UNITED STATES AIR FORCE MATERIALS TECHNOLOGY HIGHLIGHTS

Air Force Research Laboratory

Materials & Manufacturing Directorate

Wright-Patterson Air Force Base • Dayton, Ohio **Fall 2004**

Engineers Prototype and Develop Robotic Trenching Tractor

Engineers at the Air Force Research Laboratory (AFRL) Materials and Manufacturing Directorate (ML) designed, built, tested and delivered a robotic trenching tractor, which offers the standoff capability to perform cable trenching and excavation missions in dangerous locations. The Robo-Trencher, which was delivered to support the 738th Engineering Installation Squadron's (EIS) combat engineering and installation teams, established its value during Operation Iraqi Freedom when units were deployed to install and maintain fixed and deployable command and control, computer and intelligence systems necessary for Air Force operations.

The first generation Robo-Trencher was developed to protect forward deployed personnel responsible for performing cable trenching and excavation missions from hazardous situations, and to provide them a remotely operated system with which they can accomplish combat engineering installation activities.

Each Robo-Trencher is equipped with a new laptop Operator Control Unit (OCU) with situational awareness and Global Positioning System (GPS) tracking/location capabilities. The system was delivered to the 738th Engineering Installation Squadron in less than 90 days and was tested by deployed units in the field. In addition, engineers created a remote kit, which will allow the squadron to retrofit all of the trenching tractors in their inventory.

In late February 2003, personnel from the 738th EIS contacted AFRL inquiring about robotic technologies. The EIS had encountered two separate incidents with unexploded ordnance during manual trenching operations in Afghanistan. In order to meet the squadron's deployment schedule, engineers from ML's Airbase Technologies Division Robotics Research Group began developing a short-order solution using the squadron's existing hardware.

The Robo-Trencher is a modified version of a trenching tractor, the Ditch Witch 7610, the standard tractor used by the squadron. ML personnel received a Ditch Witch tractor in early April 2003. Engineers involved in this project integrated robotic components that were developed for use with the group's All Purpose Remote Transport System, a technology used for force protection and active range clearance activities.

The Ditch Witch 7610 was designed for a full range of underground construction work, including installation of power and communications cable. The tractor runs on a Deutz F4L912 air-cooled diesel engine, which produces 74 net horsepower (55 kW) under a full load. The system will trench to depths of 90 inches (2500 mm) and widths to 24 inches (610 mm), depending on the boom and chain. The standard tractor model is also equipped with several attachments that can increase the tractor's capabilities, including a centerline trenching component; a vibratory plow; a combination trencher and vibratory plow; an earth saw disc trencher; and two (continued on page 4)

Materials Experts Develop Inspection Kit for Combat Training Pod Nose Cones

A team of engineers from the Air Force Research Laboratory's Materials and Manufacturing Directorate (ML) resolved a complex technical problem with the nose cones of combat training pods on fighter aircraft. The pods play a critical role in flight training, recording and relaying aircraft positions and other information during training maneuvers.

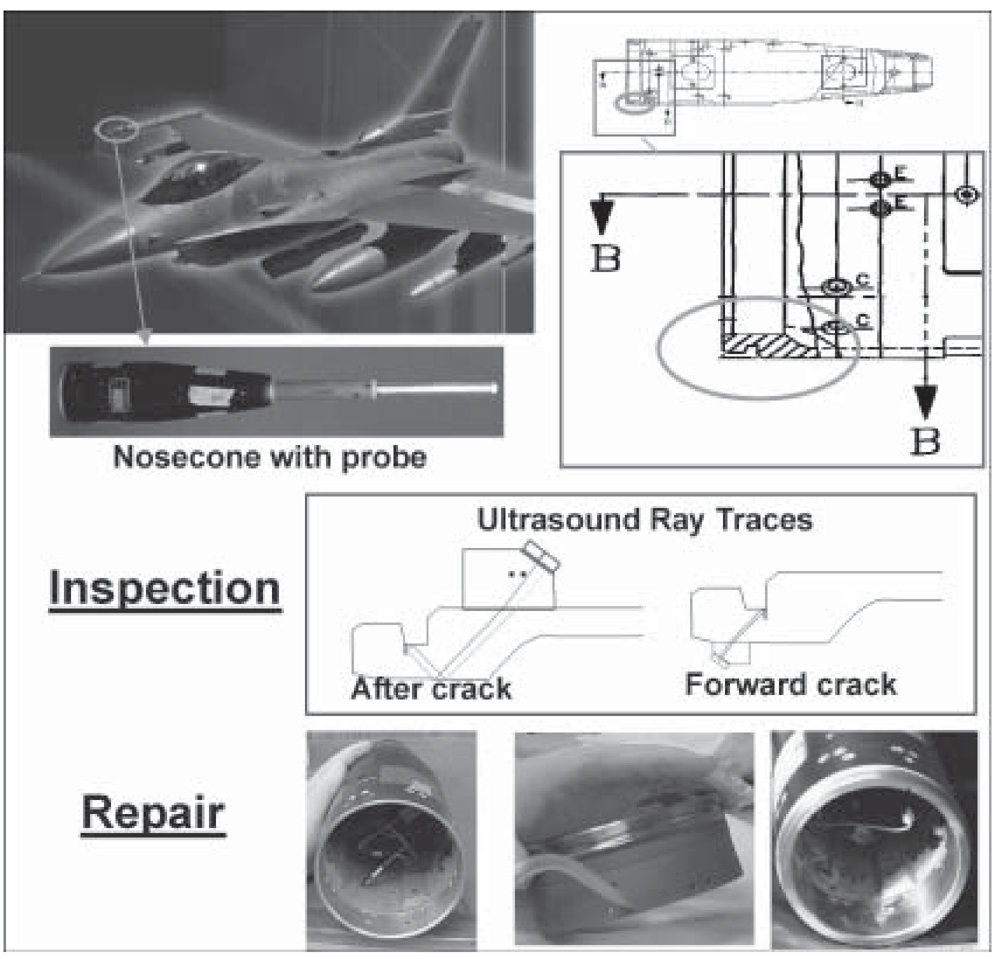
ML's investigative team, comprised of government and contractor materials experts from the Directorate's Systems Support Division, analyzed what appeared to be surface cracks in several of the pod nose cones. Their investigation resulted in the development and expeditious transition of a portable inspection kit employing ultrasound technology, and also led to the successful design and development of steel collars to repair the remaining inventory of cones—a low-cost solution that could save the Air Force more than $2.0 million.

The team's insight into design and materials characteristics enabled accelerated development of a low-cost solution to retrofit the existing nose cones with stainless steel collars, with the total cost of labor and materials at $660 per nosecone, versus $2000 for new nose castings. The Air Force can trim costs significantly by implementing the retrofit component throughout the nose cone inventory—about 1,500 units. The inspection kit provides an accurate, reliable means for locating cracks, and determining their severity, while minimizing aircraft downtime and optimizing flight-training opportunities.

Material integrity and component reliability are two of the most essential characteristics engineers design into jet fighter aircraft. In this case, a nose cone separated from an aircraft's Air Combat Maneuvering Instrumentation (ACMI) pod during takeoff. Technicians did a cursory check and identified several cones, during penetrant inspections, suspected of having cracks. The cone involved in the incident and others were sent to ML's Systems Support Division for detailed analysis. ML's failure analysis team found the crack indications to be false in many cases because surface anomalies ("folds") were trapping the penetrant and exhibiting crack-like indications. The analysis team, meanwhile, discovered the root cause was an over-temp condition caused by a coating process that negated the heat treatment of the material, leading to reduced strength and reduced fatigue life. They ascertained this with simple conductivity and material hardness measurements.

Next, the ML team developed an advanced ultrasound inspection procedure that was extremely reliable and able to detect cracks in many different orientations and locations. They then designed an inspection kit and transitioned the procedure to the field. During this transitional phase, the failure analysis team inspected more than 150 nose cones to help the flight training squadrons keep functioning. They provided hands-on training to technicians in the field and also conducted a training session to prepare additional technicians from several Air Force bases. The ML team also assisted in the retrofit stainless steel collar design, and brought in additional technical expertise from the Aeronautical Systems Center (ASC) to aid with structural analysis. The team also developed an immersion ultrasound inspection for the retrofit design, inspected test articles before and after testing to validate the design, and conducted first article inspections on several cones to assure quality.

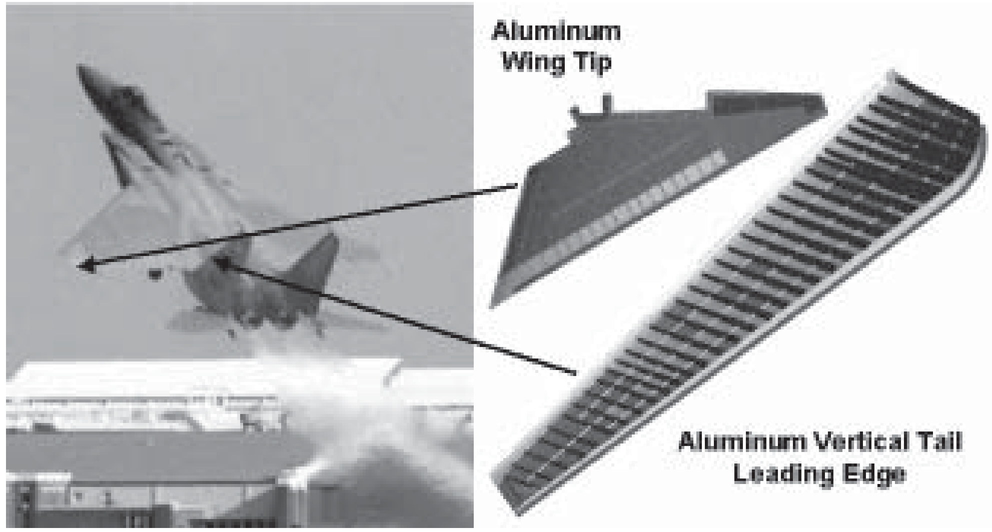
Without the new nondestructive inspection (NDI) procedure, the Air Force would not have an insight as to the scope of the problem across the fleet of combat training pods. The failure analysis team was commended for their responsiveness and professionalism in resolving a complex technical problem, and their involvement in assessing an economic solution was dubbed "invaluable." The members of the team included (government): Robert Ware, John Brausch, Kenneth LaCivita and 1st Lt. Sandra Davis; and (contractors) Noel Tracy, Daniel Laufersweiler, J. Edward Porter, Nick Jacobs, Adam Long and Thomas Dusz. Hsing Yeh of the ASC Structures Branch (ASC/ENFS), was involved in service life analysis of the current inventory nose cones and proposed repairs, as well as determining required rejection criteria and inspection intervals, and was also highly commended for his efforts.



(Left) F-16 aircraft with ACMI pod mounted at wingtip, nosecone circled; nosecone and probe assembly; sketch of nosecone with area of cracking circled; magnified image of area of cracking; Inspection: ultrasound ray traces illustrating the path of sound between the inspection transducer and the crack. Repair: photos of the nosecone with end removed; new stainless collar; nosecone with retrofit repair installed.

For more information, contact the Materials and Manufacturing Directorate's Technology Information Center at techinfo@afrl.af.mil or (937) 255-6469. Refer to item 04-200 .

Affordable Machining Program Targets Cost Reductions In Aerospace Component



Air Force Research Laboratory Materials and Manufacturing Directorate scientists and engineers, in a collaborative effort with researchers from industry and major universities, have made significant advancements in the development of analytical tools and advanced machining technologies for aerospace components. Working together under the *Affordable Machining Program* (AMP), the team has dramatically improved the parts quality of the F-15's vertical tail leading edge and wingtip using state-of-the-art, high speed machining techniques and stable cutting parameters, and by replacing the forged material stock used to build these components with stress relieved plate stock. These innovations have resulted in a calculated $16 million cost savings for the Air Force.

AMP addresses customer needs by providing low cost, high quality machined parts for aircraft components. Since machined products come primarily from a supplier base, benefits will be realized through reduced prices and shorter delivery times. Tangible benefits include reduced machining time, scrap and rework rates, tooling, and assembly fixtures, and increased part accuracy and quality. Intangible benefits include more complex machined component designs for increased affordability (part unitization) and reduced inventory.

The purpose of AMP is to develop and implement analytical tools and advanced machining technologies to enable lower cost fabrication of machined aerospace components. AMP is a cost-shared program funded by the Air Force Research Laboratory (AFRL) Metals Affordability Initiative (MAI) and industry. Primary team members include AFRL, Boeing, Carpenter Technology, Northrop Grumman, and Rolls-Royce. The subcontractors include Cincinnati Machine, TechSolve, Third Wave Systems, Vykor, the University of North Carolina (Charlotte), University of Florida (Gainesville), and Washington University.

AMP program objectives are to develop and implement the most affordable methods of fabricating high accuracy machined components, and to establish component designs and assembly approaches enabled by this precision machining capability. Using this integrated design and manufacturing strategy, AMP hopes to achieve aerospace structures exhibiting improved quality and performance with up to a 50 percent cost savings.

The team is focusing on existing and pervasive wrought material forms such as plate, bar, and forgings, therefore, additional time and expense to certify components is not necessary. Their proposed technologies will also reduce the time to market for machining modifications by increasing confidence in the process before it hits the shop floor. This, in turn, will reduce first article lead times by providing improved first time quality and lower production lead times by increasing reliability and accuracy. Pervasiveness is further enhanced by the participation of material suppliers and the machine tool industry in the program. These entities have the incentive to provide the technology to as many producers as possible. In addition, the technology partnership is involved in a range of applications to further distribute the technology throughout industry.

A high proportion of airframe, system, and engine components are machined, and the majority of these machined aerospace components are made of aluminum, titanium, and ferrous alloys. AMP addresses three important areas: (1) high accuracy machining of aluminum, enabling advanced assembly technologies to reduce the cost of airframe structures; (2) improved broaching methods for titanium turbine engine components and better, lower cost finishing methods for airframe components; and (3) improved machining methods for steels used in actuators and landing gears for further cost reduction. In each of these key areas, the team is making extensive use of experimentally validated process modeling and simulation to guide further experimental work and process optimization.

Current state-of-the-art software can be used and adjusted to significantly improve shop floor process capabilities. These validated models will then be used to improve metal removal rates for each material and to proportionately decrease machining times and costs. Improved dimensional control and quality will reduce scrap and rework to further reduce costs. High precision machining of aluminum enables advanced assembly methods, such as determinant assembly, and eliminates costly assembly fixtures, while reducing assembly time. Improving the cycle time and accuracy of titanium components greatly reduces the cost of engine and airframe structural elements, while lowering the cost of machining corrosion-resistant steels expands their range of application over carbon steels. In addition to reducing costs, process flow is improved due to elimination of quench and tempering, final machining, the need to apply corrosion resistant coatings, and a reduction in the support costs associated with plated carbon steels.

For more information, contact the Materials and Manufacturing Directorate's Technology Information Center at techinfo@afrl.af.mil or (937) 255-6469. Refer to item 04-121.

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front-mounted backhoe components. The system has a rugged one-piece frame, heavy-duty digging booms, and chains and teeth for tough digging conditions, including rocky soils and frost.

The robotic conversion enables remote operation of all tractor functions including: engine start/stop, propulsion, lights, and tool operation. The standard configuration includes fixed, panable video cameras and digital radios, which transmit command signals from the Operator Control Unit to the vehicle, and an independent transmitter/receiver pair communicates audio and video from the vehicle to the operator control unit (OCU). ML engineers purchased robotic components from Applied Research Associates Inc. (ARA), who developed technologies (the systems control computer and software package) under the direction of AFRL during the earlier ARTS program, but modified them for application to the Robo-Trencher. The standard operator control station includes the operator console, with command-input device (joysticks and switches) and video monitor, control station data encoder and transmitter, data and video receivers and antennas, and video/audio recorder. In addition, the OCU is also equipped with situational awareness and GPS tracking/location capabilities.

The completed system was operational in late June 2003, and was delivered to the squadron in mid-July. The system was airlifted from Keesler AFB, Miss., to Iraq to support communication cable installation and base infrastructure requirements during Operation Iraqi Freedom. ML engineers are currently developing a second Robo-Trencher based on feedback from the unit. The improved system will include additional features such as heading hold steering. The Robotics Research Group is also working to transition this technology to a System Program Office and private industry for future procurement and support activities.

For more information, contact the Materials and Manufacturing Directorate's Technology Information Center at techinfo@afrl.af.mil or (937) 255-6469. Refer to item 04-163.

AIR FORCE RESEARCH LABORATORY

The USAF Materials Technology Highlights is published quarterly to provide information on materials research and development activities by Air Force Research Laboratory's Materials & Manufacturing Directorate. For more information on subjects covered in "Highlights" or to be added to the "Highlights" mailing list, contact the Materials & Manufacturing Directorate Technology Information Center at (937) 255-6469 or e-mail at techinfo@afrl.af.mil. Approved for Public Release (AFRL/WS#04-0622).

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