
MASSACHUSETTS
INSTITUTE OF TECHNOLOGY

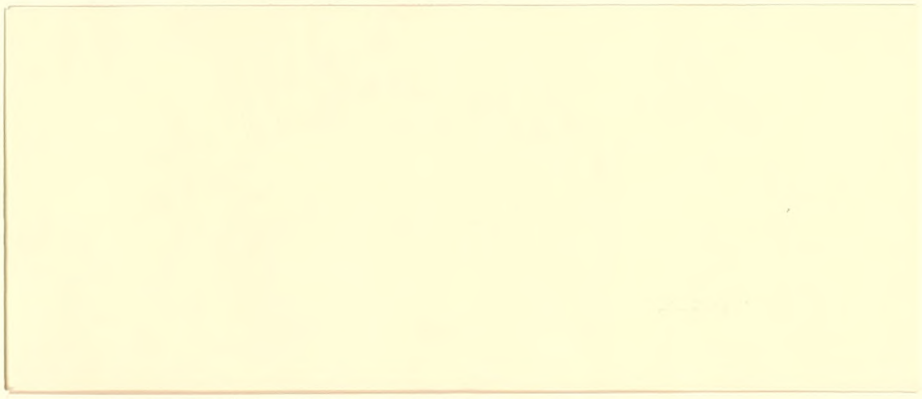
WORKING PAPER
ALFRED P. SLOAN SCHOOL OF MANAGEMENT

COMPUTER MODELS AS SUPPORT FOR COMPLEX NEGOTIATIONS

J. D. Nyhart and C. Goeltner*

WP 1955-87 November, 1987

MASSACHUSETTS
INSTITUTE OF TECHNOLOGY
50 MEMORIAL DRIVE
CAMBRIDGE, MASSACHUSETTS 02139



COMPUTER MODELS AS SUPPORT FOR COMPLEX NEGOTIATIONS

J. D. Nyhart and C. Goeltner*

WP 1955-87 November, 1987

* The authors are, respectively, Professor of Management and Ocean Engineering at the Massachusetts Institute of Technology and Ph. D. candidate, Department of Ocean Engineering, Massachusetts Institute of Technology.

The work described in this paper is being undertaken at the MIT Project on Modeling for Negotiation Management. Support from the following is gratefully acknowledged: MIT's Project Athena and the Program on the Processes of International Negotiation at the American Academy of Arts and Sciences under a grant from the Unisys Corporation.

Abstract

Eighteen computer models are identified as a basis for understanding the existing and potential roles of computers in negotiation, mediation and other forms of dispute resolution. Their functions include pattern seeking, simulation, assessment, solution seeking and education. Some are descriptive, others prescriptive. Some address a specific context whereas others primarily focus on the negotiation process. Whether or not the negotiating parties participate in the model-building process is considered a significant descriptor. The authors hope the classification of models they proffer will help forward an understanding of the state of the art, and hopefully will stimulate ideas for more comprehensive approaches.

Table of Contents

I. Using Computer-Based Models in Negotiation.

The use of computer-based models in negotiation, mediation and other forms of dispute resolution is a newly established component in the field of dispute resolution.

In the last decade, computer models have been used in a number of negotiations and disputes. During the UN Law of the Sea Conference a simulation model helped to settle a dispute about proposed contractual terms for deep seabed mining (Nyhart 1983). A Model for the assessment of cost overruns played an essential role in a shipyard's litigation with the Navy (Cooper 1980). In the negotiation about an international oil spill clean up fund, a model set one basis for the final agreement (CLC 1984). In several "mass tort" cases, a computer analysis supported the court's decision making (McGovern 1986). In several instances, the use of systems dynamics with computer support helped to resolve conflicts on the executive level (Roberts 1976, Senge 1985). In planning for large land use projects, positive experience has been made by joint model building approaches (Andrews 1981). The assessment of negotiators' utility function and the use optimization routines served in some employee relations cases to find acceptable solutions (Rohrbaugh 1980).

And recent books and papers have probed these and other uses. (Straus 1974; Sebenius 1981, Raiffa 1982, Nyhart 1984, Nagel 1987, Nyhart and Dauer 1987). From these diverse sources, it appears that use of computer-based models in negotiation is growing, though it faces significant obstacles.

This paper provides a preliminary examination of approximately twenty such uses, with the goal informing both the direction of a new research project at MIT on the uses of computer models and modeling in negotiation and a wider audience. Different approaches will be identified as a basis for understanding the existing and potential role of computers.

It appears that the use of computer-based models--and the process of model-building--as aids in negotiations and other forms of dispute resolution offer the promise of new power for managers and others in the negotiating of major disputes and everyday events. Additional help should be welcome. It is a truism to say that people negotiate about virtually everything. A glance at the following array of topics reminds one of the ubiquitous quality of negotiation:

> Negotiations over international treaties; Peace negotiations between countries in war; Arms control negotiations; International trade negotiations; Labor management negotiations; Negotiations between contractors; Negotiations about environmental conflicts; Negotiations about macroengineering projects; Tort and liability law; Negotiations about political issues; Interpersonal negotiations about private issues, etc.

And negotiations are becoming more complex. The development of technology, the rapid improvement of national and international communication, the increasing impact of man made projects on the environment (Chernobyl), rising debt of the Third World are some of the elements which lead to more and more complex conflict situations. On the more personal level there is a trend of more and also more expensive

conflicts between the citizen and, for example, insurance companies or medical institutions. Both institutions and individuals dealing with conflict resolution or prevention have to adapt rapid changes, often involving technical and transborder uncertainties.

Research is underway at MIT to develop new generic tools for negotiators, to understand their potential and to broaden acceptance of their use. Our approach focuses on development of new software and techniques for negotiation-related modeling. In order to make accessible their full power, this research integrates several other major components into a fresh concept of negotiation management (Nyhart and Samarasan 1987). These include the use of models and to modeling to achieve increased integrative bargaining--wherever feasible jointly by the parties themselves; emphasis on using them to enhance the combining of elements of a negotiation into a coherent and satisfactory outcome; their application at different times in the negotiations; and understanding the impacts of their use in negotiation.

There are three substantive parts to this paper. One reviews some basic characteristics of both negotiating and modeling that give shape to ways of thinking about using models as aids to negotiating parties and third-party facilitators (section II). A second offers a tentative set of types of roles which models have played in the materials reviewed in preparing this paper (section III). And finally, eighteen different models or approaches used in or designed for negotiations are highlighted to provide readers more detailed, but still superficial insight into this subject (section IV). Some conclusions follow.

Much of what is described is not either traditional empirical research or case studies, but rather the descriptions of projects to create and use programs and/or software. There are also descriptions of efforts underway to use models in negotiations which have not yet been written up, but regarding with which the authors obtained information.

In sections III and IV, both the text and the organization of the material is intended to review the uses and potential uses of modeling as tools to aid parties and facilitators in the negotiation process. A final note: the aim here is to describe--it is not to evaluate.

II. Ways of Thinking about Models and Modeling in Negotiations: Some Salient Characteristics.

Because people do negotiate about almost everything, sorting knowledge about the negotiation process by catepovics of subject matter (see above) does not provide a very useful mechanism. (Knowledge about the substance's, nevertheless, an elemental part of negotiation.) Negotiation scholars and others have identified several characteristics which seem more useful in enabling analysis of negotiation. Here the present authors identify only a few which bear particularly on the use of computer-based models in negotiation. Those concerning negotiation and models are mentioned separately before an attempt is made to synthesize the two to provide a scheme of analysis for understanding better how models have been used in negotiation.

About Negotiation.

a. Number of Parties. One important way to categorize conflicts is the number of parties involved. Usually we say that at least two parties are necessary for a conflict though it is often very hard for a single person to evaluate conflicting ideas and come to a decision. The other extreme case is a negotiation on the international level where sometimes more than hundred parties try to come to an agreement (Raiffa 1982).

b. Number of Issues. Besides the number of parties the number of issues is highly important. In a single issue case there are no trade-offs possible; often these cases are described as win-win or zero-sum conflicts. If there are more issues between the parties it is possible to find trade-offs and a great variety of different solutions may be available. One good strategy in such situations is to "increase the pie" (Fisher, Ury 1981). Unfortunately in this situation it is not always easy for the parties to find their own utility function, the number of reasonable trade-offs for an efficient agreement. A classification of types of negotiations in terms of number of people and number of issues is usually helpful for an analytical description of a situation, but there are other aspects, which are important for the characteristic of a certain conflict.

c. Institutional context. Here the analysis makes a further distinction concerning the kind of process in which the negotiation takes place. One major institutional context where there is experience using computer models are court related processes; models have been used in the following ways:

solutions to get from a no-win situation to a win-win situation. In these cases one should not overlook the high degree of asymmetry, one party is the engine the other is the brake; a special strategy is necessary to come to an efficient agreement which satisfies both parties.

d. Other. The relevance of the conflict, how many people(s) depend on the outcome of the negotiation is an important criterion. In international, national or regional conflicts different methods are used to come to an agreement. Political, economical and cultural aspects also belong into this category.

The following list includes further aspects which have to be considered when analyzing a conflictual situation.

- Win-win no-win situation, distributive or integrative bargaining
- Size of the conflict, political and economic relevance
- Involvement of the parties, voluntary or not
- Climate, what is the emotional relationship between the parties
- Time pressure
- Pressure from constituents
- Formality of the conflict management process
- Relevance of technical knowledge for the conflict
- Distribution of power
- Stage of the development of the conflict

-the use of a model by a master appointed by the court, i.e., a third party in the middle, trying to resolve the dispute, for example: mass torts.

-the use in a law suit of a model by one party to support its arguments.

Under circumstances where conflicts occur frequently between the same parties, formal procedures have been established to resolve the disputes in a more efficient manner. For example, the relationship between the U.S. Navy and the private ship builders is an illustrative case for formalized dispute resolution procedures. Depending on the size of the conflict, different administrative Navy-shipyard internal channels are used to resolve the dispute. However in quite a few cases the parties do not reach agreement and litigation cannot be avoided which especially in this scenario leads to quite unsatisfactory solutions. Because of the size and importance of the organizations (U.S. Navy) involved and the high frequency of conflicts the introduction of innovative conflict management procedures could be beneficial for both parties.

Another aspect of the institutional context is whether the parties come together voluntarily or not. When the Navy awards a contract to a shipbuilder, both parties have common interests and usually try to avoid unnecessary conflicts also under the perspective of long term relationships. On the other hand for the construction of a highway there is one group which has an interest in the development of the project whereas another group tries to prevent it. One group is the initiator the other builds up resistance. In the beginning there do not seem to be common benefits, the concept of integrative bargaining {10} tries to find

These are some of the more important features of conflicts which can be used for their classification, in most cases the attributes are not mutually exclusive.
They can help to develop guidelines with respect to what is the optimal conflict resolution tactic and what models could be used most effectively. We recognize that models are only a subcomponent in this process.

About Models

A model may be defined as an abstraction of reality, whose purpose is to represent a well-defined, real-world process and to help obtain insights in the functioning of this process (Psaraftis 1985). Frequently, whether planning about future events or settling disputes that have developed into conflicts people use some kind of model to reach agreement or to achieve a set goal. Mostly, this process is handled by a rather intuitive models or some type of management models. The focus in this research is primarily on computer-based models. Computer-based models are closely associated with and implemented by a computer program, which is typically used as a tool to obtain insights into a particular process. The association between the model and the computer program is sometimes so close, that the phrase "computer model" (or often only "model") ends up being used to describe the computer program itself rather than the abstracted model implemented in the program.

There are several characteristics which are useful in understanding the uses of models in conflictual/negotiation situations.

a. Context - Process. Context models basically deal with the underlying subject matter of a negotiation or planning process, for example, a simulation model of the effects of pollution emissions into the atmosphere.

A process model on the other hand, is concerned with the dynamics and structure of the negotiation. Its major parameters are, for example, determined by the number of parties and issues and the function of their relationships in a negotiation.

b. Descriptive - Prescriptive. This distinction addresses the function of the model with respect to the uses of its output. In prescriptive models, the parties get normative information. An analytic program for understanding the dynamics of past events and the strategic moves of the players or a negotiation training model are samples of descriptive models.

c. Simulation - Optimization. Sterman categorizes computer-based models basically in terms of simulation and optimization models with econometric models falling as a subset of simulation models. Simulation models are essentially descriptive. Optimization models give the user the best result or outcome and are prescriptive. Econometric models are based on statistical data from physical, economic or social science environments (Sterman, 1985).

d. Role of the Parties as Related to the Model. The main distinctions here are, first, whether the model is intended to support one or all negotiating parties, the third-party neutral, or everyone; and second, the role the negotiating parties play in the building of the model. In some cases, parties may use a ready-made program with agreed-upon parameters (an ordained model). In others, parties may be involved in varying degrees of the model building (joint model building).

These distinctions about modeling--whether models are mainly concerned with context or process; whether they are descriptive, prescriptive or both; whether they are dynamic or optimizing and whether the negotiating parties play an active role in their development--form one useful dimension for understanding more about models in negotiations.

III.Primary Negotiation Function of Models

Another dimension is the role the models have played in the negotiation process. Observation of the material described in section IV suggested five types of roles. They are identified below. Taken with the above characteristics, they form the framework both in the text and Table 1 for summarizing the eighteen models identified in section IV of this paper.

a. Pattern-seeking Models. The first group analyses complex past cases with common characteristics, in order to identify patterns useful to decision makers. Data about these events are grouped into similar categories providing bases for analysis. Hence they are focused on retrospective data and are static in character.

b. Simulation Models. The primary goal of this group is to provide simulation of a context, accurately and in varied degrees of detail, in order to represent in a real way the subject environment or situation. (Generally, most models may be said to provide some simulation.) Simulation can enable parties to experiment with different outcomes, to play "what if" and to test which different variables (i.e. issues) are the sensitive ones in terms of affecting outcomes. Getting the parties together to build a simulation model may well indicate where there are areas of agreement, articulating those areas of consensus, and where areas of disagreement exist.

The search turned up two major subcategories of simulation models: those related to the use of a common modeling approach, Systems Dynamics, and a second general grouping, labeled "context" models, focusing on discrete subject matter with the aim of simulating it. Typically, these have been developed with particular uses in mind.

c. Assessment Models. Yet another category of models are aimed primarily at estimating or judging the value or character of alternatives from among a series of several choices. Most frequently there is a substantial degree of uncertainty about the value or

character of the different choices or the likelihood of their happening. Therefore, these models involve the assignment of probability to the choices, establishing sequential seniority or preference.

d. Solution-Seeking Models. These optimization models go a significant step further, analyzing among the possible outcomes for those that most fully suit identified and pre-stated decision or solution criteria. They assign probability through following logical or mathematically constructed rules or statements. In the negotiation context, these models are collected by some under rubrics such as "conflict analysis". They include game theory and operations research applications and a variety of rule-based decision support system models.

e. Teaching Models. Some models are used in exercises and games for classroom and other teaching environments.

IV. A SELECTION OF MODELS FROM THEORY AND PRACTICE OF NEGOTIATION

The following paragraphs give an overview of different contexts and approaches of eighteen computer models related to negotiation.

Pattern-Seeking Models.

1. Cascon II (Bloomfield 1972). This model is used to analyze small wars with respect to their quantifiable characteristics, for example duration, parties involved, incidents which lead to escalation of the conflict etc. A database has been set up which includes the analysis of more than hundred historic events. If the user wants to analyze a new situation the program compares it with the old cases and investigates differences and commonalities. With this information the user gains a better understanding of the ongoing situation. He can estimate the most likely development of the present conflict and can also explore the best means to end hostilities. The primary use of the system is to analyze the characteristics of small wars, either in the past or in the present. A useful tool for the student in history or political science, it can also be used to support decision makers in order to get a more balanced view of a conflictual situation. It is even thinkable to expand the basic system to an active negotiation support tool used by both parties, which could help them in case of conflict to avoid or eliminate misunderstandings and stimulate means to end the conflict.

2. Mass Tort Management (McGovern 1986). In at least two mass tort cases, the Asbestos and Dalkon Shield cases, a court has appointed a so-called master to find ways to cope with the huge amount of very similar cases which the courts would not be able to handle in a reasonable amount of time. Computer models were used to encourage out of court settlements by deriving the most likely outcome of a court

judgment. The basis of the model in each case consisted of already settled cases and the factual data which lead to the courts decision. The next step was to collect the same data for the outstanding cases and compare these data with the already settled cases, based on the notion that the same set of variables for a plaintiff would or should lead to the same award from the court. The structure of the input data was developed with the help of defendants, plaintiffs, and the court; all data which any party thought relevant to the case were included. With the given database a functional model had to be developed which calculated the most likely award. Different extrapolation methods have been used to derive numbers which could be reasonably justified to simulate the behavior of the judge. The plaintiff then had the option to sustain his claim in court or go for the computer-based settlement.

Simulation Models.

3. Systems Intervention (Stearn, Roberts 1976). In several cases in the health management area, combinations of systems dynamics and behavioral science techniques, called "systems intervention", have been used to resolve conflicts among managers and other groups at two hospitals. Although in this instance computer models have not directly been used, the approach includes the basic principles which we find in computer supported negotiations in an integrative bargaining mode. As one of the most important conditions for a successful conduct of the procedure, representatives of all interest groups participated jointly in the model-building process. Systems

dynamics techniques were applied to model the process which lead to the conflict. This procedure enabled the parties to see the problem more rationally and gave them new insights which finally led to the creation of a commonly acceptable solution.

4. Ship Production Simulation (Cooper 1980). During a litigation about cost overruns between the U.S. Navy and a shipyard, a simulation model for ship production, focusing on the impact of change orders on cost overruns, was used to support the shipyard's claim and helped them to achieve most of their desired goals. In this case the model was not built jointly but only by one party. Because of the openness of the approach, however, the other party and the court were convinced that the computations led to reasonable results and these were finally used as a basis for a settlement. Other than in the joint model-building process, here the complexity of the underlying technical process, i.e. the impact of change orders on costs, made it necessary to let a team of experts develop a simulation model, which could capture the subtleties of the problem accurately enough in order to produce credible results.

5. Systems Thinking (Senge 1985). The use of systems dynamics models as a planning tool among executives (and implicitly to resolve differences among them) is showing promising results in several companies. The process is helping to promote understanding and overcome barriers to change. It is important that the key persons who have the power to direct change are involved in the process. Following the above mentioned approach using systems dynamics

techniques, this approach focuses on a computer modeling component. The use of easy access simulation tools which can be quickly understood by the layman is an important factor enabling decision makers make use of this technique. By building the model of the underlying problem themselves, users can trust its results and can incorporate them into their own decision making processes. Although the models created in this fashion are extremely simple, in many cases they still can capture the level of aggregation which is needed by the decision maker.

6. MIT Deep Seabed Mining Model (Nyhart 1984). During the UN Law of the Sea Conference, the dispute about the allocation of economic rent from deep seabed mining activities beyond national waters was facilitated with the help of a model simulating and forecasting the economic effects of different proposals. The model had been built by a neutral group. In several sessions, the model was demonstrated to different parties of the negotiations. Going through this learning process of the users the model was eventually accepted and then used to support each side's point of view. Simulating the scenarios according to the different proposals, the model could reveal extreme positions which then in turn were modified so that they became more realistic. This iterative process was a major aid in the negotiators' reaching consensus about the technical facts of the proposal of how to structure the deep sea bed regime.

7. Oil Spill Cleanup Cost Model (CLC 1984). During international negotiations at the International Maritime Organization (IMO) for an oil spill cleanup fund, a computer model played a major role for reaching an agreement. The model included a data base of recent oil spill statistics which was extrapolated to forecast the occurrence of oil spills world wide. All of the information was publicly available. The program had initially been developed to support the U.S. negotiators. Because of the relative simplicity of the model its credibility was never doubted and the model was later jointly used by the other participants. The main issue of the negotiation was the contribution of each country to the fund, which should be done in fair manner according to each nation's shipping interests, responsibility for oil spills, consumption etc. With the given database, the computer model could quickly simulate the effects of each country's proposal on the cost distribution. With the database accepted by all parties, it was only a question of a few iterations until an agreement could be found.

Assessment Models.

8. Adaptive Environmental Assessment (Andrews 1981). During the planning for several major construction projects with significant impacts on the environment, a workshop process has been successfully applied where a computer model was built jointly to simulate the effects of the project on different groups' interests.In the first part of this process, all participants are to agree upon the different subjects involved; the often extremely complex system had

to be divided into subcomponents, which was further refined by a group of experts in this field. In the overall planning it was important that the exchange of data among the subgroups was organized beforehand. Then each group built a first version of their submodel. Next, these submodels are connected, which is done by computer modelers. This integration process had to go through several iterations until the model would produce results satisfying everyone. The building of a joint model had an important effect on the negotiation in so far that it drew the attention away from the initial conflict and rather focused each group's effort to achieve a model which would fit into the common global system. Although in some cases the performance of the model was not satisfactory, the psychological effect of the entire procedure was helpful for diverging opinions to come closer to consensus.

9. Decision Analysis Systems (Raker 1986). Computer models have helped lawyers and clients in the assessment of the success in litigation by structuring the possible outcomes and their probabilities. The model used here is mainly a computerized decision-tree which allows the user to assess quickly the situation and to reach more objective insight into the problem. A major factor for the success of this method is whether the client is willing to listen to a rational approach or not. If so, the lawyer frequently, has been able with the help of the model to discover the discrepancies between the clients initial assessment of his case and a more realistic outcome. The decision tree model essentially incorporates the expertise of the lawyer and simulates the most

likely outcome for the case in court, the uncertainties are represented by attaching probabilities to different possible scenarios.

Solution-Seeking Models.

10. Mediator Support (Blass, Raiffa 1986). This computer model supports a human mediator in a two party multi-issue negotiation. The first task of the mediator is to establish both parties' utility function, which is here done in a discrete rather than continuous manner. With this information, the computer then calculates all Pareto efficient solutions with the given utility functions. During an actual negotiation, this information alone is not very useful yet, difficult as it is to pick a point on the Pareto frontier. The current version is more aimed at the so-called post settlement settlement, where the parties have already found an agreement, but where then with relatively few issues it is highly unlikely that the parties have found a Pareto efficient solution. There are still cards left on the table. Now the mediator can help the two parties to improve their gains, which is not always easy because of equity considerations. Usually one party agrees only for the other side to improve the outcome when its own gains are on a similar scale.

11. Computer Third Party (Kettelle 1981). This concept was derived from the specific case of U.S.- Soviet arms control negotiations, where both parties are highly unlikely to accept another country as a mediator. As a solution for this problem, a computer serving the role

of a third party is suggested. In principle, both sides provide their private information in a cryptified manner to the computer which then helps them to discover possible agreements. The main problem of this concept is the structure of the input and output data. One thing seems to be obvious, the output data of the computer have to be available to both sides. No party would accept that the computer's revealing information to the other side which might be useful to reconstruct its private information. Although conceptually possible, a software system has not yet created which would explore the potential of this idea.

12. Analytic Mediation (Rohrbaugh 1980). A program helps parties in a multi-issue, multi-party negotiation environment to reach and optimize agreements. The problem of an analytic description of the preference function is dealt with by ranking the issues. A main part of this system handles the representation of the utility function according to multi-attribute theory. The system has been used several times in public disputes. On average it takes the parties six to ten hours to establish a seemingly accurate quantification. An optimization routine then, finds a set of optimal agreements. It was frequently observed that the final results, as suggested by the computer, did not necessarily coincide with the parties' subjective feelings and often the shape of the utility function changed dramatically during the negotiation -- a fact which points to the limits of the usefulness of the concept of utility when applied to real-life negotiations.

13. Conflict Analysis Program (Fraser, Hipel 1984). This computer program is based on the principles of game theory. It is primarily designed to support the decision of one party in a negotiation or planning process. Like all quantitative negotiation support programs the first step of the program deals with the representation of the utility function. Rather than weighting the importance of each issue, this program uses a ranking system. The next input is the guessed utility function of the other parties. With this information, the program evaluates a set of decision alternatives based on game theory. It includes calculation of the stability of each possible outcome, which means whether the parties would have an incentive to settle at this agreement or rather pick another point. Apparently one vulnerability of the program is guessing the utility function of the other side. The recommendations of the program are perceived useful in accordance with the accuracy of this assessment.

14. Negoplan (Kersten et al. 1987). This non-quantitative approach is based on logic rules. It is designed to help one party to understand better the effects of different proposals in a negotiation. The user has to develop a goal tree which incorporates all available subcomponents. Sensitivity analysis performed by the program allows the user to find out how changes of his position on one issue affect his overall goal and the other subcomponents. Although not using directly a utility function, in a way the design of the logic tree can be regarded as a way to quantify preferences.

Teaching Models:

15. Diplomat (Harvard Negotiation Newsletter 1986). This expert-system has been designed to teach the principles of integrative bargaining. A player is first introduced to a negotiation scenario where a factory and the environmental protection agency negotiate about a set of clearly-defined issues whose utility function is given in monetary terms. One side is represented by the student, the other by the computer. The behavior of the computer is ruled by a knowledge base which incorporates a set of rules representing integrative bargaining behavior. With the given rule base the performance of the player can be measured quantitatively. The behavior of the student is measured against the subjective assessment of a good negotiation style as it has been programed into the knowledge base of the computer.

16. Arms Race Simulation (Kreutzer 1985). Based on Systems Dynamics, this model illustrates the main causes of arms races. The system has not been developed for the use during an actual negotiation, but it represents an other example from the Systems Dynamics world where models can be used to illustrate different proposals and their effects on the parties' interests. Because of the user-friendly interface, students can directly participate in the model-building process and gradually build more complexity into the model.

Synthesis Approaches:

Some combinations of models and other processes are designed primarily to bring together information, insights, data and analytic power from different substantive fields and disciplines. These are designed with a synthetical purpose in mind, to bridge among different traditional groupings of information or analytical approaches. Also included in this category are models or approaches specifically designed to combine two or more of the functions outlined in the above paragraphs.

17. Mediator (Jarke 1985). This approach is a computer system designed to facilitate multi-party, multi-issue negotiations. Emphasis is put on data and knowledge sharing, where the computer provides the communication protocol. The system is based on a "database centered decision support system design" because of the large amount of data used during the negotiation. The first step using the system is again the assessment of the utility function in a quantitative way. The utility functions used are non linear but additive. Much of the negotiation process focuses on discussing the marginal utility function. Though the sharing of information is encouraged, the use of private information is also necessary. Once the utility functions have been set up, the system offers several possibilities to pick a point on the Pareto frontier, for example, the use of max`min optimization. The system consists of a high degree of integration of different computer models from the communication and decision analysis fields.

18. Aristotle (Mesarovic 1982). This software package deals with the simulation of global economic, population, and similar significant parameters in different degrees of detail. The basis of the system consists of a world simulation model using Systems Dynamics approaches. The model consists of a variety of submodels which can be addressed separately. It is designed in a highly interactive way and allows the user to simulate a large variety of possible scenarios. In addition, the user can also implement his own submodels to the system. Of course, the accuracy and the insights gained depend on the structure implemented into the computer. In addition to simulation of "what-if" scenarios, the approach also allows users to perform a variety of optimization tasks once they have specified goal functions and sample space.

At MIT there a research effort is underway to focus on synthesis and integration of all available tools and to develop a framework of negotiation analysis which can be applied to a wide range of situations. Although the role of computer models is central to this research, we pay special attention to the man - machine interface and to developing new ideas for situations where the computer will find limits, that is, when the negotiator resists the machine and its output.

IV. Conclusions

From the experience reflected in the descriptions of the functional characteristics found among the many models discussed above, the following appear to be salient in terms of their usefulness.

-- Ability to simulate dynamically, taking into consideration changes over time as well as realistic portrayal of the situation under study
-- Ability to play "what if"
-- Ability to make sensitivity analyses
-- Ability to categorize large amounts of data in similar cases to provide insights regarding significant aspects of the past.
-- Ability evaluate among alternatives
-- Ability to find "best" outcomes of solutions
-- Ability to bring the above characteristics together in one program or approach
-- Ability to replicate some pre-developed decision processes based on a particular knowledge base.

Table 1 Main Characteristics of Negotiation Support Models

Model and Negotiation Function	Modeling Technique	Descriptive/ Prescriptive	Context(ctx)/ Process(prc)	Role of Party
Pattern Seeking:				
Cascon	comparative evaluation	descriptive	ctx: small wars	ordained
litigation management	comparative evaluation	prescriptive	ctx: mass tort cases	joint model building
Simulation:				
System Interaction	systems dynamics	descriptive	ctx: health management	joint model building
Naval Ship Prd.Simulation	systems dynamics	descriptive & prescriptive	ctx: ship production	ordained
Systems Innovation	systems dynamics	descriptive	prc: mediation	joint model building
Deep Ocean Mining	physical/ economic	descriptive	prc: mediation	ordained
CLC Fund	physical/ economic	prescriptive	negotiation	ordained
Assessment:				
ESSA	physical/ econ./legal	prescriptive	prc:planning negotiation	joint model building
Decision Analysis Mod.	decision analysis	prescriptive	prc:decision making	joint model building
Solution Seeking:				
Raiffa/Blass	optimization	prescriptive	prc:mediation arbitration	ordained
Kettelle	optimization	prescriptive	prc:mediation arbitration	ordained
Analytic Mediation	optimization	prescriptive	prc:mediation negotiation	joint model building
CAP	game theory metagame an.	prescriptive	prc: decision support	ordained
Negoplan	logic rules	prescriptive	prc: decision support	joint model building
Teaching:				
Diplomat	expert system	***	prc:teaching	ordained
Arms Race simulation	systems dynamics	descriptive prescriptive	prc:teaching	joint model building
Synthesis Approaches:				
Aristotle	simulation, optimization	descriptive prescriptive	prc:planning negotiation	joint model building
Mediator	multi-criter.	prescriptive	prc: negotia.	joint model

References

Books:
1. R. Fisher, W. Ury; "Getting to Yes"; 1981
2. N.M. Fraser, K.W. Hipel; Conflict Analysis: Models and Resolutions. North Holland 1984
3. J.D. Nyhart, M.S. Triantafyllou; A Pioneer Deep Ocean Mining Venture MIT Sea Grant College Program 1983
4. H. Raiffa; The Art and Science of Negotiation. Harvard University Press 1982

Conference Proceedings:
5. A.K. Andrew et al.; "Impacts of Acid Precipitation on Watershed Ecosystems: An Application of the Adaptive Environmental Assessment Process". Intl. Society for Ecological Modeling, Lousville 1981
6. J.D. Kettelle; "Conflict Termination". Proceedings 48th MORS 1981
7. D.P. Kreutzer; "A Personal Computer Workshop for Exploring the Dynamics of Arms Races". Systems Dynamics Group MIT 1985
8. H.N. Psaraftis; "Assessing Damage and Liability from Oil Spills". Coastal Zone and Continental Shelf Conflict Resolution, MIT Sea Grant College Program 1985
9. P.M. Senge; "Systems Dynamics, Mental Models and the Development of Management Intuition". Intl. Systems Dynamics Conference, Keystone 1985
10. Note by the Delegation of the U.S. (Working papers 25, 36); International Conference on Liability and Compensation (CLC) for Damage in Connection with the Carriage of certain Substances by Sea, London 1984

Articles:
11. L.P. Bloomfield et al. "Cascon II". Cambridge Arms Control Project; CIS at MIT 1972
12. K.G. Cooper; "Naval Ship Production: A claim Settled and a Framework built". Interfaces Vol. 10, No. 6 1980
13. Harvard Negotiation Newsletter January 1986; "Diplomat".
14. M. Jarke; "Knowledge Sharing and Negotiation Support in Multi-person Decision Support Systems". Center for Information Systems, NYU 1985
15. F.E. McGovern; "Toward a Functional Approach for Managing Complex Litigation". University of Chicago Law Review 1986 53:440
16. M. Mesarovic; "Concept of a Decision Participation System, An Approach to Insight Strategic Decision Analysis". Systems Applications, Inc.; Beachwood OH. April 1987.
17. Nagel, Stuart; "Microcomputers, P/G %, and Dispute Resolution". Ohio State Journal on Dispute Resolution Vol.2,Nr.2,Spring 1987
18. Nyhart; "Negotiating Conflict Over Marine Resources: The Use of Multiparty Models" Environmental Assessment Impact Review,1984
19. Nyhart and Dauer; "A Preliminary Analysis of the Uses of Scientific Models in Dispute Prevention, Management, and Resolution". Missouri Journal of Dispute Resolution 1986
20. Nyhart and Samarasan; "Elements of Negotiation Management", MIT Sloan School of Management Working Paper 1956-87
21. J.A. Sebenius;," The Computer as Mediator: Law of the Sea and Beyond." Journal of Policy Analysis and Management 2, 1:1981.
22. D. B. Straus; "Computer-Assisted Negotiation" Mimeo, The American Arbitration Association.1974

23. D. B. Straus; "Computer-Assisted Negotiation" Mimeo, The American Arbitration Association.1974
24. H. Raiffa, A. Blass; "Computer program for investigating the efficient solutions of two-party, multiple-issue negotiations". Mimeo, Harvard University 1986
25. M. Raker; "Calculating Litigation Processes". The National Law Journal 4-14-86
26. J. Rohrbaugh; "Measuring the Relative Importance of Utilitarian and Egalitarian Values: A Study of Individual Differences about Distribution". Journal for Applied Psychology Vol. 65 #1 Feb. 1980
27. Stearns, Roberts et al. "Systems Intervention: New Help for Hospitals". Health Care Management Review Fall 76 Vol. 1 no 4
28. J.D. Sterman; "A Skeptics Guide to Computer Models". Mimeo, MIT Sloan School of Management 1985