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THE ECONOMIC EFFECTS OF REUSABILITY ON DISTRIBUTED SIMULATIONS

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ABSTRACT

This paper examines whether the ability to reuse a simulation, in whole or in part, results in tangible cost savings on the overall economics of the original simulation. Specific target simulations are those created for the US Army using the mandated High Level Architecture framework for reusability. A hypothetical model was developed to determine if a simulation created for the High Level Architecture could produce quantitative cost savings due to its reusability while keeping other cost parameters constant. It was discovered that actual cost data and percentages of reusability for existing Army simulations were difficult to assess. Further, it was discovered that the economics of reusability had never been addressed from a consistent viewpoint. From a purely hypothetical, economic standpoint, reusability proves itself to be a strong economic argument for the use of the High Level Architecture framework or some similar architecture.

1 INTRODUCTION

In 1995, the Department of Defense (DoD) mandated that all computer simulations developed for DoD be compliant with a platform designed to promote interoperability and reusability. Specifically, the DoD chose High Level Architecture (HLA) as that framework. HLA provides a common framework across all classes of simulations by providing the HLA Rules, HLA Interface Specifications, and the HLA Object Model Template (Dahmann et al 1998). With this framework, the underlying language of the simulation is made interoperable with other simulations through the HLA's Runtime Infrastructure (RTI). An HLA compliant simulation is composed of *federates*, component pieces that can be put together with other component pieces to form a new simulation for purposes other than originally designed.

Though an understanding of the HLA process is not important to this effort, an understanding of its capabilities is inherently assumed. HLA is the tool that allows simulations to interact with one another through the RTI *regardless* of their underlying coded language. Properly developed federates become part of a database that can be reused an infinite number of times by any application toward any defined end goal. As an example, a federate can contain only atmospheric simulation. This atmospheric simulation can be employed in a personnel simulation, a flight simulation, a war game, or numerous other applications.

For several years, the Army has been faced with a decreasing budget. As a result, a method had to be found to realize more cost effectiveness of the dollars spent. This method has increasingly been through the use of simulations. The US Army has applications for simulation in acquisitions, training, and analysis. Simulations allow soldiers to train with the aesthetical aspects of a piece of equipment before actually using that equipment. Many different scenarios for war gaming at the upper echelons of command and control can be run on a simulation for a proposed fraction of the cost of placing all the soldiers on the battlefield. An analysis run from the results of the war gaming allow decisions for the best application of monies in deployment of field training exercises. For the acquisition arena, a proposed piece of equipment can be examined using engineering principles under several conditions before being field-tested to determine if the equipment performs as expected. All of these uses provide a cost savings to actual testing of live equipment.

Unfortunately, the question that remains unanswered is – "Where are the cost savings?" Regardless of how many times a scenario is ran in simulation, many commanders do not feel confident of their soldiers capabilities until they are actually field-tested. A piece of proposed equipment can perform perfectly well in a simulated environment and fail on the battlefield. This has led some authorities in the military to wonder if simulations have reached the point of diminishing returns (Roske 1998).

2 COST EFFECTIVENESS

As of January 16, 2001, the US Army had 234 simulation models either developed in inventory or being developed for military use. Of these 234 candidates for HLA application, 44 are being retired or transferred from Army control, 23 have no HLA status reported, 57 have been excluded or had HLA compliance waived as a requirement.

Additionally, 60 have requested time extensions for compliance. Of all 234 simulations, only 50 are currently compliant with HLA. Thus, there are a potential of 110 HLA simulations currently in Army use (47%). The question proposed here is – How does the reusability parameter built into the HLA compliance methodology affect the overall cost effectiveness of the simulation?

2.1 Literature Review

A review of existing literature on simulation economics revealed that though an attempt is currently underway to quantify the costs of simulation (Waite 2000), there has never been a case study approach using current economic business methodologies to determine cost effectiveness. It is a generally accepted principle that reusability is an economically sound practice. yet the amount of reusability that produces the greatest cost effectiveness to the Army while still meeting simulation goals has never been quantified. Within the last two years, working groups and organizations involved in simulation and modeling have been organized to investigate and quantify the 'costs' of simulation in the business sense; as yet, no actual quantification exists. Some of the organizations that have currently developed working groups include the International Test and Evaluation Association (ITEA), the National Training Systems Association (NTSA) and the Simulation Interoperability Workshops (SIW). Developing economics in simulation has also been brought up at the Summer Simulation Conference and the Winter Simulation Conference. Over the next two years, these working groups are proposing to use an existing developmental effort to capture the costs involved and develop the 'business case' necessary to apply economic principles.

Each of the project managers for the HLA compliant simulations was contacted for information for inclusion in this study. While much of the data was sketchy and incomplete, the information provided allowed the researcher to have some indication on the basis of the hypothetical study. The results of the query are summarized below:

- Cost of simulation: ranged from $150K to $40 million.
- Lifespan: ranged from 15 years to unlimited. Software updates included in the cost of the simulation.
- Percent of reusability: ranged from 50% to 100%, though not quantified directly.
- Operating and maintenance costs were given between $10K and $50K and included in the contract.

These responses represent approximately 5% of the current HLA simulations. Many respondents could not answer cost factors due to office security requirements and many respondents stated that their office does not track this information.

2.2 Economic Application

For this paper, business economics are defined as the application of present worth analysis to a hypothetical simulation environment to determine the proposed return on investment. Leaving all parameters constant (capital investment, operating and maintenance costs, proposed annual income, and rate of return) except the factor of reusability, what are the effects on the hypothetical model?

One of the fundamental difficulties in applying this methodology to an actual case study is the inherent viewpoint of the shareholders involved. The Army awards contracts for the development of simulations on the approved processes in the Army Contracting Manual. These contracts may be either 'fixed price' or 'cost-plus'. A fixed price contract means that the contractor will receive a predetermined amount of money for the production of the simulation according to the terms of the contract. This price is determined by bidding for the award of the contract and, generally, from the Army viewpoint, less cost is better (though there are other factors considered in the contract award). In a cost-plus contract, the contractor proves their costs and gets reimbursed for full expenditures. The perspective of both interested parties, the Army and the contractor, are fundamentally opposed in the negotiation of the contract. The Army wants to conserve costs and get the project developed under budget while the contractors needs to protect themselves from loss in the production of the project. This has the potential to allow inflation in the costs and a devaluation of the benefits from the contractor perspective. Therefore, all the costs reported are from the military viewpoint. This paper considers a 'cost' to be the US Army's investment in the product, not the actual cost of production that is incurred by the contractor. This, in itself, allows an economic analysis of current simulations impossible. Rather, a hypothetical case had to be developed to show the potential benefits until a true 'business case' study has been completed in the field.

2.3 Hypothetical Case Study

A hypothetical case study was developed to show what the affects of reusability could have on a quantified simulation over the lifespan of that simulation. This was necessary because actual data on the existing costs of simulation were not available or did not consider the effects of time and reusability when making economic determinations. (See paragraph 2.0 above) Though it was possible to gather information on what was *paid* by the Army for a simulation, it is not possible to determine what a simulation *cost* due to the reasons listed above. All of the costs shown in this hypothetical case are from the perspective of the Army – costs and benefits since it is from this perspective that the monies are employed.

This model uses the following assumptions:

- Capital investment costs are inversely proportional with number of times reused. This means that every *assignable* reuse to a specific contracted federate (as a percentage of a funded simulation) can reduce the capital investment cost of the original simulation inversely proportional to the number of times the federate is used.
- Return on investment (MARR) is 15%. This figure is used because the DoD calculates inflation at 10% and some benefit is desired.
- All costs paid are paid at end of period.
- Annual operating and maintenance costs (O&M) and incomes are static – no gradients. In the general sense, O&M costs are included in annual payments to the contractor as part of the overall benefit package. It is, therefore, reasonable to assume that *operation and maintenance* on an existing simulation can remain static while not including any costs for upgrades or re-engineering of that system.
- Simulation is developed in smallest possible component pieces to allow maximum percentage of reusability and flexibility.
- Simulations are discrete-event distributed simulations developed for Army end-use.
- Reusability only decreases capital investment. O&M costs and income costs remain unaffected.
- Capital investment costs are treated as one-time payments at the beginning of the lifespan.

The following definitions are necessary for this model:

- Capital Investment – the initial cost of the simulation as approved by the Army. Considered as a one-time payment.
- MARR – the desired amounts of return on investment, or benefit in dollars, used to calculate potential returns.
- Operating and Maintenance Costs – costs paid annually to maintain an existing simulation structure, whether in personnel, software or hardware.
- Income – amount of benefit in dollars generated for the Army by using the simulation annually. This income may be in savings from NOT deploying troops, or NOT testing a piece of equipment in the field several times, or NOT training a soldier on a live piece of equipment.

All analysis was developed using the principles in *Capital Investment Analysis for Engineering and Management*, second edition, by John R. Canada, et al.

This model begins with the following initial parameters:

- Capital Investment = $1 million.
- O&M = $10,000.
- Income = $170,000.
- MARR = 15%.
- Lifespan = 20 years.

Note that an income level of $170,000 is necessary to show a positive return on investment at the 15% level with one-time use of the simulation.

2.3.1 Economic Analysis

The economic analysis of the hypothetical model consists of three parts. Part 1 is the initial assessment to determine if additional analysis is desired. This is the payback period analysis. The desired solution is a product that will 'pay for itself' within its proposed lifespan. Part 2 is an overall evaluation-using present worth assessment of the initial hypothetical model. In this analysis, we are looking for the initial income level that will allow a positive rate of return using our given MARR value. It is understood that an income is defined as a 'benefit' derived from either NOT paying costs in other areas or increasing VALUE of expenditures in the simulation area. Once we determine the desired income level, Part 3 consisted of applying the "Reusability Factor" to the hypothetical model to determine any cost savings based solely on that factor. Since this is a hypothetical model, Parts 1 and 2 were performed concurrently.

2.3.1.1 Payback Analysis

The payback period is defined as the period of time necessary to recover the capital investment. The formula used is:

$$\text{Capital Investment}/(\text{Income} - \text{O\&M})$$
$$\text{or } \$1{,}000{,}000/(\$170{,}000 - \$10{,}000) = 6.25 \text{ years.} \quad (1)$$

For this model, the payback period is computed at 6.25 years. Since that period is well within the purported lifespan, this model passes the first economical analysis test.

2.3.1.2 Initial Income Determination

The second analysis is a present worth analysis to determine if the proposed MARR value is achieved. Since this model uses a MARR of 15%, the income was modified until a positive MARR was achieved. To complete a present worth analysis, the formula used is:

$$(\$170{,}000*6.2593)-((\$10{,}000*6.2593) + \$1{,}000{,}000) \quad (2)$$

The 6.2593 is the scalar value assigned to a present worth value given an annual figure to adjust for the difference in time over 20 years at 15%. Solving this gives us our positive present worth of $1488.00. Since we factored in a desired MARR value of 15% (which includes inflation) any value above ZERO in considered a good investment. A sensitivity analysis of this income level will be shown later as reusability factors are included.

2.3.1.3 Application of Reusability to Model

Using the indicated initial investment of $1,000,000.00, this model will calculate the decrease in initial cost based on the percentage of model that is reusable versus the number of times that model is reused. For example, if this model is comprised of component pieces (assumes use of HLA and development of federates that are inherently reusable) of which 10% are reusable – and that piece is reused 10 times; then, 10% of the capital investment cost can be divided between 10 simulations thus reducing the overall cost. The capital investment reductions are shown in Figure 1.

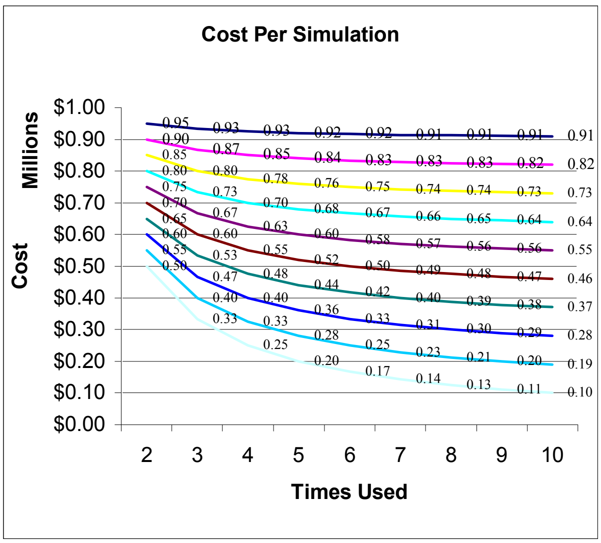

Figure 1: Percent Reusability vs. Number of Times Used

As is evident from this graphic, percentage of reusability and number of times reused both proportionately decrease the initial cost of the simulation. But, the question remains – How much reusability is necessary to gain a desired return on investment? It is understood that the more we design a simulation for reusability, the more expensive that simulation is going to be to design. So, where is the breakeven point? Unfortunately, without hard data to support the point when we begin to lose benefit over increasing reusability factors, this analysis is not possible. We can, however, use the hypothetical model to determine the expected rates of growth on different levels of reusability. With this assessment, the economic community can develop some guidelines on a recommended level of reusability to factor into design.

2.3.1.4 Reusability Analysis

This hypothetical model will specifically consider three (3) test cases: 10% reusability, 50% reusability, and 100% reusability. These percentages will be compared with three (3) different ‘times reused’ parameters: used 2 times, used 5 times, and used 10 times. Though it is understood that the number of times reused can be infinite, these cases allow an examination of what happens to the costs as the number of times used increases.

Test Case 1 – 10% Reusability used 2, 5, and 10 times:

In this test case, the 10% reusability factor is applied to the capital investment cost of $1,000,000. This means that $100,000 of the total investment will be divided between either 2, 5, or 10 simulations. Using 10% only twice lowers the initial capital investment for ONE of the simulations to $950,000 and increases the net present worth from $1488.00 to $51,488.00. The entire portion of reusability is transferred directly into savings simply because we could divide the costs between 2 projects. The results for 5 and 10 times reused are: $81,488.00 and $91,488.00

Test Case 2 – 50% Reusability used 2, 5, and 10 times:

This test case was performed as above. The capital investment of a the single hypothetical simulation becomes $750,000 when 50% of the model is used only twice. Net present values for these test cases are: $251,488.00, $401,488.00, and $451,488.00, respectively.

Test Case 3 – 100% Reusability used 2, 5, and 10 times:

Capital investment when used twice becomes $500,000. In this case, the entire capital investment is evenly divided between 2 simulations. Net present worth for this model is: $501,488.00, $801,488.00, and $901,488.00, respectively for 2, 5, and 10 times used.

Even in this simplified test case it is evident that the percentage of reuse and the number of times reused can dramatically increase the present value of the simulation. However, note that there is a greater return on investment between 2 and 5 times reused and at the level of 50% reusability. Though any amount of reusability can generate a cost savings, target values between 30 and 50% reusability AND using them at least twice will generate the greatest savings (See Figure 2).

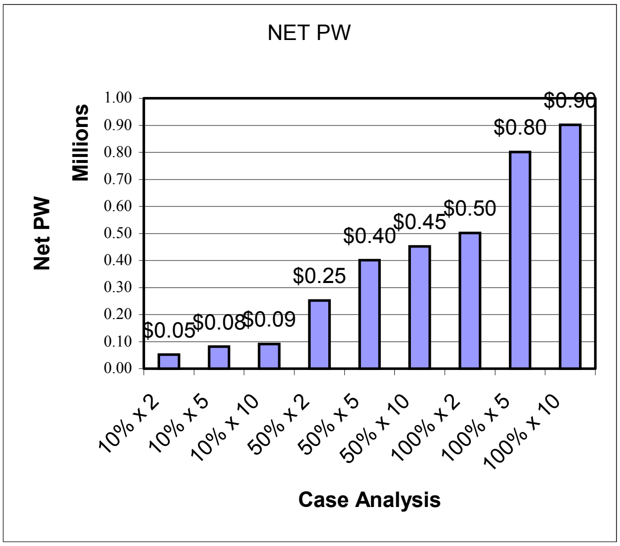

Figure 2: Test Case Net Present Worth

2.4 Sensitivity

Finally, it is necessary to know how the income level can be affected by reusability. If the capital expenditure can be reduced, it is logical to assume that the Army can realize a smaller annual profit and still achieve the desired MARR value. To determine this value, the income level was varied until the breakeven point to the nearest $100.00 was discovered. Actual income levels (or annual benefit in dollars) needed to achieve a MARR of 15% at the case study percentages and times of reuse are in Figure 3.

From this, it is evident that even reusing 10% of the simulation only 1 more time will reduce the amount of income we need to achieve MARR by $8,200.00 while reusing 100% of the simulation 10 times will reduce the amount of income necessary to only $26,000.00. This is a significant reduction in required income to show a profit or return on investment

3 CONCLUSIONS

Based on the economic analysis above, the following conclusions can be drawn:

- Reusability as an independent parameter can have significant effects on the cost and worth of a simulation.
- Initial costs decrease exponentially while worth increases exponentially dependent on percentage of reusability and number of times reused.

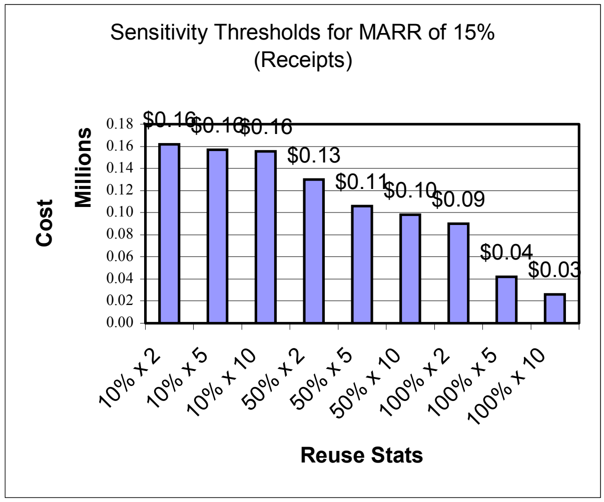

Figure 3: Sensitivity of Income Level

- Amount of annual income necessary to maintain a benefit from the simulation decreases as reusability is increased (inversely proportional).
- Benefits increase sharply when reusability is greater than 50%. At 100% the increasing value of the benefit is linear.
- Reusability as a factor of HLA can be proven economically sound through the use of generally accepted economic principles.
- HLA or some similar platform can generate actual cost savings to the Army if employed as designed.

At the present time, based on conversations with officials in the Army Modeling and Simulation Office, reusability of simulations is not tracked nor considered on an economic basis in the award of simulation contracts. This analysis proves that just that factor – reusability – can have a significant impact on the overall economic benefit of the simulation and should be considered in the development of federates under HLA, or in the award of contracts in support of future distributed simulation efforts.

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