Simulation The First- 25 Years

Look around you by John McLeod

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In line with the theme of the Silver Anniversary issue of *SIMULATION*, I would like in this Newsletter to take a brief look back, comment on the state of simulation as I see it today, and rather than gaze into my clouded crystal ball in an attempt to predict what simulation will be like in the future, to indicate some of the things I believe we must do if simulation is to become anything more than the rather esoteric art-form it is today.

Although experience has shown that readers are seldom writers, I hope to be provocative enough to elicit some comments--for publication or just for my own edification.

A Nod to the Past

The evening of November 7, 1977, will mark twenty- five years of real time that have passed since that meeting in the Colonial Inn in Oxnard, California where I organized and which resulted in the founding of what is now the Society for Computer Simulation. I will dwell little on the past, as simulation is anything but a has-been. After pushing it for 17 years I have spent the last eight years trying to keep up--and occasionally urging caution. Computer modeling and simulation are now being used for practically everything, including some things for which they shouldn't be. More on that later.

Since the Society for Computer Simulation (Simulation Councils Inc.) is the only technical society in the United States devoted exclusively to modeling and simulation, its history is inextricably inter- twined with progress in the field. And while the history and progress make an interesting story, have told what I know of it elsewhere, notably in the Fall 1963 issue of *SIMULATION* (the first by that name, its predecessor having been a mimeograph publication called the *Simulation Council Newsletter*) and in an article "Simulation Today--And Yesterday", the first of the *SIMULATION TODAY* series, published in the May 1972 issue of *SIMULATION*.

I don't want to repeat other historic details, but do consider it fitting that the participants in our founding meeting be honored by republishing their names and affiliations here. They were:

- Lee Cahn - Beckman Instruments Inc.
- R. Douthitt - Computer Research Corporation
- Floyd E. Nixon - Glenn L. Martin Company

- E.T. Mahar – Globe Aircraft Corporation
- R. Mayne, L.E. Stilwell, C.A. Wiley - Goodyear Aircraft Corporation
- R. Favreau, A.S. Fulton, H. Low, B.D. McVey - Hughes Aircraft Company
- E. Ackerlind, R.S. Anderson, J.B. Rea - J.B. Rea Company
- W. Abern, E.D. Bush, R. Chapin, R. Gilpin, O. LaPlant, J. McLeod, S. McLeod, J. Pappas, J. Pollard, W. Sedlack, J. Sherman, D. Teague, W. Uplinger - Naval Air Missile Test Center
- H. Englander, F. Fisher, D.M. Lowe, W.P. Mitchell - Naval Electronics Laboratory
- R.M. Hendrickson - Northrop Aircraft Company
- E.H. Jacobs, C. Nisson, L.L. Philipson - Rand Corporation
- L.A. Snow - Snow Electric Company
- R.L. Baddorf, R.D. Chamorro, E.J. Jagger - University of Southern California

The Spread of Simulation

As indicated by the affiliations of those listed above, the first Simulation Council was a creature of the aerospace industry, still the most powerful proponent of simulation, and with good reason: there is no other practical way to design, test, and train personnel for advanced aircraft and space vehicles--and the aerospace industry had government financial backing.

From aerospace to other industries based on the "hard" sciences was a natural and comparatively easy transfer of simulation know-how. To the best of this writer's knowledge, "technology transfer" next made simulation available to the life sciences again for compelling reasons--simulation allowed experiments to be performed on computers, experiments which in many cases would have killed experimental animals (perhaps ending the experiment prematurely) or subjected human patients to undue risks.

Furthermore, some measurements could be made with impunity on models that would severely perturb a living physiological system, while others could be made on models that could not be made at all on living systems.

Sometime later simulation technology was transferred to the area of the social sciences. Here the problem that simulation was called upon to alleviate was not one of the immediate risk to human life, but of time and human frailties. Social systems are characterized by long time-lags. They are intractable with respect to normal experimental procedures because even if experiments can be devised to study the reactions of a segment of society, irreparable damage is often done to that segment before the experimenters -- bureaucrats, social workers, politicians -- can be convinced they have made a mistake.

The use of pesticides containing DDT and the building of the Aswan high dam, with its unforeseen consequences for the Nile Valley and the Mediterranean, are cases in point.

Simulationists cannot predict the future. But by compressing the time-scale, simulation predict the probable reaction of a segment of society and its environment to alternate courses of action, provided all assumptions and data upon which the model and the simulation experiment are based are valid--and remain so during the time-frame of the study.

As Applications Change

In considering the aforementioned transfer of simulation technology it is interesting to note the varying difficulties inherent in the study of different fields.

In the early days of simulation in the aerospace industry the primary problem was, as it remains today, the complexity of the simulation, the system to be simulated. Anyone familiar with the Apollo Project realizes that simulationists were called upon to model in detail not only the spacecraft, but also the ground control stations, the world-wide tracking stations, and the communication network which tied them all together.

I have had the good fortune to witness many aspects of such simulations, and even with all the talent available I consider it a little short of a miracle that the project managers and their teams were able to "get it all together" at one time. But somehow they did, and thus simulation helped show others how to get the real system components coordinated and working as a unit.

The success of the Apollo Project is attested to by the fact that there are no corpses of astronauts on the noon -- or floating in space. The crew members of Apollo 13, which blew an oxygen tank on the way to the moon, owed their lives directly to the fact that simulation was used to diagnose the problem--at first no one knew what had happened--and to devise a procedure for getting the astronauts back alive.

Aerospace systems are extremely complicated, but obtaining the data to develop the required models has been a relatively minor problem, as simulation has usually been employed to generate specifications during system development. Then when hardware became available, performance data could be derived from measurements upon it.

Simulation in the life sciences poses a different problem. Not only are many measurements difficult if not impossible to make with current technology; taking a measurement changes the characteristics of the object measured, and nowhere does this present nature of a problem than in the life sciences. Further- more, even if sufficient data can be gathered, there remains the question of how the information concerning one subsystem relates to that which describes another: how the respiratory system interacts with the circulatory; how is the endocrine related to the central nervous system; etc.; etc.

Under the circumstances it is surprising that it has been possible to develop useful models in the life sciences. But reference to the literature proves that simulationists in that field have made great progress--vital progress, one might say.

Shifting to the social sciences, we find that one of the problems still concerns data, but in many cases too much data. Moreover, the data has frequently been gathered by different agencies under differing circumstances and for different purposes. In many, if not most cases it is also "soft", to say the least.

But the real problem with societal models is that they involve people. Unless the model is open- ended (if it is, it won't represent any realistic system of which I am aware) there will be people in the feedback loops. Now when we consider that people are non-linear, noisy, time-varying, learning systems, some of the difficulties attendant upon the modeling of societal systems can be appreciated.

Nevertheless great progress has been made in the modeling and simulation of social systems also. Harold Guetzkow, the Gordon Scott Fulcher Professor of Decision-Making at Northwestern University, was working in the field in the ‘50s, and his Inter-Nation Simulation model has been the inspiration for many variations and improvements by Guetzkow, his students, and others to this day.

The “ART” TODAY- A PERSONAL VIEW

Whether we are "in the act" or "in the audience" we are witnessing convulsive changes in computer technology in general, and simulation methodology--and applicable equipment--in particular. I use the word "convulsive" because I believe there will be a period of flailing around before we can expect to see our art and science settle down to a steady course, upwards or otherwise. There are cross-indicators of progress.

Dichotomies and Concomitances

Divergent tendencies can be recognized as the big computers get bigger while the small ones are getting smaller (but more powerful)--the ILLIACS and the micros. In the meantime, what is happening to the minis? They are unquestionably growing more powerful and, if extended memories and I/0 are included, larger. Will they be the CPU's of the future?

On the other hand, convergent tendencies can also be recognized in both the computer and simulation fields.

One of the hottest controversies in industry and government (and law) today concerns the interrelation of computation and communications. To me this seems senseless; if we look closely enough, the fields are inseparable. Is the automatic routing of long-distance telephone calls a computer or a communications function? Who cares? Only the responsible bureaucracies--and those whom they regulate. Certainly I don't. But I do care that humanity would be better served if those same organizations ceased their squabbling and got together as a single field of technology to serve the public. But then, what would happen to the lawyers?

When it comes to hardware--and software, for that matter--my crystal ball is clouded. My concern is not with legal aspects, but with the actual and potential applications of simulation: what can it do for us--and for humanity?

Those of you who try, as I do, to keep up with the voluminous literature of simulation, are well aware of actual applications, and the implications for bigger and better simulations in the future.

But what do we mean by "better" and what must we do to make them so? I have some ideas. (Do you?)

A Look Ahead--What We Must Do

Let me now note some aspects of computer modeling and simulation which I believe simulationists must give more attention to in the future, if we are to realize the potential which simulation offers.

1. Establish credibility outside our field.
2. Improve communications within our field, with potential users, and with the public.

Just two things!? Yes, but each is a case of gross aggregation.

To improve credibility will require that we develop a methodology for modeling, simulation, and analysis that is acceptable to our colleagues to the extent that they will use it, and that is comprehensible to our present and potential customers, to the extent that they will believe in it. Quite an order!

Simulationists are rugged individualists who are happily wedded to their own methods. But so long as simulationists are unable to agree as to how modeling, simulation, and analysis should be accomplished, the potential customer will have reason to wonder if we know our business.

Credibility also raises the issue of the validity of the model: does it represent the system modeled--the simuland--to the degree necessary to fulfill its intended purpose? Even if it does, having a valid model is not enough.

For the results of a simulation study to be credible, the simulation experiments for which the model is used must also be planned and executed in such a way as to make the results meaningful in the context of the purpose of the study. Random parameter juggling is fun and can be enlightening, but it will not establish credibility in the eyes of skeptics.

Further, the establishment of credibility demands that the analysis of the results of simulation experiments be as rigorous as possible. Simulationists, being human, have built-in biases: the selection of data sources (particularly in the case of "soft" data); the design of the model (what does the modeler consider important?); the design of the simulation experiments (are they designed to explore a question objectively, or to support an a-priori position of the simulationist or his client? Such biases are inherent in simulation studies, but if in fact is realized it can be dealt with by observing certain precautions.

These precautions require proper documentation of the simulation study from inception to conclusion. Besides including enough information to allow the experiment to be repeated by the investigator's peers, information that will reveal biases must be included so that the biases can be recognized, their influence judged, and the experimental results weighted accordingly. This means that the documentation must include but not be limited to:

1. The objective of the study.
2. A natural language description of the simuland as the modeler understands it.
3. A record of every assumption arbitrarily made or required:
    a. To reduce the verbal description of the system to a mathematical model. This must include sources of and reasons for selecting the data used.
    b. To program the mathematical model to run on the computer.
    c. To devise simulation experiments that will address significant questions pertinent to the study.
    d. To reconcile actual with expected results.
4. An a posteriori justification of all previous assumptions, and of any additional ones which might be required to explain the results.

A careful consideration of the foregoing factors by any concerned observer should reveal all hidden biases and allow an evaluation of their possible influence on the results of the study.

Such procedures should improve credibility outside our field.

But we still must improve communications. As a start we must do all in our power to assure that the meaning of a message received and interpreted by the receiver has the same meaning to him as was intended by the sender. This seems obvious, yet there is confusion in our own field. How then can we expect to not to confuse the public and, most importantly, our potential customers?

Communications among simulationists, and especially between simulationists and those whom we would influence, or merely inform, can be improved greatly if we will:

1. Speak and write so that our meaning will be clear to all, not just some "in" group.
2. Make clear what simulation in general--or a specific model where appropriate--can be expected to do, and what it cannot.
3. Avoid overselling. Promise only what can be delivered, and deliver what is promised--on time and at the agreed price.

In the interest of improving clarity, I have editorialized on the need for consistency in terms and definitions elsewhere, so here I will merely illustrate the point with a few examples.

I consider "verification" the process of assuring that a computer program runs as intended, whereas the purpose of "validation" is to assure that the computer model represents the simuland to the degree necessary for the study at hand.

Some writers reverse the foregoing meanings.

In the context of a simulation study I use the word "implement" to mean the putting into effect of the recommendations derived from a simulation study. Others use the word to mean getting a program to run on a computer.

Some writers use the same word to mean both of the foregoing.

Recently another element of confusion has been introduced into our vocabulary. For some 20 years a hybrid system has been understood to be one involving continuous (analog) and discrete (digital) signals. Now we have the term "all-digital hybrid", which to me is an abomination! To be sure, there is a growing need for a term to refer to all-digital systems which process some of the information in parallel and some serially, but why use a term long-established to mean something else? How about a straight-forward descriptive term like "parallel/sequential system"?

Now my concern is not that some simulationists and simulation writers attribute meanings to words that differ from mine. I'll change if I find that I represent a minority. My point is that until one meaning is accepted and understood by all, there will be confusion within our ranks. And that confusion will be obvious to others.

Inconsistency in the use of terms is of course only one obstacle to clear writing. There are others, but as books have been written on the subject I will lecture no more here but turn my attention to my second point.

I am distressed, even frightened, by those who imply, and those who seem to believe, that simulations can predict the future. Of course simulationists know that is not true, so I am concerned with others-- experts in other fields who might use simulation as a tool or who might use simulation results in decision-making. I am also concerned with the image of simulation in the minds of the lay public.

We must present simulation as a tool for gaining insight and exploring possibilities. I even advise caution in selling simulation as a means of answering "What if ... " questions. Simulations do not give "answers". Answers may be deduced by an analyst based on a simulation study, but simulation runs give only results, not answers, per se.

Furthermore, in addition to the "if" in the question of primary interest to the investigator, there are other "ifs" that must be considered. The results of the simulation will only be meaningful:

1. If the data are valid.
2. If all assumptions are tenable.
3. If the analysis of the results is free of bias.

Concerning my third point, I can only urge that all simulationists and their representatives try to adhere to the admonition, "Thou shalt not oversell." But that is not easy. Most "sellers" of simulation honestly believe that their model will do what they say it will. Only experience--and more unhappy experiences, I am afraid--can be expected to guide the overenthusiastic.

I have a friend who might say the foregoing is a "Minority Report; it deserves no further consideration." Certainly it is a minority report--a minority of one. But I hope others will find in it some food for thought, if not agreement. So I close with the question:

What would YOU advise to improve our technology and its acceptance?

OTHER VIEWS - FROM BOOKS

We have often encouraged the view that simulation is a tool which might best be used in combination with others. One does not build a house with a hammer alone. That point of view is emphasized by two books we recently received, one on methods for problem solving and the other on artificial intelligence.

Tools for Thought by C.H. Waddington (who was, until his death in 1975, Buchanan Professor of Animal Genetics at Edinburgh University). New York, Basic Books Inc., 1977. A somewhat tutorial survey of analytical methods. It begins with a discussion of applicable philosophies, works up to and through "The Classical Scientific Method", and concludes with a chapter on system modeling, with emphasis on "The World as a System".

As an indication of the author's style, and what I consider clear thinking, I quote from a discussion of The Limits to Growth:

> *"*If one were foolish enough to take its computer projections to be serious predictions of what is going to happen, they appear rightly pessimistic, foretelling catastrophic events such as halving the world's population. There is still sufficient Victorian optimism around--the belief that bigger and more costly always means better--for a lot of people, even many who should have known better, to get very hot under the collar and try to bury the whole enterprise under a fog of ridicule. It is therefore important to try to get some idea of what computer simulations of complex situations cannot be expected to do in the present state of the art.*"*

Artificial Intelligence and Natural Man by Margaret A. Boden (Reader in Philosophy and Psychology, University of Sussex). New York, Basic Books Inc., 1977. A 537-page fine-print tome which got a bit deep for me, but those better versed in philosophy and psychology than I will find its treatment of the use of computer models and simulation, as aids to study in these fields, interesting, and probably enlightening.

To illustrate the thrust of the book I quote:

> *"*Artificial intelligence is not the study of computers, but of intelligence in thought and action. Computers are its tools, because its theories are expressed as computer programs that enable machines to do things that would require intelligence if done by people.
>
> "I make no basic distinction of principle between 'artificial intelligence' and 'computer simulation'. There is admittedly a difference in emphasis between workers who try to make a machine do something, irrespective of how humans do it, and those who aim to write a program that is functionally equivalent to a psychological theory. In a computer simulation, every thought process posited by a certain psycho- logical theory has a corresponding process specified in the program. Computer simulations are thus directly parasitic upon some prior articulated theory about human psychology, whereas other programs are not."

Simulation - as it has been, is, and should be by Tuncer I. Oren

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One of the characteristics of simulation nowadays is that it is ubiquitous. Table 1 provides some figures about different aspects of simulation. For example, there are 23 associations or groups specializing in simulation. As is apparent from their names (Table 2) they differ widely in scope, application area, regional coverage, etc. Over 80 special bibliographies cover different aspects of simulation. There are over 1300 doctoral dissertations written in North America (mostly in the USA). This number is increasing by about 200/year. In Europe, over 50 have been written in France alone. NTIS (National Technical Information Services) in the USA makes available annually over 300 new titles in simulation in hardcover or microfiche editions. Over 300 books exist on simulation (mostly written in English). There are about 18 periodicals and over 100 conference proceedings on simulation. Every year there are about 12 simulation conferences or symposia. Simulation terminology comprises about 1000 terms. Simulation is used in over 200 application areas such as agriculture, earthquake, engineering, history, music, missile, and social sciences. Over 100 techniques such as bond graph, finite difference, relaxation, or variance reduction are used in different types of simulation. Well over 300 abbreviations and acronyms denote existing simulation software. Over 20 simulation languages or packages exist for combined system simulation alone. In a recent article 18 of them were reported [3]. Hundreds of simulators exist. [2]

How have we reached this state of versatility in simulation? By doing experiments on models instead of on real systems. Simulation studies may be classified in many different ways:

- Goal of experimentation-e.g., computation (with or without optimization), insight, or learning (simulation games in early stages and simulators in late stages of learning to en- force the learned concepts)
- Type of application area-e.g., artificial intelligence, ecology, education, job shop, transportation
- Type of system-e.g., adaptive, control, fuzzy, hierarchical, large scale, nonlinear
- Nature of the model-e.g., physical (scale model, analog model), or mathematical (with constant structure or with time-varying structure) with the model specified by differential equations (ordinary-stiff or not-or partial), finite difference or algebraic equations, or as a finite-state machine, or as a Markov chain
- Nature of the relationships-deterministic, stochastic
- Time set of the model-discrete, continuous, mixed
- Ratio of simulated to real time-e.g., compressed- time simulations, real-time simulations
- How the state of the model is updated-e.g., by analogy, by computation
- Device used to do the computations-e.g., manual simulation, computerized simulation (digital, analog, hybrid)
- Way of accessing the computer in computerized simulation-e.g., on-line simulation, interactive simulation, conferencing simulation, distributed simulation
- Simulation executive (time structure of the simulating software)-e.g., time slicing, significant (critical) event, process, activity

Table 1 - Some figures (approximate) about different aspects of simulation

Associations	23
Bibliographies	80
Doctoral dissertations	over 1300
NTIS documents	over 300/year
Books	300
Periodicals	18
Proceedings	over 100
Conferences/symposia	12/year
Special terminology	100 terms
Application areas	over 200
Techniques used	100
Abbreviation/acronym used to denote simulation software	over 300
Simulators	100s

Table 2 - Associations or groups specializing in simulation

ABSEL	Association for Business Simulation and Experiential Learning
ACM/SIGSIM	Association for Computing Machinery - Special Interest Group on Simulation
AERA/SS	American Educational Research Association - Special Interest Group on Simulation Systems
AICA/ASDS	Associazione ltaliana per il Calcolo Automatica - Working Group on Algorithms and Simulation of Discrete Systems
AIM/GTSC	American Institute of Aeronautics and Astronautics - Ground Testing and Simulation Committee
ASTM/E-21	American Society for Testing and Materials - Committee E-21 on Space Simulation
ASU	Association of SIMULA Users
BSS	Brazilian Simulation Society
GLOSAS/Japan	Global Systems Analysis and Simulation Association – Japan
IEEE/CS/TCS	Institute of Electrical and Electronics Engineers - Computer Society - Technical Committee on Simulation
IFIP/WG7.1	International Federation for Information Processing - Technical Committee on System Modelling and Optimization (TC7) Working Group on Modelling & Simulation (WG7.1)
IMACS	International Association for Mathematics and Computers in Simulation - formerly AICA (Association Internationale pour le Calcul Analogique)
ISAGA	International Simulation and Gaming Association
JSCS	Japanese Society for Computer Simulation
NASAGA	North American Simulation and Gaming Association
NGA	National Gaming Association
SAGSET	Society for Academic Gaming and Simulation in Education and Training
SCS	The Society for Computer Simulation
SSG	SIMULA Standard Group
SSRC/CSCP	Social Science Research Council - Committee on Simulation of Cognitive Processes
SSS	Scandinavian Simulation Society
TIMS/CSG	The Institute of Management Sciences - College on Simulation and Gaming
WSO	World Simulation Organization

Some of the early simulation studies were not even called simulations. For example, the well-known Nobel laureate and Dutch econometrician Tinbergen used to have a water-flow analog model of Holland's macroeconomy. He used the analog model until it was discarded in the mid-50s. To the people who complained that the model leaked, Tinbergen's answer was "So does our economy."

Nowadays the situation is completely different. Computerized simulation and some of its messages are well spread about. For example, the first report of the Club of Rome has sold over four million copies in Benelux countries alone.

In addition to the continuation in the future of the successful use of simulation in traditional application areas, I hope that:

1. Simulation models will be comprehensible, especially to those who will be affected by the implications of particular models. Comprehensibility is paramount in the rational selection of models in a participatory democracy.
2. If a simulation program is to be used several times, a list of questions answerable by the model will be part of the documentation provided to the user.
3. Adequate methodology will be developed and implemented for newly emerging multidisciplinary modelling. In the future, the methodological aspect will become crucial as more and more people try to model large-scale multifaceted systems.
4. Advanced modelling concepts will be used to simulate complex phenomena. For example, behaviorally anticipatory models have definite advantages over classical feedback models, especially when time delays are large. [4]
5. Robustness will be taken into account in modelling large-scale systems. [1]
6. New simulation software implementing advanced concepts in modelling and model manipulation will be part of computer-assisted model building, handling, and documentation systems. Some of the algorithmic model

manipulations may be done for consistency checks, decomposition, simplification, coarsening, elaboration, or comparison of models. [5]

7. Simulation software will be much more independent of simulation hardware.

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REFERENCES

[1] HUNT, B.R.
Large Scale System Theories: Some Paradigms from Software Systems Engineering
In T. I. Oren, editor, *Cybernetics and Modelling and Simulation of Large Scale Systems* International Association for Cybernetics, Namur, Belgium, in press

[2] OREN, T.J.
Annotated Bibliography on Simulators
Simulation vol. 27, no. 6, December 1976, pp. 193-196

[3] OREN, T.I.
Software for Simulation of Combined Continuous and Discrete Systems: a State-of-the-Art Review
Simulation, vol. 28, no. 2, February 1977, pp. 33-4S

[4] OREN, T.I.
Rationale for Large Scale System Simulation Software Based on Cybernetics and General System Theories
In T. I. Oren, editor, *Cybernetics and Modelling and Simulation of Large Scale Systems* International Association for Cybernetics, Namur, Belgium, in press

[5] OREN, T.I. & ZEIGLER, B.R.
Concepts for Advanced Simulation Methodologies
Simulation in press