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THE FUTURE OF THE SIMULATION INDUSTRY

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ABSTRACT

Seven panelists representing a wide area of simulation interest address the future of the simulation industry. The panelists raise a host of issues. But, they also offer solutions addressing the issues that they raise.

1 INTRODUCTION

The simulation industry can celebrate its technological capabilities and its applications in a wide number of areas. A look at the Winter Simulation Conference *Proceedings* will attest to these successes. But simulation is used in only a small fraction of the cases where it might be applicable.

Seven individuals representing a wide range of perspectives were invited to participate in the panel to address this concern and provide their forecast for the future of the simulation industry. The panelists are experienced in manufacturing consulting, academia, research, military, and government. Their suggestions about the future of the simulation industry are thought provoking.

They raise many issues. And they provide many possible solutions to those issues.

2 JOSEPH C. HUGAN, FORWARD VISION SERVICES

The future of the simulation industry is increasingly fractured from a market perspective. The two main areas of growth are in easy-to-use capacity planning simulation tools and high-end vertical applications that are tightly integrated with other engineering disciplines. These trends will also lead to changes in the simulation user community. The term "simulation user" could be a part time user, a full time user, or a specialist.

Recent years have seen the introduction of low-cost simulation tools that can be propagated throughout medium and large organizations. This influx of users and revenue has allowed these tools to adapt to the needs of the less frequent simulation user through the use of custom tool bars, innovative interfaces, and template models. These lower cost tools have also had the effect of stifling generic innovation in the traditionally higher priced tools. Vendors have been forced to develop new markets for simulation through the creation of vertical applications and new functionality pointed at non-traditional simulation markets like programmable logic controller (PLC) emulation or process planning.

Trends in the marketplace and offerings from the major software vendors suggest that the growth in the 3D area of the industry will come from increasingly diverse vertical applications. While the traditional market of capital justification for large projects will remain, areas such as PLC emulation, process planning, and embedded simulation are taking center stage as solutions like scheduling and business process re-engineering (BPR) had in the past.

These new applications will have a positive impact on the image of simulation. Managers will begin to realize that simulation can be an integral part of the engineering process and cost justified against actual cost reductions in engineering time. This is a much easier task when compared to the traditional process of trying to quantify cost avoidance. For example, when PLC emulation is used to verify controls code prior to equipment installation, the customer can see the benefit in lower debug and startup times for a program. This can be seen in lower costs for the controls engineers who typically have to work overtime on a tight startup. This example will also lead to shorter time to market since much of the controls debug time is no longer on the critical path for project timing.

Integrating simulation with process planning is also a trend that will save money that is easier to quantify. When process planning is integrated with simulation, the product designers and manufacturing planners enter information such as cycle times and material flow logic into a common database that can be accessed by the simulation tool. This dramatically reduces the time to develop a model, reduces data entry errors, and provides a common tool for communicating product changes, process concepts, and ideas for improving efficiency.

The makeup of the simulation user community is also going to change. While the number of users will be greater, it will take a much wider net to encompass the community. Many people will be using simulation but not necessarily consider themselves users. Even when the term is used, "simulation user" could mean many things. It could mean an occasional user of simulation for rough-cut capacity planning using a basic simulation tool. It could refer to the traditional simulation user, like attendees of this conference, who are general purpose simulationists who handle whatever projects their employers need. Lastly, it could refer to a specialist who knows the basics of simulation but is familiar with how simulation integrates with another technology like conveyor PLC controls.

In summary, the future will see simulation technology reaching into more and more places and applications. Simpler simulations will be performed by users that do not consider themselves as simulationists. Other users will begin to see their roles more focused. Specialists will be needed to integrate the foundations of simulation into the other areas of engineering that we have seen previously as sources of information or internal customers.

3 PETER LENDERMANN, SINGAPORE INSTITUTE OF MANUFACTURING TECHNOLOGY

This contribution is specifically looking from the point of view of a researcher working in a leading research institute in Asia at the usage of discrete event simulation as a tool for virtual experimentation to enable design and performance enhancement of manufacturing systems and supply networks.

In today's fast changing business environment a high degree of flexibility and scalability is required for simulation technology. It must be possible to address the entire cycle from simulation modeling, model validation, configuration of simulation runs, data input, execution of simulation, output data analysis, optimization, implementation of optimized business execution models all the way to model maintenance sufficiently fast.

These requirements have resulted in tremendous challenges that need to be tackled by the various players involved in the simulation industry, not only software vendors but also modelers and end users, service providers and consultants, and last but not least, the R&D community.

In the future, manufacturing systems and supply networks will become even more complex and customized. As a consequence, the process of modeling these systems will also become much more difficult. But this can also be regarded as an opportunity: Because such complex systems cannot be understood through spreadsheet methods any more, virtual experimentation through simulation becomes indispensable in order to understand, control, and reduce variability.

Specifically, in Asia, compared to the homogeneous North American environment, or the (reasonably) integrated European industrial landscape, supply network processes are more heterogeneous and unpredictable. The stochastic uncertainties associated with these characteristics as well as the higher complexity of the underlying processes open up additional opportunities for the simulation industry.

This is particularly true for the semiconductor industry where simulation has already found widespread application for systems design and operational performance optimization. Semiconductor supply chains in Asia are even more variable with a lot of contract manufacturers involved, making inter-enterprise processes play a more important role.

Not only in semiconductor manufacturing but also in other industries such as automotive, usage of simulation will eventually become standard. However, that does not mean that everybody will use the same simulation software. Interoperability will become a very important feature to enable different players in those industries to analyze the implications of their dynamic inter-company processes, most likely in a distributed environment. The competitive edge of a simulation software product will, therefore, also be determined by how well it integrates with other simulation packages.

To achieve interoperability, standards for modeling and communication protocols for data exchange between simulation models will have to be further developed. All the players in the simulation industry will have to work together to achieve this. It will bring benefits to everybody and ensure that the complexity of the systems that simulations are supposed to represent does not develop faster than the capability to model these systems.

The research community can play an important role in developing such standards. Serious initiatives such as the HLA-CSPIF (`http://www.cspif.com/`), a worldwide forum consisting of users, vendors and researchers to integrate and enable interoperability between commercial off-the-shelf (COTS) simulation packages are already under way.

Standards will be more interesting to some extent for suppliers of smaller systems which are used for the accomplishment of specific one-time tasks to address strategic or tactical issues. For example, a semiconductor assembly and test facility using a package from a small vendor for specific internal operational purposes might also want to analyze the interdependencies with the supplying wafer fab. Reusability of the facility's existing simulation models could be ensured only through interoperability with the simulation package used by the wafer fab which is likely to be one of the standard packages provided by a large vendor (such as AutoSched AP provided by Brooks Automation).

Such larger vendors in the future will provide systems that are suitable for a wider range of operational decisions, requiring less maintenance effort through strong integration not only with data-supplying systems such as manufacturing execution systems (MES) applications (where simulation parameters could be monitored and models updated accordingly with little human intervention) but also with planning and order management systems such as advanced enterprise resource planning (ERP) applications to reuse their functionality also in the simulation model and get a much better representation of the demand-driven world.

Not only the vendors of discrete-event simulation systems but anybody providing software that enables some kind of "what-if-analysis" likes to use the term "simulation." Under such circumstances, software vendors need to be able to express and demonstrate very clearly what discrete-event simulation *is* and what discrete event simulation *is not*. Confusion with related terms such as "simulation-based scheduling" must also not be created. And tools that are able to perform dispatching functions but nothing more should not be called scheduling tools.

In Asia, any case where an immediate positive impact on the bottom line cannot be demonstrated or at least indicated is considered useless or even suspicious. To overcome this hurdle, research issues related to the applicability and relevancy of simulation technology to the industry also need to be addressed. At the same time, more work has to be done to educate decision makers accordingly. Animation and 3D simulation can help here, especially in the sales process, even though in many cases the real value added during the usage of the simulation tool would be rather limited. But it can give decision makers confidence and a realistic picture of "what they will get," which can be of advantage particularly in Asia where people think more visually than elsewhere (illustrated, for example, by the nature of the Chinese or Japanese written language).

Another reason why simulation is still not so common as a tool in manufacturing and logistics is that – even though the systems that simulations are supposed to represent become more complex – humans still play an important role in operating these systems. This raises another set of research issues regarding how human behavior, production operators' morale, and fatigue can be modeled and analyzed through intelligent-agent based simulation.

In industry in Asia, however, the culture of conducting this kind of research is not (yet) very developed compared to North America or Europe. If at all, it is conducted in large enterprises, and they are mostly represented by multinational corporations where decisions regarding R&D are made (and executed) in overseas headquarters to a large extent.

But close collaboration between simulation software vendors and researchers at research institutes and universities will go a long way in addressing many of these challenges. Researchers in these institutions typically face less pressure with regard to time duration and immediate cash return of projects and therefore will be able to identify and resolve challenges that otherwise would not be tackled.

To support this, software vendors need to involve these researchers in implementation and customization projects with their clients. This is the only possibility for research institutes to be able to appreciate the state-of-the art with regard to simulation technology and its application in the industry. New models of strategic partnerships need to be invoked to enable this kind of collaboration. Research institutes need to accept that they might not be able to remain totally unbiased towards vendors under such circumstances.

Once the above-mentioned challenges have been tackled, new types of service providers will also emerge. They will enable more complex simulations through offering computing power to their customers. This could include a grid infrastructure that is able to handle the different scenarios to be simulated as well as the replications at the same time. Other service providers will offer archived, reusable simulation models that require much less customization effort. And with interoperability and reusability at the horizon, simulation software providers might have to make changes in the way they charge their customers for services such as by use or time-based.

4 CHARLES MCLEAN, NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

Simulation technology holds tremendous promise for reducing costs, improving quality, and shortening the time-to-market for manufactured goods. Unfortunately, this technology still remains largely underutilized by industry. A number of factors currently inhibit the deployment of simulation technology in industry today. The development of new simulation interface standards could help increase the deployment of simulation technology. Interface standards could improve the accessibility of this technology by helping to reduce the expenses associated with acquisition and deployment, minimize model development time and costs, and provide new types of simulation functionality that are not available.

One might argue that cost is the primary factor affecting widespread and pervasive use of manufacturing simulation technology. Although there are a number of issues, they could perhaps all be reduced to a cost factor. Some factors affecting an individual company's view of simulation affordability may include: the company's resources, scope and complexity of the target simulation application area, availability of turnkey or readily-adaptable simulation models and solutions, availability and format of input data, and cost and risks of implementing manufacturing systems without the use of simulation.

4.1 Data Interface Problems

Among the significant cost factors of using simulation, the "interoperability problem" is particularly significant. What is the nature of this problem?

4.1.1 Interoperability

Interoperability between other manufacturing software applications and simulation is currently extremely limited. Other applications include design, manufacturing engineering, and production management. The simulation software used to model and predict the behavior of manufacturing systems do not use the same data formats as the systems used to design products, engineer production systems, and manage production operations. Neutral interface specifications that would permit quick and easy integration of commercial off-the-shelf software do not exist.

4.1.2 Cost

The cost of transferring data between simulation and other manufacturing software applications is often very high. Users must either re-enter data when they use different software applications or pay high costs to system integrators for custom solutions. In some cases, it may not be possible to integrate "closed systems" with simulation. Closed systems are those with undocumented, proprietary data file formats.

4.1.3 Labor Intensity

The simulation model development process is labor-intensive. Vendors and industrial users alike have recognized that the development and maintenance of models of their production systems and resources is very costly. Each industrial user must build his or her models of manufacturing systems, processes, and resources. This is true even if the models represent commercial off-the-shelf manufacturing equipment. If the industrial user has several different vendors' simulation packages, unique models must typically be reconstructed for each package. The models developed for one simulation system are of little or no use to another. The simulation development process is very much an ad hoc process. Texts provide high-level guidelines, but model development is perhaps more of an art than a science. Unfortunately, this approach often leaves considerable work and possibly too much creative responsibility to the simulation analyst.

4.2 How Could the Simulation Industry be Improved?

Today simulation analysts typically code their models from scratch and build custom data translators to import required data. A better solution would be to simplify the process through modularization, i.e., the creation of re-usable simulation model building blocks. Simulations would be constructed by assembling, or configuring, modular building blocks. Similarly, neutral interface formats for transferring data between simulation and other manufacturing applications are also needed. Data would ultimately be imported directly into the simulators without translation using standard data input formats.

The development of neutral, vendor-independent data formats for storing simulation models could greatly improve the accessibility of simulation technology to industry by enabling the development of reusable models. Such neutral formats would enable the development of reusable models by individual companies, simulation vendors, equipment and resource manufacturers, consultants, and service providers. Model libraries could be marketed as stand-alone products or distributed as shareware.

Neutral model formats would help enlarge the market for simulation models and make their development a more viable business enterprise. Standard formats for models would make it possible for simulation developers to sell model libraries much the same way that clip art libraries are sold for graphics software packages today. Simulation model libraries could be expected to increase the value of manufacturing simulators for industrial users much the same way graphics libraries increase the value of photo processing, paint, and graphics illustration software packages to their users.

In the absence of standard formats, the development of simulation model libraries is probably not a viable independent business proposition. Why? Let's say that a consultant that specialized in simulating material handling systems wanted to develop and sell a library of models. The consultant would have to code the models in perhaps a dozen different formats to cover as many manufacturing simulators as possible. As each of the target simulators evolved, the model library would require constant revisions to maintain compatibility with each vendor's product. The consultant would probably have to obtain licenses and hire staff with expertise on each simulator. One can easily see how costly and risky this business proposition becomes. If the consultant only had to develop one set of the material handling system models that could be imported into all of the simulators, the viability of his or her business improves considerably.

5 ERNEST H. PAGE, U.S. ARMY MODEL AND SIMULATION OFFICE

In his 2000 contribution to this panel (Banks 2000), John Carson was succinct and accurate, "The future is not just unknown; it is unknowable. With that said, here's what's going to happen."

5.1 Military Training

Training has been a significant driver for advancements in simulation and concomitant technologies for decades. And there is no reason to believe that this trend will not continue. The military will continue to invest heavily in the use of simulation to support training—because it has to. For example, whereas there was once enough contiguous land available to exercise fundamentally large-sized Army units (e.g. battalions), the encroachment of civilization onto training ranges, and the continually expanding area of responsibility for these tactical units means that ranges can no longer support complete live training for such units. Training ranges today (and in the future) can only accommodate smaller units. Training at higher echelons requires the use of simulation.

A great deal of current focus is on the notion of "embedded training." That is, each vehicle or system fielded by the military will have a built-in capability to train it's operators, both individually, and collectively. The technology to accomplish this is perhaps easier to envision than the cultural shift required to insinuate training requirements into the workflows of the system analysis, design and acquisition communities.

5.2 Institutionalizing a Modeling and Simulation (M&S) Profession

With the belief that such things tend to lower costs and increase quality in the systems it procures, the military has a long-standing interest in software and systems engineering processes and in professional certification of engineers. As M&S expenses become more visible in military budget lines, the military has begun to seed efforts whose purpose is to identify, organize and define an M&S profession. (See, for example, `http://www.simprofessional.org`). These efforts include defining curricula for undergraduate and graduate education, establishing professional certification programs and investigating mechanisms to augment the Capability Maturity Model (CMM) with simulation-specific attributes. The certification programs and CMM augmentation will likely become institutionalized within the military simulation domain. The degree to which universities embrace M&S as a discipline, thereby producing graduates with a shared body of knowledge, will likely be the determining factor for the realization of M&S as a true profession.

5.3 Rise and Fall of the One Sims

The halls of funding agencies in Washington, D.C. abound with chants of "eliminate duplication of effort." If something has been done once, there is considerable resistance to spending dollars to do it again. Such fiscal responsibility is certainly what we, as taxpayers, want from our public servants. But the application of this heuristic in the context of M&S has given rise to an attrition in the number of models available to support analysis and training in favor of a fairly small collection of so-called "authoritative" systems. Is this a positive shift? Arguably not. First and foremost, as most attendees of the Winter Simulation Conference well know, models express *opinions*, not facts. Having multiple opinions is arguably quite useful for systems analysis. Your daily weather forecast, for example, is typically based on the results of at least three different weather models; so why would one want to design a future force structure using only a single model? Another factor to consider is that these "authoritative" systems typically have very large budgets. And these large budgets tend to be spread across many, many organizations. And these organizations, in turn, provide many, many participants to the design and development of the system. The organizational and collaborative structures are, as a result, quite complex. (Readers of *The Mythical Man Month* already know where this is going.) Organizational complexities have challenged the delivery of the current set of "authoritative" systems. In the end, these systems will likely fall into disfavor. The military will continue to spend billions on simulation, but it will be for thousands of models rather than a few.

5.4 Simulation-Based Acquisition (SBA)

There is a push in DoD generally, and within the Army under a program known as Simulation Modeling for Acquisition, Requirements and Training (SMART), to maximize the use of M&S across the product life-cycle. It is believed that the application of M&S makes "better, faster, cheaper" a reality. The military believes this, mostly, because it looks around at the commercial world and sees companies that employ simulation to improve their bottom lines. That's reasonable. These companies at least provide an existence proof that M&S can be effective. But it starts to fall apart a little from there. Does the government measure the bottom line the same way that commercial entities do? No. Does the government use simulation in the same way that commercial entities do? Absolutely not. The folks that modeled distribution methodologies for Starbucks, for example, were probably not told that they *had* to use RTI NG version 1.3.4.whatever and federate with a high fidelity, but partially-finished, latte server. They were probably allowed to do whatever they needed to do in order to optimize distribution. If government business practice isn't the same as commercial business practice, should the government, therefore, expect to reap the benefits of M&S in the same way that commercial entities do? Probably not. As the government pursues SBA, it will begin to understand the application of M&S within the governmental context, and will collect the data necessary to achieve this understanding. A realization will emerge that the government should not expect to see the same results from simulation that General Motors or Boeing sees, unless the government organizes and operates like General Motors or Boeing.

5.5 Science of Military Modeling

Despite decades of investigation, our combat models are still not very robust. Part of the problem is that there is not enough data from combat, but even where data exists our models do not fit actual outcomes very well (Gozel 2000). The notion of "PKs" itself has also been severely criticized (Deitz and Starks 1999). Clearly, with most combat models, you tell the analyst the answer that you want, and the analyst will get the model to give you that answer—with wholly justifiable values for the input parameters. Has science failed us here? Or are we just victims of the circumstance of inadequate data and highly nonlinear systems dynamics? Emerging topics of interest such as human behavior, counter-terrorism, urban warfare, network-centric warfare, and so forth, are likely to be at least as challenging from a validation standpoint. The military will (hopefully) invest in the science of military modeling to confront these needs.

5.6 Interoperability

Over the past decade or so, the DoD has become significantly enamored with making sure that any system can runtime interoperate with any other system. And despite the fact that plugging two perfectly good simulations together—simulations that weren't designed to be plugged together in the first place—is a lot like jumping out of a perfectly good airplane, there is no sign that the DoD will lose interest in this activity any time soon.

5.7 On the Relationship Between M&S and Test and Evaluation

Except perhaps for very trivial systems, system testing can never be exhaustive, nor provide us with 100% confidence in future system performance. Therefore, testing must confront the problem of *quantifying uncertainty and risk*. For example, limitations associated with the number of shots that are taken in a live fire test produce risk and uncertainty. These limitations may be overcome (somewhat) in simulation where hundreds of thousands of rounds may be fired, however risk in this context is incurred due to the fact that a model is an approximation of a system. Finding the optimal balance between hardware-based and M&S-based testing requires a delicate balance of cost, schedule and risk—with the understanding that neither cost nor schedule are infinite and risk can never be completely eliminated. Some work has been done in this area (Oberkampf et al. 2000) but much more is warranted and likely.

5.8 Rigor

DoD M&S types—particularly in the training arena—just don't practice rigor very well. In 1687 Isaac Newton stood on the shoulders of giants. Today we seem to have a hard time standing on each other's toes (Weatherly 1999). In the DoD M&S training arena it is not uncommon to see papers published that have no literature surveys. Even worse, proposals are submitted *and funded* with equally poorly-established bases in prior art. We don't avail ourselves of peer review. We should.

5.9 Summary and Disclaimer

Everything asserted above may come to pass. But, then again, it might not. Caveat reader. Certainly, there should be no question that the views expressed are the author's, and do not represent official positions of the U.S. Department of Defense.

6 C. DENNIS PEGDEN, ROCKWELL SOFTWARE

Many people view simulation modeling as a critical technology for the 21st century. It has been used to deliverer significant value to enterprises throughout the world. There are many documented successes of its application in areas ranging from manufacturing, communications, call centers, military, supply chain, and service systems. The tools and methodologies have been improved and refined over a 40-year period, and they work.

Although we can celebrate the progress and application successes, many also view simulation as a disappointment. In reality simulation is used in very few situations where it could be applied. There are many important decisions being made by enterprises without the benefit of a simulation model.

Why is this and what can be done to change this in the future? This is the central question that the simulation community faces, and is the topic of this panel.

If simulation is to reach its potential it must move beyond its current role as a narrowly deployed methodology that is used by highly technical analysts for a small set of critical design decisions. The power of simulation is that it allows us to see the future and the impact of our decisions on our system performance. We must find ways to more broadly tap this power throughout the enterprise.

As we look to the future of the simulation industry, one key is to expand dramatically the set of users that can benefit from simulation models. As long as simulation is kept in the domain of the highly skilled modeler, the human resources available to work with the technology will limit it.

One of the promising ideas for expanding simulation to a broader set of users is the concept of having pre-built models or model components that can be plugged together to form a model of our system. The idea is that we simply select these components from a library and use them directly. For example, we might build a model of our entire supply chain by simply connecting together pre-built, generic models of our plants, distribution centers, and transportation centers. The goal is to build each model component once, verify its operation, and then make it available in a library to be used in many different applications.

This is not a new idea and many simulation software vendors have pursued this concept over the past decade. Similar ideas exist in general software development. There has been tremendous progress made in this area, however significant problems remain that must be addressed to create a practical simulation framework that supports the idea of composing models from pre-built, generic models/components. Progress in this area is key to broadening the use of simulation.

In addition to making models easier to build, we must make them widely accessible and shareable. The obvious vehicle for this is the Internet. However, to exploit this as a delivery vehicle we need software that is specifically designed to support the collaborative building, viewing, execution, and analysis of simulation models across the Internet. The objective here is not to make existing tools run across the network, but rather to rethink and design new tools that fully tap the power of the Internet.

Another key to expanding the use of simulation is to broaden the role of simulation in decision-making. Simulation has been traditionally cast as a tool for making better decisions in the design phase of a system. The classic application is to help in the design of a new manufacturing line, or analyze proposed designs for a supply-chain. This design-only view, however, is too limiting and does not begin to tap the real potential of simulation in the enterprise. Models should be used as an enabler for all types of decisions from design through system execution. For example, in manufacturing a simulation model can serve multiple purposes including real-time visualization, design simulation, MES emulation/testing, factory scheduling, and real-time factory execution.

In summary, as a community we still have much work to do to bring the true power of simulation to the world. However as we will progress in simplifying model building, collaborative sharing of models across the Internet, and broadening the application domain from system design through system execution we will realize the true potential of simulation.

7 ONUR ULGEN, PRODUCTION MODELING CORPORATION

The discrete-event simulation industry can be broadly categorized into three major areas. The Simulation Software Industry includes those companies that sell one or more discrete-event simulation software products while the Simulation Service Industry refers to companies that sell simulation modeling consulting services to client companies. (Note: There is overlap among these two.) The Simulation User Industry, on the other hand, refers to companies that build their own simulation models for their own systems using their own or commercially available simulation software.

In what follows, we consider three time horizons as we look at the future of the simulation industry. The Short Term Future refers to the next three years, the Middle Term Future looks out four to eight years, and the Long Term Future considers the time period nine to fifteen years from now.

7.1 Simulation Software Industry

In the Short Term Future, the Simulation Software Industry will face the following issues:

- The overall simulation software sales will stay at the current low levels. Software sales will slightly increase for the low cost simulation software (up to $2,000) and highly specialized simulation software (e.g., supply chain simulators) while it will stay low for general simulation software priced around $10,000 to $25,000.
- Geographically, sales in Europe and some developing countries (e.g., India, China) will increase while they will be low in North America.
- There will be further consolidations in the simulation software vendor industry. Some of the simulation software vendors will either consolidate or will be purchased by bigger software or hardware companies similar to the purchase of Systems Modeling Corporation by Rockwell Corporation or AutoSimulations, Inc. by Daifuku Corporation (Daifuku then purchased by Brooks Automation) in the last few years.
- Some of the companies in the Simulation Software Industry will develop complementary decision software (e.g., scheduling tools) to increase the level of their software sales while others will emphasize their simulation modeling services to increase their overall sales.

In the Middle Term Future, the following is forecasted for the Simulation Software Industry:

- There will be two to three dominant low cost (less than $2,000) simulation vendors in the industry and two to three mid-level priced software vendors ($5,000 to $9,000). High cost simulation software vendors will continue to exist due to their simulation software's integration with other related software (e.g., robotics software) or application-specific features (e.g., supply chain simulators). The price of mid-level general simulation software will drop to the $5,000 to $9,000 range from the current $10,000 to $25,000 range. The overall sales of simulation will see a slight increase during this period.
- Some of the simulation software vendors that have been integrated with other large-size software or hardware (e.g., ERP software, Manufacturing Execution Systems Software) in the past will either lose their focus on simulation or they will separate from their parent company and become independent again. In either case, they will lose their market share significantly.

In the Long Term Future, the following is forecasted for the Simulation Software Industry:

- There will be one dominant low cost (less than $2,000) simulation vendor in the industry and one or two mid-level priced software vendors ($5,000 to $9,000). Specialized high cost Simulation Software vendors will exist with a larger variety and small volume of sales for each company. There will be a slight but steady increase in the sales of simulation software.
- Simulation software will be incorporated much more widely into the strategic business decision tools in areas such as market penetration, new product development, and new business development during this period.

7.2 Simulation Service Industry

One can classify the Simulation Service Industry into three major categories of service providers; small service companies dedicated only to simulation modeling, medium service companies that provide simulation modeling services in addition to other services (e.g., traditional industrial engineering services, facility design services, software development services), and large service companies that provide simulation modeling services to their clients as part of their other management consulting services (e.g., design of an efficient supply chain).

In the Short Term Future, the Simulation Software Industry is forecasted to face the following issues:

- Small size service companies will get even smaller in the near future and some will eventually disappear. The medium and large size service companies in general will shrink or eliminate their simulation modeling groups.
- Simulation modeling service fees will be reduced by 10-25% in the near future due to pressure from the clients to reduce their costs.

In the Middle and Long Term Futures, the following is forecasted for the Simulation Service Industry:

- Small service companies will get smaller in the Middle Term Future but finally pick up in the Long Term Future. They will eventually get back to their late 1990's level within fifteen years.
- Medium and large size service companies will increase their simulation service groups throughout the Middle and Long Term Futures.
- Simulation modeling fees will return to their current level in the Middle Term Future and eventually increase 15-25% in the Long Term Future.
- A higher percentage of simulation service will be performed by temporary contracting simulation firms as compared to the simulation consulting service companies in the future.

7.3 Simulation User Industry

The Simulation User Industry uses different policies in applying simulation in their individual companies. Some of the user companies have a common process (Standardized Applications) where simulation modeling and analysis is an explicit step in delivery of a new system while in others simulation modeling and analysis is an optional step which depends on the project manager and timing available on the project (Case by Case Applications).

In the Short Term Future, the Simulation User Industry with Standardized Applications will increase its use of the simulation modeling while companies with Case by Case Applications will decrease their simulation use.

In the Middle and Long Term Futures, both the Standardized and case-by-case Applications of the simulation modeling will slightly increase for this industry.

8 JAMES R. WILSON, NORTH CAROLINA STATE UNIVERSITY

> Having been brought up in a serf-owner's family, I entered active life, like all young men of my time, with a great deal of confidence in the necessity of commanding, ordering, scolding, punishing, and the like. But when, at an early stage, I had to manage serious enterprises and to deal with [free] men, and when each mistake would lead at once to heavy consequences, I began to appreciate the difference between acting on the principle of command and discipline and acting on the principle of common understanding. The former works admirably in a military parade, but it is worth nothing where real life is concerned, and the aim can be achieved only through the severe effort of many converging wills.
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> —Petr Kropótkin, *Memoirs of a Revolutionist* ([1899] 1968, p. 216)

One of the most remarkable developments in the computer industry in recent years has been the rise of open-source software, as exemplified primarily by the emergence of the Linux operating system. I believe (and hope) that the future of the simulation industry will evolve in a similar fashion, with the following key features:

- The formulation and widespread adoption of standards for data exchange between simulation modules developed for different types of simulation modeling as well as for data exchange between simulation modules and other types of software for Enterprise Resource Planning (ERP), scientific and engineering applications, and operations management.
- Internet-based development of high-quality open-source libraries of reusable simulation modules (model components) via intense beta testing and suggestions for improvement—that is, peer review—by the entire worldwide simulation community.
- Free access to these open-source libraries over the Internet.

If in fact the future of the simulation industry evolves according to a Linux-like paradigm, then every segment of the international simulation community—vendors, academics, consultants, and users—will effectively become codevelopers of a comprehensive simulation software platform that I will half-seriously call "Simulux."

There is nothing particularly original in these ideas, which admittedly have been "borrowed" from Eric Raymond's seminal essay "The Cathedral and the Bazaar" (Raymond 1998). Perhaps the only thing of indisputable value in my contribution to the discussion on the future of the simulation industry is my strong recommendation to read Raymond's essay.

It is not at all clear that the conditions are right for the development of Simulux. In the first place, it is arguable whether we currently have anything that could be clearly identified as the nucleus for the development of Simulux in the way that the Minix operating system for 386 machines provided the initial scaffolding for Linux. Equally important, it is unclear how the project coordinator(s) for Simulux will emerge. In any case, the project coordinator(s) for Simulux must be able to recruit and energize the entire worldwide simulation community based on Kropótkin's "principle of common understanding" to achieve the required "severe effort of many converging wills" as quoted above.

It is appropriate to close this discussion with a quote from Raymond (1998, p. 20):

> Voluntary cultures that work this way are not actually uncommon; one other in which I have long participated is science fiction fandom, which unlike hackerdom explicitly recognizes "egoboo" (the enhancement of one's reputation among other fans) as the basic drive behind volunteer activity. …
> We may view Linus' method as a way to create an efficient market in "egoboo" — to connect the selfishness of individual hackers as firmly as possible to difficult ends that can only be achieved by sustained cooperation.

My greatest fear is that instead of such a total mobilization of the international simulation community, we will find the simulation industry swallowed up by large commercial organizations for which modeling and simulation is at best a sideline; and if this occurs, then the total absorption of the field by much larger disciplines is a distinct possibility.

9 SUMMARY

Joe Hugan indicated that areas such as PLC emulation, process planning, and embedded simulation are now taking center stage. He also said that the makeup of the simulation community is going to change. Peter Lendermann indicated that simulation will become indispenable in the future as more complex networks are modeled. He said that interoperability of simulation software with other software is crucial. He calls for standards as did the next panelist.

Chuck McLean said that the development of new simulation interface standards could help increase the deployment of simulation technology. He discussed data interface problems, including interoperabilty, and the labor-intensive nature of simulation model development. He provided suggestions for improving the situation.

Among other items, Ernie Page told us that the military will continue to invest heavily in the use of simulation to support training. He said that modeling and simulation are likely to be institutionalized as a profession. He indicated that the military will continue to spend billions on simulation, but it will be for thousands of models rather than a few. As the previous two panelists indicated, he also sees interoperability as an important matter.

Dennis Pegden said that although we can celebrate the progress and applications of simulation, many view simulation as a disappointment since it is used in only a very few of the situations where it could be applied. If simulation is to reach its potential it must move beyond its current role as a narrowly deployed methodology that is used by highly technical analysts for a small set of critical design decisions. He indicated three solutions for this problem. Expand the set of users. Make models more widely accessible and shareable. Broaden the role of simulation in decision-making.

Onur Ulgen was very specific in his predictions for the future. He predicted the state of the simulation industry for three time periods into the future. For example, in the next three years, he predicted that software sales will stay at their current level with gains in Europe and some developing countries, but low sales in North America. He also mentioned further consolidation in the simulation software vendor industry.

Jim Wilson hoped that simulation can evolve in the way of open source standards such as Linux. His greatest fear was that the simulation community will be swallowed up by a much larger organization for which modeling and simulation is at best a sideline. He remarked that if this occurs, the total absorption of the field by much larger disciplines is a distinct possibility.

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