ROBOTS FOR AIRCRAFT MAINTENANCE

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Above is an ARMS robotic workcell operated by Delta Air Lines to remove coatings from jet engine components during overhauls. At right is a closeup of the business end of the robot arm — the end effector — removing the liner (the waffle-like substance).

On a Space Shuttle launch, the two solid rocket boosters fire for two minutes as the Shuttle drills its way through the atmosphere to an altitude of about 25 miles. Then they separate from the orbit-bound Shuttle "stack" and drop Earthward to a parachute-softened splash in the ocean. They are retrieved by recovery teams and delivered to a land facility for refurbishment and reuse.

An early step in the refurbishment process is stripping the paint and thermal protection material from the booster segments. Removal of the thermal protection material is a particularly difficult job. Designed to protect the rocket from the intense heat of atmospheric friction, the material is extremely tough and removal-resistant. It must not only be removed, it must be taken off in such a manner that the casing of the booster segment is not damaged.

HEADING SPINOFFS IN THE FIELD OF TRANSPORTATION ARE NEW ROBOTIC WATERJET CLEANING SYSTEMS DERIVED FROM SPACE SHUTTLE TECHNOLOGY

In the early days of Space Shuttle development, NASA realized that something substantially better than conventional manual stripping techniques would be required for booster refurbishment. Accordingly, Marshall Space Flight Center and a contractor initiated development of an advanced stripping system based on hydroblasting, or high pressure waterjet cleaning. The contractor selected was United Technologies' USBI Company, Huntsville, Alabama, NASA's contractor for Shuttle recovery and refurbishment operations at Kennedy Space Center (KSC).

The original system consisted of a fixed, gantry-mounted robot and a turntable in an enclosed workcell. A later development, now in use at KSC, is the Mobile Robotic Hydroblast System, which can be driven directly to the site of booster processing to provide initial waterjet stripping prior to disassembly of the booster components. It employs a high pressure waterjet, operating typically at a pressure of 12-17,000 pounds per square inch, to slice through the thermal protection material and blow away the particles. It can also be regulated to strip the layers of paint and primer beneath the outer protective coating.

To prevent damage to the casing, hydroblast parameters—such as the angle of the waterjet to the workplace, water pressure and flow rate—must be precisely controlled. That cannot be done effectively by manual operation, which is also difficult, inefficient and dangerous to the operator. Waterjet control, therefore, is accomplished by a computer-directed six-degree-of-freedom robot mounted on a transportable platform; the platform has a watertight plexiglass-enclosed cabin that protects the robot controller and its two operators from heat, humidity and debris. This system typically takes

12 minutes to strip a booster segment where manual stripping took four to six hours.

The NASA/USBI technology has found new applications and a new company has been formed to pursue further development and commercial marketing. Still located at Huntsville, the USBI advanced technology group that developed the system has become Pratt & Whitney Waterjet Systems, a unit of Pratt & Whitney's Overhaul and Repair Operation (Pratt & Whitney, in turn, is a division of United Technologies Corporation, Hartford, Connecticut).

The system is now known as ARMS™, for Automated Robotic Maintenance Systems. Commercialization of the technology began in 1991, when the Air Force awarded Waterjet Systems (then USBI), a contract for a Large Aircraft Robotic Paint Stripping system employing waterjet technology (see page 87). Since then, Waterjet Systems has introduced a second commercial application of the technology, this one involving removal of coatings from jet engine components.

To protect them from the intensely hot and corrosive environment of an operating turbine engine, jet components such as vanes, combustion chambers, burner cans and turbine blades are coated with a variety of substances — aluminum oxide, boron nitrite, ceramics, magnesium zirconate and many others. The type of coating used depends on the component's job in the engine system.

When it is time for overhaul, the engine is disassembled and its parts stripped of these coatings. The customary way of doing this is by acid bath and grit blasting cleaning processes. These processes are highly labor intensive and they involve use of toxic stripping chemicals; workers must wear special protective clothing and a breathing apparatus to protect them from the fumes.

The ARMS system uses only minimal labor and does the component cleaning job significantly faster. For example, on a Pratt & Whitney demonstration, an engine compressor front assembly case was cleaned by an ARMS unit in an hour and a half, which compares with an average of 16 hours for manual cleaning of the same component. This provides a benefit in increased productivity by reducing the time it takes to strip, clean and return the parts to service. The system also extends the service life of the component, because waterjet stripping minimizes the amount of "substrate" (the part's surface) lost. And there is an environmental bonus in the reduction or elimination of the need for toxic chemicals, waste disposal and human protection equipment.

ARMS' equipment is contained in a soundproof, waterproof, enclosed workcell that includes the robot, a variety of nozzles and end effectors, a waterjet pump and a turntable. The part to be cleaned is mounted on the turntable, which rotates while the robot-controlled nozzle remains fixed; alternatively, the workpiece is held stationary while the robot moves over its surfaces. A computer controls the robot program; the location, position and speed of the turntable; and the water pressure and flow rate.

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Early in 1992, Delta Air Lines became the first customer for an ARMS workcell. The unit was delivered in the summer of 1992 and by yearend Delta had completed acceptance testing and started engine component cleaning operations at its Atlanta (Georgia) Technical Operations Center. (Continued)

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ROBOTS FOR AIRCRAFT MAINTENANCE
(CONTINUED)

Aircraft, civil and military, must periodically be repainted for protection of their surfaces. The biggest part of the job is getting the old paint off.

The most widely used method of removing the paint involves use of a methylene chloride-based chemical stripper. The chemicals are sprayed on, not just on wings and fuselage but on such areas as wheel wells, engine inlets and exhausts, and other hard-to-get-at places. The stripper is allowed to set for one to five hours, then washed off; in many cases, the stripper is reapplied and rinsed a second or third time. The job still requires finishing touches by putty knives, scrapers, brushes and sanders.

It's a time-consuming and increasingly costly job and it's getting more difficult with the advent of tougher environmental and occupational safety regulations, because chemical stripping poses problems of hazardous waste disposal, along with provision of protective clothing and equipment for maintenance workers.

Aircraft operators are looking for a better way to do the job and the U.S. Air Force is showing the way with a demonstration effort. The USAF's Oklahoma City Air Logistics Center, in conjunction with the Wright Laboratory Manufacturing Technology Directorate, Wright-Patterson Air Force Base, Ohio, has initiated a program to automate aircraft paint removal and eliminate methylene stripping by the year 2000.

In July 1991, the Air Force contracted with USBI Company, now Pratt & Whitney Waterjet Systems, for design and development of a Large Aircraft Robotic Paint Stripping (LARPS) system. LARPS is a cousin to Pratt & Whitney's ARMS commercial jet engine cleaning system; both spring from the waterjet stripping technology developed by USBI and Marshall Space Flight Center for removing paint and thermal protection equipment from space boosters (see pages 85-86).

LARPS is now well along in development and scheduled for 1995 installation at Oklahoma City Air Logistics Center, where it will be tested to verify the design and ultimately replace manual stripping on a variety of large aircraft.

LARPS will consist of a robot arm mounted on a vertical column, which in turn is mounted on an automatically-guided transporter. The vertical column rotates on a turntable assembly located on the deck of the transporter. The robot arm moves up and down the column to reach various aircraft surface heights, and the transporter moves the robot from location to location following buried guidewires. The robot arm directs a high pressure jet of water or frozen carbon dioxide to strip the paint,

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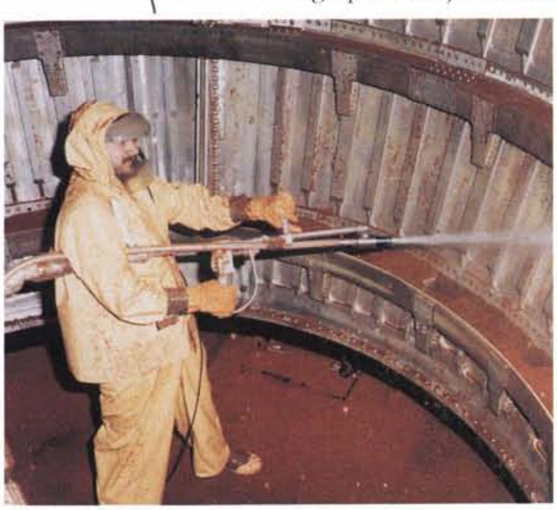

In the 1970s, NASA developed an automated system (far left) for removing thermal protection material from booster components. A spinoff of that technology is the ARMS system for cleaning jet engine components (near left).

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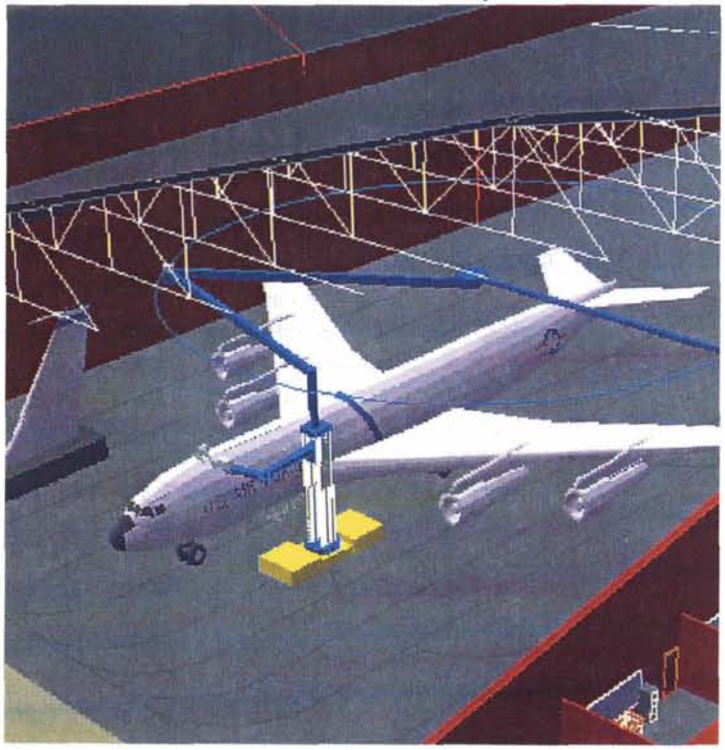
computer-guided around the complex contours of the aircraft by input from a series of sensors. A computer subsystem controls the whole operation, supervised by a LARPS operator in a room adjacent to the work hanger.



Now in development is a major advancement of the technology, the LARPS robotic paint removal system for use on military or civil aircraft. The prototype system shown here is scheduled for 1995 service at the Air Force's Oklahoma City Air Logistics Center.

Intended to reduce stripping time by 50 percent in comparison with the manual process, LARPS is designed to cut hazardous waste by 90 percent, eliminate personnel exposure to hazardous environments, and effect a significant reduction in stripping costs. For one specific airplane type, the Air Force estimates a 55 percent reduction of material costs, 43-49 percent savings in labor costs, and an overall cost reduction of more than 50 percent.

Pratt & Whitney Waterjet Systems believes that LARPS has enormous potential in both military and civil aircraft maintenance. The company is working to extend the process certification to commercial jetliners, which offer a very broad international market; Pratt & Whitney is working with a special task force of the International Air Transport Association that is studying alternative techniques for aircraft paint stripping.

There is similar broad potential for the companion ARMS waterjet stripping system for jet engine components.

Use of the technology need not be confined to paint stripping. It could be adapted to aircraft painting, to improve aircraft surface paint quality and consistency and eliminate workers' exposure to flammability and solvent inhalation hazards. The technology also has potential in automating such aircraft inspection techniques as x-ray, ultrasonics, dye penetration, infrared or "CAT-scanning", to relieve workers of tedious repetitive tasks and generally improve inspection efficiency.

And there is additional potential beyond aircraft maintenance uses. Pratt & Whitney Waterjet Systems conducted an experimental test in which the technology was used to strip paint from an Army Hummer, and the company thinks its systems could be adapted to stripping such large objects as ships, railcars, military tanks and other combat vehicles.

Pratt & Whitney believes the waterjet technology will spawn a whole new industry and thereby eliminate a major use of toxic chemicals in the world marketplace. •