*Proceedings of the 2000 Winter Simulation Conference*
*J. A. Joines, R. R. Barton, K. Kang, and P. A. Fishwick, eds.*

# ENTERPRISE SIMULATION: FRAMEWORK FOR A STRATEGIC APPLICATION

Milind M. Datar

Concert (AT&T – British Telecom)
200 Laurel Avenue, # D3-3A9
Middletown, NJ 07748, U.S.A.

## ABSTRACT

The term Enterprise Simulation (ES) is gaining acceptance among simulation practitioners. It is coming to represent certain tangible attributes, and its benefits seem apparent in providing a top-down perspective in system analysis. It is envisioned as the next wave of simulation applications that may bring simulation to a higher ground of applicability in the business application arena. ES does so by promising to extend the benefits of simulation modeling and analysis as it is performed today. Linking singular instances of analytical efforts (simulation and otherwise) with limited scope in a network has the potential of delivering extraordinary value to decision-making at the corporate level. Moreover, advances in distributed simulation concepts and networking technology can provide the much needed push to ES by serving as enablers. This paper offers to explain the motivation behind ES, and explain its relevance to the business environment of large, complex organizations. A development framework is presented with technical and managerial issues in its implementation.

## 1 INTRODUCTION

The success of Enterprise Simulation (ES) in simulating wargaming back in 1990 proved its role in analyzing the behavior of complex systems, which by definition are comprised of a multitude of independent systems. The ES model representing this complex system was an aggregate of independent models. These models were independent representations of tanks, artillery equipment, and personnel carriers. Added to these were set of other models representing personnel movements and actions, ammunition storage, communication resources, etc. This network of independent simulation models truly represented the environment of war, and due to its extensive nature added value in evaluating realistic wartime scenarios. Real-world decisions could only be made by evaluating situations in these extensive simulation environments. In wargaming simulations, the benefits inherent in an ES were evident. This is due to the fact that simulation of only personnel movements and actions, or of only artillery equipment, is not enough to make decisions impacting any real world battle scenario. The independent models representing other factors had to be combined to better represent a battle scenario.

This paper contends that the same rationale can be applied to a business context. For example: the value in analyzing and optimizing customer service centers is severely limited in scope for an organization as a whole if its product offerings are out of synch with its markets or the skill set of its personnel. In this case, aggregation of models (simulation and otherwise) in each of the relevant business functions or units can provide tremendous value for decision-making for an organization as a whole. Due to its extensive nature, this aggregated effort can provide a top-down perspective on issues that are not specific to a business function but are conceptually at a higher or corporate level.

This paper explores and develops the applicability of the ES concept to the business environment of large organizations. It also describes the developments in distributed simulation concepts, and networking technology germane to this application.

## 2 ENTERPRISE SIMULATION AND VIRTUAL DISTRIBUTED SIMULATION ENVIRONMENT (VDSE)

In this section a proposed ES framework and potential applications to highlight the value of ES to an organization are presented. In the framework, the applicability of Virtual Distributed Simulation Environment (VDSE) architecture to ES is explained. In the Potential Applications and Advantages sub-section, it is shown that while the individual models can provide the analyst with local, operational optima, the ES effort offers the benefits of strategic value to an organization.

### 2.1 Virtual Distributed Simulation Environment (VDSE)

In order to truly model a large organization's behavior it is imperative that input from all the relevant business functions in that corporation's environment is incorporated. The models providing this input from the business functions or units are the building blocks of an ES model. An ES model thus developed can deliver results that represent the corporation as a whole. This is accomplished by networking these models of business functions. These models providing inputs to the ES model can be legacy systems, databases, spreadsheets, and others. The data sources can also exhibit randomness, such as real-time data collectors or simulation models. These are critical to truly represent randomness within some of its individual business functions at their appropriate level of depth. These constituent simulation models in an ES network can be legacy models that are 'local' in scope representing only a specific business function.

The ES model becomes a distributed simulation model when there are two or more simulation models in the network. This would conceptually be based on distributed simulation approach creating a Virtual Distributed Simulation Environment (VDSE). This promises to be a better model for a complex or large organization's behavior.

### 2.2 VDSE Framework

An ES model requires an executive to control the aggregate of its local constituents (data sources and simulation models) that are linked in a network. In order to perform its role of controlling VDSE members, some of which might be simulation models, this executive needs to be a simulation model itself. The executive is responsible for implementing the objectives of ES. It does so by coordinating the actions of VDSE members. Given the objectives, it chooses the involvement of VDSE members that are pertinent to an ES run. The ES executive is an independent member of the VDSE, however from an implementation perspective, it can be located either separately or within a VDSE member. VDSE members that are simulation models are all candidates for implementing the ES executive.

The VDSE members are independent of each other and continue to serve the "local" needs of the business function that they represent. From that perspective, they should be extensible in their domain to continue to add value to that business function. These could be legacy models or developed specifically in support of the ES effort. As mentioned earlier, these VDSE members do not necessarily all need to be simulators. Instead they can be static or dynamic data inputs that support the ES by representing a single activity or a complete business function. Examples of these non-simulation members of ES include: a spreadsheet of costing information in Accounting, real-time data gathering system on the Shopfloor, etc. The significance of these members is in improved quality of inputs to the ES. The quality of these sources is due to their location within the business function that they represent. This helps keep them updated, and diminishes delay and other problems associated with procuring data from organizational units in a simulation project.

The linking of VDSE members requires a physical medium as well as the ability to transfer information among models on independently developed platforms. Depending on the geographic scope of the ES model, the physical medium is provided by LAN (Local Area Network), WAN (Wide Area Network), or the Internet. Needless to say, the timeliness and quality of inputs improves with a more extensively networked ES. This enables more business units to participate in the ES. The independent and legacy nature of VDSE members necessitates a platform-independent capability to transfer data amongst the VDSE members, including the executive. This creates a need for a mechanism for consistent interpretation of data by all VDSE members across the network. Both CORBA and MQ Series can fulfill this need.

Another data issue in ES is that individual data elements from respective VDSE members need to interact with the executive, and each other. This requires that the data structure across VDSE be harmonized for meaningful application of data by every member. Without this consistency it would be difficult for VDSE members to utilize input from each other despite successful transfer across independent platforms.

Since an ES based on VDSE architecture has at least two simulators as its members, it is essential to synchronize the their time flow mechanisms. Based on their original designs, the constituent simulators are likely to have different simulation clocks. It is important that these are synchronized so the models can communicate with each other. The VDSE member models can also have varying time units. It is imperative that they are factored in appropriately for the simulators to be in step with each other. A Synchronization mechanism is required to ensure that the chronological dependencies among events are maintained across independent simulations throughout ES execution. To this end two synchronization algorithms, Optimistic and Conservative, are available. In the Conservative protocol, comparison of time-stamps across all simulation instances is performed to establish the right sequence of events. A simulation event is not slated for execution unless it is guaranteed that its timing is less than that of all the other events across the network. This ensures that the cause and effect relationships amongst events are not violated. In contrast, the Optimistic algorithms allow these violations to occur, and the simulation "rolls back" once the violations are detected. The nature of these algorithms significantly impacts their implementation. Conservative algorithms tend to be slow while Optimistic algorithms have large memory requirements. There is no clear consensus concerning which synchronization algorithm performs better. Indeed the optimal approach depends on the application (Fujimoto 1999).

### 2.3 Potential Applications and Advantages

The global value of the simulation effort is achieved by going beyond the focus on a single business process. For example, instead of just modeling customer service process effort is also expended on modeling sales, ordering, on-site provisioning, and billing processes. When integrated the sum of the individual modeling efforts addresses issues at an enterprise level.

ES can be implemented either by building sub-models of pertinent business processes and integrating them, or by networking existing models into an enterprise model. The former is more prevalent today. This approach is uneconomical considering those sub-models supporting ES are usually built from naught. Also such development in support of ES sometimes disregards modeling at a level of detail that might be vital to the objectives of ES itself. By utilizing legacy models in a VDSE framework towards an ES the modeling effort can be made significantly efficient. Yet the benefits of ES are still obtainable. Consider a scenario where two separate simulation models exist for two manufacturing facilities. These have raw material, labor productivity, product demand, and manufacturing process parameters as inputs. The outputs are product quality, finished product volume, inventory data, and cost of goods. Now if these models were linked and supported with distribution data, it would enable getting an aggregated view of this organization's manufacturing operations function. It would enable strategic decision making for manufacturing operations. Questions such as: "Which plants should serve which specific markets?", "Which plant can provide the best return for future capital spending?", and "How do the make or buy decisions change when considered from the view of this combined manufacturing model?" . . . . . can be answered via this aggregated view.

Additionally, consider a marketing model that has econometric data, industry data, market segments' data, customer service profiles, and pricing dependencies as inputs. The model has demand forecasts for finished product and customer service by geographic regions, *pro forma* profits, and required marketing budget as outputs. If this model were to be networked with the manufacturing model above, the resulting ES model can address some serious strategic issues such as:

"Which product-mix portends a better outlook in the face of long-term financial objectives?", "Can the organization realistically go after a target segment with new products/services?", "Is it better to manufacture or buy subassemblies in pursuit of market share?"

The advantage of the ES model in the example above is in providing a holistic or corporate level analysis of business issues. This value is in the ability to perform "what-if" analyses on strategic options with quality information on markets and organization's manufacturing capability. Considering that all of this information and models pre-existed in the organization, the cost of ES effort is in networking these resources and developing the ES executive. The tool can also be an effective tool for training managers in strategic thinking, and team building. Finally, like any simulation project it can serve as a catalyst for change across the organization.

At a micro level ES can provide results based on better quality data since it is run on data resident in its local constituencies. The performance of such a tool is also enhanced due to the distributed nature of its architecture that is inherent in a VDSE.

## 3 ES DEVELOPMENT

This section highlights challenges in the development and implementation of ES. Enablers in support of this effort are also described. It is important to note that the severity of these challenges, and suitability of enablers below would vary for specific individual ES modeling effort.

### 3.1 Feasibility

This tool that has potential to address issues at an organizational level is not without its organizational pitfalls when it comes to development and implementation. It is not too far-fetched to imagine resistance to share information in local models from any business function. So a project with this visibility needs a high-level motivation and/or champion to facilitate the sharing of systems (data sources and models). Leadership is key to define goals, and provide direction to the overall effort. Support will also be needed in the program management of this effort by continually providing clarity in objective definition and scenario development.

### 3.2 Risks

There are technological risks involved in integrating legacy systems (data sources and models) and making the ES "run" in a desired manner. New technologies enabling integration of data across disparate platforms are not always stable and pose issues. For example, there are security issues inherent in sharing data over the Internet. Also despite conceptual developments in distributed simulation (described in the following sub-section) there are uncertainties inherent in implementing an ES concept. Here again, the new technologies are not tested for supporting implementation of these conceptual developments.

### 3.3 Technology Enablers

There have been many attempts to formalize the integration of independent simulation models. One approach views this as a composition of software components, and rightfully so (E. H. Page, and J. M. Opper 1999). Forming a network of various legacy data sources and models is indeed orchestrating these software sources towards a common goal. However, due to the presence of simulation models in the ES architecture it is imperative to take a formalized approach towards integration. The linking of 250 simulators in SIMNET was founded on standards for networking simulators known as Distributed Interactive Simulation (DIS) standards (IEEE Std 1278.1 – 1995). This approach was broadened to High Level Architecture (HLA). In the HLA parlance, an ES could be a special case of a Federation. “A Federation is defined as a named set of simulations interacting via the services of the HLA Run-time Infrastructure (RTI) and in accordance with a common object model and a common rule set to achieve some desired purpose” (R. E. Nance 1999). HLA suggests rules and guidelines for implementing distributed simulation environments (Cheikes 1997, DMSO 2000). These are comprehensive in supporting universality and interoperability among VDSE members. RunTime Infrastructure (RTI) provides the coordination, synchronization and data exchange among the VDSE members to enable a coherent execution of the ES. The reason for providing common runtime-infrastructure services to VDSE members is to enable coherency in data exchange among data sources, thereby maintaining the independent nature of VDSE members and the flexible nature of ES as a whole. This realizes HLA’s goal of interoperability and reuse of simulations. HLA’s emphasis on object orientation for modeling behavior of distributed systems, however, hinders it in leveraging legacy systems in a VDSE.

A widely deployable web-based network simulation framework using CORBA IDL-based APIs and a publisher-subscriber model for communication has been proven in concept (Cholkar and Koopman 1999). New mechanisms enabling transfer of data across independent platforms continue to emerge, and promise to further ease the task of networking independent models.

It needs to be said at the conclusion of this section that the recommended approach in building an ES would be to leverage the above concepts and experiences to address individual ES modeling situations. Rather than conforming to any particular blueprint, development needs to be customized since organizational situations and enterprise goals being modeled can vary widely.

## 4 SUMMARY

The precursor of Enterprise Simulation is really wargaming simulation, as practiced by military with computer supported models (Mastaglio 1999). Drawing on the success of SIMNET for the military, the concept of VDSE is proposed for implementing ES models for large business organizations. Pre-existing legacy models are leveraged for minimizing modeling effort. With marginal cost of developing ES executive and networking these legacy data sources, ES models extend the value of legacy models beyond their original and narrow purposes. This integration of legacy models into ES addresses issues, and offers solutions at a strategic level. High-level issues in the development and implementation of such a tool are revealed. The enhancements in the commercially available simulation software are simplifying the development of singular instances of simulation models. So ES provides the next level of challenge to simulation practitioners to continue to add business value through simulation technology. Developments in networking technology and distributed simulation concepts only continue to facilitate this challenge of ES development and implementation.

## ACKNOWLEDGMENTS

The contribution of David E. Kaufman, Ph.D. of AT&T is greatly appreciated for providing valuable critique to this paper. The papers by Affeldt (1999) and Ulgen et al. (1999) also provided inspiration in support of this paper.

## REFERENCES

J. F. Affeldt. 1999. The application of system dynamics (SD) simulation to enterprise management. In *Proceedings of the 1999 Winter Simulation Conference,* ed. P.A. Farrington, H. B. Nembhard, D.T. Sturrock, G.W. Evans, Pages 1496-1500. Phoenix, AZ.

Cheikes, B. A. November 1997. What is HLA ? Available online from `<http://ltsc.ieee.org/ppt/brant_ppt/tsld017.htm>` [accessed December 1999]

A. Cholkar and P. Koopman. 1999. A widely Deployable Web-based Network Simulation Framework using CORBA IDL-based APIs. In *Proceedings of the 1999 Winter Simulation Conference,* ed. P.A. Farrington, H.B. Nembhard, D.T. Sturrock, G.W. Evans, Pages 1587-1594. Phoenix, AZ.

Defense Modeling and Simulation Office (DMSO). 2000. High Level Architecture. Available online from `<http://www.dmso.mil/index.php?page=64>` [accessed February 2000]

R. M. Fujimoto. 1999. Parallel and Distributed Simulation. In *Proceedings of the 1999 Winter Simulation Conference,* ed. P.A. Farrington, H.B. Nembhard, D.T. Sturrock, G.W. Evans, Pages 122-131. Phoenix, AZ.

Mastaglio, T. 1999. Enterprise Simulation: Theoretical Foundations and a Practical Perspective. In *Proceedings of the 1999 Winter Simulation Conference,* ed. P.A. Farrington, H.B. Nembhard, D.T. Sturrock, G.W. Evans, Pages 1485-1489. Phoenix, AZ.

R. E. Nance. 1999. Distributed Simulation with Federated Models: Expectations, Realizations and Limitations. In *Proceedings of the 1999 Winter Simulation Conference,* ed. P.A. Farrington, H.B. Nembhard, D.T. Sturrock, G.W. Evans, Pages 1026-1031. Phoenix, AZ.

O. M. Ulgen, J. Shore, G. Coffman, D. Sly, M. Rohrer, D. Wood. 1999. Increasing the Power and Value of Manufacturing Simulation Via Collaboration with Other Analytical Tools: A Panel Discussion. In *Proceedings of the 1999 Winter Simulation Conference,* ed. P.A. Farrington, H. B. Nembhard, D.T. Sturrock, G.W. Evans, Pages 749-753. Phoenix, AZ.

E. H. Page, and J. M. Opper. 1999. Observations on the complexity of Composable Simulation. In *Proceedings of the 1999 Winter Simulation Conference,* ed. P. A. Farrington, H. B. Nembhard, D.T. Sturrock, G.W. Evans, Pages 553-560. Phoenix, AZ.

## AUTHOR BIOGRAPHY

**MILIND DATAR** has 14 years of experience in business operations management, primarily in service industry. He has managed technology projects by providing expertise for evaluating and improving business processes. This has engaged him in an instrumental role in delivering on tactical and strategic business goals. Currently, Milind is Program Manager of Service Development at Concert, a global venture of AT&T and British Telecom. His training includes an M.S. in Operations Research (George Washington University) and an M.B.A. (University of Western Ontario). His interests also include decision-support, role of Internet in business operations, and strategic issues in the management of services. He is a member of Omega Rho, Phi Delta Gamma, INFORMS, IIE, and HIMSS. His email address is <datarm@att.com>.