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DISTRIBUTED SIMULATION IN INDUSTRY – A SURVEY PART 1 – THE COTS VENDORS

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ABSTRACT

Distributed simulation is used very little in industry, especially when compared with the interest in distributed simulation from research and from the military domain. In order to answer the question why industry lags behind, the authors have carried out an extensive survey, using a questionnaire and interviews, with users, vendors, and developers of distributed simulation products, as well as with vendors of non-distributed simulation software. Based on the results the discrepancies between the different "worlds" become clear enough to enable the formulation of clear guidelines for further developments of standards for distributed simulation. This paper reports on the first part of the survey, namely a questionnaire targeted at vendors of commercial-off-the-shelf (COTS) simulation packages. Analysis of the answers obtained establish that it is indeed the case that industry is relatively underdeveloped in the area of distributed simulation and also sheds some light on the reasons behind this.

1 INTRODUCTION

Distributed simulation is an application of distributed systems technology that enables models to be coupled over computer networks so that they interoperate during a simulation run. Initial research on distributed simulation has been conducted in the defense (Singhal and Zyda 1999). It is a promising approach allowing for the interoperability between models and the reusability of them (Fujimoto 2000). Besides interoperability and reusability Fujimoto mentions other benefits of distributed simulation, such as reduced execution time, geographical distribution, integrating simulation models from different vendors and fault tolerance. Other benefits are apparent as well, for instance the possibility to reuse existing components, support for information hiding, and support for integrating heterogeneous models (Boer 2005).

In order to carry out distributed simulation, simulation standards were initiated in the defense community, culminating in the High Level Architecture (HLA), which is the most recent and most advanced approach for integrating simulation models and the facto standard for all simulations of the Department of Defense (DMSO 1998a), (DMSO 1998b), (DMSO 1998c), (Kuhl, et al. 1999).

Although the initial step in designing and developing the HLA standard was carried out by the defense community, this large effort was intended to support the industrial community as well. However, in the industrial domain application of distributed simulation is still in its infancy. The research community is aware of this phenomenon. In order to find out the reasons behind it, in the last years separate panel discussions were organized at the Winter Simulation Conference (Taylor, et al. 2002), (Taylor, et al. 2003). Some researchers have proposed methods for migrating the HLA concept into the industrial domain (Straßburger 2001), (Rabe, et al. 2001), (McLean and Riddick 2000), (Revetria, et al. 2003) which led to new insights regarding the applicability of HLA in industry. Furthermore, a forum, called HLA-CSPIF was initiated that aims to create reference models for integration of distributed simulation models created in commercial-off-the-shelf (COTS) simulation packages (Taylor, et al. 2006). This forum has recently become a CSPI Product Development group under the Simulation Interoperability Standards Organization,

Most computer simulation models in industry are created using simulation packages (Nikoukaran, et al. 1999). COTS simulation packages are the most advanced and widely used packages that are commercially available (Nikoukaran, et al. 1999), (Tewoldeberhan, et al. 2002). Law and Kelton identify several advantages of COTS simulation packages over general purpose programming languages, explaining why simulation modeling has become more and more popular in recent years (Law and Kelton 2000).

One reason why distributed simulation or HLA is not applied in industrial simulation projects might be that COTS simulation packages hardly support HLA or even distributed simulation. Consequently, simulation practitioners that apply COTS simulation packages for their daily use do not have a chance to apply distributed simulation.

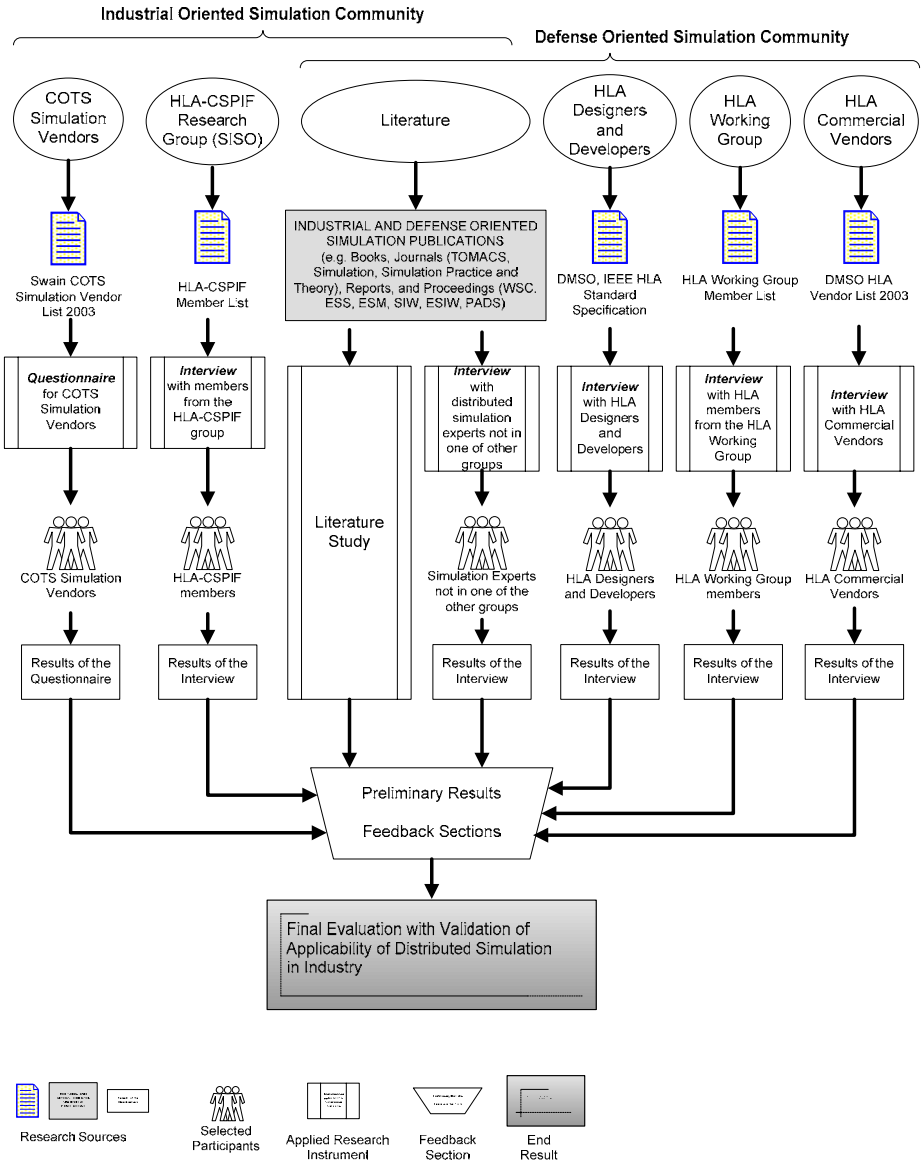

Figure 1: Survey on Distributed Simulation in Industry

On the other hand the simulation practitioners do not seem to request facilities for applying distributed simulation, like transparent HLA interfaces. This might be caused by the fact that simulation practitioners cannot see the benefits because they do not have the proper tool for it. So it seems we are stuck in a deadlock, caused by a chicken-egg scenario.

We have set up a research effort to investigate this scenario more deeply aiming at a solution to overcome the deadlock. Basically there are three *research questions* to be answered. First of all the hypothesis that HLA is hardly applied in industry has to be validated. Secondly we have to find reasons behind this phenomenon. If these obstacles can be overcome then, thirdly, we have to find ways to remedy the situation:

- RQ1: *Is it true that the HLA standard is hardly applied in industry?*
- RQ2: *If so, why is HLA hardly applied in industry?*

- RQ3: *What is needed to overcome this situation?*

In order to obtain answers to the above questions we conducted an extensive survey with experts in the field. The survey fell apart into three segments. First of all we interrogated the COTS vendors, using a questionnaire, mainly aiming at an answer to research question RQ1 (although the other ones have been touched briefly). The paper you are reading here deals with this part. Secondly we addressed a broader group of experts questioning them in much more detail on the other research questions as well. The results of this survey are discussed in the companion paper (Boer, de Bruin and Verbraeck 2006a). Finally, we analyzed the answers we obtained and formulated at a list of requirements for adapting or redesigning existing distributed simulation architectures. This is the contents of (Boer, de Bruin and Verbraeck 2006b). This requirement list answers question RQ3. The complete research is captured in Figure 1 and this paper deals with the leftmost column in this figure only.

The next section deals with the methodology we applied. Section 3 discusses the questionnaire in more detail. In Section 4 we discuss and analyze the answers we obtained. Section 5 gives the conclusion and an indication of the follow up of our survey.

2 APPLIED METHODOLOGY

In our overall survey we followed the Delphi approach, the purpose of which is to elicit information and judgments from participants to facilitate problem solving, planning, and decision making (Linstone and Turoff 1975), (Linstone 1978). Delphi is a method that proves to be particularly useful when the individuals who need to interact cannot be brought together in a face-to-face exchange because of time or cost constraints (Kenis 1995). The Delphi method is iterative. The results of an initial survey are summarized and then form the basis of a second follow on survey. Results from the second survey are the basis of a third survey and so on (Linstone and Turoff 1975). Accordingly, after getting the preliminary results, we maintain a continuous relation with the involved experts in follow up sections in order to gather sufficient feedback for the validation of the end result.

In order to obtain an answer to our first research question RQ1 *"Is it true that the HLA standard is hardly applied in industry?"*, we tried to identify a community which has continuous and intensive contact with the industrial simulation area. The most appropriate group for this purpose would be the totality of software companies that carry out industrial simulation projects. However, it is impossible to identify all companies involved in these types of projects. If we interrogate only some companies, the results cannot be used to give a proper general answer to our questions because we do not know how many other projects are conducted out there. As a consequence, we needed to address another group. The community we have recognized as appropriate consists of the COTS simulation package vendors who provide tools for their customers in industry. COTS vendors adapt their packages to the market needs they perceive. They have a continuous and intensive connection with industrial simulation practitioners who request new features in the package based on the projects they intend to carry out. In this way the COTS vendors have an opportunity to gain information about these projects, and thus about applying distributed simulation in industry. Therefore, our primary aim is to mobilize this group for providing an answer to our questions. Furthermore, COTS vendors can provide information regarding HLA support within their tool.

After selecting the participants the researcher must identify the collection procedures that he intends to apply. The literature mentions four basic ways of data collection: observation, questionnaire or interviews, documents, and media (audio and visual) material (Creswell 2003), (Seale, et al. 2004). Due to the fact that there is a large number of COTS simulation package vendors active in the market, the type of the survey that we have chosen for our initial investigation is a structured questionnaire.

3 THE QUESTIONNAIRE

In this section we briefly describe the questionnaire for the COTS simulation package vendors, we present the way the questionnaire is designed, how the participants are selected and the way the data is collected.

3.1 Design of the Questionnaire

The questionnaire mainly deals with question RQ1 *"Is it true that the HLA standard is hardly applied in industry?"* Before asking specifically about the HLA standard we intend to find out whether their simulation package supports integration with external applications in general and whether the vendors are aware of any distributed simulation projects in industry in which their COTS packages were applied. Only if, as we expect, they give positive answers here, we turn to the application of HLA and ask them whether they support the HLA standard and whether they have had any chance to apply it. Thus, this first part of the questionnaire aims to give an overall picture about the integration approaches that are supported and applied by the COTS vendors and their customers. This is the main part of the questionnaire.

We added some open questions in order to get a provisionary answer to questions RQ2 and RQ3. For instance, when feasible, we asked about the problems and difficulties that the vendors or their customers were confronted with when they applied HLA or other architectures. We also tried to disclose the vendors' vision regarding the fu-

ture of distributed simulation and the HLA standard. This might give some indication with respect to question RQ3

3.2 Selection of the Participants

In order to get an adequate assessment of the opinion of the COTS simulation package vendors, we tried to contact as many vendors as possible. In order to obtain a large number of vendors, we have taken as a basis the survey conducted by James Swain (Swain 2001). The reason why we have chosen this list for the questionnaire is its openness, comprehensiveness and scientific character.

- *Openness.* The Swain list is an open scientific survey. It does not have any commercial intention and COTS vendors can add the description of their simulation products to the list at any time.
- *Comprehensiveness.* It is a long-term, continuous survey, which started in 1995 and is still running. The results have been published three times consecutively by Operation Research/Management Science Today (OR/MS Today) (Swain 1995), (Swain 1997), (Swain 2001) and since 1997 it is available on the web.
- *Scientific.* It is produced by INFORMS (Institute for Operations Research and the Management Sciences)

Of course there are COTS simulation packages which are not represented on the list. This can be caused by different reasons, for example, because vendors have no information about this survey or they do not want to participate in the survey. In spite of this possibility, we expect that this phenomenon does not influence the outcome of the survey, be it only because the Swain list contains the main and most well-known simulation package vendors.

The list contains 39 organizations, from which we have invited 35 organizations to participate. We have ignored 4 organizations, because the description of their activity does not fit in our target group, for example they do not provide simulation packages but only optimization modules. Furthermore, two additional COTS simulation package vendors, Wolverine Software and Lanner Group, though not on the list have been addressed because their products have been presented during the last years at the exhibition of the Winter Simulation Conferences.

3.3 Data Collection

For the 37 COTS simulation package vendors that we have contacted we made two options available for filling out the questionnaire: either through a web site or by filling out a template file and submitting it by FAX. We had the chance to collect data both through the web site and fax; however the web site was more popular. We obtained filled out questionnaires from 19 vendors (52%). They are presented in Table 1. In view of the evaluation of the survey it is relevant to observe that the main organizations are among these 19 ones.

Table 1: Participating COTS Simulation Vendors

Simulation Package	Name of Company
AnyLogic	XJ Technologies
Arena	Rockwell Software
AutoMod	Brooks Automation
Crystal Ball	Decisioneering
eM-Plant	Tecnomatix
Enterprise Dynamics	Incontrol Enterprise Dynamics
Extend	Imagine That, Inc.
FlexSim	FlexSim Software Products, Inc.
GoldSim	GoldSim Technology Group, LLC
GPSS World	Minuteman Software
HighMAST (SAGE)	Highpoint Software System, LLC
Micro Saint Sharp	Micro Analysis & Design
ProModel	ProModel
ShowFlow	Webb Systems Limited
Simul8	Simul8 Corporation
SLX	Wolverine Software
VisSim	Visual Solutions
WebGPSS/microGPSS	Flux Software Engineering
WITNESS	Lanner Group

4 ANALYSIS OF THE COLLECTED DATA

The results of the questionnaire are quantitatively analyzed. For the quantitative analysis we have followed the series of steps presented in (Creswell 2003, pp. 159-161).

First of all we give an overview of the results we obtained. In Table 2 we show the response on the quantitative questions from our questionnaire. We also included a few open questions. Here are some of them. Regarding questions 1 through 3 we asked the vendors to specify which protocols and middleware they have used to achieve interoperability. The most common answers were: COM (mentioned 13 times), WinSock (8 times) and HLA (7 times). We asked the vendors who answered “yes” on question 4 about their experiences. Difficulties they encountered were data alignment (i.e. specification of the HLA FOM), translation of HLA concepts into COTS terms, exchange of heterogeneous data, verification and debugging of the distributed models, the heavy structure of the HLA RTI, performance, and complex runtime management. Regarding question 6 we asked what other standards the vendors were considering. Most of them stated that they intended to stay with low level technical protocols or middleware in their future versions like WinSock, COM, DCOM or .Net.

Table 2: The Quantitative Results

Question 1		**YES**	**NO**
Have, to your knowledge, any projects been carried out successfully that link two or more separate simulation models created in your package?		**13**	**6**
Question 2		**YES**	**NO**
Have, to your knowledge, any projects been carried out successfully that link two or more separate simulation models created in your package with models created in other simulation packages?		**10**	**9**
Question 3		**YES**	**NO**
Does your simulation package support interoperability with external applications (e.g., data bases, spreadsheets, optimization software, etc.)?		**18**	**1**
Question 4		**YES**	**NO**
Have, to your knowledge, any projects been carried out successfully in which simulation models created in your package are integrated using the HLA standard?		**7**	**12**
Question 5	**IT SUPPORTS**	**YES**	**NO**
Does your company make efforts to support HLA as an additional feature in your package?	**5**	**6**	**8**
Question 6		**YES**	**NO**
Does your company make efforts to support other standards than HLA for distributed simulation?		**13**	**6**

Before starting this survey our hypothesis was that distributed simulation (including the HLA standard) is rarely applied in industry. Looking superficially at the results in Table 2 it seems that our observation was contradicted. The answers given reflect that COTS simulation vendors recognize the success of their package in different industrial oriented distributed simulation projects both when homogeneous models, developed in the same simulation package, and when heterogeneous models are integrated. Evaluating the questionnaire we were surprised to see a picture featuring quite HLA-minded COTS simulation package vendors. We expected that almost none of the COTS packages would support HLA, whereas the answers on question 4 showed that there are quite some successful HLA related projects and the answers to question 5 indicated that there is a significant support for the HLA standard.

On the other hand, analyzing the results in more detail there seems to be some discrepancy in the answers, especially when looking at the combination of answers that vendors provided to questions 3, 4 and 5. On the one hand, there are vendors who claim that they do not provide an HLA interface and they do not want to support it in a future version, whereas they or their customers have carried out HLA related successful projects. On the other hand there are vendors who state that they provide an HLA interface and they support it in their package as an additional feature, however they never carried out successful HLA related simulation projects. Furthermore, there are vendors who claim that they provide an HLA interface and they also applied it in successful HLA related projects, however they do not want to support it as an additional feature in their packages. Further, there are vendors who affirmed that they do not provide an HLA interface and they never applied it in any successful project, however they support it as an additional feature in their package.

In order to get a clearer picture we sent out a second questionnaire, in line with the Delphi methodology. The results of our additional questionnaire indicate that the vendors interpret the notion “supporting HLA” in different ways. Studying HLA, for example, or attending presentations regarding HLA, or providing low level protocols, such as WinSock, is considered by them as an effort to support HLA as an additional feature, which to a certain extent might be true. However, this is far from what we would call de facto support and service for an efficient HLA interface for simulation practitioners.

So, although there seems to be active interest in HLA by about half of the COTS vendors, this interest is rather tentative and aiming at low level solutions. This conclusion is strengthened by other results from the main questionnaire.

First of all we already mentioned some complaints about HLA that we obtained by the vendors who actually used HLA. Also the organizations that refuse to consider HLA as an additional feature in their future package versions see drawbacks:

- The cost is too high to incorporate it as a supported feature considering the benefits they would gain from it.

- It is very military specific and so is weighed down by support for features not required in many cases.
- The implementation of the HLA standard has not the expected performance when applied to accomplish interoperation between simulation models.
- The system management of running the model is complex and not easy to support in a general architecture.
- There are representation problems of the very different attributes to be exchanged.

One of the vendors explicitly stated "I recall reviewing the HLA approach, and being impressed with its scope and ambition, but skeptical about its practicability."

Our conclusion is also supported by an analysis of the distributed simulation projects mentioned in relation with questions 1, 2 and 4 focusing on the ones in which HLA was applied for interoperability. From this analysis we concluded that:

- We found only very few cases in which HLA was applied in industry when integrating COTS simulation packages.
- In the cases where HLA was applied to integrate COTS simulation models, this occurred mostly in defense oriented projects.
- COTS simulation packages are rarely applied for distributed defense oriented simulation models.
- When an organization intends to accommodate distributed simulation this is mostly done by creating "homespun" architectures based on low level technical solutions (e.g. WinSock, CORBA, COM, etc.) instead of HLA.

5 CONCLUSIONS AND AN INTRODUCTION TO THE NEXT PART OF THE OVERALL SURVEY.

The questionnaire aimed to validate our hypothesis that the HLA standard is rarely applied in industry. Looking superficially at the results it seemed that our hypothesis was contradicted. Deeper analysis, however, unveiled several inconsistencies which seemed to favor our hypothesis again. Our conclusion is that, although the questionnaire could not support us to completely validate the hypothesis, from the analysis that we have carried out and a second round of questions we conclude that the hypothesis as it is still stands. As a matter of fact, in the next part of the overall survey it will be firmly validated.

Concerning the second research question, there are several arguments we collected from the questionnaire, indicating why the HLA standard is hardly applied in industry. The heavy structure of the HLA RTI, performance issues, alignment of shared data, a complex runtime management, verification and debugging, and translation of HLA concepts into COTS terms lay a burden on the developer, resulting in an unfavorable cost benefit ratio.

Regarding the third research question we conclude that although some of the COTS simulation package vendors are planning to support distributed simulation or HLA in the future, currently there does not seem to be a big drive into this direction. Finally, we have observed that when an organization intends to accommodate distributed simulation this is mostly done by creating "homespun" architectures based on low level technical solutions (e.g. WinSock, CORBA, COM, etc.). On the other hand, there are quite a few organizations that do not have any intention at all to support connection with other packages.

The next step in our survey was to take the above mentioned results as a starting point for a series of in depth interviews with open ended questions which generated more extensive answers to our research questions. Now that our hypothesis behind research question RQ1 is strengthened the next step was to delve more deeply into the other ones. We conducted interviews with people from a much bigger population than only the COTS vendors who naturally cast light at these problems from their own point of view. A report on this second round is given in (Boer, de Bruin and Verbraeck 2006a).

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REFERENCES

Boer, C. A. 2005. *Distributed Simulation in Industry*, Ph.D. Thesis, Erasmus University Rotterdam, The Netherlands. Available via <https://ep.eur.nl/handle/1765/6925> [accessed June 22, 2006]

Boer, C.A, A. de Bruin, and A. Verbraeck. 2006a. Distributed Simulation in Industry – A Survey, Part 2 – Experts on Distributed Simulation, Accepted in *Proceedings of the 2006 Winter Simulation Conference*, eds. L. F. Perrone, F. P. Wieland, J. Liu, B. G. Lawson, D. M. Nicol, and R. M. Fujimoto. Piscataway, New Jersey: Institute for Electrical and Electronics Engineers.

Boer, C.A, A. Bruin, and A. Verbraeck. 2006b. The Use of Distributed Simulation in Industry - A Survey, Submitted to the *Simulation: Transactions of The Society for Modeling and Simulation International.*

Creswell, J. W. 2003. *Research Design. Qualitative, Quantitative, and Mixed Methods Approaches.* 2nd ed., Thousand Oaks, California, USA. SAGE Publications.

DMSO. 1998a. High Level Architecture Object Rules v1.3, Technical Report, Defense Modeling and Simulation Office.

DMSO. 1998b. High Level Architecture Interface Specification v1.3, Technical Report, Defense Modeling and Simulation Office.

DMSO. 1998c. High Level Architecture Object Model Template v1.3, Technical Report, Defense Modeling and Simulation Office.

Fujimoto, R. M. 2000. *Parallel and Distributed Simulation Systems*, New York, USA: John Wiley and Sons, Inc.

Kenis, D. 1995. *Improving Group Decisions. Designing and Testing Techniques for Group Decisions Support Systems Applying Delphi Principles*. Ph.D. Thesis, University of Utrecht, Faculty of Social Sciences.

Kuhl, F., R. Weatherly, and J. Dahmann. 1999. *Creating Computer Simulation Systems: An Introduction to the High Level Architecture*, New Jersey, USA: Prentice Hall.

Law, A. M., and W. D. Kelton. 2000. *Simulation Modeling and Analysis*, Boston, USA: McGraw-Hill.

Linstone, H. A. 1978. The Delphi Technique, in *Handbook of Future Research*, ed. J. Fowles, London: Greenwood Press, pp. 273-300.

Linstone, H. A., and M. Turoff. 1975. *The Delphi Method. Techniques and Applications.*, London, UK: Addison-Wesley.

McLean, C., and F. Riddick. 2000. The IMS MISSION Architecture for Distributed Manufacturing Simulation, in *Proceedings of the 2000 Winter Simulation Conference*, Orlando, Florida, USA: Association for Computing Machinery Press, pp. 1539 - 1548.

Nikoukaran, J., V. Hlupic, and R. J. Paul. 1999. A Hierarchical Framework for Evaluating Simulation Software, *Journal of Simulation Practice and Theory* (SIMPRA), 7(3), pp. 219-232.

Rabe, M., F. W. Jaekel, and F. F. De Gurtubai. 2001. Modelling and Simulation for Globally Distributed Enterprises, in *The 4th International EUROSIM 2001 Congress*, Delft, The Netherlands.

Revetria, R., P. E. J. N. Blomjous, and S. P. A. Van Houten. 2003. An HLA Federation for Evaluating Multi-Drop Strategies in Logistics, in *European Simulation Symposium and Exhibition Conference*, Delft, The Netherlands.

Seale, C., G. Gobo, J. F. Gubrium, and D. Silverman. 2004. *Qualitative Research Practice*, London, UK: SAGE Publications Ltd.

Singhal, S., and M. Zyda. 1999. *Networked Virtual Environments. Design and Implementation*, New York, USA: ACM Press. Addison Wesley.

Straßburger, S. 2001. *Distributed Simulation Based on the High Level Architecture in Civilian Application Domains*, PhD Thesis, University Otto-von-Guericke.

Swain, J. J. 1995. Tools for Process Understanding and Improvement: Simulation Software Survey, *OR/MS Today*, 22(4), pp. 64-79.

Swain, J. J. 1997. Simulation Software Survey: Simulation Goes Mainstream, *OR/MS Today*, pp. 35-46.

Swain, J. J. 2001. Power Tools for Visualization and Decision Making: 2001 Simulation Software Survey, *OR/MS Today*, 28(1), pp. 52-63.

Taylor, S. J. E., A. Bruzzone, R. Fujimoto, B. P. Gan, S. Straßburger, and R. J. Paul. 2002. Distributed Simulation and Industry: Potentials and Pitfalls, in *Proceedings of the 2002 Winter Simulation Conference*. Piscataway, New Jersey: Institute for Electrical and Electronics Engineers.

Taylor, S. J. E., B. P. Gan, S. Straßburger, and A. Verbraeck. 2003. HLA-CSPIF Panel on Commercial Off-the-Shelf Distributed Simulation, in *Proceedings of the 2003 Winter Simulation Conference*. Piscataway, New Jersey: Institute for Electrical and Electronics Engineers.

Taylor, S. J. E., X. G. Wang, S. J. Turner, and M. Y. Low. 2006. Integrating Heterogeneous Distributed COTS Discrete-Event Simulation Packages: An Emerging Standards-Based Approach, *IEEE Transactions on Systems, Man and Cybernetics*, 36(1), pp. 109-122.

Tewoldeberhan, T. W., A. Verbraeck, E. C. Valentin, and G. Bardonnet. 2002. An Evaluation and Selection Methodology for Discrete-Event Simulation Software, in *Proceedings of the 2002 Winter Simulation Conference*. Piscataway, New Jersey: Institute for Electrical and Electronics Engineers.

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