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SIMULATION PRACTICES IN MANUFACTURING

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ABSTRACT

Manufacturing companies are one of the major users of simulation. Manufacturing systems are complex and dynamic using simulation companies have saved tens of millions of dollars. This panel will discuss the simulation process and practices typically found in manufacturing companies.

The panel will address practical approaches to problems relating to: model definition, data collection and input distribution definition, output analysis, management expectations, time constraints, and presentation of model results.

The following statements address the use of simulation at each of the panelists' respective companies and serve as a starting point for the discussion.

KENNETH G. MAIN

The ALCOA Tennessee Operations is composed of two major plants. The south plant is the smelting and casting facility, the north is the fabrication rolling division. The main product is aluminum can sheet which is sold to manufacturers for the production of beverage containers. Computer simulation was first used at ALCOA in the industrial engineering department. The first models were for local area capacity analysis. These were time-consuming to develop and most were applicable only to the original situation. When engineers went back to analyze the same areas, they found that the models had to be re-written. In the early eighties, the facility had to be modernized in order to stay in business. One of the additions was a material handling system in the fabrication division. I was the head of the control project portion and was required to verify the design of the system using simulation. This was my first experience with simulation modeling and it turned out to be a very positive one. We found that our first model was adaptive to the ever-changing design of the system during its development. As the system design evolved, new questions would arise about equipment capability and capacity. We found that, with a few alterations, our model could answer the new questions. We probably used that first model at least six times.

During the modernization process, I investigated the possibility of increased capacities in our various production areas. The management department wanted to know if we could get a certain percent more capacity without any major capital expenditures. We went back to the material handling model and tried to generate an incremental step increase. Our initial thinking was that we needed more storage space and furnaces to achieve the increased capacity. We added a lot of detail to the model in order to discern the difference in capacity that we were expecting. We took the data from the model run and ran it through a screening analysis of the statistical processes we were using. We discovered that we didn't need any more capital improvements to achieve the increased capacity. This resulted in a savings of several million dollars. Because of these impressive results, the simulation modeling process was implemented in several other areas of production. The simulation teams were, again, trying to minimize capital expenditures by achieving increased capacity through small, incremental changes. Over the last two and a half years, we have spent a lot of time fine-tuning this process. We use a multidisciplined team of industrial engineers, electrical engineers, mechanical engineers, production operators, supervisors, and maintenance personnel. The team focuses on root causes, through root cause analysis, to develop potential change factors. In parallel, a sub-team builds a model that represents the area. Then the model is validated against actual production runs and run through various change scenarios which are outlined by a well-defined design of experiments. The data from the simulation is put into a multiple regression analysis of the design of experiments. From the results, we can see how to improve the various production areas and minimize capital expenditures. This process is now being used in a plant-wide integration model which we are studying to determine how to reduce the flow time of our product from when it is cast until it is delivered out the back door.

Our main simulation process is having a sub-team build a model simultaneously to the main team analyzing root causes. Their main emphasis is getting the model to work correctly. We work with the industrial engineering department to gather data from the plant. Because our data does not usually fit normal, gamma, exponential, etc. curves, we create continuous distribution functions as model inputs to provide the variability to our simulation models. We compare the outputs of the models to actual raw data and then do statistical analysis using non-parametric methods, because, like with the input data, our output does not fit normal distributions. When the model is validated, we are then ready to run the design of experiments.

Simulation and tools for statistical analysis are extremely useful in combination. Over the last several years, ALCOA employees have been trained to do statistical analysis and it is becoming commonplace. When we make presentations to management teams, we routinely use statistical displays of the data generated from a model. Most of our presentations are focused on the output of the multiple regression analysis of the design of experiments using contour plots. This provides a multi-dimension view and shows how to get capacity through various levels of input change factors.

Animation and business graphics are used during the actual model design, de-bugging and verification stages. They are especially helpful to engineers and maintenance people for determining if systems are functioning properly. They promote a hands-on kind of confidence in the people who will be using the output of the model before it is run to generate useful data for our statistical packages..

JERRY G. FOX, STEPHEN K. HALADIN

Whether the project is short or long-term, involving one discipline or several, the goals are similar: meet management's objectives, on-time, on-budget and with "zero" production loses. In all cases, the factor that will determine if this occurs is the quality of the engineering.

Solid engineering strategies that are established independent of vendor influence or bias are the way to assure that your project will get on track and stay on track. It's also the best way to assure the changes made to the original design are implemented because the owner initiated a change - not because the plan required a costly "fix".

Using technology that allows pilots to fly new airplanes from the safety of a testing facility, Boeing simulation groups "flight test" new factories or manufacturing techniques. This allows identification of problems before actual construction or commitment to major changes.

Computer simulation has been in use at The Boeing Company for over two decades in support of military and commercial airplane programs. This paper discusses issues related to its recent rapid growth and where simulation is headed in the near future.

Boeing's Manufacturing Research and Development (MR&D) Simulation Group over the past six years has played a key role in evaluating and applying simulation to real manufacturing problems, promoting its use, and transferring the technology to Industrial Engineering groups. In 1986 MR&D recognized the emergence of simulation as a strategic tool for manufacturing modernization at Boeing. State-of-the-art simulation hardware and software systems were evaluated and AutoSimulations' AutoMod simulation software was purchased. MR&D immediately began reaping the benefits of the technology. The Industrial Engineering operating divisions were quick to see the value of the technology. Joint projects were established and training initiated with Industrial Engineering groups.

Over 100 manufacturing simulation projects have been done since 1986. Some of them having a lifetime of six years starting from an initial concept through factory installation. Simulation has been used to promote advanced manufacturing concepts, evaluate competing vendor equipment designs, size facilities, estimate equipment requirements, forecast manpower requirements, address operational issues such as alternative work weeks or JIT and to make quantitative decisions prior to committing thousands or millions of dollars. Over 60 percent of the projects have been in direct support of increased production requirements which occurred during the late 1980's and

Boeing's new 777 airplane program. Much of this work involved the building of new facilities. Current projects are moving from evaluating new facility designs to evaluating how we can schedule work through our facilities most efficiently. This type of work ranges from rearranging equipment to form product lines to looking at a variety of ways to reduce the amount of inventory on the shop floor.

Simulation's potential as a tool in Boeing's strategy to reduce waste through continuous process improvement is being realized. Because of this, demand for simulation has grown dramatically. The key to meeting this demand is successful deployment of the technology into the customer community. The Industrial Engineering organizations, with support from MR&D, have stepped up the challenge. Currently there are 40 people from 12 groups performing simulation projects. Each group is extremely talented and all share information and resources when the need arises. To take advantage of this talented pool of individuals the Boeing Simulation Technology Forum (BSTF) was formed in 1990.

The BSTF is a company-wide group of simulation practitioners and managers located at Boeing sites throughout the United States. The BSTF was formed to increase the benefits of simulation through the sharing of ideas and resources. Information on techniques, equipment, software, applications, and simulation conferences is exchanged through telecommunication video conferences. Video conferences are held between Boeing sites in Seattle, Wichita, and Philadelphia. Topics have covered the life cycle steps of a simulation project, specific applications such as enplaning/deplaning a 747-400, and a vendor panel discussing the future of simulation technology. Video conferences are recorded so those that can't attend can still benefit from what was presented. This sharing of information brings new analysts quickly up to speed and widens the perspective of "power analysts."

The BSTF has provided a vehicle for education and training both to simulation providers and customers. Educational material and the simulation experience necessary for selling the technology is shared among the groups. This lets smaller groups focus on applying the technology rather than selling it. In addition, product training session done at Boeing facilities are coordinated with all simulation groups. On-site training allows us to focus on our needs, saving time and money. All groups strive to be successful through training and internal process improvement. Based on BSTF's experience, the most successful users of the technology have engineering or computer science degrees with a background in statistics. Although much of the information required to do meaningful credible manufacturing simulation studies can be learned; a mentor, college, or outside consultant is often required to get started in the technology. Many of the early frustrations with the technology, prior to BSTF, could have been avoided if the available support was properly leveraged.

We feel that through the BSTF we can influence the direction of simulation vendor products by presenting them with a consolidated unified position. This is extremely important since such an enormous investment has been made in the technology. By enhancing our current set of simulation tools and satisfying our manufacturing customers there will be no need to invest in other manufacturing simulation products. This doesn't preclude the use of other simulation tools. As the users' applications broaden from traditional manufacturing Industrial Engineering studies and encompass other areas such as Finance, Facilities, Engineering, and the shop floor, other software tools may by required.

Future activities in Engineering might include modeling our current engineering and business processes to identify where improvements can be made, thereby reducing the amount of time it takes to bring a new product to market. In the area of Facilities, we have identified requirements for cellular manufacturing facility design software which takes into account the wide variety of parts Boeing manufactures. In the area of Finance, a faster method of estimating costs for new commercial aircraft designs that use advanced manufacturing technologies is required. On the shop floor there is a need for an easy to use simulation or scheduling tool that can be used periodically without having to dedicate an individual to learning and using the tool. Several of these areas are being pursued now that simulation technology is being applied and effectively used in manufacturing. It's time to determine how other areas of the company can be improved by taking advantage of what discrete event simulation technology has to offer.

Simulation will play an increasing role in Boeing's future. It provides a risk-free environment to dream, design, and improve our business. This will result in more efficient facility layouts, improved flows, reduced work-in-process and flow times, more effective use of our resources, and much more efficient identification and solution of problems. The use of simulation at The Boeing Company has proved to be one of the most beneficial tools for continuous process improvement.

CINDY SCHIESS

Design Systems, Inc., Design Systems Canada and Design Systems de Mexico specialize in the engineering and design of manufacturing systems, conveyors and other transport systems, automated storage and retrieval equipment, controls systems - virtually every capital investment related to material handling. We also provide innovative strategies for optimizing the effectiveness of operating personnel through the application of advanced techniques in ergonomics and time/motion analysis

Design Systems made its mark serving automotive supplier manufacturing and assembly plants throughout the United States, Canada and Mexico. Today , we count among our client companies the widest range of industries, including:

- Appliance
- Food and beverage
- Off-highway and construction vehicles
- Recreational products

as well as automotive component groups throughout the United States, Canada and Mexico.

Design Systems is organized in specialty engineering groups, each staffed with dedicated engineering and technical personnel. These groups work independently and in concert with each other to provide the type and level of expertise needed for each project. Simulation is one of these speciality groups.

Simulation has been used at Design Systems since 1988. It was first experimented with while working on a few jobs where the client also required that a graphic simulation be performed to test out the layout design. It has evolved to the point where almost all projects involve some simulation. Simulation is also performed as a separate service to customers.

Design System's simulation projects usually fall into the following categories and functions:

- Existing material handling systems
  - Investigate production problems and recommend improvements
  - Impact of product/model changeover
  - Investigate planned system modifications
- New material handling systems
  - Validate design parameters
  - Verify system performance

Design Systems provides the customer with simulation support throughout the life cycle of the project, validating and optimizing design and process decisions.

Concept engineering support takes place prior to the production system going out for bid as a macro verification of the manufacturing process.

Detailed Engineering Support uses the simulation model to validate the production system for Customer's approval of the Supplier's final design.

Final Design Verification validates the "as built" condition prior to the start-up of the production system.

System Design Maintenance continues throughout the life of the production system, from startup through successive model changes.

DR. HWA SUNG NA

Manufacturing Simulation at Ford Motor Company

Goal:

Use simulation technology as a "PROTOTYPING" tool in the manufacturing system's design and development process, to improve investment and operating efficiency.

Objectives:

Put the tools in the hands of the end users -- manufacturing and process engineers.

Strategy:

- Achieve widespread usage of the technology via broad based training for engineers and management;
- Ensure proper usage through on going support;
- Encourage early usage of modeling concept for maximum impact;
- Reach out to our Facility & Tooling suppliers for best results;
- Use commercialized simulation software packages for the ease of maintenance;
- Work with software suppliers for tool improvement.

Implementations:

(A) Training:

We have a number of training courses available to both Ford engineers and engineers from our supplier companies. We make regular management presentations and reports at various forums for the managers. And we provide special training classes on request.

(1) Regular courses for discrete event simulation:
- Simulation Overview --
  1-day, offered quarterly (prerequisite for all other courses);
- Introduction to Simulation Methodology --
  Session A, using WITNESS (hands on)
  Session B, using SIMAN (hands on)
  3-day, monthly (prerequisite for corresponding advanced courses);
- Advanced Simulation Classes --
  3-day, hands on, software specific, offered quarterly.

(2) Program sponsored classes:

Program managers can request special training sessions. In these sessions, all participants are engineers related to the specific program, including members from system integrator as well as their subcontractors. The basic course material covered will be the same as the regular classes, but discussion and hands on experience will be focused on the specific tasks of team members.

(3) Workcell and kinematic simulation training:

Since Ford has (worldwide) on ROBCAD as its workcell and kinematic simulation tool, regular training classes are provided by Tecknomatics for Ford engineers and its supplier personnel.

(B) Support

(1) Consultation and Assistance:

To provide on-going support for our users, internal user groups (one for discrete event simulation and one for workcell simulation) are formed, and help desks are provided by the software suppliers, at centralized Ford locations -- Alpha facilities. Members of the Ford manufacturing community can call up the help desks on a daily basis for assistance or on-site consultation, after the training classes. Corporate and divisional staff with simulation expertise will provide the first line assistance in defining scope and objectives of the studies and in sorted out the modeling approaches, as well as providing specific technical assistance in utilizing the software packages.

(2) Software Loan libraries:

To facilitate the ease of access to the software necessary for simulation studies, software loan libraries have been established by corporate staff organizations (Alpha Simultaneous Engineering). Members of Ford manufacturing community can sign out copies of the software for a limited time period if their project warrants a loan. This is often used while a regular purchase order is being prepared.

(3) Simulation Labs

To ease the barrier of accessing the necessary hardware required for such studies, simulation labs have been established at Alpha facilities too. Users can bring their simulation problems to the lab, use the hardware and software, as well as gain direct access to the help desk for consultation.

(C) Methodology and Guideline:

To obtain the best results and to achieve maximum impact for simulation studies, we have developed specific guideline and methodology for all members of Ford manufacturing community.

(D) Partnership with software tool suppliers:

Last but not least, we believe in working with our tool suppliers to improve the capabilities and the ease of use of simulation packages. In our effort to "unlock" simulation technology, to put the tools in the hands of hundreds of end users, who are not necessarily simulation experts or computer scientists, we encourage and require the tool makers to provide us with tools that will no longer be part of the bottleneck for simulation efforts.

FRANK GUDAN

Simulation Uses for Manufacturing Concept Models

Simulation models are often developed after the process sequence has been defined and the layout is stable. Unfortunately, production improvements identified by experimenting with the model may be limited to time constraints and cost in making engineering changes for a proposed manufacturing system. In may cases, the simulation model may be used primarily to validate the capacity of a proposed system and identify potential production problems that may require minor modifications.

At General Motors, simulation is being implemented at the beginning of the manufacturing development process. During this concept development phase of production proposal, engineering costs are minimum and most recommendations identified from the model can be implemented. These early production models are used to study proposed manufacturing systems in three phases: (1) layout concept, (2) sensitivity to production variables, and (3) investment analysis.

In the first phase, layout concept, models are developed at the macro level to determine basic manufacturing resources to meet the production capacity requirements. Examples for simulation applications are single vs. dual line processing, target line rates for major manufacturing segments for the entire system, and operating strategies such as just-in-time material handling systems. In this phase, proposal changes are frequent and the model must be easy to update. It is important to include the appropriate level of detail in the model. For instance, determining if a proposed manufacturing system should use automatic guided vehicles or conveyors for material handling does not require the same level of detail as determining the number of carriers to install on a conveyor. Many process engineers are not aware of the power of today's simulation languages to respond quickly to these types of analyses. For example, with AutoMod, alternative conveyor systems, i.e. power and free and electrified monorail, can be interchanged in a model without disturbing the processing logic code.

After the concept proposal for a manufacturing system is approved, the second phase, sensitivity to production variables is initiated. In this phase, detailed data are added to the model to test robustness in market demands, production delays, model mix, etc.. This is the time the process engineer can use the model to identify problems such as grid lock from model mix scenarios that surface at production start up. Also, additional manufacturing costs from marketing demands in color proliferation and low volume options can be determined.

In the third phase, investment analysis, the model is used as a continuous improvement tool to reduce investment dollars and still maintain the required production capacity. This phase occurs prior to vendor specification orders and the models are used for detailed workcell layouts and resource utilization studies. In many cases, the models are used by the process engineers to write vendor specifications for equipment orders.

Engineers have the tools to do a thorough job in designing manufacturing processes for individual mainstream systems, subassembly operations, and work cells. However, there are very few tools other than simulation that can be used to study how the individual processes will perform when they are integrated into a common system. This system integration approach can also be used to identify over and under capacity operations for wise investment dollar usage. The alternatives for not utilizing simulation in system integration in manufacturing are benchmark numbers and rules-of-thumb.

It is important to note that animation, especially 3D animation, can be extremely useful to demonstrate changes to marketing and design personnel who are not familiar with manufacturing processes. An additional usage for 3D animation is to explain the new proposed systems to plant personnel for feedback to improve their workplace environment.

In summary, simulating manufacturing proposals early in the development process allow maximum opportunities for selecting the best production system. It is also important to use simulation modeling techniques before engineering decisions are finalized and changes become costly to make.

AUTHOR BIOGRAPHIES

JERRY G. FOX is manager of Simulation and Integration for Boeing Commercial Airplane Group's Manufacturing Research and Development. He received his B.S. in general engineering from the U.S. Military Academy in 1966 and his MBA at the University of Tennessee in 1971. He has over fifteen years experience implementing real-time process management and control systems in the U.S. and Japan. The central thrust of his group is advancement of simulator technologies so complex manufacturing applications can be evaluated faster with less emphasis on programming skills.

FRANK GUDAN is a senior project engineer at the General Motors Technical Center. He has a B.S. degree in Industrial Engineering form the University of Michigan. Mr. Gudan has extensive experience in manufacturing systems and simulation. In his current position, he is a simulation project leader for the new car platforms and provides consulting support in simulation methodology and usage. Mr. Gudan is also a simulation representative on several corporate committees.

STEPHEN K. HALLADIN is a senior engineer at Boeing Commercial Airplane Group in Seattle, Washington. He has a B.S. degree in electrical engineering from Oregon State University. Joining Boeing in 1979, Mr. Halladin has worked as a member of the Manufacturing Research and Development organization staff. In his current position, he is responsible for transferring simulation technology to line organizations by providing consultation and project support.

KENNETH G. MAIN, P.E., is a Senior Staff Electrical Engineer with Tennessee Operations, Aluminum Company of America, where he is currently assigned to manufacturing simulation modeling and statistical analysis of the plant and major production centers. His major emphasis providing information on capacity, throughput and system capabilities on the heavy industrial manufacturing processes for determining the most economical and practical solutions to meet the plant's continued improvement growth objectives. His twenty-three years of engineering experience include machine tool, furnace combustion and rolling milling electrical and electronic control systems. He was the electrical and control systems project manager for Alcoa's 30-ton, fully automated material handling system, integrating the three largest production centers of the plant. Mr. Main is a registered Professional Engineer in three states. He is a member of SME and currently is chairman of the AutoMod Users Association. He holds a B.S. degree in Electrical Engineering from Purdue University.

HWA SUNG NA is a Principal engineer at Ford Motor Company, Alpha Simultaneous Engineering. Her current assignment is to manage simulation technology at Ford, concentrating on the development and the transfer of such technology within Ford manufacturing community. She has a Ph.D in Electrical Engineering from the University of Illinois. She joined Ford Motor Company in 1977 after her experience in research and teaching at the University of Michigan. She spent eleven years at Ford's Electronics Division as a manufacturing staff engineer, then joined Robotic Applications Center at Ford in 1988. She became Alpha Associate when the Center merged into Alpha Simultaneous Engineering. Hwa Sung Na has extensive experience in manufacturing technology applications, including robotics, computer vision, AI expert systems, discrete event simulations, and factory floor scheduling. Currently she is the co-chairman of Ford Simulation Users Group. She has developed Ford simulation training classes and taught over 300 engineers in the applications of such technology in the past four years.

VAN B. NORMAN, President of AutoSimulations, Inc. received a B.S. in mathematics at the University of Utah in 1969. He spent six years at Eaton-Kenway, where he implemented the first simulation animator. In 1982, using his experience in factory automation and simulation, he co-founded AutoSimulations, Inc., where he co-authored AutoMod, AutoSimulation's first graphic simulation software. He has authored papers on the application and future of simulation in manufacturing. His interests are in world-class manufacturing operations and simulation research.

CINDY SCHIESS is the Simulation Assistant Group Manager at Design Systems, Inc. in West Bloomfield, Michigan. She has been employed by Design Systems, Inc. for the past five years and involved with simulation for the past ten years. Ms. Schiess has participated in a variety of simulation projects including manufacturing systems, warehousing, distribution centers, office facilities, material handling systems. Theses projects have been done for various industries including appliance, automotive, beverage, cabinet, paper, and rubber products. She has a B.S. degree in Industrial Engineering from the University of Wisconsin - Platteville.