LOCKHEED MISSILES & SPACE COMPANY

Through a real-time industrial-control system based on the Microsoft® Windows™ for Workgroups operating system with integrated networking, plant managers and operations personnel monitor and control all equipment, processes, and operations at the Advanced Metal Finishing Facility of the Lockheed Missiles & Space Company. At the same time, management has raised fault tolerance and lowered costs while providing the facility with a system that is easy to learn, modify, and use.

Maintaining consistent quality control and ensuring successful day-to-day operation of any manufacturing environment is always a challenge. But when the item being manufactured is the nose cone of the Trident missile or the fuel tank of the NASA Space Shuttle, to give two examples of products of the Lockheed Missiles & Space Company, that challenge is enormous. Systems engineers in the Special Programs Group at the Lockheed Advanced Metal Finishing Facility in Sunnyvale, California, face such a challenge every working day. These engineers are responsible for the control and operation of every system and subsystem in their 83,000-square-foot plant—the most advanced facility of its kind in the United States and a vital contributor to the success of this $5 billion aerospace and defense-manufacturing giant.

To accomplish their work, the engineers enlist networked computer systems for everything from regulating temperature and chemical mixtures in 40 separate vats—as well as 80-foot-long paint booths—to running the filtration equipment that maintains air purity in clean-rooms. These systems also must help ensure that nothing escapes the scrutiny of equipment operators, maintenance personnel, and plant management. That's because the facility is being watched more closely than ever by corporate management and government regulators. On one hand, the plant must keep costs to a minimum; on the other, it must meet increasingly stringent state and federal Environmental Protection Agency (EPA) standards and maintain strict compliance with the highest Department of Defense military specifications (MIL SPEC).

All this leaves a very narrow margin for error, particularly within the computer system providing the plant's essential monitoring and real-time control. For critical parts to be produced on schedule and to specification, the system must be reliable every day of the year.

Obsolete System Brings Downtime, Problems for Users

Unfortunately, this wasn't the case in late 1991. Even as the rest of the company was cutting back, the Lockheed Advanced Metal Finishing Facility was growing, and its proprietary, minicomputer-based system was beginning to hit its limits. For starters, system downtime was becoming intolerably frequent, affecting operations on two fronts, says Special Programs Group Leader Ken Forster. Not only did downtime cost the facility directly between $5,000 and $12,000 an hour, it also had serious consequences for compliance with EPA regulations.

"A big role of the system is to continuously record and archive critical data covering our wastewater and other effluents," Forster explains. "But if the system went down on a Friday night after most of the maintenance people had left, we could lose a whole weekend's worth of data, exposing us to the liability of fines totaling hundreds of thousands of dollars."

One particularly serious problem might occur when tanks were ready to be loaded with a recipe— a critical specification for temperature, chemical mix, and oxygenation required to meet the exacting standards of plating aerospace parts. Recipes are frequently updated and stored in the system database. If the system goes down, however, recipes cannot be accessed, tanks cannot operate, and parts cannot be finished. "Virtually everything could come to a halt while we waited for repairs," says Forster.

Ease of use was another problem. "Even when the system was running smoothly, it never ran as effectively as it might have, since it required users to deal with an old-style, character-based interface," Forster says. "Users had to enter 40 keystrokes, for example, just to obtain a common, single-page graph or report." The lack of online help also caused difficulties, he adds. "Often, people ended up digging through shelves of manuals to find what they needed."

Cost-Effective Functionality in a Visually Oriented Approach

In early 1992 Forster was assigned the task of developing a new monitoring-and-control system for the facility. The objectives were straightforward: the new system must be more fault tolerant, less costly to support, and easier to use than the proprietary system then in use. He considered several approaches before choosing one based on Microsoft Windows for Workgroups operating system.

Forster says price-performance considerations are what initially led him and his colleagues to Word for Windows. "After putting it through a heavy resource-usage evaluation, we saw that Word for Windows was fully capable of running the kind of solution we needed, and at a lower cost than other approaches," he explains. He also believed its functionality made it a particularly good fit. "Its built-in graphics would support the user interface we wanted as well as a variety of custom applications, and its network support would be ideal for controlling the costs of real-time data input."

Another plus was the availability of development tools, among them InTouch—a toolkit which is specialized for industrial-control applications based on the Windows operating system and which incorporates a touch-screen user interface—from WonderWare, of Irvine, California.

Using WonderWare InTouch, Borland® C++, Microsoft Excel, and the Microsoft Visual Basic™ programming system, Forster and two of his colleagues spent the next nine months developing the new system. They applied C++ to areas dealing heavily with the network server and Microsoft Excel to areas requiring graphical display of data, such as vat conditions, hazardous-material status, and other information crucial for EPA compliance. Visual Basic was applied to the user-interface work—with advisory input from members of the group at Lockheed that developed the interface for the NASA Space Station control system. "That's how important it was for us to get the user interface right," Forster says.

According to Forster, Visual Basic was particularly helpful during usability testing. "Essentially, it let us bring in prospective users, ask them what they wanted

changed, and make the change on the spot," he explains. "Giving people that instant feedback really helped them see the value of the new system."

Tighter, Facility-Wide Control of Essential Operations

In January 1993, a fully operational monitoring-and-control system was deployed at the facility under the name B/071. Replacing the proprietary, minicomputer-based system altogether, B/071 consists of seven 386/486 PCs with 20-inch, touch-screen monitors and a central server connected under a peer-to-peer topology using Windows for Workgroups and Network DDE as the network operating system. For communicating with and collecting real-time data from the plant floor, the B/071 network is tied into a second network of industrial controllers with direct connection to sensors within the 24 major subsystems throughout the plant. The controllers are constantly gathering and updating real-time process data, which they send to a dedicated interface card on one of the B/071 computers. In turn, this card translates the data into Network DDE format for use within B/071. For example, the on/off status of a pump is relayed from a sensor in the pump to a controller; it sends the data to the B/071 system, which displays the pump's operating status for users via a graphical on-screen representation.

On a typical shift, B/071 is used by 10–20 employees including operators, engineers, safety and maintenance personnel, and managers. Users obtain information through maps and diagrams that they can adjust as needed to see more or less detail, and they issue commands to control the operation of any subsystem within the facility through menus and dialog boxes.

For example, if effluent levels appear to be rising unacceptably, users can direct the temporary shutoff of valves releasing water into the environment; meanwhile, they can adjust pump operations so that less effluent is produced. If the temperature in an aluminum- or magnesium-anodizing vat becomes too high, users can slow or halt the conveyance belt carrying the metal part toward the vat until the temperature is returned to specification. If clean-room air quality falls below a certain standard, users can adjust air-filtration equipment accordingly.

In the event of equipment malfunction, B/071 displays a special red design, sounds an alarm, and directs users to the location of the malfunction. Meanwhile, Windows Help instructs users on how to repair the malfunction and informs them of other actions they might be required to take, such as checking on the status of related operations or making changes in the way those operations are proceeding.

Reducing Downtime and Costs

According to Forster, B/071 is delivering a number of benefits, foremost among them reliability. Supporting a high-speed data link, a serial backup connection, RAID, and a backup scheme in which a copy of the application kernel runs on each of the seven PCs, the system has dramatically improved fault tolerance, he says. "In the half-year that the system has been online, we haven't lost access to a single recipe."

Reducing loss of access to recipes is part of a larger reliability improvement at the facility, Forster adds. Since B/017 has been online Mean Time to Repair, the standard metric for manufacturing reliability, has been cut in half. This represents a major cost savings, and one that's expected to continue. "We anticipate that the application will save us at least $70,000 in its first year of operation, fully covering its cost of development," Forster explains.

In addition, the facility now automates middle-of-the-night recording of data required for EPA compliance and, through B/071's links to Microsoft Excel, makes a graphical portrait of the data available at any time. According to Forster, this automated reporting ultimately means lowered costs and better EPA compliance, without requiring the establishment of a special reporting process.

Forster also appreciates the system's ease of use, particularly in terms of its online help facility. "By

providing users access to immediate information on the source of a problem and how to solve it, B/071 has become the operator's eyes and ears into the metal-finishing process."

Ease of modification is another advantage. "People from the Fire Department who do periodic inspection tours tell me that they would like to see certain changes made," Forster says. "So, using Visual Basic, I go in without interrupting operation and make the changes in minutes—versus a week for that sort of modification under the old system."

A Foundation for the Future

As Forster notes, B/071, along with his group's consideration of Windows NT, fits smoothly into the facility's computing strategy for the future. More important are the immediate implications of what the application can do to lower costs even further and establish even tighter EPA and MIL-SPEC compliance. Forster says he's happy with the foundation that's been established by the success of B/071. "We take a lot of pride in what the facility has been able to do with the system."

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Ken Forster
Special Programs Group Leader
Lockheed Advanced Metal Finishing Facility

Solution Summary

Industry
Aerospace and defense manufacturing

Business Application
Manufacturing monitoring-and-control system

Solution Architecture
Seven workstations with and a central server connected under the Windows for Workgroups and Network DDE network operating system, in turn connected to a plant-wide network of industrial controllers for gathering real-time data and effecting supervisory control throughout 24 major subsystems

Products Used
Microsoft Access® database
Microsoft Excel
The Microsoft Office
Microsoft PowerPoint® presentation-graphics program
Microsoft Visual Basic Professional Edition
Microsoft Windows for Workgroups
Microsoft Windows™ Software Development Kit
Microsoft Word for Windows
Borland C++
WonderWare InTouch

Development Resources
Three internal developers: lead programmer, assistant programmer, and documentation specialist

Development Time and Cost
Nine person-months; $70,000 total

Benefits
Cuts downtime in half and removes need for service contract, saving $70,000 in first year of operation; slashes the time required to update system interface from one week to minutes

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