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TWENTY-FIFTH ANNIVERSARY KEYNOTE ADDRESS

THE WINTER SIMULATION CONFERENCE: CELEBRATING TWENTY-FIVE YEARS OF PROGRESS

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ABSTRACT

In this paper we survey the past, present, and future of the Winter Simulation Conference (WSC) as well as the field of simulation. We begin by outlining the origins of WSC and its "Early Years" (1967–1974), a period in which the structure and traditions of the conference were formed. Then in the first part of the Keynote Address, Joseph M. Sussman reviews the evolution of simulation and WSC over the past twenty-five years. Thomas J. Schriber presents the second part of the Keynote Address, highlighting WSC's "Renaissance Period" (1976–1985) in which the conference was reestablished and its traditions were reinforced. In the third part of the Keynote Address, James O. Henriksen summarizes WSC's "Coming-of-Age Period" (1986–1992) in which both the conference and the field of simulation reached maturity as professional activities. Stephen D. Roberts concludes the Keynote Address by assessing the prospects for the future of these activities.

THE ORIGINS OF WSC

Although in some sense the origins of the Winter Simulation Conference can be traced to certain computing seminars held in the late 1940s, the initiative to hold a national conference on the scale of the current WSC took shape in the spring of 1967. This initiative resulted primarily from interactions between three individuals—Harold G. Hixson, an Operations Research Analyst with the Air Force Logistics Command and the System Simulation Project Manager of SHARE (the IBM scientific users' group); Arnold Ockene, an IBM employee responsible for marketing and support of GPSS; and Julian Reitman, a prominent user of GPSS in the Norden Division of United Aircraft Corporation and a leader in the Institute of Electrical and Electronics Engineers (IEEE). Serving as General Chair of the Conference on Applications of Simulation Using the General Purpose Simulation System (GPSS), Hixson arranged for SHARE to sponsor the conference. Serving as Program Chair, Reitman secured additional sponsorship from the Association for Computing Machinery (ACM) and two groups within IEEE—the Systems, Man, and Cybernetics Group (later designated IEEE/SMCS) and the Computer Group (later designated IEEE/CS). Ockene served as Publicity Chair. Held November 13–14, 1967, at the Hilton Hotel in New York City, the conference had a planned attendance of 225 and an actual attendance of 401. Col. Ken Swanson of the Air Force Logistics Command delivered the Keynote

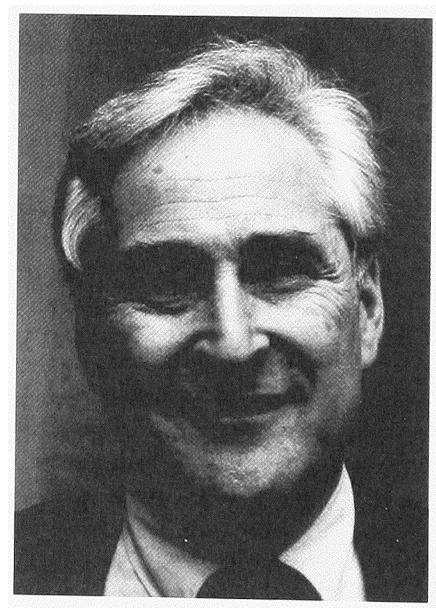
Address entitled "Objectives of Simulation." In addition to thirty-four presentations on GPSS-based simulation applications, Geoffrey Gordon, the original developer of GPSS, gave a luncheon address entitled "The Growth of GPSS."

Because of the technical and financial success of the 1967 conference, a second conference was held December 2–4, 1968, at the Hotel Roosevelt in New York City. Julian Reitman served as General Chair and Arnold Ockene served as Program Chair for the Second Conference on Applications of Simulation. In addition to the original sponsors, the 1968 conference gained sponsorship from Simulation Councils, Incorporated (SCi, later designated SCS). The scope of the 1968 conference was expanded to include papers on any simulation language or any aspect of simulation applications; and as a result, the 1968 conference grew to twenty-two sessions with a total of eighty papers. Sessions on statistical considerations, development of new languages, and tutorials on new languages complemented the applications sessions; and attendance jumped to 856. While there was no permanent record of the 1967 conference, the 1968 Conference Committee published a 368-page *Digest of the Second Conference on Applications of Simulation.* Thus most of the structure and traditions of what is now known as the Winter Simulation Conference were crystallized by 1968.

The Third Conference on Applications of Simulation was held December 8–10, 1969, at the International Hotel in Los Angeles. Arnold Ockene served as General Chair, and Philip J. Kiviat served as Program Chair. In addition to the previous sponsors, the 1969 conference also gained sponsorship from the American Institute of Industrial Engineers (AIIE) and The Institute of Management Sciences (TIMS). The *Proceedings of the Third Conference on Applications of Simulation* totaled 513 pages, and it established the basic *Proceedings* format followed in all subsequent years.

The Fourth Conference on Applications of Simulation was held December 9–11, 1970, at the Waldorf-Astoria Hotel in New York City, with Philip J. Kiviat serving as General Chair and Michel Araten serving as Program Chair. In the following year, the official conference title was 1971 Winter Simulation Conference: Fifth Conference on Applications of Simulation. The 1971 WSC was held December 8–10, 1971, at the Waldorf-Astoria Hotel in New York City, with Michel Araten serving as General Chair and Joseph M. Sussman serving as Program Chair. Although there are no surviving records of conference attendance for the period 1969–1973, it is widely believed that the attendance at WSC '71 was approximately 1200—the largest attendance of any WSC.

There was no WSC in 1972; the 1973 WSC was held January 17–19, 1973, at the St. Francis Hotel in San Francisco, with Joseph M. Sussman serving as General Chair and Austin C. Hoggatt serving as Program Chair. The 1974 WSC was held January 14–16, 1974, at the Washington Hilton Hotel in Washington, DC. Michael F. Morris was the General Chair, Harold Steinberg was the Program Chair, and Harold Joseph Highland was the *Proceedings* Editor for WSC '74. With addition of a separately designated position for the *Proceedings* Editor on the 1974 Conference Committee, the organizational plan for future Conference Committees was completed. In addition to the previous sponsors, WSC '74 gained sponsorship from the Operations Research Society of America (ORSA). Although refinements to the structure and traditions of the Winter Simulation Conference have been made continuously over the past twenty-five years, the innovations introduced during WSC's "Early Years" have proved to be remarkably durable.



JOSEPH M. SUSSMAN

SIMULATION—A HISTORICAL PERSPECTIVE, 1967–1992

When I was asked to give this Keynote Address to the 1992 Winter Simulation Conference, the Twenty-Fifth Anniversary Conference, it was suggested that I speak on my perspectives on simulation and how they may have evolved from those early days to the current time. It is certainly a great pleasure for me to be able to give you my point of view on simulation and hopefully there'll be some perspectives here that you'll find interesting and useful.

For some years, we have recognized simulation as a very powerful tool—it permits us to model complex systems in a rather detailed way. Using simulation we have a modeling framework that allows us to represent system components at various levels of detail depending on our view of reality. So, a rail terminal can be a microsimulation of individual car movements or simply a delay function. The elegance of the technique as we map operating units into model elements is unmatched in the world of systems analysis.

Often we have characterized simulation as a technique of last resort since it has tended to be expensive because it requires a stepping through time of a model, as opposed to analytic solutions that might represent closed-form answers. Though it is a technique of last resort, it turns out in the real world, we quite often require simulation to represent reality at a level of detail that is appropriate to answering the relevant questions about system performance (this degree of detail usually precludes analytic models). This can lead to model complexity and, certainly back in 1967 and to the current day, we are concerned with highly complex models that can simply fail computationally—that is, they can simply grind to a halt, forcing us to reduce the level of detail in our models to be able to get something that is computationally feasible.

It has seemed to me that the fundamental output of simulation models is, in fact, insight into system performance. Over the years I have tended not to use simulation models to get precise numerical results. Rather, building the model provides insight into the way in which the system actually operates. Running the model and observing its behavior suggests mechanisms for making that system better. The insights we gain from building and running a simulation model are often as useful, if not more so, than the particular numerical results that we get from it. I must admit this is a realization that has evolved for me over the years. I recall in my early simulation work being overly persuaded by particular numerical results. But, in recent years, I have become convinced that less concern with specific numbers and more with model structure and behavior are indeed appropriate.

My own professional field is transportation and in early 1967 and the early 1970s my main focus was on intercity rail transportation with an emphasis on freight. My current emphasis is on intelligent vehicle highway systems which involve the routing of automobiles over complex urban networks. In both cases I was dealing with very complex systems. I was very concerned with network flow issues. The systems were both highly probabilistic. In both cases the model had complex multidimensional objective functions (although I must say that concern with environmental and energy impact is much greater now than then). And simulation has turned out to be the relevant tool in both situations. Though it's a tool of last resort in practice, it has been the tool of choice for me for many years as my professional interest has evolved within the transportation field and the difficulties in using analytic closed-form representations for complex systems has continually been a factor.

Let me make some comparative statements about simulation in 1967 versus 1992, beginning with statistical issues which are of course of major interest in the probabilistic systems that we are concerned with. It seems to me as I look back on the statistical work that was going on in those early days that, with the exception of a few pioneers like George Fishman, most of our modeling was, in fact, the use of fairly conventional statistics without regard to the fact that we were speaking of an environment that was very special: the simulation environment is one in which we are able to replicate and control in a variety of ways. This enables us to use statistical techniques in very innovative ways. I think in the early years we tended not to do this and I think currently we're doing a much more effective job of effectively utilizing statistical techniques that take advantage of the special environment of simulation modeling.

From the point of view of platforms on which to build simulations, we're certainly much better off now than we were in the late 1960s and early 1970s. Back in the early years of the Conference, we were dealing primarily with large mainframes and accessibility and interaction were limited. Now we are dealing with highly powerful personal computers that can sit on the modeler's desk, and interaction with the computer model on a personalized basis is much more feasible. From a software system point of view, we've made major strides. Clearly from a language viewpoint, we're dealing with a much more sophisticated environment. The modeler has many more choices of languages to use to properly structure a simulation. So from the perspective of the environment in which we do our modeling there is no question that substantial strides have been made.

Graphical support is another area in which we have made major advances. Back in the early years graphical support was limited. Often, we dealt only with static representations of results. Now we have a variety of techniques that allow us to dynamically observe the model in simulated time. This gives us some of the insights into system performance we discussed earlier. In addition, we now have graphical support for model construction as well. As we extend these concepts, we will certainly move toward a more efficient system of visualization and model construction through interactive graphical support.

Another area in which substantial progress has been made is in the relationship between optimization and simulation. Simulation, or a single run of a simulation model, produces a set of results about a particular operation, but indeed the real challenge is to vary input parameters of those models to ascertain when optimal performance may occur. We've seen the development of packages that allow us to use optimization techniques in the context of simulation modeling, taking advantage of the very special environment of simulation to do so in an effective way.

So certainly we have seen very substantial changes in the world of simulation in the twenty-five years since this Conference began. We have faster devices on which to run our models. The elegance of the languages that we have to structure models has advanced substantially, and our ability to interact with our models, during both model building and model operation is greatly enhanced. Visualization of system operation through graphical devices has become an important tool.

So, in all, one could argue that simulation from its early beginnings has evolved into a much more sophisticated tool with much more credibility in the world of systems analysis. I think people here at this Conference can be very proud of their contribution in helping to develop that credibility over time.

Now, I should raise one caution that I first raised back in a tutorial paper I gave some years ago. This deals with barriers to the use of simulation, or more accurately, the lack of them. The very elegance and "one-for-one" modeling framework of simulation make it a highly accessible technique. Even back in the 1960s and 1970s barriers to the use of simulation were modest when compared with other systems-analysis techniques. Indeed, the very usefulness of some of the modeling and language tools we have also presents a major danger in that we can easily have unsophisticated people using simulation in an incorrect manner. I'm sure all of us in our organizations can point to such situations. The very accessibility of the technique is in fact, both its strength and its weakness. One must be quite sure when one builds a simulation model that methodological issues, for example, statistical issues, are properly reflected in the analysis of the results. Validation should be done in some kind of an organized and effective way. Otherwise, the use of simulation methodology can lead to what seems to be very credible results but, in fact, are dead wrong. We all have a professional responsibility to be concerned about ensuring that simulation, a technique that we all value, is used properly in the world of systems analysis.

It's very interesting to me, as I look at the *Proceedings* of this Conference, to recognize that there is a tremendous focus on simulation methodology, and this to me represents a continuing maturing of the field. About forty percent of the papers in this Conference are methodologically based. They deal with questions of statistical analysis, language platforms, output analysis, and input generation—a variety of methodological issues are addressed. And this is very different from the early days of the Conference. In those days my recollection is we focused much more on simulation applications and we were, at that time, feeling our way, very delicately, through the methodological issues. People came to these early conferences to get some sense of how one went about modeling in particular technical situations, in the world of manufacturing, the world of transportation, and a variety of other applications areas; and we were learning in an ad hoc way, again with the exception of several pioneers, about the methodological issues that we faced. This has changed substantially as the Conference has evolved over a twenty-five-year period.

In conclusion, I'd like to make a comment on what seems to me to be a very interesting organizational issue that has developed over the years in the Winter Simulation Conference. In the early years, I think it's fair to day that one could point to a dynamic tension, hopefully a creative tension, that existed between the ad hoc organization of the Winter Simulation Conference and the sponsoring societies such as ACM, IEEE, etc., who financially guaranteed the Conference. While these organizations wanted to see this conference succeed, there was a concern that a new society might emerge, a simulation society that might be competitive with the sponsors.

It seems to me, as I think back on those years, that I envisioned that the ad hoc nature of the Winter Simulation Conference would lead to two possible outcomes. The first possibility was that the ad hoc organization would degenerate and that the Conference would slowly but surely sink into oblivion. The other hypothesis I had was that the Conference would spin-off a new society dealing with simulation and with particular emphasis on discrete, probabilistic simulation. And in fact neither of those happened. What did happen, which I frankly viewed as unlikely at that time, was that a viable, stable, sustained conference with continued sponsorship by professional societies has developed and that it operates with a strong degree of professionalism and strong quality control. Although I viewed this as improbable, in fact, that is precisely what has happened. A quite effective professional mechanism has been developed for advancing the field of simulation.

Now if somebody had told me the Conference would continue for all these years without a society actually spinning off, I would have expected that it must have been done by accepting every paper that came down the pike to generate attendance, keeping the Conference viable from a financial point of view but not viable from an intellectual point of view. But in fact this is not the case. It is quite clear the Winter Simulation Conference has maintained strong quality control, accepting less than fifty percent of the papers that are submitted for presentation and publication in the *Proceedings*. This is a quite respectable ratio and reflects to me that we have not only a financially viable conference but, more importantly, one with a great deal of professional stature.

So I congratulate the current and recent administration of the Winter Simulation Conference. You have developed a viable, continuing, sustained, high-quality conference without the necessity for forming yet another professional society. My congratulations to all those assembled here for putting together a professional forum that I believe is entirely first-rate. You can all be proud of what you've accomplished.

Again, it's a great pleasure for me as one of the so-called "Founding Fathers" to come back and have the opportunity to discuss with you my perspectives on the evolution of simulation over this period of time. It's quite clear we've made tremendous progress, and it's quite clear that we have the basis for more progress as simulation continues to be a viable, effective element in the arsenal of tools that we bring to the analysis of complex systems. I am quite confident that the community that has been pulled together in the framework of the Winter Simulation Conference can certainly accomplish that goal.

Thank you for your attention.

THOMAS J. SCHRIBER

THE RENAISSANCE PERIOD (1976–1985)

OVERVIEW

Aspects of the continuation and evolution of the Winter Simulation Conference and in the field of simulation itself during the era from 1976 to 1985 are commented upon here in a series of three sections. The first section describes how the 1974 WSC almost marked the end of the then-fledgling conference series, and how the series was brought back from the brink in 1976. The second section details some WSC initiatives which took place during the 1976–1985 WSC Renaissance Period. And the third section traces several of the developments in the field of simulation that took place during this period. Space limitations preclude comprehensive treatment of the material, so the description is brief and only selected highlights are included.

THE 1976 REBIRTH OF THE WINTER SIMULATION CONFERENCE

Perhaps the most interesting thing about the Winter Simulation Conference's Renaissance Period (1976 to 1985) is that there almost was no Renaissance! The Winter Simulation Conference began in November of 1967 (as the Conference on the Applications of Simulation Using GPSS, with Harold G. Hixson as General Chair, Julian Reitman as Program Chair, and Arnold Ockene filling the critical role of Publicity

Chair) and then was regularly repeated six times in approximately one-year intervals through January of 1974. But the Winter Simulation Conference planned for 1975 did not take place, and it seemed all but certain that this break in continuity would be the death knell for the WSC.

Why didn't the planned 1975 conference materialize? Briefly, 1975 General Chair Harold Steinberg (who had been Program Chair in 1974) was reassigned to new duties at a new location by his employer, IBM, and it eventually became clear that Steinberg's new superiors within IBM were unwilling to give him the release time needed to function as General Chair. This situation evolved in such a way that it was not feasible to appoint a replacement General Chair in timely enough fashion to have a 1975 Winter Simulation Conference. Further contributing to the negative situation in 1975 was the fact that the books had never been officially closed on the 1974 conference. As a result, the societies that sponsored the 1974 conference were not sympathetic when asked to supply seed money (working capital) for a 1975 conference, even though the not-for-profit series of conferences had a perfect record (except for 1974) of repaying the seed money (and then some) to sponsoring organizations at the conclusion of each conference. The weakened faith on the part of the sponsoring societies, coupled with loss of momentum and continuity in failing to have a 1975 Winter Simulation Conference,[1] made it seem unlikely that the series could or would be resumed.

But the series was resumed in 1976 after all, thanks largely to the initiative of Robert G. Sargent and the work of Paul F. Roth, Harold Joseph Highland, and Thomas J. Schriber. Sargent, a Professor at Syracuse University, had replaced Alan Pritsker at the conclusion of the 1974 WSC as the person appointed by AIIE (the American Institute of Industrial Engineers, now known as IIE) to look after AIIE interests in the AIIE-cosponsored WSCs. He conceived the idea that the WSC might be kept alive by having NBS (the National Bureau of Standards, now known as NIST, the National Institute of Standards and Technology) become a cosponsor of a 1976 WSC. Sargent discussed this idea with Paul Roth, an NBS employee who was chair at the time of ACM/SIGSIM (ACM's Special Interest Group for SIMulation, itself a cosponsor of the WSCs). Sargent's idea resonated with Roth, and a rump session of interested sponsoring-society representatives was called in Washington, DC in October 1975 to survey the damage resulting from the canceled 1975 WSC and to ponder the possibility of NBS cosponsorship of a 1976 WSC.

The merits of having NBS become a WSC cosponsor were put forth to society representatives at that meeting. NBS was experienced in the mechanics of staging conferences and even had a person assigned full-time to that function. NBS was also positioned to provide such conference services as professional budgeting, franking privileges for mailing out the Call for Papers and the Preliminary Program, and even the meeting rooms and breakout areas within which a conference could take place. And the year 1976 marked the Bicentennial of the United States, which increased the potential receptivity of NBS to the possibility of becoming a cosponsor of a 1976 Bicentennial Winter Simulation Conference held on NBS premises. In view of these considerations, the society representatives agreed that NBS should be invited to become a WSC cosponsor and Paul Roth agreed to pursue the matter.

Roth then met with Dr. Ruth Davis, Director at that time of the Institute for Computer Sciences and Technology within NBS, and she agreed that NBS would cosponsor a 1976 WSC. With NBS on board, the organizations that cosponsored the 1974 WSC then joined NBS as cosponsors of a 1976 conference. Harold Joseph Highland, a Professor at the State University of New York at Farmingdale, agreed to be General Chair. (Highland had been *Proceedings* Editor for the 1974 conference, was to have been Program Chair for the aborted 1975 conference, and had been slated to be General Chair for a 1976 conference. The usual succession at the time was that the Program Chair in one year became the General Chair in the following year.) Highland persuaded University of Michigan Professor Thomas J. Schriber, who had been active on the program of the WSCs each year from 1968 forward, to become 1976 Program Chair, with Sargent serving as Associate Program Chair. The three also took on the task of being *Proceedings* Coeditors, with Highland overseeing the operational details as carried out by a staff of students he recruited for this purpose. Working against tight deadlines, Highland, Schriber, and Sargent met in early

[1] There actually was a December, 1975, Winter Simulation Conference which took place in Sacramento, California, and was solo sponsored by the Society for Computer Simulation (SCS). This conference was unilaterally organized by SCS in response to the cancellation of the cosponsored 1975 conference. (SCS—then known as Simulation Councils, Incorporated—had become a cosponsor of the WSCs beginning with the 1968 conference, and to this day continues to be a cosponsor.) When the cosponsored WSC got back on track in 1976, the 1975 SCS solo-sponsored conference was not repeated. The Sacramento conference therefore was one of a kind. The consensus is that the 1975 Sacramento conference falls outside the regular succession of Winter Simulation Conferences, and so that conference has consistently been excluded from the various WSC listings that have been compiled from time to time over the years.

spring of 1976 to plan the conference. The technical program was conceived and custom-built by Schriber and Sargent, who contacted professional simulation acquaintances and past conference participants and persuaded them to give application papers, fundamental and advanced tutorials, and to be on panels at the conference. The conference took place at NBS in Gaithersburg, Maryland, in December of 1976, and was both a technical and financial success. (The conference was attended by 306 people.) Timely advanced planning was carried out for a 1977 conference, and since that time the baton has been passed on smoothly year after year, bringing us to the point that we are now able to celebrate twenty-five years of Winter Simulation Conference progress!

SELECTED WSC DEVELOPMENTS DURING THE 1976–1985 PERIOD

A number of developments in the evolution of the WSC during the 1976–1985 period are commented on in the following subsections.

Establishing a WSC Board of Directors and a Set of Bylaws

The 1967 Conference on the Applications of Simulation Using GPSS (the first "WSC") was organized and staged in ad hoc fashion by people interested in making such a conference happen. (More details are provided in the Twenty-Fifth Anniversary Panel Discussion immediately following this article in these *Proceedings*.) This ad hoc approach was then reflected quite naturally in the informal model used as the basis for organizing succeeding conferences. During the Early Years (1967–1974) there was no group known as the WSC Board of Directors but only a collection of individuals asked by one or another sponsoring society to be a liaison between the society itself and the "simulation conference" that the society had agreed to cosponsor. And there were no written procedures (bylaws) to govern the behavior of this collection of individuals. Indeed, it may have been the informal and relatively ad hoc nature of things that made possible the developments leading to the cancellation of the planned 1975 WSC.

After the scares of 1974 and 1975, some WSC cosponsors told their conference representatives they would no longer cosponsor WSCs unless those concerned formed a WSC Board of Directors and developed bylaws for the Board. AIIE representative Bob Sargent took the initiative to obtain copies of the charters for several other continuing conferences and used ideas from these charters to formulate a first draft of bylaws for what would be known as the WSC Board of Directors. After inevitable time lags and revisions triggered by considerations internal to the nascent Board, Sargent's third revision of the bylaws was approved by the Board in April of 1979. (Meanwhile, the sponsoring societies were content to know that bylaws were under active development.) These bylaws were then sent to the sponsors for their approval and were met with various objections by virtually every society. A Board member at that time, Saul Gass (representative of ORSA, the Operations Research Society of America), tried to rewrite the bylaws in a way that would simultaneously answer the various objections of the sponsoring societies. But other objections then surfaced, some of them incompatible on an intersociety basis, resulting in a metastable situation in which the Board operates under bylaws that have not yet been (and may never be) officially approved by all of the sponsoring societies.

Structuring the WSC Tutorials

Tutorials were a part of WSCs during most of the early years, but they were not organized or categorized in any particular way. For the 1976 WSC, Schriber and Sargent introduced the idea of having a Fundamental Tutorial Track and an Advanced Practitioners Track. The Fundamental Tutorial Track would be designed for those just entering the field of discrete-event simulation; and it would include an introduction to the concepts and principles of simulation, language tutorials, analysis of input, analysis of output, and design of experiments. And the Advanced Practitioners Track would be designed to present similar material but at an advanced level for more seasoned simulationists.

This structure has evolved over the years to the point that the 1992 WSC, for example, has Introductory Tutorials and Software/Modelware Tutorials (corresponding to the original Fundamental Tutorial Track), Advanced Tutorials (corresponding to the Advanced Practitioners Track), and State-of-the-Art Reviews, Analysis Methodology, and Modeling Methodology (for advanced practitioners but also for experts and researchers, a group not yet large enough during the Renaissance Period to warrant sessions with this degree of sophistication).

Thanks to the continuation of abundant multilevel tutorials given by experts, the WSC has been a potent force for education in discrete-event simulation over the years. (An interesting aside is that because of these explicit WSC educational components, some government and military personnel can get budgetary approval to attend WSCs under circumstances when this otherwise would not be the case.) It is truer today than ever before, for example, that a person just entering the field of simulation can obtain a substantial and high-quality introduction to most or all important facets of discrete-event simulation at very low cost by going to a WSC and diligently attending the sequence of fundamental tutorials. It is similarly true that advanced practitioners can increment their capabilities importantly and researchers can better position themselves in their work by paying careful attention to appropriate educational sessions provided at the WSC.

Establishing Exhibits as Part of the WSC

In the early days of the WSC there was vigorous concern on the part of society representatives that the WSC should not be "tainted by commercialism." And so no provisions were made for vendors to come together in a common exhibit area to show their wares to interested WSC attendees. Those vendors who wanted to have a presence at the WSC followed the approach of renting a suite of rooms in the conference hotel and holding open houses to demonstrate their products. This was relatively cumbersome for the vendors, and roaming through the hotel looking for these open houses was an inefficient use of time for conference attendees. And it could be awkward trying to slip away politely from an open house once you got there.

This all changed during the WSC Renaissance Period. During the 1982 WSC, James O. Henriksen (President of Wolverine Software Corporation, then and now vendor of GPSS/H) buttonholed WSC Board Members Bob Sargent and Tom Schriber over a beer to discuss the merits of having an Exhibit Area as an official part of future WSCs. Henriksen argued that WSC attendees would be well served by having an Exhibit Area in which state-of-the-art products could be reviewed efficiently and in businesslike fashion, and that such an area would also provide an additional source of revenue which would help hold down the cost of conference registration. Encouraged by Sargent and Schriber, Henriksen then put the case in writing to the Board. The Board appointed IEEE/SMCS (Institute of Electrical and Electronics Engineers/Systems, Man, and Cybernetics Society) representative Julian Reitman, a seasoned Board member, to study the proposal. Reitman reported back to the Board in due course, and after Board deliberation it was voted to experiment with an Exhibit Area at the next possible opportunity. Because of timing, it wasn't feasible to do this at the 1983 WSC, and so the experiment took place at the 1984 WSC. Under the direction of 1984 WSC General Chair Udo W. Pooch the experiment was a success, and an Exhibit Area has been an important part of WSCs ever since.

Graduating to *Proceedings* with Hardback Covers and Word-Processed Contents

There were no *Proceedings* at the original "WSC" (the 1967 conference). Subsequent WSCs have been characterized by *Proceedings* given to registrants at the time they check in for the conference, which greatly facilitates the selection of sessions to attend, the taking of notes at sessions, and the postconference review by attendees and others of ideas presented. For the 1968 through 1983 conferences, these *Proceedings* were softbound and did not hold up well over time after heavy use at the conference and then later in personal and professional libraries. (About two hundred libraries obtain the WSC *Proceedings* each year from IEEE as a result of IEEE's open-order program.) Under the leadership of 1984 *Proceedings* Editor Sallie Sheppard, General Chair Udo W. Pooch, and Program Chair C. Dennis Pegden and with the blessings of the Board, the WSC began the use of hardback-covered *Proceedings* with the 1984 conference. Although more expensive to produce, these *Proceedings* are not only substantially more durable than their softbound counterparts but have a much more professional appearance as well.

In a parallel development, the spontaneous use of word processors on the part of some authors to prepare *Proceedings* entries began during the latter part of the WSC Renaissance Period in response to the advent of personal computers in 1981. The use of word processing and prescribed formats for WSC *Proceedings* entries evolved during and beyond the Renaissance Period to the point that now a WSC *Proceedings* is a highly professional document.

Spreading the Board Workload and Expanding the Conference Planning Horizon

In the early years of the Renaissance Period, the Chair of the WSC Board of Directors personally handled all of the Board's work, with other members of the Board serving only in an advisory capacity. This approach came to an end in 1981 when Board Chair Bob Sargent successfully championed a resolution that the Board should have a Vice Chair and a Secretary and that the Chair should offload appropriate duties to the Board members filling these new roles.

As indicated earlier, there was also a time when planning for each next WSC was done in fairly ad hoc fashion on a year-by-year basis. This approach became more structured and formalized during the Renaissance Period. The idea was put into place of having an Associate Program Chair and an Associate General Chair as understudies preparing, respectively, to be the Program Chair and the General Chair in the following year. The planning horizon was stretched to three years, with formal appointment each year of a Board member to be the Board Liaison person directly responsible for the conference taking place in another three years. Throughout the Renaissance Period, however, members of each Conference Committee (with the assistance of the Board Liaison, when necessary or desirable) handled all aspects of the conference, e.g., choosing a conference hotel, handling the mechanics of conference registration, both before and during the conference, and so on. (Beginning with the 1990 WSC, paid conference professionals are now employed to handle as many of these details as reasonably possible.)

Iron-Man Stint as WSC *Proceedings* Editor

Even as it is now considered a once-in-a-lifetime honor to be either a WSC Program Chair or General Chair, so also is it considered a once-in-a-lifetime honor to be Editor of a WSC *Proceedings*. (The task is monumental to a point that can be appreciated only by those who have served in this demanding capacity.) But during the WSC Renaissance Period, one and the same person served as WSC *Proceedings* Editor five different times! This person, Harold Joseph Highland, was WSC *Proceedings* Editor in 1976, 1977, 1978, 1979, and 1982. (The 1976–1979 string was finally broken in 1980, when Tuncer I. Ören was both Program Chair and *Proceedings* Editor. Ören was WSC *Proceedings* Editor again in 1981. Then, perhaps as a result of having grown wistful, Highland returned to be Editor again one last time, in 1982.) On top of that, Highland had prepared for his Renaissance Period tour de force by being the 1974 WSC *Proceedings* Editor. And so, in total, he was Editor for six sets of WSC *Proceedings*! (Also recall that in 1976 he was back-from-the-brink WSC General Chair as well as being *Proceedings* Editor.)

It might be noted that Harold Joseph Highland was not content to focus his considerable editorial (and other) energies and talents exclusively on the Winter Simulation Conference. During the nine-year period ending in 1983, he edited over twenty sets of conference proceedings; and as of 1983, he had also written some twenty-two books. (A brief Highland vita can be found in the 1983 WSC *Proceedings* in connection with his appearance as Keynote Speaker at that WSC.) During the 1972–1980 period, Highland also edited thirty-two issues of the ACM/SIGSIM publication, *Simuletter*.

The preceding use of the term *Editor* warrants comment. Beginning with the 1976 WSC, credit for coediting the WSC *Proceedings* is given in the *Proceedings* to the Program Chair and the General Chair as well as to the Editor (Editor-in-Chief). This is in recognition of the major role that both the Program Chair and General Chair play in stimulating, promoting, and facilitating the creation of the papers that make up the contents of a WSC *Proceedings*. The substantial chore of accomplishing all operational aspects of producing a *Proceedings* falls to the Editor himself or herself.

SELECTED DEVELOPMENTS IN SIMULATION DURING THE 1976–1985 PERIOD

Selected developments in the area of simulation itself during the 1976–1985 period are pointed out in the following subsections.

Growing Recognition of the Importance of Simulation

During the WSC Renaissance Period, simulation made significant headway in establishing for itself a reputation as one of the most effective methodologies there is for helping deal at a detailed level with the complex systems and problems so often faced in practice. Simulation started out with one or two strikes against it in this regard. Some of the challenges encountered in the late 1950s and the early 1960s in attempts to use simulation are spelled out in the Twenty-Fifth Anniversary Panel Discussion immediately following this article in these *Proceedings*. And, in the chapter on "Computer Simulation of Management Systems" appearing in the 1969 first-edition of his successful book, *Principles of Operations Research*, Harvey M. Wagner called to the reader's attention in the first section, entitled WHEN ALL ELSE FAILS ..., that "Most operations research analysts look upon digital computer simulation as a 'method of last resort'" (Wagner 1969, p. 890).

Progress made in simulation languages, methodology, and education as well as in computer hardware during the Renaissance Period and beyond have brought things to the point that simulation now commands substantial use and respect. Interesting insights in this regard are provided by Harvey Wagner himself. In his Keynote Address at the 1977

WSC, only eight years after his aforementioned book first appeared, Wagner spoke favorably and optimistically about simulation. (Unfortunately his Keynote Address is not recorded in the 1977 WSC *Proceedings.*) And then some eleven years later, in his invited 1988 Harold Larnder Memorial Lecture (entitled "Operations Research: A Global Language for Business Strategy" and presented to the Canadian Operational Research Society), Wagner put simulation in an extremely positive light (Wagner 1988). In the lecture he argues that "the concepts and vocabulary of operations research have become a pervasive part of the thinking of modern American industrial managers and that the related models are playing important roles in informing the decisions that they make." For purposes of his supporting analysis, he puts operations research activities into the five categories of mathematical-programming models, discrete-optimization models, dynamic models, multivariate statistical models, and computer simulation models. On the topic of simulation, he states that

> computer simulation models have enabled companies to test strategies before implementing them and thereby substantially reduce the risk of adopting an unworkable approach. The ambitious nature of these applications is impressive. Of all the techniques mentioned, computer simulation is the most resource intensive. Nevertheless, the number of applications of this approach probably *exceeds that of mathematical programming by a factor of ten to one* [emphasis added].

That simulation outpaces mathematical programming in its applications by an estimated factor of ten to one is remarkable, given the frequent use of linear programming and other mathematical-programming techniques.

Another index on the importance of simulation and the growth in its recognition is provided by a longitudinal survey sent to a random sample of members of the Operations Research Society of America at five-year intervals in 1973, 1978, and 1983 (Harpell, Lane and Mansour 1989). Deliberately directed separately to educators and practitioners, the survey asked them to rank the quantitative techniques believed to be most important to teach operations-research majors. Based on sample sizes of about one hundred in each group, the educators and practitioners respectively ranked simulation in positions three and four in 1973; three and four again in 1978; and then two and two in 1983. (In 1983, educators gave first rank to linear programming and practitioners gave first rank to statistics.)

These reports and findings are only several among a larger number of reports and survey-based findings over the last fifteen to twenty years which all lead consistently to the conclusion that simulation is now widely recognized as perhaps the most highly effective method that can be used to cope with complex problems and systems at an appropriately detailed level.

Language and Methodological Developments and Textbook Literature

This subsection comments on aspects of simulation languages and methodology during the Renaissance Period and surveys some of the simulation textbook literature before and during this period.

When the WSC 1976–1985 Renaissance Period began, simulations were run in batch on mainframe hardware (often with only one turnaround a day) using languages such as IBM's GPSS/360 and GPSS V; Pritsker & Associates'[2] GASP IV and Q-GERT; and CACI's SIMSCRIPT II.5. Some attempts had been made to provide an interactive capability, but this fledgling capability was crude by today's standards and was not within the reach of most people anyway.

It can be noted parenthetically that GASP IV was the first widely used combined discrete-continuous simulation language, and its introduction in 1974 triggered a wave of combined simulation applications in a broad diversity of industries and academic disciplines during the Renaissance Period. A. Alan B. Pritsker's formulation of the general principles of combined discrete-continuous simulation, reflected in GASP IV, was significant in the evolution of the field of simulation. (For more details about simulation modeling languages, see the Twenty-Fifth Anniversary Panel Discussion in these *Proceedings.*)

The WSC Renaissance Period witnessed the replacement of GASP IV and Q-GERT with SLAM (developed by A. Alan B. Pritsker and C. Dennis Pegden), with the first SLAM textbook appearing in 1979 (Pritsker and Pegden 1979) and the first WSC SLAM tutorial taking place at the 1979 WSC. Within half a dozen years, an improved version of SLAM (SLAM II) was released (Pritsker 1984), and the simulation system TESS (The Extended Simulation System) was made available as well to support modeling and analysis for SLAM II users. TESS made strides toward providing the "simulation practitioner's workbench" which had been forecast in a 1983 article as an eventual development in simulation (Henriksen 1983).

[2] Pritsker & Associates, Incorporated is now known as Pritsker Corporation.

The appearance of SIMAN, a modeling language designed by Dennis Pegden, also took place during this period. A SIMAN textbook was published in 1982 (Pegden 1982), and a SIMAN tutorial was given at a WSC for the first time in 1983. In his design of SIMAN's modeling framework, Pegden accommodated ideas proposed by Bernard P. Zeigler in *Theory of Modelling and Simulation* (Zeigler 1976). As for operational details, "SIMAN represents a completely new design for a FORTRAN based simulation language. SIMAN incorporates a new data structure which allows it to run on mini and 16 bit micro computers as well as large computers" (Pegden 1982, Preface).

SIMSCRIPT continued to evolve during the 1976–1985 WSC Renaissance Period. Originally developed within the RAND Corporation and appearing in pre-Renaissance 1963 (Markowitz, Karr, and Hausner 1963), SIMSCRIPT evolved through several stages (Wyman 1970) and reached the level of SIMSCRIPT II.5 by 1973 (Kiviat, Villanueva, and Markowitz 1973). In Renaissance year 1976, SIMSCRIPT's original event-oriented world view was supplemented by the addition of processes and resources (Russell 1983). And then, in 1982, a continuous modeling capability was also installed as a standard part of SIMSCRIPT II.5. (Animation came later to SIMSCRIPT in 1987 in the form of PC SimAnimation.)

The first language tutorial ever given at a WSC was a SIMSCRIPT tutorial held at the second (1968) "WSC." SIMSCRIPT tutorials have continued to be a regular part of WSCs ever since. Ed Russell gave his first WSC SIMSCRIPT tutorial at the 1973 WSC; and with the exceptions of 1988, 1989, and 1990, he has given a SIMSCRIPT tutorial at each subsequent WSC.

The major Renaissance Period developments in GPSS were the introduction of Wolverine Software's mainframe GPSS/H in 1977 and of Minuteman Software's GPSS/PC for personal computers in 1984. An upwardly compatible superset of IBM's GPSS V, GPSS/H was designed and implemented by James O. Henriksen (Henriksen 1977) and was the first compiler-based implementation of GPSS. (A feature of GPSS/H novel for simulation languages at that time was inclusion of an interactive capability.) Later during the Renaissance Period (1983), GPSS/H was also implemented for VAX-family computers (and has been implemented more recently for personal computers).

Minuteman Software's GPSS/PC was designed and implemented by Springer W. Cox, with this effort beginning in 1981 and with GPSS/PC first shipping in 1984 (Cox 1984). GPSS/PC was modeled after IBM's GPSS V but was designed expressly to run on the IBM Personal Computer. By exploiting the PC environment, GPSS/PC was not just a simulation modeling language but was a simulation environment specifically designed for interactive use, providing such features as a context-oriented editor and online help. (These features were later augmented in 1986 with the introduction of graphics and animation into the GPSS/PC simulation environment.)

Tutorials on GPSS began at the fifth (1971) "WSC" with one given by Tom Schriber, who has given a GPSS tutorial at each WSC since then. Starting with the 1986 WSC, there have been two or even three GPSS language "tutorials" at WSCs, reflecting the fact that unlike SIMAN, SIMSCRIPT, and SLAM, for example, GPSS is a multivendor language. In particular, Schriber's generic GPSS tutorial is now typically complemented by independent WSC sessions specific to GPSS/H and GPSS/PC.

A substantial simulation textbook literature had materialized in the 1960s and the early 1970s, characterized by books such as (ordered chronologically, and with the list intended to be suggestive, not exhaustive) *Industrial Dynamics* (Forrester 1961); *SIMSCRIPT—A Programming Language* (Markowitz, Karr, and Hausner 1963); *Computer Simulation Techniques* (Naylor et al. 1966); *Computer Modeling and Simulation* (Martin 1968); *Essentials of Simulation* (Mize and Cox 1968); *System Simulation* (Gordon 1969); *Simulation in Business and Economics* (Meier et al. 1969); *The Design of Computer Simulation Experiments* (Naylor 1969); *Design and Use of Computer Simulation Models* (Emshoff and Sisson 1970); *Simulation and Analysis of Industrial Systems* (Schmidt and Taylor 1970); *Simulation Modeling: A Guide to Using SIMSCRIPT* (Wyman 1970); *GPSS Primer* (Greenberg 1971); *Computer Simulation Applications* (Reitman 1971); *SIMSCRIPT II.5 Programming Language* (Kiviat, Villanueva, and Markowitz 1973); *Computer Simulation Experiments with Models of Economic Systems* (Naylor 1971); *Simulation of Discrete Stochastic Systems* (Maisel and Gnugnoli 1972); *Concepts and Methods in Discrete Event Digital Simulation* (Fishman 1973); *Systems Analysis* (McMillan and Gonzalez 1973); *The GASP IV Simulation Language* (Pritsker 1974); *Simulation Using GPSS* (Schriber 1974); *The Application of GPSS V to Discrete System Simulation* (Gordon 1975); *Statistical Techniques in Simulation* (Kleijnen 1975); and *Systems Simulation: The Art and Science* (Shannon, 1975).

Note that the first three of the preceding books predate the first (1967) "WSC," with the first two books being world view and language specific. The first book, on the topic of Industrial Dynamics (later to become known as System Dynamics and as Urban Dynamics), was cited in the *New York Times* by Professor John R. Platt of the University of Chicago as "one of the seminal books of the last twenty years ... books that as far as we can now guess might be comparable in ultimate importance to, say, Galileo or Malthus or Rousseau or Mill" (citation repeated on the book's inside front cover). It might also be noted that the Industrial Dynamics world view had been described and computer implemented even earlier than 1961 (Forrester 1958). A tutorial was given at the 1970 "WSC" on DYNAMO (software implementing the Industrial Dynamics world view), and a later textbook appeared on System Dynamics during the Renaissance Period (Roberts et al. 1983). Even later, Macintosh software (STELLA) implementing System Dynamics became available. But Industrial Dynamics and its derivatives have not played a role in the WSCs, which are devoted principally to discrete-event simulation and occasionally include some aspects of combined discrete-continuous simulation. (Industrial Dynamics and its derivatives employ a world view based on continuous simulation.)

During the WSC Renaissance Period, continuing developments in modeling languages and simulation methodology are reflected in such books as (ordered chronologically, and with the list intended to be suggestive, not exhaustive): *Computer Modeling and Simulation* (Martin 1968); *Simulation with GPSS and GPSS V* (Bobillier, Kahan, and Probst 1976); *GPSS Simulation Made Simple* (Donovan 1976); *Theory of Modelling and Simulation* (Zeigler 1976); *The Process View of Simulation* (Franta 1977); *GPSS/H Users Manual* (Henriksen 1977, Henriksen and Crain 1983); *Modeling and Analysis Using Q-GERT Networks* (Pritsker 1977, 1979); *Principles of Discrete Event Simulation* (Fishman 1978); *System Simulation*, second edition (Gordon 1978); *Introduction to Simulation and SLAM* (Pritsker and Pegden 1979); *Simulation: Principles and Methods* (Graybeal and Pooch 1980); *Simulation and the Monte Carlo Method* (Rubinstein 1981); *Computer Simulation in Business* (Watson 1981); *Discrete System Simulation* (Bulgren 1982); *Simulation Modeling and Analysis* (Law and Kelton 1982); *Introduction to Simulation: Programming Techniques and Methods of Analysis* (Payne 1982); *Introduction to SIMAN* (Pegden 1982); *A Guide to Simulation* (Bratley, Fox, and Schrage 1983); *Introduction to Computer Simulation—A System Dynamics Modeling Approach* (Roberts et al. 1983); *Building Simulation Models with SIMSCRIPT II.5* (Russell 1983); *Simulation of Waiting-Line Systems* (Solomon 1983); *Discrete-Event System Simulation* (Banks and Carson 1984); *GPSS/PC Reference Manual* (Cox 1984); *Elements of Simulation* (Morgan 1984); *Introduction to Simulation and SLAM II*, second edition (Pritsker 1984); and *Multifacetted Modelling and Discrete Event Simulation* (Zeigler 1984).

Simulation books appearing during the Renaissance Period reflect the language and methodological developments of the period and the writing of general simulation books suitable for a variety of introductory courses. The replacement of the earlier GASP IV (Pritsker 1974) and Q-GERT (Pritsker 1977, 1979) with SLAM (Pritsker and Pegden 1979, Pritsker 1984) is evident, as is the introduction of SIMAN (Pegden 1982) and the expansion of SIMSCRIPT (Russell 1983). What was arguably the most used language of the period, GPSS, saw the appearance of three new textbooks (Bobillier, Kahan, and Probst 1976; Donovan 1976; and Solomon 1983) to supplement the three earlier GPSS textbooks (Greenberg 1971, Schriber 1974, and Gordon 1975) and saw another twenty-one printings of the Schriber (1974) book. (That book has now been through twenty-nine printings and is still in print.) And the appearance of Wolverine Software's GPSS/H and Minuteman Software's GPSS/PC is marked by corresponding reference manuals.

On the methodological side, the pre-Renaissance textbook treatment of experimental and statistical aspects of simulation (e.g., Naylor 1969, Naylor 1971, Fishman 1973, and Kleijnen 1975) was continued and extended during the Renaissance period by such books as Crane and Lemoine (1977), Fishman (1978), Rubinstein (1981), Morgan (1984), and Bratley, Fox, and Schrage (1983). (These books do not limit themselves to experimental and statistical facets of simulation, but it might be argued that these aspects of the books constitute their major strengths.)

As for books generally usable for a wide spectrum of introductory simulation courses, such pre-Renaissance books as Martin (1968), Mize and Cox (1968), Gordon (1969), Meier et al. (1969), Emshoff and Sisson (1970), Schmidt and Taylor (1970), Maisel and Gnugnoli (1972), and Shannon (1975) took the form during the Renaissance Period of books such as Gordon (1978) (a second edition of Gordon (1969)), Graybeal and Pooch (1980), Bulgren (1982), Law and Kelton (1982), Payne (1982), Banks and Carson (1984), and Morgan (1984). (It could be argued that some of these books have a place in the preceding paragraph as well.)

Explicit comment is in order for Bernard P. Zeigler's two Renaissance Period books (Zeigler 1976, 1984). The 1976 book is widely regarded as having laid a foundation for simulation, and the 1984 book won the TIMS/College on Simulation's Outstanding Simulation Publication Award in 1988 (see below). (Zeigler's third simulation book, *Object-Oriented Simulation with Hierarchical, Modular Models*, was published beyond the end of the Renaissance Period, in 1990.)

Additional important textbook developments have taken place since the end of the Renaissance Period, including the appearance within the past several years of books containing student versions of industrial-grade simulation software, but detailed comment is not called for here.

The Accommodation of Simulation within Professional Societies and Journals during the Renaissance Period

Prior to the Renaissance Period, professional societies were already accommodating simulation in some cases by supporting special interest groups within the societies and by cosponsoring the WSCs. For example, The Institute of Management Sciences/College on Simulation and Gaming (TIMS/CSG; now known simply as TIMS/College on Simulation, or TIMS/CS) was formed in 1963. And within the Association for Computing Machinery, SIGSIM (Special Interest Group for SIMulation) was formed in 1967. Even prior to the 1963 founding of TIMS/CSG, The Simulation Council (later known as Simulation Councils, Incorporated and then as the Society for Computer Simulation) was formed (in 1952, under the leadership of John McLeod) with the intention of accommodating professional interests in continuous simulation. (SCS now accommodates interests in discrete-event and combined discrete-continuous simulation as well, but its predominant thrust currently continues to be in the area of continuous simulation.)

As for WSC support, societies cosponsoring the 1974 WSC, for example, were the American Institute of Industrial Engineers (AIIE), ACM/SIGSIM, TIMS/CSG, the Institute of Electrical and Electronics Engineers/Computer Society (IEEE/CS), the Institute of Electrical and Electronics Engineers/Systems, Man, and Cybernetics Society (IEEE/SMCS), the Operations Research Society of America (ORSA), and Simulation Councils, Incorporated (SCS). Also cosponsoring the 1974 WSC was IBM's SHARE (the IBM scientific computer users' group). (Cosponsors of the various WSCs are listed in the corresponding WSC *Proceedings*.)

Research in methodological aspects of simulation increased significantly in quality and quantity during the WSC Renaissance Period. As a result, several professional societies established simulation departments or areas in their journals to tap into and further encourage this stream of research. In some cases the initial title of such departments was not "Simulation," but with the passage of time often evolved to this point. Consider *AIIE Transactions*, for example. This journal had no departments prior to 1976. Then, in 1976, it created a department entitled Simulation and Interactive Games, with Richard E. Nance as Editor. This departmental title was then changed in 1977 to Simulation, Gaming and Information Systems and remained that way until Nance stepped down as Editor in 1981. The departmental title then became Simulation, with Bruce Schmeiser as Editor (1981–1985). Simulation continues to be the departmental title (with William E. Biles as Editor from 1985 forward).

After the *AIIE Transactions* development in 1976, a Simulation Department was established in *Management Science* in 1978 (with George S. Fishman serving as first Departmental Editor and continuing in that capacity until 1988, when James R. Wilson, Program Chair of this 1992 WSC, replaced him). At the same time, a simulation thrust was established by Richard E. Nance in the Computational Structures and Techniques Department of *Operations Research* (where Nance was Departmental Editor from 1978 to 1982). When Peter D. Welch became Departmental Editor (1982–1987), the title of the department was changed to Simulation, Implementation, and Evaluation of Stochastic Models. When Bruce Schmeiser then became Departmental Editor (from 1987 forward), the departmental title was changed to Simulation.

Two years after the initiation in 1978 of these developments in *Management Science* and *Operations Research*, a Simulation and Statistical Computing Department was formed within the *Communications of the ACM* (*CACM*), with Robert G. Sargent serving as first Departmental Editor (1980–1985). Sargent's successor was Richard E. Nance. After *CACM* eliminated its departmental structure, Nance was instrumental (with the active cooperation of then-ACM/SIGSIM Chair Stephen D. Roberts and the support of Robert G. Sargent) in having the one-time *CACM* Simulation and Statistical Computing Department evolve into a specialized ACM journal for simulation, *Transactions on Modeling and Computer Simulation* (*TOMACS*).

Finally, in the area of journals and apart from its monthly publication *Simulation*, the Society for Computer Simulation started an archival journal, *Transactions of the Society for Computer Simulation*, toward the end of the WSC Renaissance Period (in 1984, with Olgierd A. Palusinski as the first editor).

As mentioned above, the primary thrust of SCS is currently in the area of continuous simulation, but discrete-event simulation is both accommodated and encouraged as well, as witnessed by the fact that SCS has consistently been a WSC cosponsor from 1968 forward.

The TIMS/College on Simulation has also been instrumental in stimulating and promoting recognition of significant contributions in the field of simulation. Under Chair Robert G. Sargent (1978–1980), the College in 1980 established an annual Best Simulation Paper Award for the best simulation paper to appear in *Management Science.* The scope of this award was later broadened (1987) to recognize the best overall annual simulation publication in the form of a journal article, a proceedings article, a book, or a monograph, independent of the source in which it appeared. The title of the award was also changed at this time to Outstanding Simulation Publication Award. Winners of this award over the years have been Lee W. Schruben (1981); coauthors Stephen S. Lavenberg and Peter D. Welch (1982); coauthors Marc Meketon and Philip Heidelberger tied with coauthors Averill M. Law and W. David Kelton (1983); coauthors James R. Wilson and A. Alan B. Pritsker (1985); Lee W. Schruben (1987); Bernard P. Zeigler (1988); Luc Devroye (1989); coauthors Xi-Ren Cao, Philip Heidelberger, Rajan Suri and Michael Zazanis (1990); and Ward Whitt (1991).

Late in the WSC Renaissance Period, the TIMS/College on Simulation also established a Distinguished Service Award to recognize individuals who have provided extraordinary cumulative service to the simulation community over a long period of time. First presented in post-Renaissance Year 1986, this award may be given up to one time each year. Award winners have been John McLeod (1986); Richard E. Nance (1987); Robert G. Sargent (1988); Harold Joseph Highland (1989); George S. Fishman (1990); and A. Alan B. Pritsker (1991).

A RETROSPECTIVE

The 1976–1985 period was an extraordinarily rich and significant one for the field of simulation. This period was characterized by exciting developments in the areas of simulation software and supporting computer hardware, methodological progress and archival documentation of this progress, simulation education, and professional recognition of simulation. In parallel with these developments, the Winter Simulation Conference evolved apace during this Renaissance Period by establishing a firm organizational and financial structure, by putting into place solid procedures for succession, and by providing a high-quality annual forum within which the simulation community comes together to teach and learn and be stimulated to bring about further progress in the field. As documented elsewhere in these *Proceedings*, these Renaissance Period developments have continued to unfold favorably over the subsequent years, bringing both the field of simulation in general and the WSC in particular to the positive position they enjoy today.

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JAMES O. HENRIKSEN

THE COMING-OF-AGE PERIOD (1986–1992)

OVERVIEW

This portion of the keynote address tracks the evolution of the Winter Simulation Conference and the field of simulation from 1986 to the present. Due to limitations of time and space, the narrative will take the form of illustrative and evocative observations that capture the spirit, if not the details, of our collective progress. Four sections comprise the narrative. First, changes instituted with the 1986 conference are presented. Second, the evolution of WSC over the 1986–1992 period is discussed. Third, developments within the simulation community at-large over the same period are presented. Finally, issues raised in the first three sections are brought together in a summary of where we've been over the last twenty-five years and just exactly where we stand today.

WSC '86

By 1986, the pattern of WSC alternating among Washington, DC, the West Coast, and somewhere in between, in a three-year cycle was well established. WSC '85 had been held in San Francisco, and WSC '86 was to be held in Washington, DC. WSC attendance is always highest in years when the conference is held in Washington, probably in part due to the large presence of the federal government and military in the DC area. Attendance at WSC '85 had been 350, a good showing for a West Coast conference. As General Chair for WSC '86, I knew that improving on WSC '85 attendance was virtually guaranteed, but I was determined to maximize the improvement by instituting some changes to WSC. Through the combined efforts of an exceptional Conference Committee, we were able to achieve a fifty percent increase in conference attendance, and in the process, usher in a new era for the WSC.

What did we do in 1986 that was different? Most of the changes fell into four areas: (1) taking a less conservative approach, in general, to running the conference; (2) promulgating standards; (3) recognizing overtly the commercial components of WSC; and (4) promoting the conference with a more marketing-oriented approach. These areas will be discussed in succession in the paragraphs which follow.

While the WSC is run each year by a volunteer committee, long-term policy decisions are made by the WSC Board of Directors. In the mid 1980s, the Board was very conservative. In view of some of the problems the conference had been through in the preceding ten years, I cannot fault them for their approach. (It has been said that good judgment comes from experience, and experience comes from bad judgment.) I recall vividly an incident that captures the conservative nature of the Board. In December 1985, we (the WSC '86 Committee) presented the Board with a draft copy of the WSC '86 Call for Papers. In anticipation of the surge of interest in simulation in manufacturing, we explicitly mentioned that an entire track of the program would be dedicated to simulation in manufacturing applications. The Board took exception to this, and made us remove the reference from the Call for Papers. Why did they do this? First, it was felt unfair to make a pitch to any particular subset of the simulation community, and second, it had never been done before.

Our judgment was vindicated when the anticipated surge of manufacturing-related paper submissions actually materialized. As a result the WSC '86 program included the first full track devoted to manufacturing, and the track was by far the most heavily attended at the conference. In our future dealings with the Board, we were inclined to invoke the Hopper Principle,[3] perhaps more often than we should. I often told the committee that with some of the things we were trying, if we succeeded, we would be congratulated, and if we

[3] It's easier to get forgiveness than it is to get permission.

—Grace Murray Hopper

failed we would be run out of town.

WSC always includes a mixture of speakers ranging from nervous first-timers to seasoned veterans. For this reason, we felt that it was very important to promulgate standards that made it very clear what was expected of program participants. One of the objectives we set was to make the conference *Proceedings* the best possible archive of the conference. To achieve this objective, we vigorously enforced a longstanding WSC rule requiring all nonpanel presentations to be represented by a written entry in the *Proceedings*, with the added requirement that each entry must be a minimum of three *Proceedings* pages in length. Our interpretation of the WSC rule was quite literal: no paper, no talk. We also included written *Proceedings* entries for panel sessions, including position statements for panelists.

While these policies caused some difficulties, they made it possible for the first-timer to make more informed decisions about which sessions to attend, and they improved the archival value of the *Proceedings*. Other changes we instituted included issuing more rigorous requirements for the appearance (typography, layout) of papers and issuing thorough guidelines for making oral presentations. In the ensuing years, increased availability of high-quality word-processing software and laser printers has made it easier to describe appearance requirements and has made it easier for authors to comply with the requirements.

One of the fundamental strengths of WSC is that it serves as a meeting place for people from academia and industry. Included among the people from industry are software/consulting organizations who serve the simulation community. In the earlier years of WSC, standards for inclusion in the WSC program of software-vendor presentations were somewhere between nebulous and nonexistent. To get on the program, a vendor either had to have a product that was widely used or (s)he had to give a presentation that had some "academic" merit in order to describe software products to WSC attendees. In 1986, we tried to be much more explicit about the role of software-vendor presentations by providing two software tutorial tracks, General-Purpose Software and Special-Purpose Software. These titles were somewhat euphemistic. What they really meant was that, if, in the estimation of the WSC Committee, your software were of widespread interest or in widespread use, your presentation could be included in the former track. Subject to limitations of time and space, virtually any other products could be included in the second track, without your having to conjure up some quasi-academic smoke screen. In other words, we recognized the mutual benefit to WSC attendees and software vendors of disseminating product information.

The last of the changes instituted in WSC '86 that I will describe is our attempt to take a more marketing-oriented approach to promoting the conference. The cornerstone of our approach was putting together a brochure (Preliminary Program) that had an attractive color picture on the front cover, and some real "punch" in its text. We located and paid (!) a local photographer for the right to use an attractive picture of downtown DC on the cover of the brochure. (I didn't ask the Board's permission!) When you opened the brochure, the first thing you saw was "WSC '86—What's in it for me?" After all, Reagan was in office and we were in the heart of the me-decade, so it seemed appropriate. Seriously, we wanted to convey in the clearest possible terms the different ways in which the conference was of value to the novice, the experienced practitioner, and the expert. To get the message out, we enticed the Board to increase our marketing budget and managed to overspend what they authorized, but it paid off, and it set the precedent for even greater marketing efforts in the ensuing years.

THE DEVELOPMENT OF WSC FROM 1986 TO 1992

Bob Crain, the General Chair of WSC '92, and I work together. Having served as General Chair of WSC '86 and having watched Bob over the past year, I have some perspective on what it's like to run the conference now, compared to what it was like in the halcyon days of yesteryear. It's like comparing modern baseball to the so-called dead-ball era. The intensity level has been cranked up, across the board. In the sections that follow, I'd like to comment on some of the changes that have taken place.

A number of significant changes have improved the quality of the WSC program. Although Track Coordinators were added to the Program Committee in 1986 to assist the Program Chair in dealing with the increasingly onerous chore of organizing the program, the duties of the Track Coordinators were substantially expanded in 1990 when for the first time full contributed papers (instead of extended abstracts) were required in the first week of April for review by the Program Committee. This has enabled a much more careful screening of submitted papers, and it has enabled a more proactive approach to recruiting presentations by individuals possessing particular skills.

It's interesting to compare the program of the first WSC (Conference on the Applications of Simulation Using GPSS) to the present program. The first WSC was exactly as described, *totally* devoted to applications. There were no tutorials and no methodology sessions. In contrast, the present program includes both of the latter. In fact, there are separate Introductory Tutorial and Advanced Tutorial tracks, and separate Modeling Methodology and Analysis Methodology tracks. In addition there is a State-of-the-Art Review track. Thus five of the ten tracks of WSC '92 are devoted to tutorial/methodological matters.

Software/Modelware tutorials are now clearly labeled, with the name of the vendor coming first. This is not to imply that WSC has descended into an era of overt hucksterism. On the contrary, vendor presentations attempt to maximize the understanding of their wares on the part of conference attendees. Thus, the first-time WSC attendee can get a very good understanding of what software tools are available, compressed into a two-and-a-half-day period. This is a service both to the attendee and to the software vendors.

Marketing efforts have continued to increase, and they now include overseas advertising. This will result not only in increased attendance on the part of overseas members of the simulation community, but also in increased participation in the program.

The management and administration of the conference has grown to a point where, beginning in 1990, a professional conference-planning company is used to assist the volunteer program committee.

It's interesting to note that in the early years of the conference, individuals served as Program Chair one year and General Chair the next year. In this day and age, both of these positions have come to be regarded as once-in-a-lifetime honors, with equal emphasis on "honor" and "once-in-a-lifetime."

DEVELOPMENTS WITHIN THE SIMULATION COMMUNITY (1986–1992)

The single most important development in the 1986–1992 time frame is the emergence of the PC as the platform of choice for simulation activities. (Workstations are second to PCs by a notable distance, but both are way ahead of mainframes and minis.)

Simulation is an experimental science. In the process of solving a problem, we learn what the *real* problems are. Therefore, the most valuable tools are those that facilitate exploration of problems and subproblems. Good tools can help structure and administer the exploration process, but they should not do so at the expense of making difficult or even precluding any reasonable requests on the part of the user. The PC is an ideal platform for such exploration. The implications of the ready availability of such a hardware platform are far-reaching. Some of the more obvious include the following:

A. Lower hardware cost, coupled with virtually cost-free operation, ***potentially*** places simulation within the reach of a much wider community of users.

B. The trade-off between hardware and software costs has changed to a point that software costs virtually dominate. Thus the ***potential*** for use of simulation afforded by reduced hardware cost may be mitigated by the lack of concomitant reductions in software cost.

C. The PC is a visually oriented medium. The graphical capabilities cry out for exploitation. This may take the form of animation, to visualize complex system interactions, or graphic displays that provide statistical insights. A number of years ago, I was quoted in a ***Business Week*** article as saying "Watching cartoons on a screen is no substitute for good statistical work." (At the time, it was easy for me to say, since my company didn't have any animation software to offer!) While the statement was and remains valid, I regret one major implication of the statement. In retrospect, my statement seems to imply an antagonistic relationship between statistics and the use of graphical techniques. Nothing could be further from the truth. Animations are ***straightforward*** exploitations of visual capabilities. Capturing statistical insights visually is a greater challenge; however the rewards to be reaped from continued improvement in this area will be substantial.

D. The right hardware/software enables simulationists to do easily that which they know they should do, but which in the absence of proper tools would be very difficult. Consider the chore of modeling empirical data that is to be used as input to a simulation model. We generally assume that the data are IID, i.e., independent and identically distributed, although the appropriateness of this assumption varies widely from case to case. There are at least three alternative (competing?) methodologies for modeling IID data: the use of generalized distribution families, e.g., Johnson; the use of Bézier curves; and, of course, the fitting of classical distributions to the data. Visually oriented software has been developed to implement all of these strategies. With computerized, visually oriented software based on a sound underlying methodology, input modeling can be a relatively short, insightful activity (almost fun). Without the proper software, it is a daunting task, often done inadequately.

E. The PC provides an ideal learning environment. People remember most that which they *discover* (Polya 1957). "Discovering" the central limit theorem by watching the distribution of the sample mean as repeated replications of a model are actually being run is much easier and more memorable than rederiving the mathematics. Often the best answer to a student's question is "why don't you *try* it?"

F. Taken collectively, all of the above considerations foster ever-increasing expectations of PC-based software. Coupled with necessarily lower costs, increased expectations present a real challenge to the software developer; users want more, but are willing to pay less for it. (This subject will be dealt with in greater detail below.)

It is increasingly apparent that no single vendor can fulfill all the expectations of the simulation user. Consider the user who wants to manipulate model inputs/outputs in a spreadsheet. This is a perfectly reasonable thing to want to do, but is it the place of the simulation software vendor to implement a spreadsheet capability? Obviously not! Other non-simulation vendors have already implemented superior spreadsheet programs. Therefore, the best course of action for the simulation software vendor is to build a spreadsheet *interface* (based on a widely accepted industry standard) into his software.

As the simulation community has matured, the standards for what constitutes a good simulation have gotten notably higher. A good indicator of this trend is the appearance of second editions of well-known simulation textbooks, invariably thicker than the first editions by substantial amounts. Unfortunately, the amount of time a student of simulation can spend learning his or her trade is limited. Furthermore, as the use of simulation penetrates new markets, it will be used by individuals who have less and less time to devote to the learning process. The key to success in teaching students and placing simulation within the reach of less sophisticated users is leverage obtained through improved methodology and improved software tools that implement improved methodology. Thus, the modern standards for good simulation simultaneously challenge the teacher, the researcher, and the software vendor.

One of the standards for what constitutes a good simulation deserves special mention, namely animation. Over the 1986–1992 period, the use of animation has become totally entrenched in certain applications. For example, it is now difficult to imagine a complex manufacturing material-handling application being simulated without the use of animation to portray the operation of the system. The real difficulty with animation is that it can be regarded more as a religion than just another tool in the simulationist's tool kit. For example, I once developed a model of an automated system to supply rolls of newsprint to a collection of newspaper printing presses. Years later, I developed an animation of the system. The animation looked great, and watching rolls of newsprint arrive at printing presses "in the nick of time" gave me a warm, fuzzy feeling. However, the animation fails to show *the* critical measure of performance, namely the distribution of the "nick-of-time" random variable. I could see this with a simple histogram. The key to use of animation, like the use of any other tool, is recognizing when it is and is not useful. These days, we are probably animating more simulations that needn't be animated than we are failing to animate simulations that should be.

To conclude this section, I'd like to describe in some greater detail the pressures that have been brought to bear on the simulation software industry over the 1986–1992 period. I distinctly recall having a conversation with Alan Pritsker roughly seven to eight years ago. Alan's company had been the victim of a competitor's ad that had been done with questionable taste, if not legality. Alan gave me a pep talk about promoting our profession and avoiding any activity that might give the simulation community a black eye. After all, we were in an expansionist marketplace, and we'd all get our fair share. Right?

Over the 1986–1992 time frame, competition in the simulation software industry has increased significantly. The number of competitors has increased, and some markets have begun to saturate. The relationship between a developer's development costs and the price that can be charged for a product has changed dramatically. Consider the graph at the top of the next page. In the old days, software vendors could operate in the flat portion of the curve; i.e., a wide range of prices could be charged, almost independent of development cost. The determining factor in establishing a price was the elasticity of demand; i.e., charge what you can get. The flat portion of the curve was bounded on the right by a point beyond which increasing the price gave rise to increased user expectations, and therefore, increased development costs to fulfill these expectations. ("For *that* much money, I expect more.") With the advent of widespread use of the PC, vendors are forced into an operating region to the left of the flat portion of the curve. This is a region in which, paradoxically, devel-

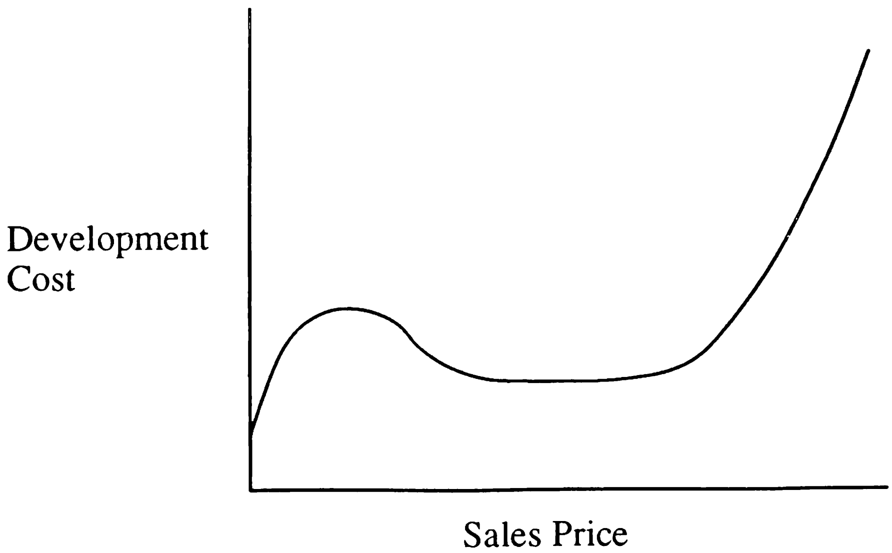

Figure 1: Simulation Software Sales Price versus Development Cost

opment costs *increase* while sales prices *decrease*.

How is this possible? Consider a buyer's expectations when (s)he purchases a text editor for $49.00. (S)he expects to take it out of the box, pop a diskette into their machine, go through a quick installation procedure, and be on the air in a matter of minutes. Hidden beneath the surface lie the carcasses of many "compatibility dragons" the developer has had to slay. The user expects the software to work, no matter what kind of keyboard or monitor he has, and no matter what release of the operating system he is running. Some users may even use the same software on a number of different operating systems. All of this is a tall order for $49.00. If the same user were buying a different piece of software for $25,000, and were told that—by the way—it runs *only* on a BelchFire Model 4 or above, under release 3.87 or later of the operating system and requires a GeeWhiz Monitor, he'd probably never bat an eye. Hence, the paradox.

Collectively, the circumstances described above place great pressures on the software developer. The rate of progress is slowed, and the long-term viability of software companies is brought into question. Thus the PC is a double-edged sword: on the one hand, it makes it easier than ever for individuals to get into the software business, and on the other hand, it makes it easier than ever to fail.

PUTTING IT ALL TOGETHER

Over the past twenty-five years WSC has undergone considerable evolution. What began as an applications-only conference has matured into a conference containing educational and methodological sessions on a multiplicity of levels. Yet, some things remain the same. If you look at the program for the first WSC, you'll see descriptions of talks that sound virtually identical to some of the papers in this year's conference, e.g., "Graphical Environments for . . . ." Of course, the graphical environment of 1992 offers one hundred times the capability at one hundredth of the cost, but the objectives are still the same, namely, to improve the effectiveness of the simulationist.

It's easy to get carried away with the glamour of high technology. One can speculate what great deeds Isaac Newton could have accomplished if he had a PC as a platform for computation and exploration. (Strictly speaking, given Newton's association with apples, it might be more appropriate to consider what he could have done with a Macintosh.) One can envision his making great strides. However, what if he spent a month editing `CONFIG.SYS` and `AUTOEXEC.BAT`, several months straightening out issues of memory-management software, and six months to learn Windows? The progress of mathematics might have been set back by fifty years! The bottom line is that the importance of tools must always be secondary to the purposes for which they are applied.

WSC is an important meeting place for academics, government/military people, and people from private industry, because it keeps producers and consumers of tools and methodologies in touch with one another. While the simulation software industry has grown significantly more competitive, people from competing companies are able to set aside their differences and work cooperatively for the good of the conference.

The easy problems are behind us. The problems that remain will require the leverage afforded only by simultaneous improvements in education, methodology, software development, and innovative, intelligent applications of simulation technology. WSC will continue to serve as a catalyst in promoting these improvements.

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STEPHEN D. ROBERTS

PROSPECTS FOR THE FUTURE

INTRODUCTION

In this part of the Keynote Address, I will discuss the prospects for the future of the Winter Simulation Conference and the field of simulation. The continued success of WSC depends directly on the future growth of the simulation profession. However the reverse is not true, since it is possible for simulation to grow while the conference falters. Many factors that influence the future growth of the simulation field are linked to broader issues. In the latter part of this discussion, I will examine some of those factors and the opportunities they represent.

Unlike the general field of simulation, the future of WSC rests entirely with the attendees and the leaders of the conference. Unless WSC carefully and continuously adjusts to the changing face of simulation, the conference may not follow the success of the field. WSC's constant challenge is to continue to be a showplace for current advances in simulation technology while providing a window on the future potential of the field.

THE FUTURE OF WSC

The growth, character, and scope of WSC are significant characteristics of an evolving conference. This evolution can be seen in the history of the conference and in the changing nature of the community that employs simulation.

Growth of the Conference

The preceding discussions of WSC history revealed steady growth of the conference since its rebirth in 1976. At this writing, WSC appears to attract about seven hundred attendees when it is held in the Washington, DC area; and WSC attracts about six hundred attendees when it is held elsewhere. "Is WSC large enough?" is an often-heard question. Some believe that one of the keys to the success of WSC is its intimacy. It is possible for a two- or three-year attendee to get to know almost everyone having a similar interest. A session with attendance of fifty to seventy-five is small enough for attendees to feel free to ask questions and perhaps visit with the speakers at the end of the session. This year there are ten parallel sessions. For many conference participants, the large number of parallel sessions means that many interesting sessions are in conflict. A larger conference would increase the number of parallel sessions and increase the difficulty of choosing among presentations.

Nonetheless, there is growing demand for participation in the conference program. Because of the large volume of good contributed papers in recent years, the current acceptance rate for full-length contributed papers is roughly fifty percent. If the conference does not expand to accommodate the increased volume of high-quality contributed papers, then the participation by attendees in the actual presentation of WSC must drop; and there then there will be added incentive for special-interest groups to spin-off more narrowly focused conferences. The challenge is to find ways to enhance conference participation without sacrificing the quality of the conference. Perhaps future Program Committees will develop other formats such as poster sessions or demonstration booths to enlarge participation.

Character of the Conference

The character of WSC is unique but changing. There is the constancy of volunteerism that gives the conference spirit and breeds participation. On the other hand, the composition of WSC's volunteer leadership has changed significantly over the past twenty-five years. WSC is always stimulating and thought-provoking because of the vigorous debate among the many professions and special-interest groups that constitute the conference. This diversity of interests and orientations of conference participants is one of WSC's greatest strengths, and the internationalization of WSC may be the next logical step in the evolution of the conference.

Volunteerism

Perhaps the most important ingredient in the success of WSC has been the volunteerism created and fostered by the conference. Everyone associated with the conference is a volunteer. The conference does not have any paid staff. In some sense this has become a burden, since volunteers generally do not have the experience to manage completely a conference that currently has approximately seven hundred attendees. Recently the WSC Board of Directors contracted with a conference-management firm to administer many of the details of running the conference, such as hotel negotiation, food planning, local arrangements, badges, signs, registration, etc. However, volunteers make all the decisions concerning the operation and content of the conference.

Another characteristic of WSC volunteerism is that everyone pays for their own registration. Many conferences waive registration for conference organizers and sometimes for speakers. WSC has never done this. All conferees pay the same price whether they are members of the Board of Directors, Conference Committee members, session chairs, speakers, or listeners.

Academic and Industry Influence

In contrast to the early years when applications-oriented practitioners dominated the conference, academics and vendors have led WSC in recent years. Some may view this with alarm. However, the composition, cohesiveness, and outlook of the practitioner community has changed substantially in recent years. Today many practitioners are viewed (and view themselves) as clients of particular simulation-software companies. Although simulation users no longer constitute the single driving force behind the conference, future WSC leadership must find new ways to ensure that the conference addresses the needs and interests of this group.

The 1967 conference leading to the formation of WSC bore the official title "Conference on Applications of Simulation Using the General Purpose Simulation System (GPSS)." Since then, many vendors have developed other simulation languages and simulation-language tools. Interestingly, GPSS remains to this day the only multivendor language, as individual vendors separately develop and promote all of the other languages and products. The tight association between vendor and language is somewhat unusual within the computer-software industry, although special-purpose software, like spreadsheets and word-processing packages, certainly have individual vendor implementations. In spite of the fragmentation of the simulation user community along the lines of vendors' product families, practitioners collectively represent an essential industrial component of WSC.

International Influence

One of the dramatic changes in world affairs is the internationalization of virtually all activities. With the demise of the Cold War, greater cooperation and competition have eased tensions between the East and the West. It is now relatively easy to cross national borders. International transportation has improved and many companies use global sourcing for production. Furthermore, the emergence of the German and Japanese economies has changed the economic focus. The general growth of the Pacific Rim and the development of the European Economic Community now means that there are many other significant interests in economic activities. These global developments can influence simulation. There is a rapidly growing interest in simulation outside the North American continent. Somehow WSC must seek to become an international conference if it is to remain a premier event of global stature.

Scope of the Conference

The scope of WSC has changed slightly over the years. Historically its primary emphasis has been discrete simulation. The Board of Directors selects a Conference Committee from previous WSC participants to organize and run each year's conference. Each year's program includes a combination of methodology, application, and tutorial sessions to represent the broad spectrum of simulation interests. In addition, the range of application areas covered by the program is an important factor in determining the popularity of the conference. The final critical factor in the success of WSC is its sponsorship, which also reflects the diversity of interests of conference participants.

Discrete Only?

The discrete-simulation interests have tended to dominate WSC. The Conference Charter states that the scope of WSC should encompass "discrete and combined" simulation. The interest in discrete simulation has been constant and continuing. Combined simulation was a strong interest in the late 1970s, but that interest has waned in recent years; and recent conferences contain only a few papers on this subject. Continuous simulation was intended to be the focus of the Summer Computer Simulation Conference. Although members of the continuous simulation community have often lamented the lack of papers dealing with continuous simulation at the Winter Simulation Conference, this interest group has never been very visible in WSC. Furthermore, like continuous simulation, training-oriented simulation has never been a major component of WSC. In spite of these traditional divisions, the boundaries between all of these interests are blurring. With the renewed emphasis on modeling, there is less concern about whether the basis for simulation-model building is a logical relationship (as for a queuing network) or one emphasizing continuous change (as for a system of differential equations). Quite possibly WSC should include a broader interest in simulation that incorporates all techniques for model representation and all types of systems. Clearly, a variety of professional groups employ simulation-based techniques. It is not uncommon for social scientists, physicists, mathematicians, chemists, and biologists nowadays to use special-purpose simulations to analyze their systems of interest. Whether the conference should expand its mandate to include these interpretations of simulation is a matter future conference program leadership will need to address.

Organization of the Conference Program

The current organization of the conference program has evolved over the lifetime of WSC. The program has been organized into "tracks" for some time. In structuring the program for WSC '86, we introduced tutorial, methodology, and application tracks that persisted throughout the conference. Also for WSC '86 we divided the tutorial sessions into introductory and software tutorial tracks, we divided methodology sessions into analysis and modeling tracks, and we set up a separate track for manufacturing. Each program committee has continued and only slightly modified this organization. Whether this organization is sufficiently robust for the future will depend on the evolution of simulation. However, as a "model" of the current state of simulation technology, it works very well for most attendees. Other organizational structures and modes of presentation will need to be considered in the future.

Applications

A critical aspect of the conference scope is the range of applications areas presented at the conference, since these topics generally draw large audiences. Previous conferences have included topics such as computer performance, health care, agriculture, judicial systems, communications, military operations, manufacturing, production planning, inventory control, scheduling, and so forth. Since 1986, there has been one entire track devoted to manufacturing; however other subjects have had "minitracks." The challenge to future Program Chairs is to stay abreast of current simulation applications and include those in the conference. The drawing power of the conference depends mainly on the program, and a strong program comes from people who proactively lead simulation interests. With the global concern for competitiveness, it can be expected that the conference will continue to emphasize those applications related to competitiveness such as manufacturing, production, and quality.

Sponsors of the Conference

A key feature of the current structure of the Winter Simulation Conference is the participation of the sponsoring societies. Presently eight organizations sponsor WSC—the American Statistical Association (ASA); the Association for Computing Machinery/Special Interest Group on SIMulation (ACM/SIGSIM); the Institute of Electrical and Electronics Engineers/Computer Society (IEEE/CS); the Institute of Electrical and Electronics Engineers/Systems, Man, and Cybernetics Society (IEEE/SMCS); the Institute of Industrial Engineers (IIE); the National Institute of Standards and Technology (NIST); the Operations Research Society of America (ORSA); The Institute of Management Sciences/College on Simulation (TIMS/CS); and The Society for Computer Simulation, International (SCS). Each of these organizations has a representative appointed to the Board of Directors; and each representative has one vote (except for the IEEE representatives, who have half a vote each). Except for NIST, each society invests an equal amount of seed money in each conference; and each society receives an equal share of any conference surplus (IEEE/CS and IEEE/SMC split a share of the seed money and any surplus funds). A conference having such a large number of sponsoring organizations is unique among meetings of technical societies. WSC is often considered to be a model for a conference based on collaboration among several large professional organizations.

Board members have had terms of approximately eight to ten years, thus providing stable leadership to WSC. There are provisions for adding (or removing) sponsoring societies of WSC. The most recent addition to WSC's sponsorship is ASA, which was added in 1985. Because the Board selects the General and Program Chairs of the WSC and creates policies for the conference, the Board plays a pivotal role in determining the future of the conference. Conference scope, as represented by the sponsorship of WSC, is critical to the future of the conference. The introduction of new sponsors—say a European simulation society—could change substantially the scope and traditions of conference. For example, the conference currently returns to Washington every three years. In the second year of each three-year cycle, the conference is usually held in the western part of the United States, while in the last year of the three-year cycle the conference is held somewhere in the middle of the country. All the conferences are held in the warmer climates, since WSC is always held in December and there is a need to minimize the probability of cancellation or curtailment of the conference due to winter weather. To date, no location outside the United States has been given serious consideration. These and other important decisions affecting the future of the conference rest with the future members of the Board of Directors.

THE FUTURE OF THE SIMULATION FIELD

Fundamental change in simulation methodology has a profound change on simulation practice. At the heart of simulation is computing technology, which has been the driving force behind the usefulness of simulation as a technique for large-scale systems analysis. Raw computing power has made simulation feasible and available to people at their desk tops. Simulation modeling methods, through simulation languages and simulation environments, have harnessed computing power for simulation purposes. Modeling methodology also makes simulation technology accessible. Analysis methods solve complicated representational problems. A simulation will need input models, often statistical distributions, as they are generally the lowest-level input to the simulation. Output methods provide a means of experimentation with the model and make the results of the simulation meaningful to the user. Of course, the application is what motivates the use of simulation and the need for simulation methodology.

Computing Technology

Over the past two-dozen years computing has changed dramatically. Mainframe computers with batch input and output have given way to microcomputers with interactive input and output. What was mainframe power costing hundreds of thousands of dollars in the 1960s is now available on the desk top for a few thousand dollars today. No doubt the miniaturization of computers will continue, and the economics of computing will become even more beneficial—more machine for less money! All this will aid in the use of simulation by promoting longer simulation runs, more replications, and more complex models. It is easy to see bigger simulations running on bigger computers. We would expect this trend to continue in the near future. There are three changes in computing technology in the near future that may significantly change simulation methods. These are the development of parallel/distributed computing architectures, incorporation of real-time simulation, and the growth of visualization methods.

Parallel/Distributed Architecture

Simulation modelers may want more than just raw computing power. They may want to participate in the multimedia world using live-action videos, and they may want to have access to advanced technologies like voice recognition. Such escalation of user expectations will require significant increases in computing performance. Serial-computing architecture is widely considered to be a limit on the growth of traditional computing power. Designers of computers apparently can only boost clock speeds so far with microelectronics, and transistors can have connections made only so thin. Perhaps the "semiconductor wall" can be pushed back indefinitely, but economics may work against this approach. An alternative is to employ several computers in parallel or in some form of a cooperating (distributed) network. The basic idea is that a central processing unit (CPU) will become as cheap to produce as a unit of memory. So a machine or system composed of many parallel CPUs will be almost as inexpensive as one having only memory, but far more intelligent. In fact, changes in current single-chip technologies are employing these parallelism ideas with multifunctionality specifically for floating-point operations, graphics calculations, and message passing.

For simulation, the central question is how best to use this developing technology. There are many types of parallelism, even to the point where the term *parallel* is difficult to define. Single-instruction parallel architectures are unlikely to take simulation as far as some other applications, since simulation tasks generally do not operate on data expressed in a large uniform array. Multiple-instruction parallel architectures appear to be more applicable to simulation, but the design of communication among interacting processors is critical. Some architectures share memory while, in others, memory is distributed. These design issues are serious concerns for simulation-software developers, because simulation software needs to take careful advantage of the computer architecture if high computation efficiency is to be realized. These concerns raise fundamental questions regarding the processing of a simulation and how best to divide it into communicating processes. A central complication in simulation is that simulation processes must be synchronized with respect to simulated time. An important challenge for simulation software designers is take all of these factors into account without undue user involvement.

Bear in mind that most of these observations apply to what we know about the existing simulation applications. But what if the very nature of simulation applications changes? What if the simulation incorporates multimedia presentation through live-action video or interaction with the user via voice recognition? Now the processing requirements are not only extensive, but extremely complex as simulation processes incorporate various forms of input and output. Therefore, the full benefit of parallel/distributed simulation will be realized only when the software exists to support the simulation applications. It is a grand challenge for the next generation of simulation-software developers.

Real-Time Simulation

Just as computing changed from batch operation to interactive operation, simulation is likely to move from an off-line planning tool to an on-line operational tool. Thus timeliness of simulation results will become equally important with correctness of the simulation. Real-time simulations can range from managing and controlling actions on a factory floor (via simulation of alternative management strategies) to control of sound, graphics, and full-motion video in a multimedia presentation of an interactive simulation. A real-time simulation implies that the simulation is embedded into the management and control of an actual system in operation, and the simulation must meet timing constraints in scheduling activities. The simulation provides decision-making assistance by examining the alternative controls through simulation of their impact. The simulation would be parameterized by the information drawn from various sensors connected to the system being controlled. Timing is critical because if the simulation results are not known within an appropriate amount of time, the robot on the factory floor might pass the workstation it was supposed to service, or the sound in the presentation might be too late in the video. The timing can be quite complex, as the time required to provide a service may change dynamically or be changed by some random event such as an operator pressing a key on the display or someone walking in front of the robot. A real-time simulation must be able to adapt to unexpected change and recover from unexpected errors, such as a part slipping from a robot's grip. Real-time simulations need to be fast, predictable, reliable, and adaptable.

Many of the issues that confront developers of parallel/distributed simulations also confront developers of real-time simulations. If the timeliness constraints are to be met by reliable simulations, then greater computing power needs to be made available. Much of this power is expected to come from the careful decomposition of a simulation into subsystems and allocation of those subsystems within a distributed architecture. Also, simulation languages and packages that affect control and operation will need to incorporate a convenient representation of timing constraints, fault tolerance, and other run-time information. It is likely that solutions to problems in parallel/distributed simulations will have direct influence on real-time simulations, since simulation processes require careful communication and cooperation. Learning to divide a simulation for these purposes is a second grand challenge.

Visualization

Perhaps no other single technology has brought as much excitement to simulation as visualization. In the 1970s and before, flowcharts and networks were used to describe simulations visually. In the early 1980s, modelers were presenting their results with bar graphs, pie charts, and so forth, often in color. In the late 1980s, animation was added to simulation and combined simulation/animation became almost a way of life. In some instances, animation became more important than the simulation. Today, there exist a variety of animated simulations, sometimes acting with the simulation, sometimes after a simulation, sometimes in two, two and one-half, or three dimensions. These animations often import drawings from computer-aided design packages and other drawing tools. Pictures reveal more information than words, and simulations that can produce pictures are generally more interesting than those that just produce numbers or text. The benefits of these kinds of visualizations are: (1) they bring a wider spectrum of interested parties into the simulation; (2) they facilitate validation of simulation-model behavior since people who have no simulation experience, but have real system experience, can view the animation; and (3) they facilitate verification since pictorial representations embody so many variables. The amount of information is also a problem because there are no systematic means of summarizing the information and there can be no statistical inference. But visualization is still in its infancy. Ultimately, there is the "virtual world," perhaps a real-time holographic representation of an experimental system—a "holodeck" from Star Trek. Virtual reality has captured the imagination of people inside and outside the simulation community, and the concept represents an ultimate visual representation of a system. While there is no system that provides that expected kind of representation, the general problems of making virtual reality practical are still fundamentally related to available computing power. Visualization requires massive information and processing whose magnitude seems completely dependent on the future success of parallel/distributed computing technology. It is unlikely that the problems related to providing any truly practical form of virtual reality will be resolved soon. Nevertheless, the potential is fantastic and extremely exciting. It is truly a grand challenge.

While virtual reality may be a distant goal, there are more immediate visualization opportunities in the form of multimedia presentations that could combine sound, graphics, and video. Perhaps the central system would be a traditional simulation, but a full range of audio and video input and output would augment the simulation. The presentation of simulations in a form that nonsimulation people can understand has been a constant challenge to the simulation community. Presentation multimedia integrated into the simulation may greatly enhance the acceptability of the simulation and engage more decision makers in the modeling and analysis.

Software Advances

It is impossible to discuss computing hardware without considering software opportunities. Software will render the hardware functional and available to a wider range of users. Software users now cover a broad range of sophistication, from the person who has only a one-time use for simulation to solve a particular problem, to people for whom simulation is a full-time job. Most users fall somewhere in between, although the larger potential number probably exists at the novice level. A growth area in WSC over the past decade has been in simulation languages and simulation modelware. Vendor-software presentations occupy two tracks of the present conference. Vendors provide an important component of the conference. Software advances have been critical to the widespread use of simulation technology. Some of the critical future issues include the interoperability among software systems, the trend to object-oriented designs, the use of artificial intelligence, the opportunities for improved simulation analysis, and the fostering of application products.

Interoperability

Traditionally simulation software attempts to address most of the needs of the simulation user, regardless of the user's level of sophistication or interest. More software is appearing that addresses specific needs and specific users. It is becoming increasingly clear that a single simulation vendor will be unable to supply all the software required in a given simulation project, and it is likely that different vendors will specialize in specific areas like graphics, animation, output analysis, manufacturing, and so forth. For instance, the rapid changes in animation require a specialized staff that can assess the existing computing technology and adapt the developments into simulation-related products. Similar comments apply to other components of a simulation project. "Featurism"—the rapid proliferation of optional features for simulation-software products—drives up the development cost of simulation packages; and in some sense, this phenomenon also impairs the usability of the resulting products. A potential resolution of these problems is that different vendors may choose to emphasize certain selected aspects of the typical simulation project, such as the analysis of output. Thus, if a simulation user must employ several software products during a simulation study, these products will need to exchange information conveniently. Such interoperability implies that standards of information exchange (such as file formats) or a common environment (such as Microsoft Windows) become accepted across several products with different vendors (or that there be simple translation). A word processor imports graphics and spreadsheets, and it exports to a desktop-publishing system. A simulation may need to import output from an optimization system, or it may need to export output to a spreadsheet. Convenient exchange of information is being accepted for other widely used software systems; why not for simulation software?

Object-Oriented Design

Objects form the foundation of any software package, especially simulation products. It is the predefined object-categories (classes) within a simulation product that make it easy to use and understand. All the modeler has to do is to select, for example, a queue and then write its specification (ranking rule, capacity, etc.). While these predefined objects are easy to use, they can also be very restrictive. Consider the difficulties of modeling a tennis game using a queueing-network representation. Most simulation products allow for some procedural extension of their "language" (that is, the set of basic simulation-oriented symbols) through resort to a general-purpose programming language; but few simulation products allow extension of their fundamental object-categories. This lack of extensibility means that the creation of a new kind of entity, say a tennis player, will not have the same status as a built-in entity. In such a situation, only product vendors can determine the true features of a simulation product.

Object-oriented designs attempt to overcome the inherent limitations of procedural extensions by granting to users certain "designer" privileges. Users may create their own object-categories. The properties of "inheritance" and "genericity" can be used to derive new classes from existing object-classes. For example, fixed-path vehicles may "inherit" the properties of general vehicles, and there may be "generic" methods for deciding the path to travel between two locations. Objects from one category can become a property of another, as in the case where the new kind of vehicle needs certain statistical properties. Functionality can be "overloaded" so than different objects can perform the same function. For instance, several different material-handling devices may "move" something from one location to another. Communication between objects occurs through messages passed back and forth. The key is that an object decides for itself what to do and "encapsulates" all of its functionality.

Object-oriented designs have the potential to provide a natural mechanism for exploiting parallelism in a simulation. Objects and object-categories may be assigned individual processors and used as targets during synchronization. By encapsulating all simulation functionality, users may easily extend object-oriented simulations. The very notion of objects facilitates visualization. Object-oriented simulations may more naturally adapt to visual interpretation through animation and multimedia applications. A view of simulation usage based on objects may be a convenient means to create interoperable systems. Indeed, some computer operating systems have adopted this structure for linking, compiling, and running software. By having such potential, object-oriented simulation platforms may provide a unifying structure that can form the basis of a wide variety of future simulation products.

The downside of the object-oriented influence is that object-oriented concepts and terminology are quite abstruse and it's not clear how easily novice users can assimilate these ideas. It is unlikely that the following will be well received: 3+4 is the result of object 4 sending object 3 the + message. Therefore if the object-oriented concepts are to have impact at all levels in the chain of simulation users, then we must devise a more accessible formulation of these ideas and concepts.

Artificial Intelligence

The idea of an artificially intelligent inanimate object conjures up all sorts of images. In some ways the fascination with virtual reality is reminiscent of the past hyping of artificial intelligence (AI). Yet, even though the early images and potential suggested by the promoters of AI have never been fully realized, the success of "smart" devices and software cannot be denied. In limited instances, forms of expert systems have achieved impressive results—remember the "smart" missiles and bombs used in the recent Gulf War. Many real systems contain intelligent devices. "Smart" machines can inspect, change tools, modify operations, etc. Simulation of smart systems requires that the simulation objects have "expertise." Expert-system technology, primarily through rule-based production systems, is beginning to appear in simulation software. Also, simulations are beginning to provide help with experimental expertise in control of real-time systems. It would appear that AI is becoming a useful tool in simulation, and new simulation software products and simulation environments will implement some aspects of expertise. In advanced simulation environments, this expertise may help the less well-informed user select appropriate modeling-and-analysis tools and interpret the resulting outputs. Eventually, however, a system becomes "too smart"; and users may no longer understand what is being done. To walk the line between too much information and not enough information seems to be a constant challenge.

Analysis

With all the emphasis on computing technology, it is easy to overlook the substantial benefits of continuing advances in analysis methodology. There has been a trend in simulation to explore bigger models, and models that more closely resemble the real world. All this detail requires extensive information processing and creates a tremendous input/output burden, requiring far greater computing power. Visualization increases the need for more computing power as well as the software to harness that power. In the pursuit of a complete representation of a given system, it is easy to forget that the purpose of using a model is to avoid dealing with all the information in the real system. While representational issues are important, there is also the important issue of how to deal with the information that a simulation produces together with the information that the simulation requires as input. Animation, interactive input and output, broad modeling capabilities, real-time computing, etc., are simple problems in comparison with the hard problems of coping with simulation information. Everyone should recognize that a few minutes spent looking at an animation doesn't say much about the totality of the system behavior, even with all its visual attractiveness. The challenge of analysis is to provide help in dealing with the glut of information being produced.

All simulations require some input during or preceding their execution. Often a statistical distribution or stochastic process provides the input. Sometimes actual historical data generated by the real system or queries to a data base provide the input to a simulation. With the growing complexity of simulation models, the required inputs are more complex. In particular, we need more general probabilistic input models to handle time-dependent input processes and multivariate distributions. Current research is producing a broader variety of such probabilistic input models, but the difficulty in understanding the interdependencies with time and between variables is challenging. The specifications for these input models need to be simplified and oriented toward characteristics that are meaningful to users. Also we need more effective ways for combining subjective information (that is, beliefs and experience of knowledgeable persons) with data to build and estimate input models when data are scarce or extremely difficult to obtain. An interactive visual display that is easily modified by the user coupled with flexible data-fitting procedures could provide useful input models by combining experience with data.

With greatly expanded data-storage and computing capacity readily available, much future research and development will focus on computationally intensive methods for robust, distribution-free analysis of simulation output. For example, we anticipate wider use of resampling techniques such as the jackknife and the bootstrap. The basic idea of resampling plans is to study the properties of a statistical estimator (such as the bias or standard deviation of the estimator when sampling a target distribution) by repeatedly sampling with replacement from an observed set of data (where the given observations were originally taken from the target distribution), recomputing the estimator for each such sample, and using the resulting estimator properties to infer the corresponding properties of the estimator when sampling the target distribution. The advantage of this approach is freedom from the constraining assumptions of traditional parametric statistical theory—for example, assumptions about the functional form of the target distribution. However, the generality of resampling plans involves the substitution of computational power for more traditional mathematical analysis. This is likely to be a recurring theme in the future of simulation analysis methodology.

Another important theme of simulation analysis in the future will be methods for handling the multiplicity of simulation inputs and outputs whose interrelationships must be explicitly considered in the design and analysis of efficient simulation experiments. This includes building simulation metamodels in which several output responses of interest are expressed as functions of the important design (input) variables for the following purposes: (1) approximation of the unknown simulation response surfaces; (2) prediction of future responses in the real system; and (3) optimization of expected system performance, possibly subject to some constraints.

Much future work in simulation analysis will also focus on techniques for simulation optimization and sensitivity analysis. Although we have witnessed explosive growth in this area in the last decade, additional development is required before many of the newer techniques (such as the likelihood-ratio, score-function, and perturbation-analysis methods) can be routinely applied to large-scale simulation experiments.

Simulation Environments

Extensive future software developments will mean that the simulation user will face a vast array of tools and techniques. Somehow all this development will need an environment that permits the user to identify and use the appropriate tool and to switch easily between tools. The platform for providing these facilities may be the simulation environment. The simulation environment plays exactly same role that an operating system plays in managing the software subsystems of a computer. The simulation environment manages resources and provides the means for users to navigate among them. All simulation users now recognize the importance of the graphical user interface in an operating system and the direct application of such a graphical user interface to simulation environments. Furthermore, it is easy to see how new developments in operating systems have direct consequences for the simulation environment. Environments in the future will be visual, interactive, and intelligent; in addition, they will work with a wide variety of hardware and software resources. It is not hard to conceive of a simulation environment that incorporates sound, video, and a host of other sensory equipment for understanding systems through simulation. Although a universal simulation environment might be a laudable goal, it is unlikely to happen in the near future. What is more likely is that interoperability will be addressed. Interoperability is in the best interest of the software vendors. A universal simulation environment is not.

Future of Simulation Applications

In a peaceful world, economic conflict and cooperation surfaces as a prominent concern, as individuals and nations attempt to amass economic security, instead of military security, for themselves and their communities. There is now global competition on a level never before witnessed. The impact of this fundamental shift in the relationships among communities is not well understood, and it is the subject of keen debate and discussion. Simulation will undoubtedly find a role as people try to find ways to develop an advantage in the production of goods and services. Effective production seems to center on the quality of products and services, the cost of those products and services, and the timeliness of their production. The number of simulation applications dealing with these topics should increase. On the other hand, the role of competition may have a negative side in that there may be less sharing of information in an effort to maintain a competitive advantage. The intensity of competition among North American vendors of simulation products has increased greatly. Non-American vendors of simulation products will join in the pursuit of market share in the near future. The market may shift to the European Economic Community, where there is evolving perhaps the largest base of simulation users and software developers. Because simulation users are often closely allied with individual vendors, vendor loyalty may become an even more important tool; and vendors also may opt out of disclosure of tools and techniques.

In addition to problems involving competitiveness, there remain world-class problems. These would include the environment, poverty, overpopulation, disease, health care, education, and ethnic conflict. All these are problem areas for anyone in any place and provide significant opportunity for the simulation community at large.

CONCLUSION

Suppose that all computing-technology restrictions were totally eliminated. Suppose simulations could be represented, executed, and presented in a perfectly convenient and user-friendly way. If we overcame all the technical problems of simulation, what would be left? The answer is that people have always, and will always, pose the ultimate limits to our use of simulation. The grandest challenge of all is the development of human potential. Although technical problems are unlikely to be totally resolved, it is certain that the imagination and insights that people have will never be replaced. People and their interaction with simulation will offer the continual challenge. How can the users of simulation be taught, shown, and urged to develop their skills so that simulation is used ethically and appropriately in solving problems that concern us individually and as groups?

Somehow the packaging of simulation technology for use by the less sophisticated users must contain the appropriate safety nets. The challenge is to make things sufficiently easy to use without encountering the dark side of simulation misuse. Overenthusiastic marketing tends to oversell the technology, and it is too easy to perpetrate a cruel hoax on the naive user. Much of the simulation advertising tends to pander increasingly to that end, resulting in disillusionment, misuse, and missed opportunity.

Simulation problems have grown so much in complexity and scope that collaboration in solving problems offers the best hope. Software vendors and research methodologists cannot function separately. Software needs methodology, if it is to address problems of fundamental importance. Research needs convenient access to technology, since methodology alone is sterile and pointless. Users need simulation that employs the finest methods within the best software to solve real problems. Perhaps the most valuable contribution of the Winter Simulation Conference is that it is a meeting place to bring these different interests together.

AUTHOR BIOGRAPHIES

ROBERT C. CRAIN has been with Wolverine Software Corporation since 1981. He received a B.S. in political science from Arizona State University in 1971, and an M.A. in political science from the Ohio State University in 1975. Among his many Wolverine responsibilities is that of lead software developer for all PC and workstation implementations of GPSS/H. Mr. Crain is a member of IEEE/CS, SIGSIM, and ACM. He served as Business Chair of the 1986 Winter Simulation Conference and is General Chair of the 1992 Winter Simulation Conference.

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Professor Sussman was the Program Chair of the 1971 Winter Simulation Conference, and he was the General Chair of the 1973 Winter Simulation Conference. He has authored many publications, has lectured extensively in the U.S. and abroad, and has served as the Head of the Department of Civil Engineering and as the Director of the Center for Transportation Studies at MIT.

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JAMES O. HENRIKSEN is the President of Wolverine Software Corporation, located in Annandale, Virginia (a suburb of Washington, DC). He is a frequent contributor to the literature on simulation and has presented many papers at the Winter Simulation Conference. His first WSC paper, entitled "Building a Better GPSS: a 3:1 Performance Enhancement," was presented at the unofficial 1975 Winter Simulation Conference. This paper detailed early results in the development of the world's first (and still the *only*) compiled-code implementation of GPSS. In the years since 1975, he has contributed papers dealing with event-list algorithms, simulation of conveyor systems, and modeling methodology. A number of the methodology papers presented examples for which the "obvious" solutions encouraged by the world view of the simulation software used could be significantly improved upon with some additional thought.

Mr. Henriksen served as the Business Chair of the 1981 Winter Simulation Conference and as the General Chair of the 1986 Winter Simulation Conference, and he has served on the Board of Directors of the conference as the ACM/SIGSIM representative. From 1980 to 1985, Mr. Henriksen served as an Adjunct Professor in the Computer Science Department of the Virginia Polytechnic Institute and State University, where he taught courses in simulation and compiler construction at the university's Northern Virginia Graduate Center.

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