Proceedings of the 1989 Winter Simulation Conference
E.A. MacNair, K.J. Musselman, P. Heidelberger (eds.)

Direct Connect Emulation and The Project Life Cycle

Max W. Hitchens, President
Thomas K. Ryan, Project Manager
HEI Corporation
350 Randy Rd.
Carol Stream, IL 60188
312-665-5500

ABSTRACT

Simulation modeling is viewed as an evolving process. Initial models are broad-based and are used to answer concept questions. These answers lead to system decisions which allow construction of more detailed models. These models are used to answer more detailed system questions, giving rise to still more representative models. These more detailed needs begin to bridge the gap between system design and design implementation. Direct connect emulation extends the use of simulation modeling into the actual startup and operational phases of the system. Emulation is defined as an intermediate stage of simulation where the model represents the "as specified" mechanical plant and equipment. At this point it contains sufficient detail to accurately test the control logic by direct connection to the controller. Verification and maintenance monitoring is defined as the final stage of simulation modeling where the model represents the "as built" mechanical plant and equipment.

1. INTRODUCTION

It is my intent in this paper to describe the separate phases of the project life cycle, to describe how simulation in its various forms can support these stages, and to give some brief conclusions as to the value of these simulation applications.

2. THE PROJECT LIFE CYCLE

HEI views automation projects in particular, and development projects in general, as a cycle of activities, a Project Life Cycle. Simply put, an idea is conceived, it then moves to design, the design is fabricated, the fabrication is installed, the installed process is then operated (figure 1).

Figure 1

Simulation, in its various stages of simulation, direct connect emulation, and verification and maintenance monitor, is the engineering tool that supports this entire life cycle.

CONCEPTION

Conception is having an idea, and bringing the idea out of the mind into an environment where it can grow. For corporations, the process of conception includes "selling management." No idea or plan can become reality until it is funded.

It is often said that a picture is worth a thousand words; a corollary is that a moving picture is worth ten thousand words. Automated systems are dynamic. A static picture or description of an automated system does not show the interaction of the components or how the system functions as a whole. Only an animated picture, as generated by Automation Master, can show these factors.

Simulation is a communication tool to sell management on a project. Statistics show what has happened in a system, but an automation model generated with real time animation shows what has happened and how it happened (figure 2).

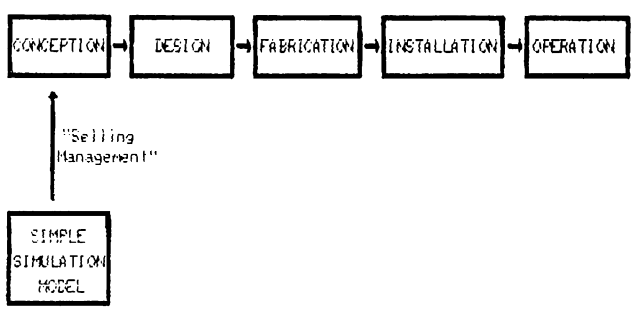

Figure 2

DESIGN

A study by A. T. & T. demonstrated that a problem that is discovered and fixed during the design stage for a cost of $100 would cost $10000 or more to fix after the design is completed. Simulation in its traditional stage is the engineering tool to assist the designer in finding problems early in the project life cycle.

The design of an automated system is its plan consisting of blueprints, operational descriptions, and specifications. Planning an automated system is a balancing act: getting the best possible results for the least cost. The engineer must be aware of such design pitfalls as lack of flexibility, inefficiency, insufficient capacity, overdesign, an imbalanced system, and design errors.

The designer selects from several alternatives. With a large number of ways to accomplish any function, the designer chooses the best approach for the specific application. Choosing the best approach requires evaluation of each potential design, testing and weighing the merits and drawbacks of each. Simulation gives the system designer the ability to evaluate potential designs on a computer model to select the approach that works best for the specific application. Using this computer model, the system designer can change operating conditions and get immediate visual feedback on the results of the change.

One of the important elements of an automated system design is the overall strategy to be used in operating the facility. Developing an operating strategy is an interactive process. A strategy is developed, implemented, then refined to improve its performance. The operating strategy is becoming increasingly important as the cost of hardware escalates. Improving the operating strategy increases the efficiency of an automated system without additional hardware cost. A good simulation model that is representative of the physical plant, running in real time, allows the designers to develop the most efficient operating strategy in their office, before the automated system is even built (figure 3).

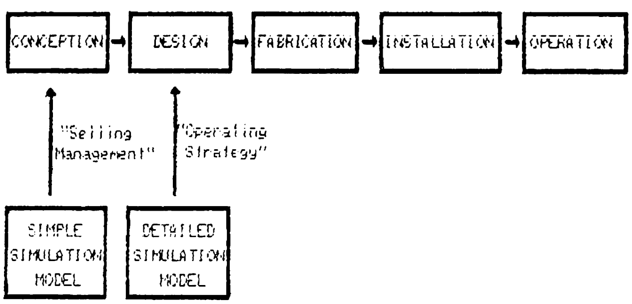

Figure 3

FABRICATION

The third phase of an automation project is fabrication, during which each subsystem is built and the software is written to control it. The computer which is running a variation of the original simulation model is connected to the automated system programmable controllers or computers to test the software implementation. The programmable controllers, or computers controlling the automated system, use the emulation model as a replacement of the physical equipment so that the control logic for the entire facility can be tested. This technique is called direct connect emulation.

Another article I read lately indicated that debugging of software can be as much as 40% on the entire software development schedule. Our own experience using direct connect emulation to debug control software shows that for every day of debug time spent in the office using an emulator, three days in the field are saved.

The success of the implementation of the system design in the control software can be observed on the direct connect emulation model. If the design is precisely implemented, the operation of the automated system model in emulation will be exactly the same as it was during design simulation. But few systems are implemented exactly as they have been designed. An emulation model allows correction of costly deviations from plan before the actual automated system is running.

INSTALLATION

Emulation increases return on investment by reducing the installation time. Capital is not idle waiting for the control logic system to be debugged after installation.

Emulation also speeds the integration of components from different vendors. Each vendor uses the emulation model to mimic the operation of the other vendors' equipment so that when the subsystems are physically integrated in the field, all subsystems cooperate with each other.

The mistakes made testing the system control logic are made on the emulation model, so that no safety hazard is presented, or equipment damaged, during the control software installation process.

No changes in the control software are necessary to go from emulation testing to actual operation. The emulation model eliminates the need to send a programmer into the field for months to install and debug the control system (figure 4).

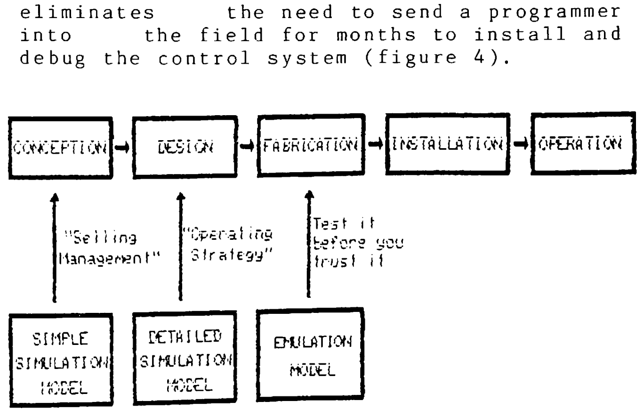

Figure 4

In the installation phase of the project, the various components and subsystems are assembled and integrated into a total system. Installation is where the results of mistakes in other phases start to become apparent. Changes made during conception, design, and fabrication are much easier and cheaper than changes made during installation. After an automated system has been installed it is difficult and expensive to change.

Installation is the most costly phase of the project. Until the installation, progress payments for design and fabrication are a small portion of the total expenditure. But the subsystems and components of the system arrive at the facility accompanied by invoices for payment. Consequently, the installation phase has great and immediate effect on the financial statement.

The emulation model is used during installation to verify that the physical installation matches the design. It is used as a verification monitor to compare the "as specified design" with the "as built system." Diagnostic tolerances are set to zero and an error log enabled. Every activity that does not match the emulation model running in the verification monitor causes an error. The error log shows each difference between the installed system and the emulation model. The installed system can be corrected, or the emulation model changed to reflect "as built" installation (figure 5).

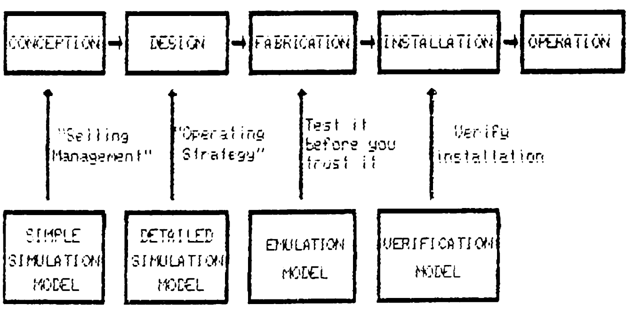

Figure 5

OPERATION

The final phase of system automation is its operation. Operating the automated system provides the payback for all the long hours and money spent in design and construction. The operation is the longest phase of the project.

The emulation model is used after the system has been installed as a diagnostic tool. It becomes the maintenance monitor for the operating department. The model has been continuously refined throughout the design, fabrication, and installation stages. After the automated system has been installed the emulation model is an accurate and detailed model of the automated system. As a maintenance monitor, the emulation model runs in parallel with the operation of the installed system. The model activity is continuously compared with the activity of the operation. When a discrepancy between system operation and the model occurs, outside of specified tolerances, an error condition is generated. An alarm can be sounded, machinery halted, or other appropriate action taken.

Totally unattended automatic systems are manageable using the verification and maintenance monitor. Personnel are not required to diagnose an error. The maintenance monitor informs maintenance personnel exactly what went wrong when.

Changes to the automated system that must be made during operation can be implemented on the emulation model before they are put into the production system. Production is not halted when the system is upgraded.

The use of the direct connect emulation model closes the loop from conception through design, fabrication, installation to operation with no surprises (figure 6).

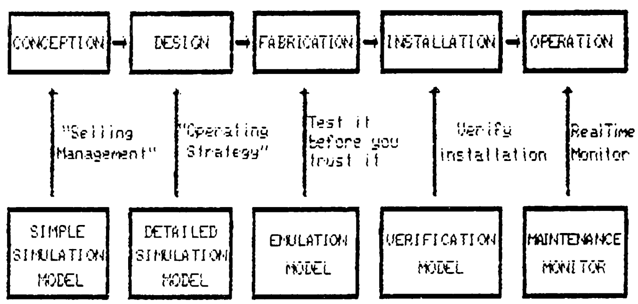

Figure 6

3. WHAT IS THE DIFFERENCE: SIMULATION, EMULATION, AND VERIFICATION/MAINTENANCE MONITOR?

In a simulation model, two essential elements exist. One element represents the behavior of the process/system being modeled. The other element is a control logic or decision making engine that helps manage what the simulation model is trying to do. Typically, these elements are collocated in the same processor/computer.

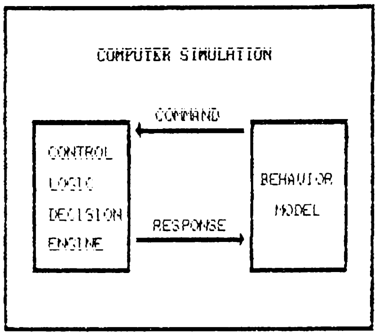

Figure 7

The two elements are constantly repeating a cycle of:

1. control decision
2. command
3. behavior decision
4. response.

In an emulation model, the two essential elements still exist. Instead of being contained in the same process/computer, they are now located in two separate systems/devices. These separate devices may be computers, PLCs, single boards, each connected to the other via a cable or a buss or some connectivity device.

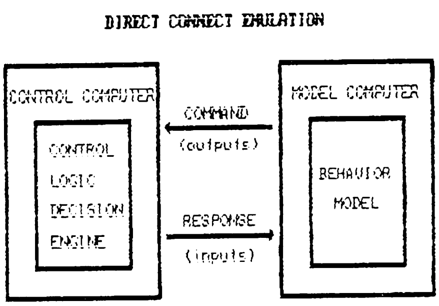

Figure 8

The cycle being repeated is very similar;

1. control decision
2. command (output)
3. behavior decision
4. response (input)

In a monitoring environment, the real world behavior has been added to the two essential elements that existed previously.

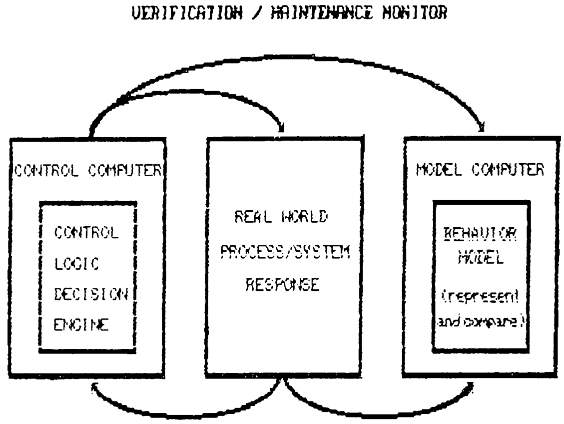

Figure 9

In this environment the cycle consists of two parallel sequences.

controller/real world	controller/real world/monitor
1. control decision	1. control decision
2. command (outputs)	2. listen to outputs
3. real behavior decision	3. model behavior
4. response (inputs)	4. listen to inputs and adjust model behavior

4. WHAT DO I MEAN BY "DIRECT CONNECT EMULATION"?

In direct connect emulation, the controller and its software are physically separated from the emulation model computer and its software/model.

The control software that is being tested/exercised is essentially the exact same software that will be installed to run the real world system/process. It contains no added code or activity to accomplish the behavior response task. This insures that the control software will have no interferences from the behavior response model once installed in the field.

Most behavior model implementations in the control computer are relatively simple, immediate or time delayed feedback to the control logic by activating inputs in direct response to the outputs activated by the control software. This approach is fine for small or very simple operations but breaks down where the interaction of the physical elements being influenced by the control devices is a factor. Implementing an entity based, time/speed/distance bounded model in a separate computer allows these interactions to be modeled. It is also then possible to base the behavior model on the engineering drawings of the process/system being built rather than on the control scheme for the process/system being built.

A direct connect emulation allows the construction of the model to be divorced from the control scheme being tested. Both the control scheme and the behavior model are built from the same reference materials/drawings. The control scheme represents the control response to information derived from input devices located in the system being controlled. The behavior model represents the actions/responses of the materials/entities being influenced by the control devices/actuators. It is passive in that its decisions are based on the behavior that should occur for the control decision made by the control scheme, whether that control decision is correct or not.

5. CONCLUSIONS

Simulation has proved in many applications to be a valuable engineering design tool. Until the advent of direct connect emulation, simulation tools were not available to assist in the fabrication, installation, and operation phases of automation projects. The application of direct connect emulation to the control software debugging/testing task can reduce the cost of the activity by 50-70% or more. It also allows the startup or installation phase to precede much more quickly and efficiently. The fact that the software has been tested prior to startup and that the emulation can be used as a verification monitor allow this improvement.

AUTHORS BIOGRAPHIES

MAX W. HITCHENS is the president of HEI Corporation. Mr. Hitchens' degree is in mathematics, from Rose-Hulman Institute of Technology. He has created simulations for IBM, Texas Instruments, General Motors, Procter & Gamble, Sara Lee, Monsanto and others. He has been consulted on automation projects totalling well over one billion dollars. Mr. Hitchens is active in the Society of Computer Simulation (SCS) and the Computer and Automated Systems Association of the Society of Manufacturing Engineers (CASA/SME). He has conducted workshops on real time simulation for the International Material Management Society (IMMS) and CASA/SME, and has presented papers at AUTOFACT and other conferences. He has also published technical papers in various trade journals.

Mr. Hitchens holds a patent on the real time simulator and diagnostic monitor for use in industrial automation.

THOMAS K. RYAN is project and operations manager at HEI and is responsible for direction of technical applications. Mr. Ryan is a graduate of West Point, and in addition holds a Master's Degree in business administration. After leaving the Army, Mr. Ryan held operations and engineering management positions at Procter and Gamble. These positions included warehouse management, maintenance management, engineering project development and project management, and multiplant support responsibilities for a real time data acquisition and information system. His experiences during 10 years with P&G included simulation of automatic guided vehicle systems and emulation of control systems.