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THE NEW DESIGN: THE CHANGING ROLE OF INDUSTRIAL ENGINEERS IN THE DESIGN PROCESS THROUGH THE USE OF SIMULATION

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ABSTRACT

The ever-increasing use of Digital Manufacturing and Virtual Factory environments is allowing the Industrial Engineer (IE) to be brought into the design process as a true systems integrator. The shop-floor role moves into the computer world as digital mockups, rapid prototyping, assembly simulation, ergonomic workplace assessment, and robotic simulation necessitate production requirements validation. This panel discussion will provide insight into the current and future use of IE's and Discrete Event Simulation (DES) in a multi-disciplinary design environment.

Included here in these proceedings are initial position statements from the various participants at the time of its publishing, which formed the basis for the panel discussions.

Disclaimers: The views expressed in these position statements are those of the individual panel participants, and do not necessarily represent the views of the employee's company or other individuals employed by the company.

1 POSITION STATEMENT OF THE PANEL MODERATOR

The following statement is the opinion expressed by the panel moderator.

Deidra L. Donald, Deneb Robotics, Inc.

1.1 The Past – No DES in the Design Process

IE Profile: Troubleshooters, problem-solvers. Without DES, the IE was rarely involved in the design process, if a company even employed an IE. We were called in after the design was complete, usually to get the line working to production rates that everyone "thought" would work. Our role was typically to figure out how to fix the impossible as cheaply as possible. Since complex process problems are intangible, most product designers left these problems to be figured out "later." Unfortunately, "later" usually meant "if we had known about it earlier, we could have done something about it, but now it's too costly to fix."

The IE was called in as the Problem-Solver, where designers felt that a simple solution must be at hand if they understood the facility as well as the IE did. In most cases the IE could have prevented the problem easily with involvement before the plant was built. Since IE's weren't consulted, the problem typically was more complex than a simple fix. This type of environment led to a solitary, lonely job full of high pressure, telling managers the bad news: "Unless you want to spend large amounts of money, this rate is the best you'll get." As IE's, we hoped the designers would learn from these mistakes and get us involved sooner; we found that history often repeats itself.

1.2 The Present – DES at the Beginning and End of the Design Process

IE Profile: Completers, validators. Typically design decisions are made in consensus with several other disciplines based on both process and product information brought to the table with today's concurrent engineering environment. IE's have to convince other people, who often don't understand process engineering issues, that the design must be changed. In the process of simulating the facility, the IE/Simulation Engineer becomes: the Completer, ensuring that all factors have been considered; and the Validator, combining information from other disciplines to evaluate the system's behavior as a whole. The process information required causes designers to begin evaluating many of these concerns in advance. Finally, IE's have started to impact the design by validating the production rate through the use of simulation. Startup costs are dramatically reduced as we smooth out the complex process issues before the workers run into them.

An abnormally large majority of our modeling time is spent in the "data gathering" phase, which consists mainly of pestering other engineers for the information needed to accurately simulate the system. If data collection and processing takes longer than the actual simulation modeling task, then a rapidly changing design environment becomes a moving target for the IE. Information from one department may be obsolete before obtaining the rest of the information from another department. Unfortunately, this data collection process causes us to rely on other human beings that also have a full-time job to do.

Product designers may understand what information is required for the simulation. They may even understand the results from the simulation – then why is it so hard to "extract" information from them? They see the simulation engineer coming to gather information from them in the same way they see their trip to the dentist resulting in an extracted tooth. This information benefits the IE – product designers rarely see where process simulation will benefit their own job, so they view the IE as a "necessary evil." Unlike those who visit their dentist for preventative cleaning, they choose to wait until there is a large problem that requires painful – and expensive – surgery to fix. Designers won't understand why they have to provide an IE with this information until the IE again has to perform miracles to meet production requirements. And they're all still surprised when they see the enormous bill.

Today, most companies have found two places in the design process where DES shows obvious benefits: the beginning (the "proposal" stage) and the end (the "validation" stage). The simulation is used to win the proposal – this win is an obvious benefit of the simulation, where its promotion helps to justify its use: "If we hadn't validated the line and convinced our customer that our design works, we wouldn't have won the job." Then the model is shelved until "better data" is created. In the validation stage when the simulation model is revived, or recreated, the payback on the model is not easily seen unless the analyses uncovers a major production flaw in the overall system. Although the flaw is detected, designers are not happy to hear of it because of the re-processing work required, like weld studies, capital equipment justification, and tooling changes. Through quantifiable analysis, the simulation allows us to find a logical, low-risk solution.

Although DES has changed the role of the IE so we can impact the design earlier, the position is still largely misunderstood and under-appreciated. The IE is the bearer of both good new and bad news: "I have a guaranteed, low-cost solution! Of course, you'll have to re-process the entire line to do it…." Unfortunately, decisions must be made whether the change should be made at all, simply due to the cost of change at such a late date in the program. If it means the difference between making the required production rate or not, sometimes it becomes necessary just to spend the money – and who do the designers blame for the extra work? You guessed it – the IE.

1.3 The Future – Integrated DES in a Digital Manufacturing Design Environment

IE Profile: Systems integrators, communicators. IE's understand the flow of material, and thus the flow of information, through the facility. The new challenge is to interpret this information in a format that other disciplines, management, and customers can understand. As the Information Age is dawning, IE's are positioned to work closely with program management to create the most efficient, cost-effective facility. Simulation allows IE's to integrate the systems information from other groups into one easily understandable medium.

The Digital Enterprise helps IE's harness the power of this information as data is captured and stored in a standardized format. Resource and process planning tools provide a method for structuring the design process and capturing the processing data. Product Data Management (PDM) systems store version-controlled CAD information. Enterprise Resource Management (ERP) systems store valuable information about your current processes. Lessons learned from past programs will be readily available, and these systems will provide a means to logically estimate process data. This data will be accurate enough to simulate sooner in the design process, instead of waiting until the validation stage where the cost of change is enormous.

Within the Digital Enterprise, the simulation process becomes more automated than ever before. The data collection process becomes faster as data is readily accessible. We don't have to "force" other people to provide us with data on a reiterative basis. We just have to convince them to give us access to it, have the PDM inform us when changes occur, and we can retrieve the information ourselves. IE's also become more efficient model builders in the digital manufacturing environment. By leveraging the simulation output from other disciplines such as robotic workcell simulation and ergonomic workplace assessment, IE's build their DES model faster and with less fudging of data.

As we achieve faster modeling time, we can provide analyses in time to enhance the designs for other disciplines. For example, by finding net throughput issues with a robotic weld line, the timely information can be fed back to the robotic processing department for changes before they download the offline programming into the robots. This information saves the designer re-processing time and money. Better yet, if the designer receives the information before they purchase the robots, they could opt for a different solution altogether. By providing this feedback, the IE is overcoming the designer's main objection to providing data for DES – "What's in it for me?"

As these objections are overcome, IE's and DES become more integral to the design. We know we are modeling a facility to avoid the problems a typical start-up encounters, and we need to be able to explain and demonstrate this to the rest of the staff. In this role, IE's supplement systems integration and become masters of communication.

In the design process, the majority of the decision makers don't work with processes, they work with product – part prototyping, tooling, conveyors, architectural facility layout, etc. These engineers are used to working in a highly visual CAD environment with 3D solid geometry, where part interference checking, tolerance stackup, and stress analysis are the closest they come to process simulation. They concentrate on feasibility by designing virtual prototypes of the parts and tooling. If we find throughput issues associated with their design, how do we communicate effectively with these designers? Numbers? Charts? We understand our charts, but do they? In this instance, it's as though we're dropped into a foreign country and no one understands a word we're saying. And talking louder doesn't seem to help.

If we don't know their language, how do we communicate? If they need to ask us something, how hard do we listen? Or, if we are the ones asking, how important is it to us that they understand? It's very important, when changes need to occur. They aren't likely to learn our language, unless they see the benefits. Would it be easier for them to understand us if we spoke their language?

In the product world, the language is visual – and DES tools today can be the interpretor. In the Digital Enterprise, 3D CAD geometry is readily available to use, and IE's will use this medium to assist managers, product designers, and customers in understanding the behavior of the facility. This step is a natural progression of the design process as long as the visualization process is actually a part of automating the model building process. For example, once an ergonomic workplace assessment analysis is completed for a manual workstation, the discrete event simulation can benefit from this work. Through an integrated toolset, we can automatically import this sequence into the DES environment. Or better still, the environments can be seamlessly shared in the same application window.

In the Digital Manufacturing environment, as DES becomes more integrated with the other enterprise tools, simulation becomes the device for interpreting complex process issues to visually-oriented designers, management, and customers. Through simulation, IE's will be the main systems integrators for manufacturing design. IE's will work closely with program management during the design process to reduce risk and provide cost information. The Information Age finally rewards us with the capability of leading the design process through our capability to digitally integrate, analyze, and communicate the most valuable commodity – information.

2 POSITION STATEMENTS OF THE PANEL PARTICIPANTS

The following statements are the opinions expressed by the panel participants.

Jeffrey Abell, DaimlerChrysler Corporation

Manufacturing engineers (ME's) are being asked to design systems to fabricate product with more demanding requirements: More complex components, sophisticated processes, changing materials, lower costs, higher throughput, better reliability, fewer defects, and so on. In addition, the ME must deliver the system in less time, with fewer resources, and with higher first time capability. Traditional methods certainly got the job done, but fall short when compared to the current business requirements of getting the job done faster, at lower cost, and with higher quality. In order to accomplish this task, the ME's must rely on computer simulation and related technologies.

The primary goal of computer simulation (whether it's kinematic, FEA, DES, electrical, or digital mockup) is to gain knowledge of a system's performance under a given set of conditions ***without creating a physical prototype***. If the system is very simple then it is probably not worthwhile to develop a simulation model because the cost and time of creating the system would be exceeded by the modeling process. However, it is generally cheaper and faster to create a simulation model of a manufacturing system (especially automated systems) than to create the system or a prototype. It is generally forgotten that several prototypes are built in the course of a manufacturing program, with various purposes. The elimination of one prototype from a given program would more than pay for the simulation study. In addition, any subsequent prototypes or system builds would be higher quality because many more questions can be answered with deliberate sensitivity and optimization studies. The three business directives of "faster, cheaper, and better" can be met with the proper use of modeling and simulation.

The use of simulation is driven by the data flow of the product & process development process. In some cases, if a step in that design process is simply automated, and taken no further, then it is worth questioning if that is a valid use of simulation. However, if steps are eliminated or if more information can be gathered and more questions answered, then the simulation and analysis was probably worthwhile.

In order to achieve the situation described above the ME of the future must understand the interactions between various complex systems in the factory. He must be a great technician, a master programmer, and have several years of experience with the systems being modeled. At the interface of many different systems and disciplines, the ME must understand how to coherently develop a simulation model or a federation of models (borrowing from HLA) that accurately describes the behavior of the system. The simulation models of the future will accurately model (in a natural format) all systems within a factory, including controls, material handling, workers, robotics, etc., in an integrated fashion. The challenge will be to develop the design processes that will allow these systems to be designed independently and then tested collectively. This will be the future of the manufacturing design process.

Nick Andreou, General Motors Corporation

The engineers that conduct themselves in roles that were defined by their grandfathers, will have no role to play in today's virtual factory.

A few years ago, it was acceptable, perhaps even flattering for IE's to be asked to assess the viability of a manufacturing system proposal. It was acceptable to wait for the completion of a Manufacturing plan, to begin conventional work on throughput assessment, or line balancing, or layout details, or manpower planning.

Today, it is a requirement that ME's deploy Manufacturing Math Modeling tools and techniques during the concept development of manufacturing systems. Some of these modeling tools involve DES (for throughput and layout configuration synthesis), WorkPlace Visualization (for Design For Assembly and ergonomic considerations), 3-D Plant Layout (for virtual factory development) and Finite Element Analysis (for tool & equipment structural durability).

The conventional silos of engineering disciplines ensures that organizations work on the development of products and the manufacturing systems that make them, in SERIES. This means that every iteration and concept consideration is painful and disruptive. This means that one group cannot begin work on a system until the other group has finished its work... with a complete disregard for how one group influences the other.

The virtual factory is an environment where all engineering, material handling, service, product, and facility personnel, etc., synergistically co-develop the manufacturing system together. This represents a digital factory, comprehending all the aspects of the system.

New challenges exist. How do we get everyone to talk the same language? How do we get people to think about their areas of expertise years earlier than ever before? How do we allow others to play in our conventional engineering sandboxes, long since reserved for only our special groups? How do we spend money to get this done, if it is not clearly "My" work?

The management and the engineering community simply needs to focus on getting the job done faster, cheaper, better and smarter than ever before. They need to design products and manufacturing systems that will be reused program after program, for drastic cost reduction and reliability improvements.

The easiest way to fund virtual factory initiatives, is to arrange for what I will call, an "Analog" budget. The old ways of making physical mockups to demonstrate a single iteration of a build (whether it's a product or tooling build), will give you more budget money than you could ever spend by using digital assessment (and provide 50 times more relevant information... and it's reusable). A small portion of the old budget earmarked for plant startup "Panic Teams," to solve surprise startup problems, easily pays for throughput, system configuration synthesis and analysis work. The examples continue, but I will stop here for now.

The most valuable element of the engineering endeavor are the engineers. Whether they actually do the models themselves, or if they prefer to manage the projects and leverage others to perform the Manufacturing Math Models, it doesn't matter. What matters most is that collectively, the team understands the nature of the upcoming program, and defines what models are required. They must figure out what are the requirements for the system, and how do we invent a manufacturing solution that meets all the program requirements, and how do we prove or validate that the system works. This validation must occur in plenty of time to allow others to modify their plans every time one of the members must change the configuration of their element. Electronically, this can happen virtually for free, and virtual instantaneously.

Finally, 3-D representation of everything in the virtual factory (even virtual reality), is a must, so that all members of the Virtual Factory community, can see and understand each others' systems. It is not enough for a modeler to understand his model, but that everyone must be able to understand every aspect of their assumptions and their configurations. A well animated, 3-D model communicates better than any other way that we have found.

Robert J. Schreiber, The Boeing Company

To be provided at the conference.

AUTHOR BIOGRAPHIES

DEIDRA L. DONALD is the product manager for QUEST at Deneb Robotics Inc., a developer of digital manufacturing solutions based in Troy, Michigan U.S.A. She has over 10 years of industry experience with discrete event simulation focusing in the aerospace, automotive and distribution industries. Prior to Deneb, she most recently assisted in developing Virtual Manufacturing initiatives at Lockheed Martin Skunk Works. Donald received a Bachelor of Science degree in Industrial and Operations Engineering from the University of Michigan Ann Arbor and is a member of **IIE**.

DR. JEFFREY A. ABELL, P.E., CMfgE is a Senior Systems Specialist and Supervisor, Manufacturing Simulation and Analysis, Advance Manufacturing Engineering, DaimlerChrysler Corporation (Auburn Hills, MI U.S.A.). He is responsible for platform support and new technology development related to simulation and analysis technologies. Previously, he was an Advanced Manufacturing Engineer, Advanced Development Group, Delphi Automotive Systems, Troy, MI, where he conducted and supervised development projects in the area of Virtual Manufacturing. Prior to returning to industry, he was an Assistant Professor of Manufacturing Systems Engineering at GMI Engineering & Management Institute, Flint, MI. He also worked previously as a Manufacturing Engineer for General Motors in Dayton, OH. He has a B.S. in Mechanical Engineering from General Motors Institute (1985), and M.S. and Ph.D. in Systems Engineering from Oakland University (1987, 1992). Dr. Abell's research interests include all aspects of manufacturing system modeling, simulation, control, analysis, and optimization, robotic simulation and analysis, and the application of Artificial Intelligence to manufacturing design problems. Dr. Abell is a licensed Professional Engineer, a Certified Manufacturing Engineer, a Senior Member of **SME**, and a member of **SCS** and the National Society for Professional Engineers, **NSPE**. He is currently the Vice President-Membership for SCS, and has served SCS as Secretary and Associate VP-Standards. He has published a book and several conference and journal papers.

NICK ANDREOU, P.E. is the Manufacturing Math Modeling Group Manager, North American Car Group at General Motors Corporation (Warren, MI U.S.A.). His group's activities lead the corporation with innovative Manufacturing Math Modeling and continually defying conventional corporate organizational structure. His group assists classically-structured engineering departments in moving into digital manufacturing and out of the traditional engineering discipline ownership-type structure. Andreou's experience with GM began as he received a B.S. degree in Industrial Engineering from General Motors Institute (GMI, 1973), sponsored by the Windsor, Ontario GM trim plant. At the Windsor plant he held various positions including Tool & Equipment manufacturing engineer, industrial engineer, production supervisor, and pilot coordinator. He completed his M.S. degree in Engineering Management, with a concentration in Manufacturing, from University of Detroit (1984). Andreou has held many previous positions at GM's "Central Office" in Warren, MI, such as contributing the Manufacturing prospective for future programs, developing future vehicle interior systems, and working closely with customers. His next assignments involved Vehicle Windnoise development, Door Systems Lead Engineer, Body Systems Engineer, and Total Vehicle Integration Engineer, before spending a few years in Systems Engineering with Vehicle Technical Specifications and requirements engineering. He then became an Engineering Group Manager in the Manufacturing engineering area, where he was responsible for designing and implementing General Assembly Tools and Equipment. In this position, he first began to take an interest in Manufacturing Math Modeling to help design and validate tools and equipment faster and cheaper than by building actual tools as prototypes. Within a few years, Andreou then took over the Discrete Event Simulation group, started the Work Place visualization group, the Unigraphics Design group for Manufacturing, the structural analysis group for tools and equipment, and finally, the 3-D layouts/virtual factory group. All of these Manufacturing Math Modeling initiatives were "firsts" in GM, and have served as models for the rest of the company to benchmark.

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