SOME CONSIDERATIONS FOR IMPROVING FEDERAL MODELING

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INTRODUCTION AND SUMMARY

A recent issue of SPECTRUM (IEEE) has an editorial(1) concerning "systems thinking." In alluding to the state of mind of a "systems thinker" it denotes the shortcomings of systems science and engineering in terms of the specific area of modeling. The editorial refers to shortcomings in the modeling process identified by an MIT workshop on systems sciences, including questions of: validity demonstration, adequacy of data bases, model compatability, model documentation, and model incorporation of stochastic effects and uncertainties. These shortcomings are discussed in the context of the recommendation of the workshop that a "National System Center" be established to conduct needed basic research in the general areas of large scale systems analysis, modeling methodologies, and tools for policy analysis and synthesis.

A second recent article,(2) in "Natural History," on the computerized ecosystem, describes the increased understanding brought to the Great Lakes through the use of mathematical modeling and simulation. The article depicts the tool of mathematical modeling as very meritorious but "widely misunderstood by both scientists and lay persons." The reason given for the misunderstanding is the absence of a "common language" about modeling. The language of modeling is portrayed as being "unknown...to many managers and even to a good proportion of the scientific community." Therefore the subject of modeling seems to "generate feelings of apprehension and distrust." The article goes on to characterize a mathematical model as being more than a simple organization of coefficients, equations, programs, etc., but a dynamic conceptual framework. It generalizes that a model incorporates a vision of the future enabling the analyst to evaluate current states and the interrelation of states, and to look forward to envision future states. It makes the very strong point that modeling is a dynamic process and that as the model becomes better developed and more data become available, the model and the information which it generates grow. Therefore the process is iterative and dynamic.

An interesting inference drawn from these articles and others is that there is growing awareness by the technical community of the complexity and sophistication of modeling and a growing concern for better understanding of the process and identification of the problems. What is equally interesting is that these concepts have been enunciated in the same month in two very disparate publications with two very disparate viewpoints: 1) system science research, and 2) a particular application. If we are to presume that there is a growing preoccupation with the process of modeling itself and the questions pertaining to the uncertainties and imperfections in the process, both in the practitioner aspect and the interpretation aspect we can hopefully surmise that we are at the beginning of a period of introspection and self-examination concerning the very nature of this tool which has been developed and become increasingly sophisticated in the last 15 or 20 years.

Another publication lending further impetus to the awareness of the defects and shortcomings of the process is the 1976 Report to the Congress from the General Accounting Office(3), which attempts to describe and quantify the loss to the Government in the poor use, misuse, and nonuse of the modeling process, and which makes recommendations that certain management practices be developed to improve the Government's approach to modeling. Among these recommendations are:

> "....formulate standards for, and..... develop and provide guidance to Federal Agencies for improving management of computerized models."

which can be seen to overlap the concerns expressed by both the MIT workshop and the ecological systems application paper.

What we appear to have, therefore, is an emerging concern with perfecting the process of modeling, a concern that the process itself improve: that better practices be invented; that guidelines for managing the process of modeling be synthesized, that all-in-all, the newly emerging, rampantly growing modeling organism be transformed from its adolescent stage into one of recognizable useful maturity: in other words, that professionalism and discipline be given to the technique.

On the other hand, what is <u>not</u> identified as a problem in the literature, or elsewhere, is any hint of imperfections in the computerized tools of modeling. Quite to the contrary, the development of modeling languages and software can be perceived as having far outstripped the capabilities for using these tools. Therefore, we are confronted

by well-engineered user programs being employed in a rather undisciplined fashion by practitioners. What is indicated is that research and development must be focused on achieving a catch-up in the maturity of the application process, not in the tools themselves. Questions of who should sponsor such research and who should perform the research are ones which must be solved. It is hoped that this paper will galvanize those who are concerned with the problem into identifying the sources of resources for such research efforts.

Our concern then is with large scale computer-based decision making models and the problem of how to improve their utility. The discussion in this paper deals with models employed throughout the Government; however, conclusions drawn for Government modeling can in general be applied more broadly. The paper will discuss the extent of Government modeling activities, define the basic problem of the utility of large scale models, summarize the opinions of various developers and users of large scale models, and then discuss problems encountered in defining the research environment for solving these problems.

GOVERNMENT MODELING

The U.S. Government is the largest sponsor and consumer of models in the world. Estimates have indicated that over one-half billion dollars is being spent annually on developing, using, and maintaining models in the Federal Government. Large scale models are employed in the decision-and-policy-making functions of Government. They can be classified by type: e.g., mathematical, simulation, econometric; or by end use: e.g., war gaming, engineering, resource allocation, futures projection. Government models are developed both by the Government and by contractors such as universities and private organizations, both profit and non-profit. The application of complex decision making models at all levels of Government and industry is increasing, due to better trained analysts and development and refinement of analytic decision making methodologies. However, the final utility of these models has been questioned, especially in the Federal Government.

Consider the utility of a model as some function of its being useful, useable, and used.(4) A model can be considered useful if it shows promise of attaining its stated objectives. It can be considered useable if it is understandable and plausable to both technicians and decision makers, economic to run on a computer and accessible to those who wish to use it. If a model is useful and useable, it has a chance of being used. What are models? Distilling the opinions from a number of experts, modeling can be defined as the process of solving complex system problems and making system decisions using data generated by a computerized conception of the system. The conception can be mathematical; it can be functional; it can be symbolic. The process of modeling is complex and imperfect. It is initially conducted at a high level by sophisticated analysts who are familiar with the problem and who are supported by statisticians, programmers, etc., and who may or may not use problem-oriented languages to implement their model on the computer. The entire process can be partitioned, according to Emshoff and Sisson (5) into various tasks or phases:

1. Defining the problem,
2. Analysis of data requirements and sources,
3. Formulation of subsystem models,
4. Implementation and debugging,
5. Model validation,
6. Design of simulation experiments,
7. Analysis of results and presentation to management.

Management of the modeling process is similar to management of engineering projects and requires, as does good engineering practice, the existence and use of management metrics: specifications, guidelines, standards, and objective planning techniques. The subtleties of modeling, however, have contributed to the lack of development of these metrics. As a result, the Government and others have experienced waste in many steps of the modeling process.

In addition, and as indicated by one of the previously referenced articles, there is a problem in the communication between management and technologists in the modeling process itself. There is no common language of understanding. Therefore, the models and the process are frequently misunderstood. The General Accounting Office (GAO), in its report to Congress, points out that the Government-sponsored models are largely 1) misused, 2) unused, 3) not validated and 4) not documented. GAO's solution to this problem is to request that a body of standards be developed to make the process more manageable and cost-effective. It also proposes that the Government adopt a formal lock-step phased approach to model development. As part of its solution, GAO requested that the Department of Commerce undertake the necessary work to develop the appropriate body of standards. It did not indicate what resources are available to do this. The main questions to confront the Government developer of better practices are: 1) can such standards actually be developed, and 2) if developed, can they be deployed and enforced? 3) should the modeling improvement responsibility be organizationally centralized or decentralized more and 4) basically, is this a problem which the Government alone should solve or indeed participate in the solution of at all? That standards or guidelines could be developed to improve some of the problems alluded to by the GAO, e.g., documentation, seems reasonable. That good management practices can be infused into the Government modeling process in a formal or quasi-formal sense is questionable.

SOFTWARE IS NOT THE PROBLEM

It should be noted here that an obvious target for the application of standards is software. However, in the modeling context, and particularly the simulation application, software shows the least apparent need for standardization. Problem-oriented languages for sumulation have, in general, been developed responsibly. They have been engineered. They have internal diagnostics. They exhibit practices of good software engineering. Also, a large

majority of programming language applications in the modeling field do not use problem-oriented languages, but FORTRAN, a language currently being subjected to a standardization process. Simulation languages themselves have attained a degree of reliability and sophistication far in advance of their wide use, as indicated by the very slow process of change in simulation language development. Incremental changes have been made by language developers over the years. The language GPSS, for example, over the last ten years (which encompasses GPSS 360 through GPSS V, IBM's versions) has not incurred a great deal of change in basic structure; but upwardly compatible enhancements have been made. We see the same pattern in other simulation languages such as SIMSCRIPT and SIMULA, leading to the conclusion that the software has taken its "great leap forward" and is now waiting for the process of modeling to catch up. This situation is tantamount to having built a modern motor car in the year 1800 where the state of the civilization and technology was obviously not ready for the application of such a product! It is quite clear, from reading recent GAO reports and articles, that nowhere does a software problem seem to manifest itself. Therefore, we must look outward from software to the management of the modeling process for a place to begin to implement professionalism and discipline.

EXPERT OPINION CONCERNING MODELING IMPROVEMENTS

In order to clarify some of the issues involved, a study has been performed which has accumulated, quantified and weighted opinions of various expert model practitioners and theorists as to the major issues confronting the subject improvement of the modeling process.(6) This was done to identify the main issues confronting the Goverrment in model use, but the comments and opinions may largely be generalized to include the entire modeling community.

Opinion briefs were obtained from a group prominent in modeling. The group could be characterized by affiliation:

University
Non-profit company
Profit company
Government

or by application area:

Analysis
Simulation
Economics

A good cross-mix was achieved. This group voted on their degree of agreement, or non-agreement, with certain propositions. The results reported here are from partial raw data, due to publication time constraints. The complete report will be finished about December, 1978.

Using a rudimentary weighting of raw scores, the propositions can be ranked and numbered on a scale of of 1 to 18, indicating a range between highest and least agreement averaged over all opinions. Of 18 basic propositions, those showing significantly high agreement (descending ranking) were:

1. Documentation Plan and Guidelines

   Model developers should specify a documentation plan at the beginning of the project and have it approved by the Government Contract Officer's Technical Representative (COTR). The Government should develop documentation guidelines for computer models, similar to the NBS FIPS PUB 38, "Guidelines for Documentation of Computer Programs and Automated Data Systems."(7)

2. RFP (Request for Procurement) Statement of Work

   The RFP statement of work should indicate the technical and management aspects the developer must follow, including specification of the analytical procedures, data to be used, reports required, and briefings that must be given. If a contract is to advance the state of the art or a research area, then it should be so stated in the RFP and a procedure be established to ensure user-developer interaction to ascertain final model specification.

3. Relationship Between Developer and User

   The scope of work should stipulate who the ultimate user(s) will be, and that meetings between the developer and user(s) be held to enhance developer-user concurrences.

4. Modeling Forums of Users and Developers

   The Government should establish modeling forums that deal with specific application areas and/or methodologies that are of concern to Government model sponsors and users. Whenever possible, a modeling forum should be organized with the support of the appropriate professional organizations and industrial groups.

5. Data Availability

   Prior to the issuance of an RFP, most modeling projects should undergo a preliminary data availability and costing assessment, where this assessment would be used by the sponsor to continue or stop the effort. The RFP should require an explicit data collection effort to be conducted by the model developer or other designated group. The availability of suitable data, as measured at certain milestones, should be a basis by which the sponsor and developer determine whether or not the modeling project objectives can be attained.

6. User Training

   All modeling projects should explicitly address the training issue. If formal training is required by the contract, then training should include how to use and analyze the results of the model, along with data maintenance and program change procedures. If training is not required, the model specifications should state why it is not needed.

7. Verification and Validation

A detailed verification and validation test plan should be required of most modeling projects. The project reports should describe the results and their implications to the future use of the model. Exceptions to a detailed plan should be based on a model's complexity and proposed use.

8. Phased Management Approach

The Government should develop the idea of a phased approach to modeling.

The GAO report suggests a five-phase approach to the management of a model development project, with each phase having a checkpoint that must be passed before the next phase can be initiated. Under this approach, the Government could contract for all or some of the phases, but would reserve the right to cancel the project if the Government felt that criteria for passing a checkpoint had not been met. The suggested phases are: problem definition, preliminary design, detail design, evaluation, and maintenance.

9. Definition of Large Scale Models

The Government should develop a basis for classifying models. Any future modeling standards or management procedures would then be applied based on the level of a model's classification.

Those propositions showing significant disagreement (ascending ranking) were:

18. Model Testing, Verification, and Validation Center

The Government should establish a center at which certain classes of models would undergo verification and validation testing by an independent staff of analysts.

17. Post Review

The Government should establish a post-review panel that would evaluate a model and provide guidance to potential users as to the model's strengths and weaknesses.

16. Government Modeling Research Center

The Government should create a new agency, namely a Government Modeling Research Center (GMRC), that would coordinate and direct some of the Government modeling research activity. The research activities at the GMRC could include developing model research goals, validating present models, developing software and documentation standards, conducting training programs, organizing standard data bases, testing algorithms, comparing methods, organizing a library of models, etc. Much of this research could be done by contractors, but the GMRC would be responsible for coordinating and directing these efforts.

Conclusions can be drawn by characterizing the propositions. There is agreement that improvements are needed in the process of model project initiation (propositions 1, 2, 5); in developer-user communication (propositions 1, 2, 3, 4, 6); and in model quality control (proposition 7).

Negative opinions can be projected into almost total rejection of the concept of increased bureaucratic intervention (proposition 18, 17, 16).

Some interesting assessments may be obtained by examining results categorized by respondent affiliation grouping. The table indicates, by group, the first and second highest, and lowest, ranking propositions.

Respondent Affiliation	Proposition Ranking	Proposition Subject
University	1	Documentation plan & guidelines
	4	Modeling forums
	16	Government Modeling Research Center (GMRC)
Non-profit	1	Documentation plan & guidelines
	2	RFP statement of work
	17	Model post-review panel
Profit	8	Phased management approach
	5	Data availability
	18	Model test verification and validation center
Government	8	Phased management approach
	1	Documentation plan & guidelines
	18	Model test verification and validation center

Particularly interesting is the Government category which indicates favoring a more rigid approach to both the development process and to documentation and disfavoring the establishment of a centralized research function. Overall, these rankings indicate concern with communications (proposition 1, 4) and initiation (proposition 1, 2, 5) and management (proposition 8).

In summary, the experts have expressed a consensus opinion indicating concern with both the starting of the modeling process and the communication between model users (decision makers) and developers (model builders).

CONCLUSIONS

The goals for improvement of the modeling process are clear. They are:

1. Provide tools to improve communication between model users and developers.

2. Improve the model development process through better preliminary definition specification and initiation of modeling.

3. Improve the modeling process through establishment of quality control techniques.

The path to reach these goals is not so clear. Since the early 1970's the goals have been enunciated repeatedly by GAO reports, research reports and the opinions of expert practitioners.

At least three times within that period, the National Bureau of Standards has attempted to secure appropriated funds to underwrite research on improvement of the large scale modeling process and has failed. The most recent and most successful attempt was an NBS modeling standards initiative in the Fiscal Year 1979 budget report which successfully traversed the budget process but failed final Congressional budget review. The NBS program proposal included the development of guidelines for model documentation, model development, and model procurement, which would have gone far in satisfying the above goals.

At this point, the prospects for near-term unilateral Government agency sponsorship of the undertaking appear dim unless the attention of Government policy and decision makers is focused on the problem. Unfortunately a problem must not just be important - it must appear to be important. And the desired attention can only be focused with a large expression of concern from the constituency of the problem requiring attention. A possible medium for organizing the constituency into a unified voice might be a cooperative research organization such as the "National Systems Center," proposed by the MIT workshop.(1) Certainly such a center, in its quest for better understanding of systems would more than likely be able to subsume the goal of improving large-scale modeling, and provide the leverage necessary to gain support for the problem.

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