T&P CHEMISTRY

The chemistry of 21ST CENTURY

Extensive interactive databases, voice-activated video conferencing, nanotechnology. No noise. No dirt—it's all so eerie.


Duncan

It was late July and the Midwest had broken 50-year records for combined heat and drought conditions. Denise Johnson scanned her Simulated Test Marketing (STM) database. Denise was in the process of performing her quarterly update to the sales forecast at Sunshine Manufacturing, a mainstream producer of lawn and garden implements in the U.S.

An hour before, she had moved the setting for her office walls from transparent to opaque to shut out the rest of the world while she focused on a plethora of world trends encompassing demographics, weather, and economic conditions. Each of them appeared in its own window before her on the large, blank wall. Denise spoke to the wall: "Weather, Mid-Western U.S., 90-day Projection." The information presented itself in both text and color graphic format, spread out across a topographic representation of the middle U. S.

"Compress forecast data to include top 20% sales regions in this segment." Denise's interest level peaked at this point as she noted a dramatic change in upcoming weather conditions. She paused thoughtfully. "Economics window," she spoke aloud again. Another window appeared which included factors such as average US income data for the prior year.

What had looked pretty interesting before now became compelling. If the analytical models Denise had been finessing for the past six months were correct, company revenues were poised for a major surge. Finally, she was ready to share the good news.

"Save forecast data in existing format and close all other windows." The wall went blank except for the remaining window. "Open videocon." Another window appeared immediately to her right. In the top of the window was a series of thumbnail photos comprising her personal, frequent phone listing. "Select Wayne Edwards." she said. Wayne's photograph enlarged to fill the screen, nearly life-sized. "Calling Wayne Edwards." The words blinked on and off, superimposed over the bottom of the photograph. After a few seconds the photograph was replaced with an actual image of Wayne sitting at his desk. "Wait 'til you see what has just come out of the sales forecast algorithms! I have made them available, so just pick up SF-SF-2019-3," she said.

"Whoa!" he exclaimed, "where did this come from?"

"Well," Denise replied, "it seems that our weather is about to break and when it does, the demand for lawn and garden implements is going to break with it." Denise leaned forward: "There is a lot of cash built up in our primary customers' bank accounts, just crying out to be spent on lawn and garden tools. According to recent sales history, folks have been putting off purchases on everything from garden tractors to weed-eaters."

The whole thing made John feel old.

"Don't I know it." Wayne responded. "Sales have been abysmal for 3 years. Okay, I'll take it from here."

Wayne's office was located a little closer to the action in Production Operations.

He talked to the wall. "Primary Capacity Planning", he called out, and a large window appeared before him. The window represented three major areas: supplier

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By William L Duncan
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MANUFACTURING

capability, internal assembly capacity, and shipping. "Constrain to internal assembly operations," he said, and the window responded. It showed him a 3-D graphical representation of all manufacturing capacity in stacked bars, depicting workload against available capacity in hours. "Interface sales forecast SF-2019-3." Suddenly the picture changed. About a third of the work centers depicted over-capacity conditions, blinking red. "Apply excess capacity for alternate work centers against all over-capacity locations." About half of the over-capacity warning lights immediately disappeared. "Narrow analysis to over-capacity work centers," he said, and immediately all of the non-red locations faded from view.

Wayne noted that about two-thirds of the remaining over-capacity work centers were composite co-curing operations. He decided to evaluate outsourcing options. "Open primary composites outsource capacity database," he said, and another window blinked open to his left. At the bottom of the window, which contained a listing of certified composites suppliers with whom Sunshine maintained strategic partnerships, a message flashed, "Specific process required!" and Wayne responded "Co-cured aluminum and carbon fiber epoxy." Only three names remained from the original supplier list.

A quick scan of the graphs showed Wayne that only one of the three suppliers would be required. The top supplier, Halbrook Composites, had enough capacity to do the job. "Apply Halbrook outsource capacity to internal operations simulation." When the computer added these numbers, only two internal work centers remained in an over-capacity position.

Wayne repeated the analysis for these two areas. After a couple of hours, he was satisfied that he had a plan for achieving a production ramp-up that could support the dramatic surge that lay ahead.

At this point it was lunchtime and Wayne decided to take a break.

Wayne decided to eat his lunch in one of the outdoor picnic areas. He pulled his personal digital assistant (PDA) from his pocket and set it up in front of him. "Initiate calendar search. Calendar one, Wayne Edwards; calendar two, Kathy Phillips; calendar 3, Bret Carroll; calendar 4, Duke Kentner. Request meeting time 45 minutes, start 1 p.m. today, end 3 p.m. May 28.

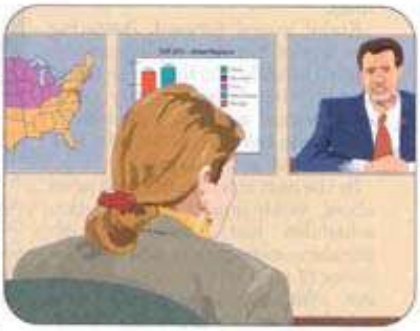
"Meeting time available," the soft voice of the PDA intoned, "today, 2:45 p.m."

"Set meeting." Wayne replied, and he watched as the PDA scrolled through each of the calendars to align and block out the meeting time.

Duke Kentner, supply chain manager for Sunshine, was connecting from his primary office in northern Arizona. Kathy Phillips, leading Sunshine's Logistics department, tapped in from a conference room at the loading center of a nearby industrial park. Behind Bret Carroll the other conferees were able to observe main assembly operations during the afternoon shift. Because Kathy was at an off-site location, all of the videocon windows displaying other meeting attendees appeared on the screen of her laptop computer.

Wayne ran briefly through the capacity analysis he had performed and waited while Duke did some specialized inquiries related to existing contracts with Halbrook Composites. "Looks like Halbrook can support the effort without any problem," Duke said.

Manufacturing had all but been absorbed into the realm of the product and process engineer.



She moved the settings for her office walls to opaque to focus on a plethora of world trends encompassing demographics, weather, and economic conditions. Each of them appeared in a computer window on the large, blank wall.

"Good," Wayne replied, and pivoted a bit in his chair. "Bret," he intoned, "how do things look in terms of finite production schedules when you lay this new master schedule into the Enterprise Requirements Planning (ERP) model?"

Bret was staring intently at the display before him. "I may have a conflict, but it's certainly nothing we can't handle."

"Okay then," Wayne said. "Kathy, tell me how this looks on the logistics front."

Kathy leaned forward, distorting the size of her face slightly as she peered intently into the screen of her laptop. "It's looking pretty good. The forward scheduling algorithms lead me to believe that we'll be able to hit the shipping targets."

By the next morning the good news about vastly-improved production schedules had spread through Sunshine management and the sales forces of most of their major suppliers. With high-level supply chain schedules, factory production schedules, and logistics laid in, the detail planning got underway. Shop production schedules networked to factory equipment ran through permutations to recommend optimum equipment utilization. Machine time, tooling availability, required preventive maintenance, and factors reflecting historical attendance and direct labor productivity were all analyzed in the construction of this detailed production plan.

John White, director of production at Sunshine's primary assembly facility, smiled around the end of his cigarette and scanned through a veil of nicotine-free smoke, as the new production plan scrolled by on his office wall. "Now this is more like it," he thought, "it's about time we got some new business in this place."

"Computer," he said, "show me required personnel additions for quarter three." In the window on his right: a list of job titles, hours required, and date ranges appeared. "Interface available assembly personnel. Constrain to regular employees." Only one job title remained with no matching name. "Hmmm, guess we've got to do some hiring.

A nanotech prototyping shop of the future might appear as in the rendering above, created by Mark J Dyer, senior research physicist, Zyvex LLC. The unit would create parts using atomically precise molecular assemblers. Contaminant control would be critical so parts would be synthesized in controlled environments using vacuum chambers and sealed process stations and handled by robot manipulators and conveyors. From left to right, nanoscale systems are first synthesized on carefully prepared substrates from raw atomic and molecular feedstock, then integrated via microrobotics into larger devices, such as microelectromechanical (MEMS) systems. Electron and optical microscopes monitor the process. Once microscale systems are completed, more conventional machining, casting, and forming techniques take over as necessary.

Open videocon." After a few seconds, Jerry's image flashed onto the screen.

"Looks like I need to hire a Category 9 Specialist," John said.

With all of the initial staffing considerations out of the way, John's mind was free to step back a bit from the details and consider it in a context of overall operations. A new manufacturing technology was emerging at Sunshine, and around it a whole new world of manufacturing processes was beginning to take shape. John knew that the Research and Development Division had been looking for an opportunity that represented sufficient revenue "upside" to justify an initial excursion into this new venture.

"Open videocom," he said.

"Calling Ron Meeks."

"Hello John, how are things in the White world?" Ron asked cheerfully.

"We have had an interesting development here, Mr. Meeks," John said. "It seems that we have a major weather pattern forming and it's going to start raining dollars in our neck of the woods."

"Well, that does sound interesting," he said, "Are you thinking about applying the new micro-assembly processes?"

"Well," White quipped, "I would have liked to wait until you guys had the bugs out of it, but I'm pretty sure that my retirement benefits would have expired by then."

"Very funny." Meeks retorted. "Which assembly components are you considering?"

"Why don't we start with something simple like unibody design on one of our smallest series of lawn and garden tractors?" White asked. "Maybe the K300 line."

"Yes, that's a possibility," Meeks said, "although I have to admit I was looking for something a little more challenging."

"Take a look at my production

workload forecast." White responded, and another window appeared simultaneously on the wall before John White and Meeks. "Looks to me like we should probably bring it in here." White motioned with his stylus and drew a virtual line between two weeks in early June.

"Well that doesn't give us an awful lot of time, but given the relatively simple nature of the structure and the fact that we have been placing orders for advanced materials for quite some time now, it might just be doable."

Over the next 30 days, the world of manufacturing at Sunshine began to undergo historic changes, albeit invisible to most of their existing employees. Sunshine had been working for many years in conjunction with other companies, some of whom were suppliers and others of whom were non-competing strategic partners, to apply a number of processes and tools emerging from the field of nanotechnology.

Manufacturing without any production machines, any noise, any dirt. It just didn't seem right.

The advent of nanotechnology in mainstream manufacturing represented a change of gargantuan proportions. The changes began in design engineering, where customer requirements had been identified.

As had been standard procedure with all such designs, customer-critical needs were converted into key product characteristics, and key product characteristics were translated in turn to quality assurance test/inspection criteria. However, almost everything else changed.

The actual equipment used for production, the work plans, tooling requirements, and even the chemistry of the raw materials involved were altered significantly. In their traditional manufacturing environment, automation in the form of decision support systems produced process plans that promised the highest quality products at the lowest cost based on historical performance. Process capability for each machine required in the various manufacturing processes evolved and was tracked over time, and three-dimensional models held in the engineering database were later integrated to produce tooling requirements, dimensions, and capability data for both tool production and part production. Numerical control programming was then generated.

But in the new manufacturing environment, the need for most tooling was eliminated. In addition, most of the discrete manufacturing process steps disappeared as well.

By the time production actually occurred, the facility that produced the new unibody component resembled a pharmaceutical lab more than a traditional manufacturing environment.

The work space for almost all of the manufacturing process was a single vat about the size of a mid-size automobile in a brightly-lit clean room, with manufacturing technologists just outside the room peering at a console of work stations resembling the bridge of the USS Enterprise. The vat was shiny steel with pipes and pumps linked to it, running in from other equipment located in adjacent rooms. Beneath the floor on which the vat stood was a series of fluid-cooled heat exchangers.

At the beginning of the process, one of the manufacturing technologists remotely operated a robot that removed the top of the vat and lowered into it a base plate, then re-sealed the vat. Working at his keyboard, he initiated the actions of a series of pumps which flooded the vat with a viscous metallic fluid. More fluid flowed from other vats in other rooms at appropriate times.

These fluids contained microscopic-sized replicating assemblers–tiny machines with robotic arms only atoms long. The replicating assemblers literally constructed the unibody structure molecule-by-molecule, beginning at the center of the base plate forming it around a single

The finished structure gleamed, virtually devoid of even the tiniest defect.

"seed." The seed contained a nanocomputer with the part design, and on its surface were patches to which the assemblers stuck. As assemblers stuck to the patches, they plugged themselves together and the "seed" computer transferred instructions to the individual assembler computers. Working like human body DNA, the new programming indicated where each assembler should be in relation to the seed and directed it to extend its manipulator arms and snag more assemblers. These then were plugged in and similarly programmed. Following the initial programming from the seed which had spread through the expanding network of assemblers, a crystal-like formation grew in the sea of liquid.

With each assembler "knowing" its location in the planned structure, it continued to snag more assemblers, but only where they were needed, to form the actual structure. In the course of a few hours, the assembler scaffolding matched the final shape of the unibody structure. At that point other manufacturing technologists, who had been monitoring the

process closely, took over primary responsibility. That initiated another set of pumps which began to drain and replace the milky fluid of unattached assemblers with a clear mixture of solvents.

Finally, one of the technicians issued a command to the seed which directed designated assemblers to release their neighbors and withdraw their manipulator arms. At that point they were washed out of the structure.

The finished product was in order of magnitude better in virtually every respect than its previous version. The structure was stronger, lighter, and monolithic. It contained no subcomponents, no fasteners, indeed virtually no wasted material. Where the need for strength was greatest, the assemblers had constructed rods of interlocked carbon fiber to counter all expected patterns of stress. Where heat and corrosion resistance were most important, similar structures were printed into the surfaces this time comprised of aluminum oxide in sapphire form.

Conversely, in lower stress areas the assemblers flawlessly effected design criteria minimizing mass by leaving wider spaces resulting in greater porosity in the structure. In various locations of the structure, its assemblers had utilized other materials to form sensors, attach points, and data recorders to monitor and communicate after-sale product performance.

Finally, when the vat had been drained and spray-rinsed, the unibody structure lid lifted and the finished structure was hoisted out to dry. The finished structure gleamed. Virtually devoid of even the tiniest defect, its surface was so smooth that it was almost iridescent–like an opal. The structure required roughly 90% less mass than its predecessor to perform all of the same functions and virtually no required componentry.

John White strode rapidly in and out of the heavily-guarded facility where this new product work was being performed. He could barely stand the drama unfolding before him as he literally watched history being made.

The whole thing seemed eerie to him–manufacturing without any production machines, any noise, any dirt–it just didn't seem right. The familiar smells of machine oil and lubricants which were as much a part of John's daily life as cigarette smoke, were replaced with the cool, sterile air of the clean room and an occasional whiff of chemical solvent. He had to admit to himself that he was seeing the beginning of the end of an era. Manufacturing had been all but absorbed into the realm of the product and process engineer. Robots had truly replaced over 99% of the direct human labor and even though the results were better in every respect, the whole thing made John feel old.