MACH 3

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QUALITEAM

World Radio History

Jaunita Reynolds encapsulates blades for travel through the laser cell.

High tech

MANUFACTURING

Some industry watchers will label the Laser Drilling Cell at GE's plant in Madisonville, Kentucky, a technology revolution. But those who brought the cell to life know it's evolution — not revolution — that's happening here.

It took 35 entrepreneurs, hundreds of long-distance phone calls, $5.5 million, a decade of laser research and a very positive team spirit to create Aircraft Engines' latest TechMod project.

"Madisonville employees were behind the laser cell from day one," says Bob Coutts, Madisonville plant manager.

"The TechMod team began with state-of-the-art equipment, added enabling technologies and incorporated them into a system that puts us at the leading edge of laser drilling techniques.

"And we're reaping the benefits," Coutts says.

An engine component begins its journey through the laser cell when the operator encapsulates the blade in a zinc block. That encapsulating block accurately positions the blade during processing, helps seal the part where required and acts as a pallet to automatically move the blade through the cell.

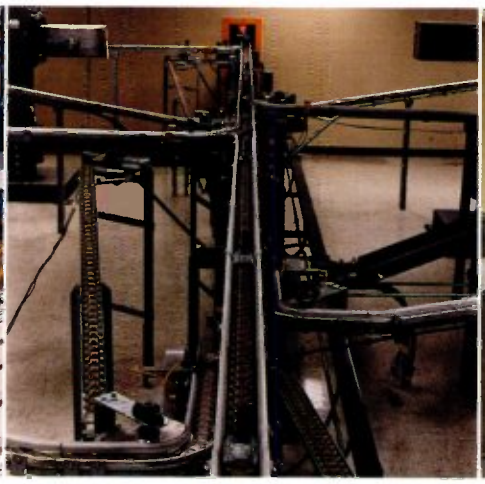
After encapsulation, the operator places the blade on a conveyor that passes it through a cool-dry unit to a queue table where the part is assigned a position to await processing based on its part and lot number.

Once the system recognizes that the cell is ready to accept another lot of parts for processing, the cell controller assures proper processing programs are in place and signals the material-handling system to start a new lot on its way.

The blade's first stop is a "pick and place" robot, which moves it to the wax injector. There, blade cavities are filled with wax to minimize splatter and assure no damage is done to the inside of the part during drilling.

Next the blade moves to the laser. With the help of numerical control programming, the laser drills 50 to 70 holes on the leading-edge of the blade. A unique breakthrough detector monitors the drilling cycle and automatically adjusts for any incomplete holes. An autofocus device ensures against system variability.

After laser drilling, the part is put through automatic water, air and grit (AWAG) blasting to remove rough edges from holes. This first-



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heats up in Madisonville

of-its-kind deburring technology was originally implemented in the airfoils operation at Evendale.

The part then moves to dewax, a pressurized cleaning process which forces steam inside and outside the blade to remove residual wax.

Finally the blade heads for the process verification module. Here a computerized system checks airflow throughout the circuits. An infrared system then rechecks for plugged holes and relative hole size.

With production and quality processes now complete, the blade moves to another queue table where an operator finishes the process by decapsulating the part and giving it a visual inspection.

Actual processing time for each blade is 10 to 12 minutes. Encapsulation, wax injection, deburr and wax removal take less than one minute each. Process verification takes about two minutes and laser drill itself takes approximately four minutes. The rest of the time is required for travel through the cell.

In total, Madisonville's laser cell cuts 15 hours from every set (77 pieces) of engine parts processed.

"It's amazing to just push a button and watch everything move," says Juanita Reynolds, a cell operator. "When you work at the cell every day you sometimes forget just how advanced this technology really is."

"Projects like the Laser Cell are GE's future," says Cell Operator Debby Henry. "And we all want to be in on it."

Early involvement of focus teams is credited with the cell's smooth implementation at Madisonville. Decisions about daily operation of the cell, safety and security were discussed for months before the equipment arrived.

"It was an outstanding team effort," says Terry Stimmel, manager of Madisonville's Flexible Manufacturing Cells Support. "The fact that all of the many people involved took ownership from day one was key to the cell's success."

Good technology travels fast. Besides producing better quality parts faster every day at Madisonville, laser techniques perfected in the cell have already spread to other locations. Laser breakthrough detectors, AWAG deburr machines and airflow modules are now being implemented in plants throughout Aircraft Engines.

The evolution continues. ■

Source:
Tom Byrne
8-332-4567

(below left to right)

Engine blades await processing.

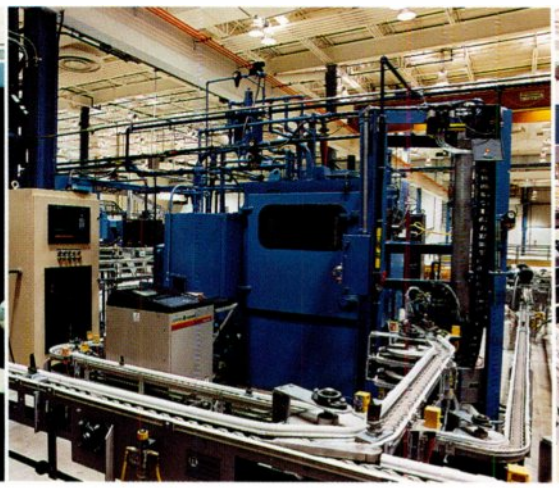
Blades move through cell toward laser drill.

"Pick and place" robot prepares blades for drilling.

Laser drilling progress.

Blades move to deburr module.

Debby Henry decapsulates and inspects newly processed blades.



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TechMod—

Sharpening GE's

PRODUCTION

The year was 1982. America was in a recession. Evidence of deterioration in U.S. manufacturing was too obvious to ignore.

Studies warned that although the United States was loaded with technology, American industry was in trouble when it came to competition and cost. There was a pressing need to translate advanced technology into economical methods of manufacturing.

During those uncertain times, a unique strategy was born. The U.S. Air Force designed a plan based on partnership between government and industry which would revitalize America's industrial base. GE Aircraft Engines and many of its subcontractors joined in that partnership, which is called Technology Modernization — TechMod.

"TechMod is a business deal that results in the implementation of state-of-the-art manufacturing technology," says Reed Yount, administrative project manager. "TechMod improves quality, productivity and cost while modernizing the U.S. defense industrial base.

"Because industry and the Department of Defense share the risks and rewards of investment," says Yount, "TechMod is a win-win arrangement for the government, the taxpayers and GE."

Aircraft Engines' biggest customer agrees.

"TechMod is proof that industry and government can work together to improve productivity and reduce cost," says an Air Force expert, Carl Lombard. He is Propulsion TechMod Program Director at the Aeronautical Systems Division, Wright-Patterson Air Force Base near Dayton, Ohio.

"Our objective is to join with engine producers and their subcontractors to enhance manufacturing capability on an industry-wide scale," says Lombard. "By making that happen, all of us as taxpayers will benefit because costs are reduced and the competitive position of American industry is improved."

The Air Force knows what's good for GE is good for American

(Left top to bottom)

Dean Clay places fixtured hardware into queue station to begin the turning process.

Norm Miller checks status of HTC lathes through visual control monitors.

Chips fly as HTC machines compressor disc.

Operator Dean Clay monitors real-time quality at Horizontal Turning Cell (HTC) controls.

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competitive edge

industry. Reed Yount's job is to find out what's good for GE.

In early 1985, Yount and his Evendale team along with Bill Sullivan and his Lynn team completed "phase one" of the TechMod process, which was a top-down analysis of factory needs. The purpose of that research was to identify high technology projects with the best technical financial payoff in each engine plant.

The result of that analysis was a GE/Air Force contract for a series of TechMod projects valued at more than $70 million, divided between in-house and vendor programs. In exchange for this technology development "seed" money, Aircraft Engines is committed to over $100 million in capital investments to implement the projects.

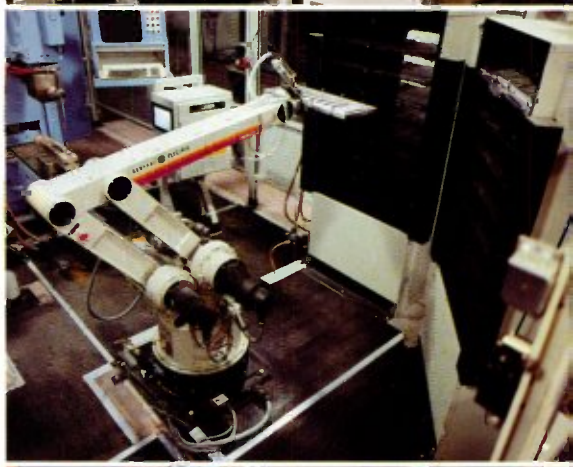
TechMod projects affect virtually every aspect of engine production and touch nearly every Aircraft Engines plant. For example, in Everett, Massachusetts, TechMod efforts have produced the aircraft engine industry's first fully integrated manufacturing cell for resistance spot welding.

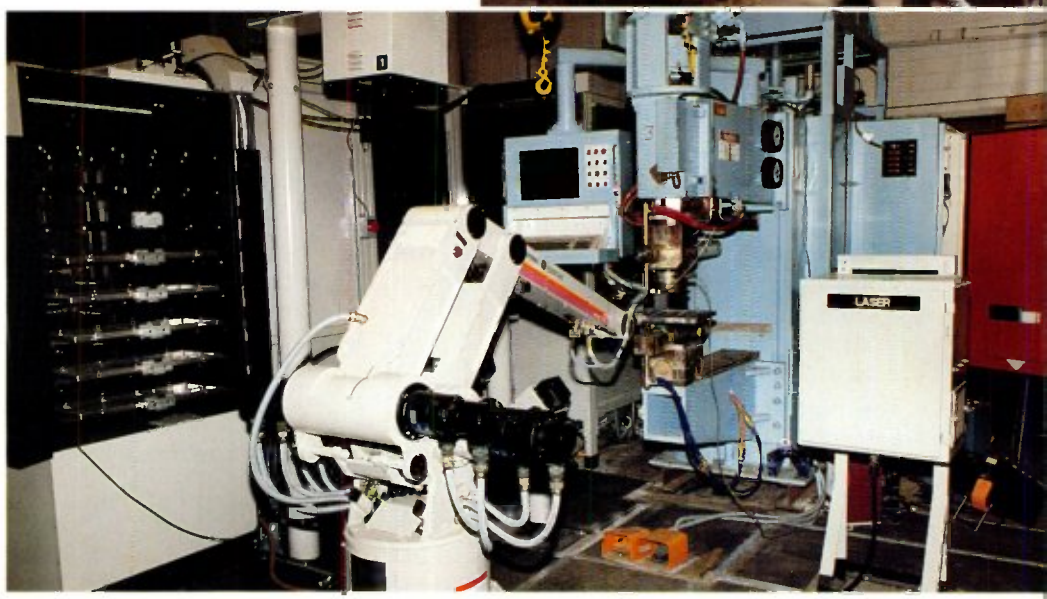
In this cell, a unique resistance weld controller, robotics and vision systems are integrated with sophisticated communications capabilities to create an efficient, user-friendly system. More traditional welding processes suffer from poor programming techniques, have no machine diagnostics and give little information on equipment variability.

"With the new cell, everything we do is 100 percent repeatable," says Production Machinist Paul Matvichuk. "Inspection is simple, quality is much improved and the whole process is cleaner and easier."

The cell includes 16 resistance welders, four (soon to be five) robotic workstations and five support computers. All the computers are connected by a local network. The system is also connected to the GE-wide DECnet™ data communications network.

"Because of the cell we've been able to bring work back to the ▶





(Right top to bottom)

Paul Matvichuk commands the robotic workstation to weld a part.

The GE-P50 robot automatically retrieves a part from the load rack.

The resistance weld machine spot welds a part.

The P50 robot positions the part precisely at the programmed weld points.

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F110-powered F-16

▶ **TechMod** (continued)
plant," Matvichuk says. "It's faster and cheaper to do work in-house."

The weld cell has increased throughput five times. Two of the new pieces of equipment do the work of 10 old ones. Instead of 36 operations required for the conventional process, only 14 are needed today.

"This system gives our customers exactly what they want," says Mike McHale, Everett's Flaps and Seals project manager. "It provides a component part of highly consistent quality at the lowest possible cost."

Another TechMod project, the Horizontal Turning Center at Aircraft Engines' Wilmington, North Carolina plant, boasts similar outstanding results. The center is a state-of-the-art metals cutting and materials handling system that automatically loads, machines, adjusts, inspects and unloads parts in a closed-loop process.

The center is made up of four cells, each with four automatic lathes and a robot for overhead material handling (Mobot). Because of this TechMod project, operators no longer need to measure or inspect engine parts during machining. It is a completely "hands off" system.

Each cut is monitored by a tool-breakage sensor. If a tool breaks, the machine tool monitor sends a signal which stops the machining process before any damage is done to the part. The machine then changes the broken tool and the process continues without interruption.

The Horizontal Turning Cell has more than doubled throughput, producing the same number of parts with 16 machines that would require more than 32 conventional lathes.

"It's exciting to see a machine perform as accurately and productively as the Horizontal Turning Cell," says Dean Clay, cell control operator. "The cell takes its own dimensions, makes its own corrections and offsets changes. The Mobot does all the lifting.

"The Horizontal Turning Cell is faster and smoother running than the old process," Clay says. "It allows us to be more productive — and more competitive."

Besides Everett's Resistance Spot Weld Cell and Wilmington's Horizontal Turning Center, eight other TechMod programs are now being implemented across Aircraft Engines. They include a Surface Grinding Cell and Laser Drilling Cell in Madisonville; a Seals and Shrouds Cell and Composites Manufacturing Center in Albuquerque; an Integrated Production Engine Administration System in Lynn; an Electronic Controls Manufacturing Center in Fort Wayne; an Integrated Production Engine Assembly System in Evendale and a Casings Flexible Manufacturing System in Wilmington.

These TechMod programs will result in a projected $400 million savings on military programs over the next ten years. GE and the Department of Defense will share in those savings. Additional projects in the future will further increase savings.

GE Aircraft Engines now has the largest TechMod program in the propulsion industry. The success of the program, according to the people involved, is teamwork.

"It takes a lot of people working together to coordinate a program

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of this magnitude." says Sonny Pierce, manager of the Manufacturing and Quality Technology Operation.

"From our Shops, to Purchasing, to Contracts, to Materials, to Computer-Integrated Manufacturing in Lynn and Evendale, to Group Engineering and Technology, to Division Marketing, to Lynn and Evendale Military Engine Programs — there are a lot of us out there working to respond to customer needs and make TechMod a reality," Pierce says.

"The key to our success is simple. When something needs to be done, we all pull together to make it happen." ■

Source:
Bob Morris
(513) 583-3738

TechMod helps suppliers too

Pursuing a systematic strategy based on cost drivers, lead times, critical resources and technology voids, GE's supplier TechMod program involves a diverse array of current and planned participants. Vendor products include forgings, castings, machined components, welded rings and raw materials.

Many of the programs underway are directed toward vital, basic industries that have suffered continuing economic setbacks in recent years. TechMod is providing major, ongoing support in the revitalization of this important national resource.

Current and proposed supplier TechMod participants include:

American Welding & Manufacturing Company - metal rings
Cameron Iron Works - forgings
Cytemp - super alloys
Hitchcock Industries - sand castings
Ladish Company - forgings
Precision Castparts Corporation, Airfoils, Inc. — airfoil castings
Precision Castparts Corporation - structural castings
Textron Airfoils Forging Corporation - airfoils, forgings
Timet - titanium
Walbar - precision machined components
Western Gear - gears, gearbox assemblies, drives
Wyman-Gordon - forgings

F101-powered B-1B

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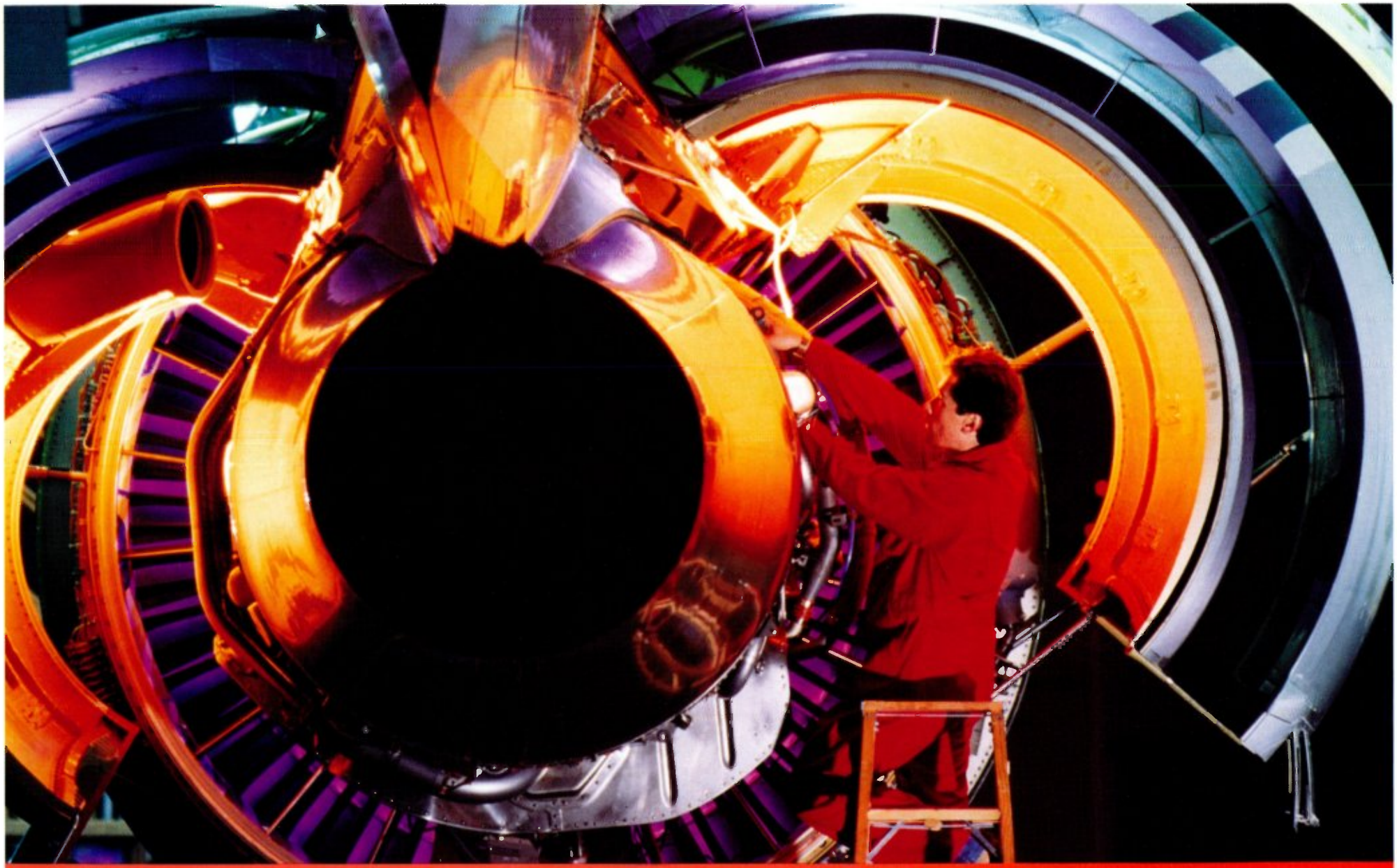
MY ENGINES. MY QUALITY.



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It was a just a tiny flaw in the fan frame tubing.

When the braze operator applied his alloy, coverage wasn't quite complete and a small leak formed in the seal. The flaw was missed in subsequent inspections, and the fan frame went on to Evendale Assembly where it was built into an engine.

The engine failed test due to the fan frame oil leak and was returned to the floor for teardown. The defective braze joint was discovered and repaired then inspected and reviewed.

Assemblers rebuilt the engine and sent it back to test. This time the engine passed with flying colors.

The cost of "just a tiny flaw" — $120 thousand in direct cost and thousands more due to delayed shipment.

"In this business it's not a matter of 'Do you want quality or do you want to ship engines?' In this business it's quality issues that keep us from shipping," says Sonny Pierce, Manager of Evendale's Quality Awareness Campaign.

"Quality is like motherhood," says Pierce. "Life can't go on without it, but every once in a while we need to be reminded just how important it is."

And last September, in the midst of a record schedule ramp-up, Aircraft Engines needed reminding.

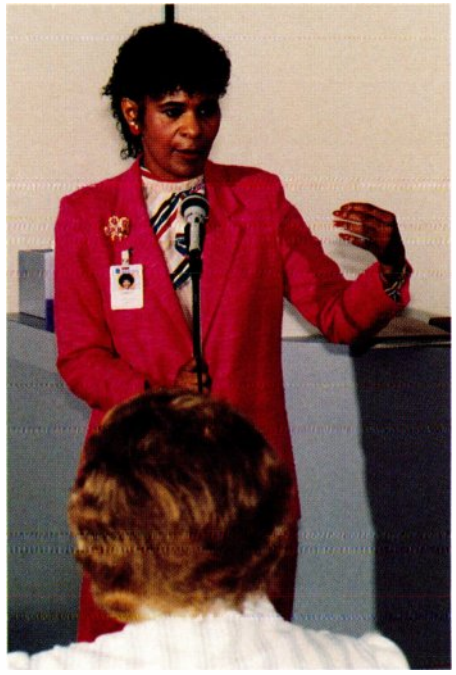
"Everyone can relate to the very difficult situation we faced. Year end was in sight and we still had a huge quantity of engines to build, test and ship," Pierce explains. "There was also pressure from both our military and commercial customers to deliver quality engines on schedule."

It was during those days that Aircraft Engines' Senior Vice President and Group Executive Brian Rowe mandated a Quality Awareness effort.

Quality Awareness brought employees together from all parts of the business — manufacturing engineers, machine operators, first-line supervisors and factory managers. Their job was to answer the question, "Is everyone in Aircraft Engines doing all he or she can to improve the quality of GE engines?"

"Quality is like motherhood. Life can't go on without it, but every once in a while we need to be reminded just how important it is."

Sonny Pierce



Cindy Williams tells other Evendale employees what she learned from the customer at General Dynamics.

Quality Awareness has two goals. First, remind all employees that quality is not someone else's job — absolutely everyone in the business affects quality. Second, enhance and support efforts to improve quality in the shops, assembly and test.

"I'm absolutely delighted about the number of people we've been able to reach with the quality message," says Sonny Pierce.

Brian Rowe began the campaign with a letter in plant newspapers. Dozens of articles emphasizing quality have followed. But print communication has only been part of the picture.

Pilots have told their story to standing-room-only crowds. Quality posters are best sellers. Quality video tapes have been shown at hundreds of roundtables and dialogue meetings.

Managers walk the shops on all three shifts to talk about quality. Employees have visited General Dynamics and Dyess Air Force Base. Those visitors are now quality ambassadors, showing video ▶

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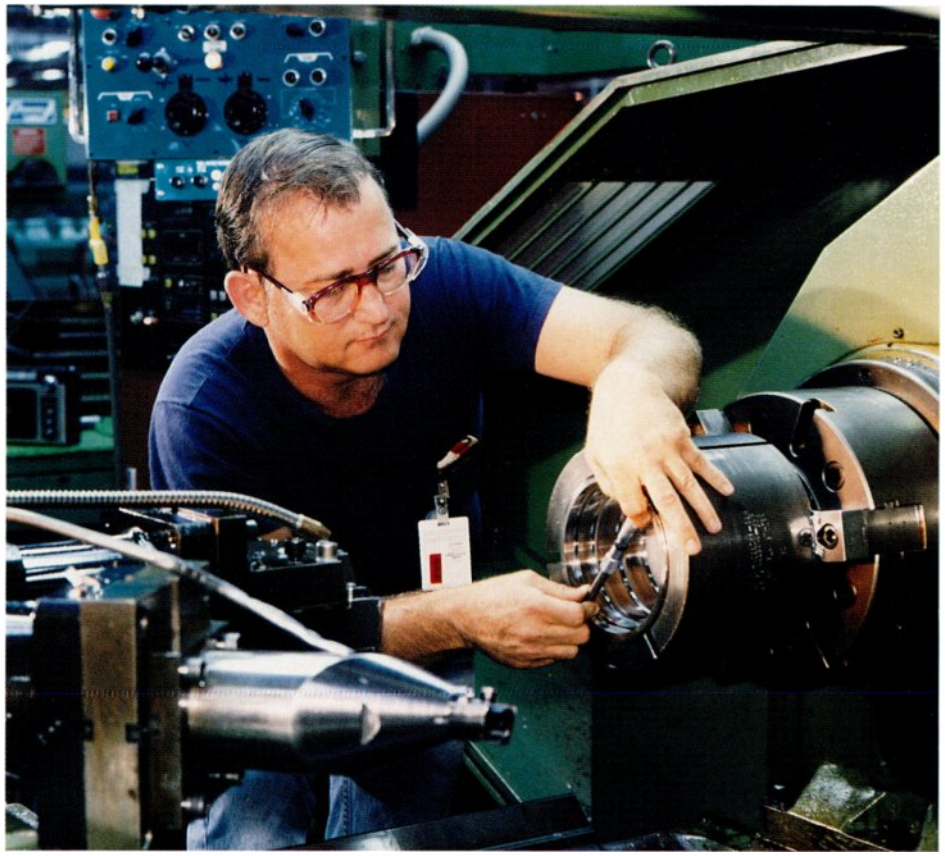

Jerry Kindred says improved communication and teamwork in his unit have increased quality and productivity.

▶ **My Engines, My Quality** (cont'd.)

tapes of customer facilities and telling their story at employee meetings.

"On the trip to General Dynamics I learned to think like a customer," says Cindy Williams, an Evendale production expediter who has led more than 20 roundtables since her visit. "My trip taught me the reality of competition. If we don't do it right the first time, our competitor will."

Of course the real test of quality awareness happens every day at each individual's workstation. The

from 73 percent to 94 percent. The number of nonconforming parts per week in the unit has dropped from 28 to 12, while rework and repair were reduced from more than two percent to less than one percent of parts. The unit's manu-

"It's an operation by operation task, but it works."

Jim Nelson, manager of Evendale's Quality Operation, says Flange and Seal is just one example of continuing progress throughout Evendale and the satellites.

"The state of quality is dynamic. You either get better or you get worse," says Nelson. "We're in search of continuous improvement. Currently, one major area we're concentrating on and succeeding in reducing, is nonconformances and related MRB actions.

"The result is threefold. The quality of our own products at each level is improving; the excellent quality of our engines is acquired more efficiently with fewer faults to correct in prep-to-ship; and hundreds of thousands of dollars in cost savings and avoidance are realized."

In 1986, Aircraft Engines reversed the steep increase of manufacturing losses it experienced in previous years. The business achieved a loss rate reduction of 10 percent in spite of many corrective actions to systems and a 50 percent build-up in production. So far in 1987, AE is on track to cut losses by another 25 percent. That will mean great cost savings as well as a consistently excellent product. By using statistical methods to reduce variations in processes and

"There's a ton of activity going on to assure quality. It's not like we woke up one morning and said 'Let's be aware of quality'."

Jim Wilson

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job of solving manufacturing problems and reducing nonconformances starts here.

"Quality takes constant attention to detail by everyone along the chain — real teamwork," says Jim Wilson, who heads up the Quality/Process Integration teams in component manufacturing. Satellites and service shops also have teams which identify their own most important quality issues.

"There's a ton of activity going on to assure quality. It's not like we woke up one morning and said 'Let's be aware of quality,' " Wilson explains. "It's that now we're working hard to implement quality through SPC and up-front checking of processes. We're involving everybody, because everybody is key to a permanent fix."

Evendale CMO has formed cross-functional Quality/Process Integration teams for turning, drilling, milling, electro-discharge machining, punch press, bench and special processes. A value process engineer leads the team which includes everyone in the unit and focuses on operation-by-operation reviews. These reviews ensure that procedures sheets, tooling, fixtures and gages are adequate to assure a part that conforms to operation requirements.

"Impact of the teams varies from unit to unit," says Wilson, "but we've seen encouraging results. The MRB rate for the F101/F110 Exhaust Duct Unit dropped 32 percent in the first 10 weeks."

Another example of quality improvements across the shops can be seen in Evendale Flange and Seal. Since the beginning of 1987, this unit's efficiency has risen facturing losses dropped from a monthly average of $88.6 thousand in 1986 to a monthly average of $23.5 thousand to date in 1987.

"It was the hourly team that increased productivity and improved quality," says unit manager Mike Carney. "Our approach is to directly communicate the plan for improvement, then give operators, supervisors, methods engineers — all our people — ownership for the plan.

"We monitor progress on a weekly basis, develop new ways to measure methods and post the results. We ask for ideas of how to improve productivity, then act on that information," says Carney.

correcting root causes, Aircraft Engines is building quality in rather than 'catching' it and fixing it.

"Of course we haven't solved all the problems yet," Nelson says . "And a major continuing effort is needed to improve the delivered quality of our vendor-supplied hardware. We are seeing improvement in supplier products too, but there are still too many delivered problems.

"The bottom line is that continuous improvement in all aspects of quality is our number one goal — always has been — always will be. Quality awareness is key to that improvement." ■

Quality success stories

A 30 percent reduction in the number of open Hold Tickets over 90 days was achieved in just seven weeks at Albuquerque.

Evendale CMO manufacturing losses were lower than target for the end of May, and are on track for overall reduction of 25 percent from 1986 to 1987.

Year-to-date manufacturing losses in Wilmington were reduced from 8.1 percent in first quarter 1986 to 5.2 percent in first quarter 1987.

Diversified frames reduced Material Review Boards (MRB's) 39 percent in the last six months.

A change in design on T700 blades will mean a reduction of 6000 MRB's a year in Evendale Airfoils.

Statistical Process Control (SPC) implementation for CF6-80C fan blades has resulted in a 30 percent reduction of MRB's.

A change in design to define stem drilled radial holes in TF-34 Stage 1 HPT blades will allow for a 2000-piece reduction in MRB's.

Product integrity audits show a reduction in Evendale "inspection escapes" from 21 percent during the March '86 COR to 7 percent during and since the February '87 COR.

Evendale total manufacturing losses year-to-date have been reduced 22 percent compared to the same period last year.

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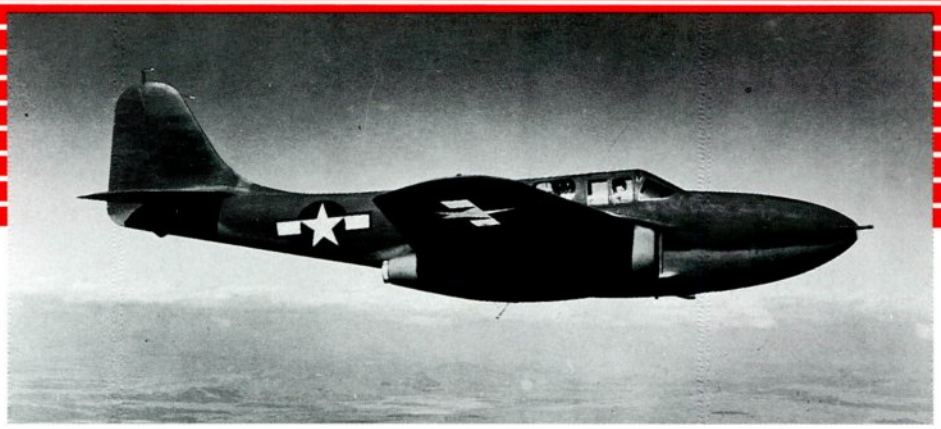

On October 3, 1942, Bob Stanley took the Aircomet up to 10,000 feet.

Krall

Burke

AFTERBURNER

Things change.

It was 1942 when, under greatest secrecy, a select group of GE engineering pioneers built the first U.S. jet engine at Lynn's River Works.

Today, GE's jet engine business has more than 40,000 employees in 12 manufacturing plants, two test centers and five service shops across the U.S. and around the world.

Things change. Today, in response to the press of foreign competition and customer demands, we share joint ventures with Volvo, Snecma, Fiat, MTU, IHI and Alfa Romeo. We have offset agreements with 15 countries and share TechMod arrangements with military customers.

We have a 35 percent share of the military engine market. In February we lost our first battle in the great engine war since 1984. Pratt & Whitney won 55 percent of the latest F-15/F-16 engine award from the Air Force and we received 45 percent.

We're in an excellent position in the commercial business with more than 60 percent of the market share — and Pratt knows it. Our competitor is feeling the loss. P&W is sharpening its strategy and redoubling its efforts to come back stronger than ever.

Things change. In the commercial market concessions have become commonplace, and airlines are capitalizing on the situation. On the military side we are faced with dual sourcing, parts breakouts, continuous audits and ever-new political realities.

We have invested hundreds of millions of dollars in technology over the last five years and will continue to invest heavily over the next five years. Our design technology, our raw materials, our manufacturing processes all push the state of the art.

Things change. A healthy business is always in transition. We must adjust to shifting markets, struggle for new products and make new technologies work in our shops.

We must carefully control our processes for peak efficiency. Our work to expand statistical methods, reduce variation in processes and correct root causes is beginning to bear fruit in on-line process control. More and more we are moving quality upstream into prevention rather than relying on heavy inspection and correction. In these changes we're finding new effectiveness.

The kind of workplace we create will determine our future. And every one of us holds a part of that future in our hands. Every one of us can keep accurate records and follow procedures. Every one of us can be a team player, communicate simply, take ownership for our job, listen carefully and be willing to try something new even if "that's not the way we've always done it."

Things change, and the outcome of these changes rests with each of us. It's up to you and me to give our best effort. It's up to you and me to work productively and stay on schedule, giving our customer a flawless product at the lowest possible price. In this business, as in every other, it's quality, cost and delivery that determine the bottom line.

Some things never change.

DICK BURKE

GEORGE KRALL

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