very many variables. This was in the days before the supposed user-friendly programming we have heard reviewed here. So in addition to scouring the current literature and knowledgeable people for the fragments and remnants of cost estimates, an equally important parallel effort was going on to create a model in which the values and basic assumptions could be easily changed. Suppose the processing plant was in Oregon with a 50-foot draft port rather than California with a 35-foot draft channel, and was 700 miles farther from the mine site. The construction of the model grew out of the heavy uncertainties surrounding deep ocean mining in the mid-1970s. Suppose someone thought that the collector at the bottom of the sea would cost $25 million instead of $9.5 million. Suppose the whole project was placed in the Bahamas with no taxes, rather than in the United States, and so on. Although today it can be still characterized as an industry of the future, laden with present uncertainties, at that time still much less was known. Having scouted the literature, performed a reasonable engineering research job, and talked with individual members of the nascent industry, the team completed—by hand—its first set of cost estimates and calculation of the discounted cash flow. These estimates were reviewed in March 1977 at a workshop sponsored by NOAA and attended by representatives of the major industry consortia and scattered knowledgeable academic and government observers of the embryonic ocean mining industry. Their critiques and comments were carefully recorded, and taken one by one into consideration in a reformulation and redrafting of the model. This redrafted report was subsequently circulated to workshop participants, and their comments once again were taken into consideration prior to publication of the report in the spring of 1978. We thus felt that we had had two good reviews by industry of the cost data and other assumptions prior to publication. As will be seen later, these early reviews held us in good stead when the model was actually put to use in the LOS negotiations over a year later.

At this point it might be useful to make three initial observations about the characteristics of the model that were to be important in some later uses.

First, we were persistent and straightforwardly open about the assumptions and the values involved. To the best of our knowledge we tried to set out the assumptions that went into the model, not only any quantitative values, but the process assumptions that we made. Second, we were also persistent about making a continuing offer to put the best data we could get into the model. Repeatedly we said that we had constructed the model so that new data, new values, could be put in as new knowledge was acquired. We said, If you don't like our data, give us

yours and we can all see what they look like. Thus the model was not built with results of a particular nature in mind. We recognized that acceptance in any of its uses was to be dependent upon its perceived neutral value. (That phrase, of course, is fraught with difficulty; it may be presumptuous to assume that any value is ever neutral.) Third, as pointed out earlier, the model was not developed with the use in LOS negotiation in mind.

Today, the model has gone through a totally new iteration. Although once the model was seen to be useful and likely to be used, the commentary and critique from the industry increased in volume, it was not until after it had been used for the purposes to be discussed shortly that we began to get anything resembling a flow of data from the consortia. And then it was mostly indirect. The current iteration of the model contains cost estimates that have come basically from the private sector in the United States. But these have also been backed up by a careful, detailed, and somewhat unique engineering effort by my colleague at MIT, Professor Michael Triantafyllou, and several graduate students working under his supervision. My colleague here today, Jim Sebenius, and Lance Antrim (who went to work at the Department of Commerce, joining the United States delegation to the Law of the Sea Conference under Ambassador Richardson) have made a careful study comparing the results of the model we put together in 1976 and the current engineering costing and economic analysis. The two efforts relate in a consistent manner.

The links to the law of the sea negotiations evolved through the imaginative and curious eye of Jim Sebenius. At the time, he was an intern from Stanford University's Engineering and Policy Program working at the Department of Commerce. He was shortly to become, during a transition period between administrations, a critical element in the Department of Commerce's presence at the law of the sea negotiations. We all are fortunate, I think, that he was working for Elliot Richardson. Dr. Sebenius' concept about the need to introduce some quantitative basis for discussion of the thorny problem of seabed mining into the negotiations met with a positive response from the lawyer who would soon head the negotiations committee dealing with these problems, Tommy Koh, Singapore's Ambassador to the United Nations and later president of the conference. I joined Ambassador Koh, Dr. Sebenius, a group of delegates to the conference, U.S. church folk, and foundation people to discuss the problems. As word of completion of the first iteration of the model was made known to this group, the Stanley Foundation made a special supporting effort in the first months of 1978, prior to the next meeting of the conference in March, to provide advance copies of the study to various members of the group of 77, that is, the developing countries, and to personnel of the Department of State and other members of the United States delegation. By that time, Antrim had joined the federal government, so four persons critical to the use of the model in the law of the sea

negotiation, Ambassador Richardson, Dr. Sebenius, Ambassador Koh, and Dr. Antrim, were in place. Their story is better told by them.

J. K. SEBENIUS (*John F. Kennedy School of Government, Harvard University, Cambridge, Mass.*): What I'll try to do first is give a sense of how the MIT model came to be used in this long-term global negotiating effort, something about where that effort came from, and then the parts of the negotiation where the model was especially relevant. Then I want to talk a little bit about how the United States delegation used the model and comment on a few aspects of its use within the United States and in the international negotiating effort.

As Dan Nyhart described, these nodules—little conglomerations of copper, cobalt, nickel, and manganese—are located typically in regions that are outside any country's national jurisdiction, so their economic lure needed to be secured by property rights for some exclusive claim to the regions that might be mined. A region for mining is very large, some 40 to 60 thousand square kilometers for a single operation. That's on the order of the size of Switzerland.

Anybody who wanted to mine these nodules needed title to them, and there wasn't any international legal apparatus that people trusted to grant it. The situation at that time regarding the oceans was very complex. There was a dramatic increase in the intensity of use of the oceans for fishing from the early 1950s to about the 1970s, when the catch leveled off and even declined a bit. There was a tremendous increase in the use of the oceans for transport, both in the tonnage and in the size of ships. Energy production was dramatically up from the outer continental shelves, and accompanying this intensity of use were many, many conflicts. Among the most visible were the cod wars over fishing rights between Britain and Iceland.

The right to do scientific research off different coasts was disputed. Many claims of different countries were extended over fish, over oil, for security purposes, for environmental purposes. They promised a world with a great deal of conflict and with feared restrictions on navigation, both commercial and military. A series of these increasing conflicts made the role of international law much more important. But international law regarding the oceans had developed in a haphazard way. The last significant attempt to codify it and grant rights—the Geneva Conventions of 1958—had left many holes. Mineral nodules were hardly part of that agenda, and so certainly this new ocean use needed a better framework in which to proceed.

Not only that, but many nations in the world of the 1970s hadn't existed or were barely independent in the late fifties. The legitimacy of such international laws as there were was called into question by these nations, who wondered why they should be required to abide by laws that they really had no part in formulating. This summary provides only a surface view of these trends, but they led by the early 1970s to a major law of the sea negotiation.

There was an extremely important event in 1970. The General Assembly of the United Nations, without opposition, declared these nodules to be the "common heritage of mankind." That declaration, in combination with some of these other trends, led to these negotiations which had many parts. One—and subsequently the most politically salient—was the attempt to construct a regime for mining these nodules: who would have the rights, under what conditions, with what obligations, environmental, financial, and so forth; how would disputes be settled. A whole set of other questions concerned traditional law-of-the-sea areas like fishing, navigation, the territorial claims, claims to different resources in the oceans as well as the marine environment, and marine and scientific research. It was, in effect, to be a "constitution" for all of the seas.

These negotiations went on actively from 1974 to the end of 1982. The participants there represented well over 150 countries and virtually every conceivable interest and ideology. The divergencies ran in so many directions—North and South, the developed and developing, East and West, the producers of the minerals that would come from the seabed, the consumers of them, and the industrialized, newly industrialized, and less developed countries.

In any case it was an extremely complex process which went on over a long time. As some of you no doubt know, the convention was recently signed in Jamaica by close to 120 countries, the United States notably abstaining. The MIT work was relevant to one particular, very central issue within this constitution-writing effort. The question was how to share any benefits that came from the mining of the deep seabed nodules. With respect to the "common heritage of mankind" notion and trying to arrange a way for broader participation in the mining, there would be two broad issues that this model directly concerned.

The first was the system of payments to the international community, almost like a system of fees, royalties, and profit shares that the company would pay the government. The second was the creation of an international mining entity that itself would mine on behalf of mankind. The model was quite useful at giving insight into both these questions.

What I'd like to do is describe briefly some of the model's uses in the United States delegation and then sketch some of the international uses.

I was working at the Commerce Department, and got an assignment to do some staff work on a bill that was wending its way through the United States Congress to enable the unilateral mining of seabed nodules. I had not heard of these things at all, and so I tried to discover what kind of work had been done to get some notion of what they were and something about their economics. I also encountered somebody in an office of the Commerce Department who said that a group at MIT had been working intensively on this for some time. At the time, the connections to the legislative and the broader international questions that were associated with this issue were unknown to me.

That's how I found the MIT model. I began to use it in doing some of

this early staff work to get some understanding of the economic and technical nature of this process of deep seabed mining. It's a long-term capital-intensive project. Studying it from the United States point of view pointed up its incredible uncertainty, uncertainty in the capital costs, operating costs, and revenues. The group at MIT had struggled mightily to get some feeling for it. Studying the model gave a much clearer idea of capital and operating costs and how those would be dependent on energy costs, for example, and chemicals, as well as the metal markets for copper, cobalt, nickel, manganese, and how those things came together in an engineering structure linked to a financial routine. So from the U.S. point of view, we used the model to get a much better sense of what the economics would look like. And, naturally, it was easy to test the effects of various tax proposals—depreciation, tax credits, environmental modifications that might be required, and otherwise.

In the international arena, the model was used in quite a similar sense to understand much more about this international entity that would be created by the negotiations. The staff work that Ambassador Koh presided over in trying to design an effective tax system for this mining involved running many, many different financial proposals, structuring them in a variety of different ways, holding a series of seminars both in tiny groups in the negotiations and in increasingly larger groups up to full plenary sessions where this model and its results could be queried and studied by the delegates, as well as off-the-record sessions and seminars held by such groups as the Quakers and the Methodists away from the negotiation on a kind of neutral ground.

The model became so popular that people would even show up early on Saturday mornings to learn more about what was at that point a very central set of questions in the negotiations.

A number of delegations as well used the model: the European community, the Indian delegation, the Soviet delegation, those of Japan and Argentina were prominent users that borrowed the model to try to get some better sense of what it was that we were negotiating.

E. L. RICHARDSON (*Milbank, Tweed, Hadley & McCloy, Washington, D.C.*): My good friend—until lately, the President of the Law of the Sea Conference—Ambassador Tommy Koh could not possibly have known, in suggesting that I precede him in speaking order, that I was going to deliver what—if this were a National Convention—might be interpreted as a nominating speech. But that is just what I want to do, because it seems to me that at this stage in the exposition, you ought to have some feel for the personalities involved. Without their contribution it is certain that the MIT model, however well constructed and however potentially useful, would not in fact have found the use to which it was put with such remarkable results.

In this story the hero is sitting to the left of our chairman. He is Ambassador Koh. He is a hero in other dimensions as well. Those of you who follow the development of North-South relations and East-West relations generally would have noted in the *New York Times* that

Ambassador Koh, at the recent nonaligned meeting in New Delhi, was the leader and principal tactician of the moderate forces there. He has been a leading force in the United Nations behind the resolutions condemning the Vietnamese occupation of Cambodia and the Soviet occupation of Afghanistan.

In 1978, Ambassador Koh was named chairman of a working group, called Working Group 2, that was charged with trying to resolve the issues under the heading then generally referred to as "financial arrangements." Under this heading were embraced all the issues inherent in figuring out how much should be paid to the International Seabed Authority (ISA) by companies, state owned or private, operating under license of the ISA in the mining of deep seabed manganese nodules.

It was a basic premise, as you've heard from James Sebenius, that these nodules belong to the world as a whole—hence the reference to them as the "common heritage of mankind." But if they belong to the world community as a whole, on the one side, and if, on the other, the costs and risks associated with exploiting them are extremely high, in what amounts, if any, and in what forms of payment, should exercise of the right to mine be required to make some contribution to the ISA? How much should be paid up front in the form of fees or advance payments of some kind? How much would it be reasonable to try to collect in the form of royalties or payments from gross proceeds and how much from net proceeds? To what extent should it make a difference whether or not the investor had recovered his initial investment? Should this affect the rate of contributions from income? How would you go about dealing with the question of what proportion of the net proceeds of deep seabed mining is attributable to operations in the deep ocean as against the proportion attributable to the value added by the extraction of the metals from the manganese nodules in the shore-based processing plant?

All of these questions had to be dealt with, and of course fundamental to them was the relationship between the amount of the investment made by the deep seabed miner and the rate of return, given the risks associated with the enterprise as a whole, that such an investor should be expected to insist upon in order to induce his investment, given the alternative uses to which his capital funds might otherwise be applied. This was the segment of the problem of deep seabed mining committed to the working group chaired by Ambassador Koh.

It happened that the conference also had among its leading participants a man who then held the title of Minister for Law of the Sea in the Cabinet of Norway, Ambassador Jens Evensen—and I might add that one thing Tommy Koh and Jens Evensen had in common is that both had received Master of Law Degrees from Harvard Law School.

Evensen was and is one of the world's leading experts on international law, and particularly ocean law. He had played a prominent role in the earlier stages of the law of the sea negotiations with regard particularly to the traditional areas of international law such as the rights and duties of coastal states, freedom of navigation and overflight, and the like,

and he had in 1977 chaired a negotiating group representing all countries in the conference seeking to develop a workable seabed mining text. To deal with the so-called hard-core issues identified in the course of the 1977 negotiations the conference created a series of working groups, including Ambassador Koh's Working Group 2. His charge, as I have said, was to answer the question of what it is reasonable to require in terms of initial fees, royalties, and rates of profit sharing, to define "attributable net proceeds," and so on.

Well, as you've heard, MIT was already developing a computer model, but it probably hadn't yet occurred to its designers that the model would have a central role in the resolution of these questions. The existence of the model created an opportunity, but it was an opportunity that could be exploited only if the model could be endowed with credibility. Fortunately, it was a model developed at an institution whose own stature was widely recognized by participants in the conference. This in itself went a long way toward assuring the model's credibility. But it was also important to find other means of creating the maximum degree of acceptability for the data that it would produce. One was an informal meeting held under the auspices of the Stanley Foundation for members of the conference who would be playing leading roles in these issues. The Stanley Foundation in other connections had already secured for itself the reputation of a neutral forum which offered the opportunity for informal discussion among people from the developing countries as well as representatives of the industrial countries and of the mining companies themselves. This reputation too was a contributor to the development of credibility and trust in the model.

Ambassador Evensen at this stage played a significant role because he began to develop an analysis of his own, to some extent even competitively with Working Group 2. Nevertheless, the fact that he did take this initiative and began to explore possible approaches to the financial arrangement issues also helped to build confidence in the MIT model because he found it increasingly useful in seeking the answers he needed.

Meanwhile Dr. Sebenius was playing a key but low-profile role. He was a member of the United States delegation, but he had by that time achieved such a reputation for total integrity and extraordinary competence that he had come to be used by Ambassador Koh as if he were a member of the Secretariat of the conference itself. And indeed he was actually in the position of having from time to time to tell his colleagues on the staff of Tommy Koh's working group that he could not tell them what had been discussed that day in the United States delegation and later in the day of having to tell me that he couldn't disclose what had been discussed in an executive session of the staff of Tommy Koh's working group that very afternoon. It takes a remarkable person to achieve that kind of status, and I don't think one can easily generalize as to the potential for others to duplicate this role in other situations.

I think it's fair to say that the opportunity to make effective use of what

was during this interval becoming an increasingly useful model to a large degree depended on Ambassador Koh's being there, on Evensen's role, on Sebenius' role, and indeed on that of a number of other people, including Inam ul Haq of Pakistan who, although in some respects a militant representative of the group of 77, is also a very bright and very intellectually honest man. Haq will not let himself make an argument that he does not believe to be intellectually valid, and if you give him an effective answer he will not bluster or try to pretend that his original point does not require qualification.

There was Anil Gayan of Mauritius, to some extent perhaps even more militant than Haq, but also very bright and committed like the others to try and find answers. There was Alfredo Boucher of Argentina, who, but for coming from the southern hemisphere and speaking Spanish, could easily have passed for a Covington & Burling tax lawyer. It was this combination that, together with the machine and its calculations, produced a really extraordinary result, a kind of mini-corporate tax code for the future financial aspects of deep seabed mining.

D. B. STRAUS: As you can see, we've set the stage to talk about how the alchemy of men and machines did get together in this particular case. Some of us, from the mediation point of view, which is the one I represent, have been interested in the potential value of computer-negotiator interaction as a means for helping to organize the discussions, and to reduce adversarial attitudes, and to elevate the quality of the decisions eventually reached.

It's a question of helping to manage complexity, of giving a sort of negotiating framework that doesn't exist without this kind of apparatus. In the final analysis, at least from the viewpoint that I represent, the activity of working together to construct and build a model, of participation with previously adversarial persons in trying to do this, is more important than the output of the computer—or at least of equal importance. I think we'll begin to get some flavor of this. Prof. Nyhart will lead us into the second segment.

J. D. NYHART: The question has been put, From the present perspective, how does one evaluate the use of the model in assisting the law of the sea negotiations?

There are pluses and minuses. It is useful to recall that my perspective is not only that of the principal investigator of the project. I was also in the rather unusual and often precarious position of directing model building while being essentially a non-computer person. With that said, there seems to me that there are several good things to be said about the use of a model in the kind of negotiation described.

First, its use provided a way of moving the negotiating parties to become clearer about values and premises. Values of an economic and political nature: What does it take to induce large investments in a novel, uncertain project? How do you best go about estimating costs? And also of a technical nature—Does extrapolation from real-world experience of ore transport, ship costs, or from comparatively primitive sizing estimates

provide the best basis for cost estimates? And legal values, too—"When do nodules acquire a market value?" holds an implicit value statement.

The model's use provides an opportunity to link together the requisite components in the system while leaving each component or subcomponent subject to examination. You can take apart a piece of the whole, look at it, negotiate over it, and put it back in place, without losing track of the whole.

Its use provides a way for looking at many different proposals and their impact in a very rapid way. This was critical in the LOS negotiation.

Its use provides a way for different negotiators to "join up." It makes it easier for them to abandon old positions, to assume new positions in the negotiation. Like a good consultant, a computer model can "take the rap."

Perhaps most importantly, its use provides a way for sides both to test and to gain credibility. It can provide the opportunity for negotiators to *gain* credibility through showing and making clear their different assumptions, through showing that they are willing to try different solutions, to experiment with different possible outcomes, through providing the way to show that they are open to change. It provides negotiators an opportunity to *test* the credibility of others through giving them—perhaps mainly the technologically less-advantaged negotiators—an opportunity to learn the language and the base concepts of the technology. The part that the MIT model played as a tool for providing some basic education in the way sophisticated investors look at investments has already been mentioned. It provides a way for negotiators to participate in the process more fully by coming up with their own assumptions, which could then be tested and examined.

All of the above advantages can be erased if computer-assisted models are used as mumbo jumbo to impress, to obfuscate the issues rather than to shed light. But this is a danger that is an old familiar friend in the law. It is the problem of the extra weight given to scientific evidence in trials. The excessive credibility that tends to accompany science in the lay or legal world always has to be guarded against.

Turning to the problems in the model, use of the last issue—the extra weight of science—provides a starting place. The internal rate of return figure of what we called our base case of around 18% became cast in concrete. Among the group of 150 negotiating countries, the fact that a place called MIT had come up with a model with a particular internal rate of return gave that figure far too much credence and power. So the first question in considering the use of computer-assisted negotiations is how to eliminate the quantitative mystique. It is important in the context of multilateral negotiations to recognize up front the power of an accepted model.

Once it was clear that the model was going to be accepted by a large population in the negotiations, the future regulatees—the deep ocean mining industry—became threatened by its use. So a related problem is

how to provide safeguards, how to reduce the threat. In fact, Ambassadors Richardson and Koh and Dr. Sebenius used the capability of the model to help generate and communicate a formula that went a long way toward protecting the vital interest of the investing, risk-taking industry while at the same time serving the interests of the nations around the globe.

One way of mitigating the power of the quantitative mystique is to have people focus on one model. As its contents, weaknesses, and strengths become known, people become familiar with it and know its limitations. In the LOS negotiations different parties made an effort to focus on the one model. To this end, MIT licensed the European Economic Commission to use it, in an effort to promote a common language rather than a tower of Babel.

A second major problem was that of data acquisition. Translated more freely, this one becomes a question of how do we know what we are doing. In market economies, most of the critical data are in the hands of the private industrial sector and frequently these data are proprietary. It is a perpetual problem in the United States and similar societies. Our effort in tracking industry data in the first iteration has already been described. In the second round, NOAA hired industry consultants to work with the MIT team in providing data. In fact, these industry consultants have put together their own model and are now operating it. On the other hand, there is the question of checking data from industry. As pointed out, we addressed this problem by providing our own independent engineering workups. These technical assumptions are set forth as an integral part of the second report. They provide a good parallel, independent basis for estimates. It is worth noting that the results of these two paths complemented and supported each other.

Closely related to the question of data acquisition is the very important question of separation of the technological function. Technical data ought, in my opinion at least, to be gathered and assembled and the model built, from a technical point of view, by persons who do not presume the answer to the problem at hand. The answer to the problem, what should be done, necessarily involves value considerations. They are the province of the policy people, the diplomats and politicians, not the technical folk.

That comment raises a related, but distinct, problem in making good use of computer-assisted models, the problem of user participation. How do you get the users aboard early and still get the model built? And, if you bring the users in, how do you keep separate the technology and value considerations just referred to? In our case, in retrospect, working more directly with the different negotiating parties during the intercessions between the law of the sea negotiations would have helped the modeling. However, we had limited capacity, they had limited capacity, and we all had limited funding. I think that ideally we should have had the funding and the time to have transferred the capability of the model to the United Nations, to the Law of the Sea Authority, in addition to our NOAA

sponsors. There are problems, huge problems, with transferring the capabilities of such a model, not the least of which are the problems of satisfactory documentation. These problems are made worse when the model-building team is an academic team spread over several different years of graduate students. But that is a different problem.

T. T. B. KOH (*Permanent Mission of Singapore to the United Nations, New York, N.Y.*): I think the best contribution I can make to this discussion is to say something about how the MIT cost model came to have such an important place in the law of the sea negotiations, to talk about what use the negotiators made of the model, why the results of the negotiations would have been different if we did not have the model to use, and what extrapolations one can make from this one successful case to the future.

I'd like to begin by returning to something Dr. Sebenius said in his earlier statement, and this was that the mandate I was given as chairman consisted of two interrelated subjects. I was given a mandate to negotiate an agreement on the tax system that would apply to seabed miners. The tax system would not only include the structure of the system but also numbers, exactly what percentage of royalties the miners would pay to the international community, whether there would be a component of profit sharing, and if so how much of the profits earned by the seabed miners would be taken by the international community.

The other part of my mandate was to get an agreement on how the first mining operation of the Enterprise, the Enterprise being an international public mining company, would be financed.

Very early in my work I came to the conclusion that in order to achieve success in negotiating the first subject, I had to link the first to the second subject for this reason: the industrialized countries were naturally much more interested in getting an agreement on the tax system that would apply to seabed miners; the developing countries, on the other hand, were much more interested in ensuring that the first mining operation of the international enterprise would be financed. So I decided that tactically I had to link these two questions and that I must make simultaneous progress on the two fronts.

Having decided that, I was then confronted in the negotiations on the tax system with what seemed, at first, to be an insuperable intellectual obstacle. The obstacle was that the seabed mining industry does not exist now and did not exist five years ago. We had no reliable estimates of what the capital or development cost for mining operations would be; we didn't know for sure what the annual operating costs would be; we didn't know what the metal prices in the world market in the future would be, and unless we knew that, we could not estimate the profits.

So on all the three parameters—development costs, operating costs, and revenue derived from sale of metals—we were in the dark. It was by a happy accident or serendipity that we had the MIT cost model available to answer a need felt by the delegations in the conference.

However, in order to get the MIT model accepted by the conference

we had to overcome many intellectual, political, and psychological obstacles. The fact that it was a study done in the United States generated some political and psychological problems. The fact that the study was financed by a grant from the Department of Commerce was an additional difficulty we had to overcome.

The most important of all was the intellectual burden. Most lawyers, including those who were in the Law of the Sea Conference, had very little knowledge of science and engineering in general and even less of computer science in particular. So the first intellectual hurdle I had to overcome was to hold seminars in order to explain to these lawyers in the conference what a computer model was all about, to explain to them how the MIT team of scholars had built up this cost model, to explain what development costs and operating costs mean, how one arrives at projected profits of a mining project, and then to make them understand what the internal rate of return was, what a payback period was. It was an intellectual burden which took about a year to overcome.

The political and psychological problems we overcame through the help of certain nongovernmental organizations, such as the Stanley Foundation, which Mr. Richardson has referred to, the Quakers, and the United Methodist Church. We were able to hold several weekend conferences and retreats away from the conference, and we were able to invite Professor Nyhart and his colleagues from MIT to come to these meetings to explain how the cost model was built, what was its utility, what were its shortcomings to the delegations. It was a very important encounter because when the suspicious third-world delegates met these American scholars from MIT they were impressed by their objectivity and by their personal integrity. They were persuaded that although the study was financed by the Department of Commerce, the MIT scholars had tried to do an objective piece of work uninfluenced by where the money came from. It was not intended to serve the interests of the American mining industry. This is very important.

The fact that the MIT cost model then came to be criticized by certain representatives of the mining industry and by the European Economic Community reinforced the growing perception on the part of the third-world delegations that it was an objective study and that the scholars were men and women of personal integrity.

Another reason why the MIT model came to be so widely accepted in the conference was because its intrinsic merit was superior to anything else we had to use. The European Economic Community was not satisfied with it, but the rival model which they put forth at the conference was a rather poor thing in comparison to the MIT cost model for this important reason. The MIT cost model was an impressive piece of work because it had disaggregated all the sums down to the component parts of a mining system, a pipe, a ship, whereas the European model used large aggregates but did not disaggregate these global sums and you didn't really know how they arrived at these much larger figures than the MIT team had. Therefore, I was able to convince the conference that when you

compared the intrinsic value of the MIT model and the European model, one had to come to the conclusion that the MIT model was the more reliable of the two.

Now I'd like to say something about what use we, the negotiators, and the conference made of the MIT model in our negotiations. I think the most important use we made of the MIT model was to demonstrate and reinforce the element of uncertainty in the economics of this new industry, and the point we were able to communicate to all the delegations from every part of the world was that we are regulating an industry whose economic prospects are very uncertain and that—although the MIT team had done the best job it could to estimate the development costs, the operating costs, and profits of seabed mining—these are, at best, estimates and that any change upward or downward in these three parameters could result in a very significant change in the profitability of the project. So that was a very important element which we got across.

The second utility of the MIT cost model was that I was able, as chairman, to use the MIT cost model to convince delegations that certain proposals they had put forward were financially infeasible. The utility of the MIT cost model was that you could put in all kinds of inputs and variables and the computer would tell you how the internal rate of return of the project would change with these new variables. We were able, for example, to convince the conference that the Indian proposal that every seabed miner should, on signature of the contract, pay a bonus payment of $60 million was such a heavy front-end burden as to make seabed mining projects infeasible.

The third value of the MIT cost model was that I was able to use it to convince the delegations to shift the emphasis in the tax system from a reliance on royalty payments, which are fixed payments, to a greater emphasis on profit sharing. This was a very important achievement which we could not have made without the model.

The last point I want to make is that I was able to use the MIT model to convince delegations that the international community's share of the seabed miners' profits should be pegged to the project's profitability, as measured both on a year-to-year basis and on a project-long basis. In other words, the international community's share of the profits of a mining project would vary from year to year and from project to project depending on the seabed miners' internal rate of return.

Again, this was an agreement that could not have been achieved in the absence of the MIT cost model. My short answer to the question, Would the results have been different if we didn't have the MIT cost model?, would be yes, it would have been very different.

Can the success of the MIT model in the law of the sea negotiations be replicated? We'll come to that in the third segment of the panel, but I just want to end by emphasizing the many happy coincidences that occurred which made this success possible. One was the fact that the negotiation was primarily about numbers and structures of a tax system, and the question I would like to flag now for discussion later is whether or not the

computer can play the same kind of helpful role when the negotiations are not primarily about numbers.

My second point was that the MIT model came to play the dominant role it did because of a felt need on the part of the conference for an agreed set of figures and facts, and the model offered this to the conference.

My third point was that the success story could not be replicated in the absence of the critical mass of people who fortuitously came together in this particular negotiation. We had some of the members at MIT who were available to the conference, we had the head of the United States delegation, Elliot Richardson, who was familiar with the MIT model and was willing to allow the conference access to that model. We had, within the conference, a small number of very talented and able men and women both in the secretariat and in the delegations without whom this success story would not have occurred.

J. K. SEBENIUS: Given Ambassador Koh's help in laying out a lot of points that I think are interesting, I'd like to embroider a few. Why did people use the model as much as they did despite the highly politically charged environment where the prospects for using a United States government-financed model, done at a United States institution, for a very important precedent-setting area would have been very dim?

Why did people use the model? I'd underline the disaggregation that Dr. Nyhart insisted on from his graduate students. They identified and documented everything, creating a huge appendix justifying from the ground up how they built the system and where all the estimates came from. That disaggregation was crucial, particularly as against other studies that were aggregated without internal justification. People could look and debate at a very disaggregated level if they wished.

A second important point was that the early apparent implications of the model seemed to cut both ways. When it came to the conference, while many developed countries claimed that virtually no taxes were possible in this highly risky industry, the model seemed to suggest that indeed some more taxes were possible. At the same time, many in the developing world thought that seabed mining would provide an absolute bonanza, a kind of engine of third-world development that itself could fuel a great deal of international progress. But the model suggested that mining would be profitable, but not a bonanza. This, along with the vocal criticism by many of the political advisers to some of the mining companies, somewhat paradoxically added to the model's credibility.

It's interesting that, initially, people latched onto the model since it seemed to offer such a certain projection of the future. People had been swimming around in such uncertainty that the model almost provided an excuse to go forward. Paradoxically, as we went further into the negotiations, the very uncertainty of the estimates around the different parameters became clear and politically relevant. Instead of the numbers that the model contained, its structure was the key—the fact that it used a measure of profitability that was calculated over time. The discounting

and the degree of risk that was associated with different tax systems became very clear to the delegates. What ultimately happened, partially as a result of this model, I think, is that the tax structure that was produced in the Law of the Sea Convention is a novel tax structure, much different than you find in most countries. It explicitly takes into account the profitability of an operation over time and in different conditions of risk. It's quite an achievement technically to allow a fair division of revenue without imposing a great deal of additional risk on operations. For example, in third-world countries when mining companies go in, the usual result of too inflexible tax systems is a constant series of painful renegotiations. We had to avoid that, and the model pointed the way for such an achievement.

There is one last point that I would make on the model's use. An example was the case of the Indian proposal for a heavy front-end load. The proposal was made and a lot of political credibility staked on it. But as the negotiations progressed, the model was introduced, and many runs came back and forth, it was quite possible for the Indian delegates to withdraw their proposal in the face of genuine learning. It wasn't a political concession as such to the other side, but instead it was a concession to a more rational look at the problem. And the model was almost like a third party to a number of delegates, so it provided a way to move that didn't involve conceding to another political counterpart. That was quite important, and some delegates went so far I think as to make actual political concessions nominally using the model. It provided an escape route from the frozen positions and deadlocked commitments that are the bane of negotiations. The way the model facilitated such movement was a nontechnical benefit.

E. L. RICHARDSON: I want to make three brief observations which may serve partly to bridge the discussion you've already heard with the discussions to follow with respect to the future international issues where computer-assisted negotiations might be applicable. What I'm about to say isn't really a critique but rather an attempt to highlight points that may be significant when the opportunity arises to apply the lessons to be drawn from this experience.

First of all, although we've been talking about a computer model whose internal calculations take place beyond the reach of human intellectual capacity to follow and which are never articulated but which rather produce their numbers on the basis of the design and the data inputs to the model, it would be a mistake obviously to understate the importance of linguistic lucidity to the potential applicability of any such model.

We have, indeed, using the word model in a slightly different sense, on this dais two models of linguistic lucidity in Ambassador Koh and Dr. Sebenius. I'm sure that in listening to them you can get some sense of what Ambassador Koh was talking about when he referred to his "seminar." And do not lose sight of his comment that it took about a year of such sessions both to create credibility for the model results but also to

educate people to understand the relevance for the issues to be negotiated of the model's findings or projections. And Dr. Sebenius along with others, but particularly Dr. Sebenius was a very important contributor of staff support for that purpose. It is not lightly to be assumed that with less capacity in these respects a successful outcome would have been reached.

I'm not sure whether it's been mentioned that it was partly on the strength of Ambassador Koh's performance in this context that, when the man who had been not only president of the conference from the beginning but before that Chairman of the United Nations Seabeds Committee, Hamilton Shirley Amerasinghe, died in 1979, Koh was the overwhelming choice of the conference to succeed him and served as president of the conference until its concluding ceremony in Jamaica last December.

My second observation is that there is needed for any such process to succeed in a large multilateral conference the judgmental capacity to assemble a group of people who can negotiate the final resolution of the issues that have been addressed by the model. As Ambassador Koh told you, he was charged with not just setting up a system of taxation but also determining what the tax rates would be and how the question of attributable net proceeds would be dealt with, and so on.

At that stage he held negotiations in the conference room of the Singapore Mission here in New York, at which he presided and at which were represented the individuals I referred to before, Haq of Pakistan, Gayan of Mauritius, and Boucher of Argentina. I was there representing all of the western industrial countries. None of us had any authority from anyone to close any deal, but we did; we filled in all the numbers, and they remain to this day in the text exactly as they came out of those negotiations. And this is the one part of the seabed mining regime that the Reagan administration did not include in its list of things it wanted to have changed.

How, then, was it possible for five people in these circumstances to produce such a result? Each of us around that table knew that we couldn't bind anyone not present. In such an exercise you must know that your fellow participants have a very high probability, if they go along, of being able to deliver their colleagues, and if you don't know that, you'd better not be there. But it is that ultimate process of very intense bargaining—and only that—that can produce the ultimate negotiated results.

I would just add, as a final point, which really brings us back full circle, that the MIT model contributed to credible data that, mediated through the process of negotiation, produced a sensible result. It was a result that could stand up to the kind of examination it has had since, especially during the review initiated by the Reagan administration on the eve of the resumption of negotiations in 1981. And, as I said a moment ago, it was the one major part of the deep seabed mining regime that emerged from that review undamaged in the eyes of the Reagan administration itself.

D. B. STRAUS: Before we go on, I would like to address a question raised by someone in the audience: "Does not the equal access to the data by all parties change the very nature of negotiations?" First let me give one answer as a mediator. I think the answer is yes, it does indeed change the nature of negotiations. It can have the effect of moving the adversarial attitude of the parties more towards collaboration, more towards what the academicians call a positive-sum result rather than a zero-sum. One of the newer skills that all of us are going to have to learn as we broaden our skills from dispute resolution to the management of the entire decision cycle is to be sensitive when parties are ready to become more collaborative. In these large-scale and complex issues there are times when the parties can see an opportunity, for their own best interests, not for altruism but for their own best interests, to move towards a collaborative study of a problem rather than withholding information and being purely adversarial. Decision-cycle facilitators must be alert for such opportunities and must be ready to encourage them. Mr. Richardson touched on one aspect of this and so did Ambassador Koh—and this was the *quality* of the agreement that was reached. An agreement, *any* agreement, used to be the only thing that mediators were interested in. But it is increasingly the quality of the agreement that is important as the issues addressed become more complex and far reaching in their impacts. The interactive and joint use of the MIT model indeed changed the nature of negotiations, but it has been suggested that the quality of the eventual agreement was also better than it might have been without it. I think this is an essential point to emphasize.

J. D. NYHART: As we were planning the structure of this session we had the idea that if we compiled and presented a list of upcoming negotiations or treaties, this might stimulate discussion as to future uses of computer modeling in negotiation.

Now when I got to that task, I found that there was no neat list. I was able to group them into major categories: (1) agricultural commodities; (2) arms control; (3) mineral and renewable resources; (4) natural resource exploration and exploitation; (5) pollution liability and compensation; and (6) trade and transnational uses of science and technology.

Arms control does not have some of the characteristics that I want to refer to in a moment. Natural resource exploitation and exploration is what we're talking about this morning. And what I feel is the most important is the last, transnational uses of science and technology.

I looked at the list afterwards and realized that there were some common characteristics. First of all, there is a good deal of uncertainty involved and complexity involved in the science and technology of all of these. Uncertainty in the agricultural products, in the commodity products, in terms of weather, etc.

Secondly, there's economic value—the ability to put numerical values on the subjects of negotiation here. I think that's important. Ambassador Koh expressed the question, "When you aren't dealing with numbers, can you get a useful hold on this kind of modeling?" I'd ask the same question.

I'm not sure you can do much or succeed, or get any leverage if you aren't dealing with some component of these large political questions that is discussable in terms of numbers, in terms of economic values.

D. B. STRAUS: We're now really into the paydirt of our panel discussion. What we are now hearing is that there is a group of users who are of fundamental importance to their governments and to the countries in which we live who are saying: We need help! We are facing too much complexity, too many parties. It is becoming increasingly difficult to understand the nature of the issues that we're up against.

These important users are looking for help—not just from computers. They need access to a whole variety of new tools, a sort of toolshed of procedures that could help at different stages of the decision cycle.

We should now try to be as specific as we can. But first we must examine a threshold question. I either heard, or wanted to hear, because I guess this is my prejudice, that negotiators should be persuaded to collaborate as soon as possible in building a model; in its design, in the selection of the issues and the data, etc. What might have happened if the law of the sea negotiators had collaborated from the start in the design and development of the MIT model? Would that have damaged the process, aided it, or not have made any difference?

J. K. SEBENIUS: It seems to me that a central question for the law of the sea model was why it was accepted. Of course it was useful, but there were lots of models that were proffered and arguably dealt with the same questions. That notion of independence and credibility was so important here that it's hard to go back and reconstruct what would have been the case had apparent advocates gotten to the model much earlier.

On the other hand, there was something else that was very important. Once the model came into general discussion and became part of the LOS conference, it became very clear that it hadn't been designed for the conference's use. For example, the United States tax system was built into the model itself, almost hard wired in a programming sense, and it took a great deal of work to disentangle it so that it could be used for the tax systems of all sorts of other countries or by an international authority.

That made things difficult. But in the process of modifying the model to handle international situations and the particular suggestions of all kinds of individual delegates and countries, those representatives came to have an influence over it and the outputs that they wanted. For example, not only did the model give the rates of return to the contractors and the miners, but it was easily modified to give a rate of payment to the international community under a variety of different people's assumptions and proposals that were structurally quite different. In a sense, the model changed from one that was owned and done only by MIT to one that was susceptible to and modified by lots of input from other people. I think that that cumulative process was important. And it's hard to judge, if that had happened earlier, whether the model would then have been seen as simply an adversary tool.

Another interesting thing that the model did with respect to these

measures that I mentioned—the rate of return to individual contractors and payments to the international authority—was that it framed the issue in terms that were quite discussable on the merits. It focused the negotiations and almost provided a language that was much easier to handle than the much larger North-South questions that this issue was a proxy for. So in a sense, the model concentrated and focused and narrowed the discussion a great deal and provided terms for the negotiations that let it go forward in an apparently more rational and productive way than the simple trading of theology back and forth, which often happens.

T. T. B. KOH: I would agree with that. I think it would not have been useful if the users had been on board at the point of model building. But it would have been very useful if, in the review process of the study, prior to publication, representatives not only of the American industry but of the European and Japanese industries and representatives of the third world, mining experts and regulatory experts had some input into the review process. My conclusion is that, in retrospect, the independence of the scholars at MIT was an important element in the credibility of the data. I don't think it would have helped that independence to have made the study subject to the control of the users, although I think the exposure of the earlier version of the study, in the review process, to a wider audience would have been a useful addition.

J. D. NYHART: I'll comment on that too from my perspective. I agree with what Ambassador Koh and Dr. Sebenius said about the independence. There's another aspect regarding management of the project. I don't think we would have got the modeling done. It was difficult enough to get it done under the circumstances, with the funding and time and human resources that we had. I think that if we were dealing at that early stage with much more complexity brought in by many more interests at the beginning, it would have been quite difficult.

I agree with the idea that it would have been very helpful to have had the criticism and input at the early review stage. The other thing I would say is that in the continuation of the modeling, the involvement of the modeling team as its use became significant was very important. The ability of Lance Antrim and Jim Sebenius—who were both on the front line of the negotiations working with Ambassadors Koh and Richardson—to come back up to MIT to give us a sense of what was going on in the negotiations so that we could work to modify the model and make it more useful was absolutely critical.

D. B. STRAUS: It seems at this point that the whole question of the nature and timing of user participation is a matter very much open for further research and development. From my point of view, at the International Institute for Applied Systems Analysis this is a tremendously underrated and underexplored question. Models are being built with very few users actually on the scene. I think this should be emphasized.

Elliot you have a different series of concerns.

E. L. RICHARDSON: They're not so much concerns, as points related to where Dr. Nyhart left off. I want to talk a little bit about the other possible uses that computer models might have for international negotiations. This is going to be a very sketchy indication of some of the considerations that seem to be relevant, but you might be interested to know that there were at least two other uses of computer models in connection with the law of the sea negotiations, neither of which, however, had anything like the practical application that the one you've heard discussed here this morning turned out to have.

One is a computer study of the dynamics of the entire negotiating process in the law of the sea negotiations. You should bear in mind that the seabed mining part of the treaty is part 17, one of 17 parts of the treaty. The issues we're talking about here are a fraction—say a sixth—of the problems dealt with in the seabed mining regime. Quite a lot of work has been done on an effort to feed into a computer the dynamics of the interactions among the attitudes of the various blocs, grouped by issue and national interest and so on, in order to see to what extent the outcomes could be understood in particular areas of negotiation in the light of these variables.

I attended a meeting under the auspices of the Overseas Development Council a few months ago devoted to a discussion of the validity of the analysis heretofore produced and the possible utility it might have in understanding better approaches to future multilateral negotiations. I'm somewhat skeptical on both counts.

I had also made an effort early on in my own role in the negotiations to feed into a computer variables affecting United States negotiating relationships with other participants in the conference. I was soon convinced that this was a worthless exercise, largely because there were no elements of the bilateral relationships between the United States and other countries that could be of any value in the negotiations in the Law of the Sea Conference. It needs to be emphasized in this connection that the United States may be a big strong country, but in a multilateral conference like this, it has very limited negotiating leverage, and none to be derived from threats or promises to individual countries extraneous to the subject of negotiation.

We fed into the computer things like the fact that the United States had a PL-480 program, an AID grant program being phased out, and other such relationships. Well, it became obvious after a little while that I was not about to go to the Secretary of Agriculture and say, Hey, let's squeeze Sierra Leone on PL-480, because they're not going along with us on seabed mining.

Hundreds of negotiations take place in any given year, and we can't arm all our negotiators with the power to apply that kind of pressure. In any event, in a complex negotiation like the law of the sea, you could still apply a sanction or promise or whatever only once. In the course of four or five years you may have a hundred comparable problems at least. As a

result, therefore, it has to be understood that the only real leverage the United States has is whatever attaches to the prospect that it won't go along in the end. One of the ironies of the Law of the Sea Conference, as Leigh Ratiner has pointed out, is that the United States may discover that what looked in advance like significant leverage deriving from the fear that we would not go along has turned out to be overinflated because, now that we haven't gone along, nobody will care.

At any rate, coming more directly to the main subject, I'm not sure that I would entirely agree with Dr. Nyhart's formulation of criteria that make a problem appropriate for a computer model in its relationship to multilateral negotiations. Uncertainty was important in the negotiations on this subject because it was important to convince members of the conference that seabed mining was a highly risky operation. It was dramatic to see the impact of a relatively minor adjustment in the prices of copper or nickel in terms of profitability as against that of rather sharp variances in estimates of the investment costs. As you come to see that what is involved is a very high risk enterprise, you begin to absorb the idea that, given these uncertainties, anybody who might be disposed to go into the activity at all would need to have a prospective rate of return significantly better than he could get investing in government bonds.

But in many cases you may be looking for the precise opposite. One of the areas in which computer models can have high relevance to international negotiations concerns environmental issues. There what you're seeking is so far as possible to reduce ranges of uncertainty and to identify variables that are so critical to the equation that it may be important to undertake additional research necessary to narrow those parameters of uncertainty even more. One could easily think of examples in which the application of computer technology would be relevant to that kind of issue, e.g., acid rain and of course nuclear power development. The role of the International Atomic Energy Agency with regard to the nuclear fuel cycle is integrally related to calculations of risk which, as you are well aware, involve very large numbers of variables.

In the context of arms-control negotiations there are a number of relatively easily recognizable opportunities. One of the most significant things about these negotiations is that they are now for the first time addressing the entire range of weapons systems from intercontinental ballistic missiles and submarine launched missiles at one extreme to conventional weapons under MBFR [mutual and balanced force reductions] at the other, with INF in between.

This means, therefore, that we have the potential for the first time of balancing complex and asymmetrical components. I won't elaborate the point, but there are also the uncertainties intrinsic to various combinations of verification devices, etc.

I will just conclude by saying that it occurs to me that one key factor in identifying the potential for the use of computers in negotiations—or at least international negotiations—lies in the recognition that an issue

either turns on or is significantly affected by a question of fact whose resolution would contribute to the ability to reach consensus on a given policy result or choice.

A second factor, obviously, is that the problem has to be of a kind that can be handled with a computer, which means that it must have variables capable of quantification, and presumably they must be numerous enough—and the data involved voluminous enough—so that it's worthwhile to do it by computer rather than by some simpler mechanism.

The process of committing a problem to this kind of exercise has the added advantage of insulating it from the more emotional and value-laden factors surrounding other elements of the debate, thereby contributing to a more rational process. I think that this can be a secondary value of the use of computer models in multilateral negotiations. They make it possible on the one side to deal with the rational issues that directly concern the model but also to generate an approach to the resolution of other issues in an atmosphere of rationality and increasing trust.

J. K. SEBENIUS: I would like to address some questions from the audience and related subjects. Some of you must be wondering what the MIT model actually looked like.

The program was written in Fortran-4, it was about several thousand lines of code, and the display capability was absolutely primitive. It was a simple printout, and it was designed much more to answer questions after the fact than it was during the case. A graphics capability would have enhanced it enormously, and today I'm sure that we could have done that much better and gotten real-time responses back and forth from either Geneva or New York to Cambridge and manipulated a lot of the particular variables much more effectively. But that's what the thing looked like and how we did it.

There is a second question relating to the nature of the model, and it's worth making a distinction here between two kinds of models that might be used in negotiation. One is of the negotiation process itself, that is, of the negotiation and its dynamics, the issues, possibly different sides' valuations on the issues, and, as Ambassador Richardson mentioned, possible linkages to other issues. But a model of the negotiation itself is distinct from what this model was, which was of the substantive issue under negotiation. It was a model of the technical and economic issues themselves.

There's a question as to whether early user participation in the development could have effectively been added to this model. My impression in this case is no, although that's a very interesting line of inquiry for research. By and large, such models of negotiations as I've seen that tried to model the negotiation itself tended to be for the tactical use of one side or another.

The second thing is that one tends to model what's specifically and easily quantifiable and chart what's happening in terms of positions on very well defined issues. Sometimes that leads to a creative process. But more often what it tends to do is set up a haggling process back and forth

on the position of an indicator, rather than defining the underlying interests and how they might actually be resolved.

There's a third question that relates to this. What happens in a negotiation when both parties have access to the same data and model? Usually one party does not want to let the other have all the information—the one who, say, wants to sell the land does not want the buyer to know the highway is coming through. In a sense the distinction that this question raises is whether negotiation primarily consists of one party getting more while the other party gets less in a situation where the buyer and seller won't see each other anymore.

In cases like seabed mining, the complexity of the issues and the uncertainties among them are such that if an agreement on the correct principles can be hammered out at the political level, then a number of the important scientific, economic, and technical issues underlying them can be elucidated jointly. In many cases, the participants figure out that their interests really don't strictly oppose each other. For example, the early Indian proposal for the law of the sea was that a bonus of a particular size be offered. A standard negotiation scenario might have been, "The Indians wanted it high, the Americans wanted it low, and they went back and forth." Instead, looking at this model, we understood that the time distribution of that payment was all important. It was possible—if the companies had a critical need for it early on and if the international community by and large was concerned with the welfare of future generations and in a much broader perspective—to distribute the payments over time in a way that met both interests. We came to understand the nature of the problem better converting it from this strictly distributive effort.

The second thing I've noticed is how important the sustainability of any agreement like this is. The financial agreements in the law of the sea are linked to a whole lot of other issues in a treaty that will have to work or be renegotiated in 20 years or so if they do not. To trick somebody in the short term in this seems to me very shortsighted and not at all in the spirit of what we want. In a practical sense, it comes right back to haunt you if it isn't sustainable.

T. T. B. KOH: I'd like to move on to a question that we're supposed to discuss in this segment, What other negotiations on the international agenda might make use of a computer model? And somebody from the audience has sent up a question asking, "To what extent can computer-assisted negotiations be useful in the area of the law of space?"

In the law of space, I don't see how a computer-assisted negotiation can be presently applicable because, as Mr. Richardson said in his last statement, the lesson or the generalization I've drawn from the law of the sea negotiations is that a computer-assisted negotiation is most useful when the outcome of the negotiation depends upon an agreement on facts or where the issue or question involved can be reduced to numbers. In the case of the law of space, those two criteria are not present.

Looking at Dr. Nyhart's list, I'm not sure which of the topics he has

included satisfy these two criteria. Let's take an example from the area of the international monetary system. As you know the Bretton Woods system of fixed exchange rate has broken down. What we now have is an international monetary system based on floating exchange rates. Some people think that the status quo works reasonably well and there's no reason to be alarmed by the breakdown of the Bretton Woods system. Others take a different view and have called for the convening of a high-level international economic conference in order to arrive at a new agreement based upon more stable exchange rates. And the question I've often asked myself is, Is there any way in which a computer might help us in answering the question whether the world is better off with an international monetary system based on stable exchange rates or is it better off with a system based on floating exchange rates?

The other area where I have been puzzled by disputes that appear, on their face, to be about facts is in the important area of arms control. Is this one area in which the computer can assist us in the negotiations? I'm puzzled for example by the ongoing talks that are taking place in Vienna, between NATO and the Warsaw Pact countries on mutual, balanced force reduction. The facts presented by NATO suggest that in the field of conventional arms the Warsaw Pact countries outnumber NATO on every component of conventional arms.

According to the facts put forward by the Warsaw Pact countries, this is not the case. According to their statements of fact, the conventional forces of the two military blocs appear to be more or less in balance. Is this a case where the issues and questions in dispute are essentially of a factual nature or not? And if they are essentially of a factual nature, would an objective assessment of the facts by a computer be helpful to the two negotiating parties? I'm equally puzzled by the negotiations on strategic issues, because here too there appear to be fundamental disputes about facts. The current negotiations in Geneva on intermediate nuclear forces is a very good illustration of this.

According to the NATO point of view, the Soviet Union has many missiles emplaced in the European part of the Soviet Union targeted on western Europe while NATO does not have any of these intermediate nuclear forces. When you look at the facts presented by the Soviet Union, they are entirely different. According to the Soviet point of view, in this segment, intermediate nuclear weapons as in the intercontinental nuclear forces, the western and eastern numbers appear to be close to parity. I'm very puzzled by this and ask myself repeatedly whether the questions under dispute are essentially questions of fact or disputes about something else dressed up as questions of facts? I think it might be interesting to hear from either the members of the panel or the audience on whether or not computer science could be helpful in the whole area of arms control negotiations both in conventional weapons and nuclear weapons.

D. B. STRAUS: Assuming that the members of this panel wanted to

persuade other international negotiators to try computer-assisted negotiations, how could we even get them to examine seriously the possibility? Because we have already recognized the various obstacles of distrust, of disinterest in sharing data, of adversarial attitudes. Is there something in Elliot Richardson's earlier suggestion of developing a showcase model of how the negotiations might progress with CAN? Could such a model be used as a selling tool to get the parties hooked, if you will, on this kind of a process?

J. D. NYHART: As I understand this, it's a different kind of a model you're asking about—it sounds like it's more of a process model. I would come back to the criteria that have been thrown out on the table by Ambassador Koh and Mr. Richardson and ask about the numbers. I mean, where do you have something solid in the form of the technology involved? I think that uncertainty is a characteristic of problems of complexity, and yet the goal is to reduce the uncertainty not to enhance it. I would rather take something that had value that was being negotiated about—such as in the Antarctic, for example, the value of either the living resources or the nonliving mineral resources—as a focal point. You know that it's going to come down at some point, as Dr. Sebenius said, to a question of somebody getting more and somebody getting less of resources of economic value. So I'd answer the question in that way.

D. B. STRAUS: Well, let us assume your requirement that the issue should include tangible values and large numbers. Then what would be the best approach to the parties? You've already suggested that a model should first be built by academics before the users get in. But how do you just make that bridge between the construction of a model and its eventual use? This bridge is obviously not being crossed very often because we are talking about almost a single case rather than what I think we are suggesting should be hundreds of cases.

T. T. B. KOH: I'd like to ask you a question, Dr. Nyhart. I'm not sure whether you are saying that arms-control negotiations do not satisfy the two criteria suggested or not. If your answer is that they don't, I would ask you why. Isn't arms-control negotiation preeminently about numbers—about the number of the men under arms, about the numbers of weapons, and the different systems of weaponry?

J. D. NYHART: The element that is missing—and it ought not to be critical, it's just that I don't know the answer to it—is "What do you use as your value?" I mean, survival is the bottom line and of course it's the most critical thing. I would suspect, and again I'm speaking from total ignorance, that both the United States and the Soviet Union have already undertaken some rather sophisticated level of modeling these problems. I hope this is being done, but I just don't know.

J. K. SEBENIUS: I'd like to make another distinction that may help this a little bit. I think that computer modeling is used a great deal in arms-control negotiations, but mostly by one side or by the other side with respect to the suspected or feared capabilities of the other and how the

two would fare in this exchange or that contingency. I think what we're mostly talking about here is the models that are of joint use, and I'd add another criterion to those that Ambassador Koh laid out.

There's a distinction between uncertainties that we might think of as natural or technical or economic versus those that we think of as strategic or game theoretic or behavioral, where what you're trying to model is what somebody else actually has done or is doing. I think that models of the former tend to be more useful than those of the latter case for a fair number of reasons. The type of uncertainty is important.

This leads me to think that in arms-control situations, the place where a joint model might be very useful is in a subcategory of those. Say United States and Soviet negotiators were very worried about what to do about a crisis situation that might involve accidents. They very well might get together to try to build a model of a variety of such situations and the possible responses of one side and the other to determine what kind of system they'd like to agree on that would tend to minimize that possibility.

I can imagine a very useful model and a collaborative attempt there, whereas a joint model on what the real intentions of the Soviets or the United States are seems a lot less plausible.

T. T. B. KOH: But if I may say so, the negotiations in Vienna are not about intentions. It seems to me that in Vienna the two military blocs, NATO and the Warsaw Pact, have an agreed objective and the agreed objective is to negotiate mutual balanced force reductions and what is preventing them from making progress in these negotiations is that they proceed from such divergent assertions of fact.

So my simple question is, Why can't we help the two negotiating parties narrow the gap which apparently exists between them about what the facts are? Why can't the Stockholm International Peace Reasearch Institute, for example, build a computer model to help NATO and Warsaw Pact in their talks in Vienna?

Why can't academics from countries in the two military alliances get together and independently see whether or not they are able to build a joint computer model which can be of some utility in comparing the conventional armed forces of the two sides. I mean these are some of the questions I'd like to raise.

E. L. RICHARDSON: Before coming to the question of MBFR, I want to go back to Dr. Nyhart's question about what you might wish to obtain as the end point of your calculations, of what is the equivalent of an answer in the arms-control field to the question of internal rate of return, given certain assumptions, in seabed mining.

The answer is implicit in the title of the negotiations in Vienna, "mutual and balanced force reductions," and it's certainly the understood objective of the START negotiations and the INF negotiations: namely, rough parity or equality under conditions of optimal stability. Some combinations or mixes of weapons on each side are more inherently unstable than others, e.g., a situation in which each side's forces consist

predominantly of intercontinental ballistic missiles with a high degree of accuracy and significant vulnerability in their placement. Under that sort of circumstance, each side has a relatively greater incentive to launch a preemptive strike. So the objectives of arms-control negotiations, broadly speaking, are to achieve parity at lower numbers with at least as great stability in the mix on each side as you had to begin with and, if possible, to increase that stability.

Now you can visualize getting out of the computer the optimization of various combinations of weapons mixes, locations, and so on, and you could also feed into a computer calculations designed to answer questions about parity given the asymmetries of the mixes of weapons systems on each side.

You could assign quanta that would equate range, accuracy, vulnerability of the launching site, velocity, and so on, so as to give you answers as to the relative equivalence of mixes of systems in which one side had fewer bombers, more fighters, etc. That is at least theoretically highly possible; I don't know whether it is being done, or has been done. I have been arguing for quite a long time that something like that should be done. And as I said a moment ago, the most important thing about the East-West negotiations now is that for the first time they do address in one form or another the whole range of systems. It's like taking the microphone, a glass, a pad of paper, and a couple of other objects and putting them on one side of a scale and then looking around this dais to find another combination of objects that will balance the other side of the scale. If there are relatively few objects on the table, it may be very difficult to get the two pans of the scale to balance, but if you piled onto the table all kinds of odds and ends, it would be a lot easier for each side then to pick out a number of things that would balance each other.

So in one sense the fact that we now have negotiations across this range is complicating, but in another it could be simplifying. You could, for example, visualize using a computer to determine the equivalents between the mixtures, i.e., what combination of things on one side would balance out a very different combination on the other.

Going directly now to MBFR, I'm afraid, Ambassador Koh, that the problems of fact here don't on their face lend themselves to either involvement of neutral arbiters or the use of a computer. The reasons why the numbers are in disagreement are things like whether or not certain units in a Soviet army corps are to be deemed to be combat troops or not, or whether they're performing roles that in the NATO side are performed by civilians. You thus get counting problems that are essentially definitional; there are also disputes arising over the question of whether or not you count aircraft on a basis that recognizes their downtime while being serviced, and so on. What are the effective combat numbers? And there are questions of when troops are on the line, and part of the problem is that the Soviet forces can of course readily be withdrawn into the Soviet Union and relatively rapidly redeployed on the Polish-German frontier, and so the question then is, How should this affect the balance?

These are the hangups, and the possible involvement of neutrals would raise the question of what the Russians—or for that matter NATO—would let you do in arriving at an independent count. The western numbers, of course, are obtained from satellite and aerial photography, mainly, and by espionage. But even so, whatever may be the relevance of the MBFR example, there is certainly ample room in the field of arms control for the resourceful use of computer technology.

D. B. STRAUS: Mr. Richardson, while you're still close to the microphone, a number of questions have been handed up from the audience. Assuming that computer-assisted negotiations can broaden the arena of discussions in this field, in the arms field, what would be the next practical step? In other words, where should the model be built? Should it be a United Nations initiative, some have asked, or should it be another MIT model, or should a softer approach be made to try and get an agreement among the parties that such a model should be built?

E. L. RICHARDSON: I think the idea of equivalence is a useful one. There are a lot of subjects, by the way, in which it would be useful to do quite a lot of work on quanta. That's where you would have to begin before you could feed anything into a computer and get something useful. There was, of course, one major, crude step taken early on in arms-control negotiations with the evolution of the concept of the "launcher," when it was decided to deal with submarine-launched missiles, ICBM's, and bombers as equivalents: they were all launchers and could thus be traded off for one. Numbers of warheads and throw-weight are less crude measurements. What is needed, I think, is to carry the quantification process much further.

You touched, Ambassador Koh, on the INF problem, and you asked, What's the answer to the point being made by the Soviet Union about so-called forward-based systems on the western side and the weapons that could be launched from naval vessels in European waters? Well, part of the difficulty is that the West is saying that you can't equate these fighter bombers, which are deployed primarily in the event of possible conventional conflict, with weapons that can reach western European cities from Soviet soil, even from east of the Urals, in 7 or 8 minutes. Since these are noncomparable on their face, there's no ready way of dealing with the factual question of equivalence there until you can define terms of equivalence. You'd have to sell the concept before you got to that stage, and if you made significant progress in defining those terms, it would then be relatively easy to wheel out the computers.

The initiatives for this could come from a lot of places. It could come from the United Nations. Indeed, it could be a very useful exercise for the United Nations, and I personally would like to see it come from there for a lot of reasons. I think we are underutilizing the United Nations. The United Nations ought to get off its polemical kick on the politicization of extraneous matters and get at some of these things. Ambassador Koh is just the man to lead such an effort, and I can't think of a better result to

come out of this discussion than that he would take that on as his next project.

J. D. NYHART: I'd like to answer some questions from the audience. One is about modeling of values. Yes, it can be done and I think it ought to be done: it was not done in this case. More is known about the problems of separating facts from value, I think, with each passage of each year and it should enter into modeling efforts and I hope they will in the future.

Second, somebody asked about environmental impacts. There has been a really monumental study done called DOMES, the Deep Ocean Mining Environmental Study financed over several years by the Department of Commerce, NOAA, looking at the environmental impacts of deep ocean mining. There was one effort to take these data and to put them into the context of impact on return, or whether it was significant or not in dollar terms. My impression is that the environmental impact of the deep ocean mining by this country, for something that has not come into being yet, has been reasonably well addressed.

Somebody asked if at MIT, the software was available for purchase by industry. We have licensed it to the EEC. As you know universities all over the country are trying to make money from their research projects. We have responded at one time to a potential inquiry by industry saying that we could license it, and would like to get involved with them.

T. T. B. KOH: I think perhaps I would close the discussion on this note, that the experience I've had in the law of the sea negotiations with the use of a computer has awakened me to the importance of this branch of learning and the efficacy of the computer in multinational negotiations. I think we, in the diplomatic community, should be much more aware than we have been in the past of how the computer scientists can help us in our negotiating process. And off the top of my head, I can think of several areas in which the computer may be helpful in our negotiations, arms control being one. The management of marine resources is another; the enactment of environmental legislation both at sea and on land is a third. In the economic negotiations, I can also see a role for computer-assisted negotiations.

So I go away reinforced in my convictions that this is an area where the two cultures ought to get to know each other much better.