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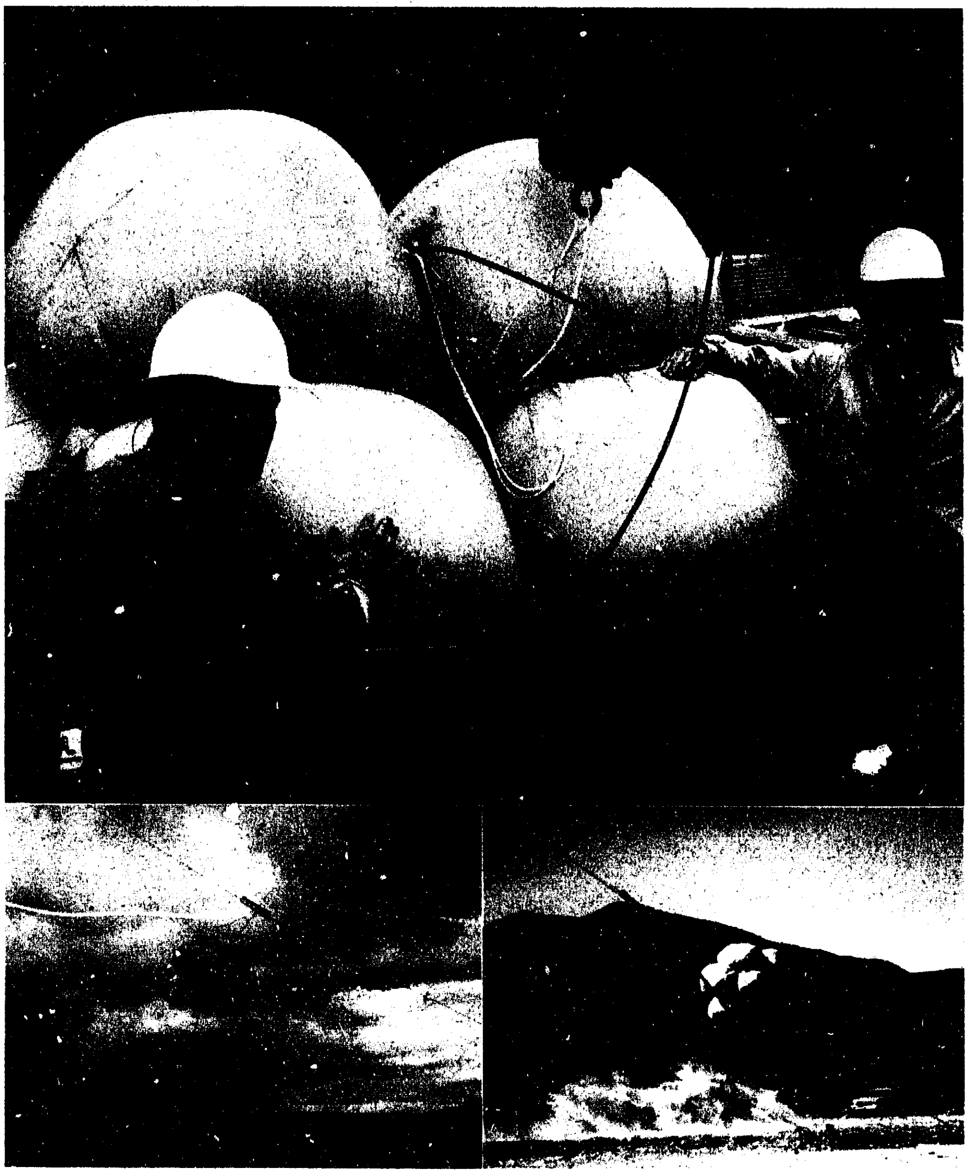
February 1994

Testing Technology

SANDIA NATIONAL LABORATORIES • Albuquerque, NM • Livermore, CA • Operated by Sandia Corporation for the U.S. Dept. of Energy

Landing on Mars on a pillow of air

Airbags soften the impact for the Pathfinder Lander



Top: NASA's Tom Rivellini and Sandia's Don Waye prepare the Mars lander's airbag impact attenuation system for testing. Lower left: the inflated airbags, surrounding a simulated lander, slide down the cable support at Sandia's Coyote Canyon test facility. Lower right: The airbag system just after impact, while rebounding from the surface.

Testing news in brief

DOE chooses Martin Marietta to manage Sandia

The Energy Department awarded Martin Marietta a five-year contract, effective October 1, 1993, to manage and operate Sandia. Martin Marietta succeeds AT&T, which had managed Sandia since 1949. The transition has been essentially seamless, and Sandia's customers, partners, and associates will notice little or no difference. Norman R. Augustine, Martin Marietta's Chairman and CEO, has pledged "an aggressive program of technology transfer."

Warren Siemens, *Org. 4200, (505) 271-7813, FAX 271-7856*

New surface drill string facility set up to study acoustic telemetry

Orpheus Range is a new testing facility at Sandia National Labs for developing data on acoustic telemetry for drill strings. In principle, sound waves can be used to transmit important drilling data for such items as drill bit navigational information, temperature, pressure, drill bit diagnostics, and rock formation data. To prove the utility of acoustic transmission, researchers will study data transmission on a horizontal surface drill string 450 meters long. A fully instrumented laboratory trailer will collect data on the surface tests and move to field test sites as the program progresses.

Doug Drumheller, *Org. 6111, (505) 844-8920, FAX 844-3952*

Interstate-40 bridge tested by dynamic excitation

A vertical shaker system developed at Sandia supplied two types of dynamic excitation to a bridge scheduled for renovation on Interstate 40 in Albuquerque, New Mexico. Random vibration excitation at 2 to 12 cycles per second generated peak forces of approximately 2,000 pounds (8,900 newtons). The second type of excitation was a stepped sinusoidal input from 2 to 5 cycles per second with a force amplitude of approximately 500 pounds (2,230 newtons). Researchers performed tests in the undamaged condition and after each of four progressively severe cuts in a main plate girder. The data from the tests provide baseline information on damage conditions. Sandia engineers developed and operated the device, while Los Alamos National Laboratory provided data collection. New Mexico State University sponsored the experiments to develop new bridge maintenance and inspection techniques.

Michael Nusser, *(505) 844-2268 and*
Randy Mayes, *(505) 844-5324, Org. 2741, FAX 844-0078*

STARS missile launch from Kauai successful

Sandia launched the first operational Strategic Target System test missile from Sandia's Kauai Test Facility on August 25, 1993. Sandia developed the STARS missile for the Ballistic Missile Defense Organization. This was the second successful launch of the STARS system (the first launch, FTU-1, was a test flight in February 1993). The M-1 mission, a joint British-U.S. project, delivered two payloads to the Kwajalein Missile Range target area in the Marshall Islands.

Margaret Weber, *Org. 2725, (505) 844-2122, FAX 844-1168*

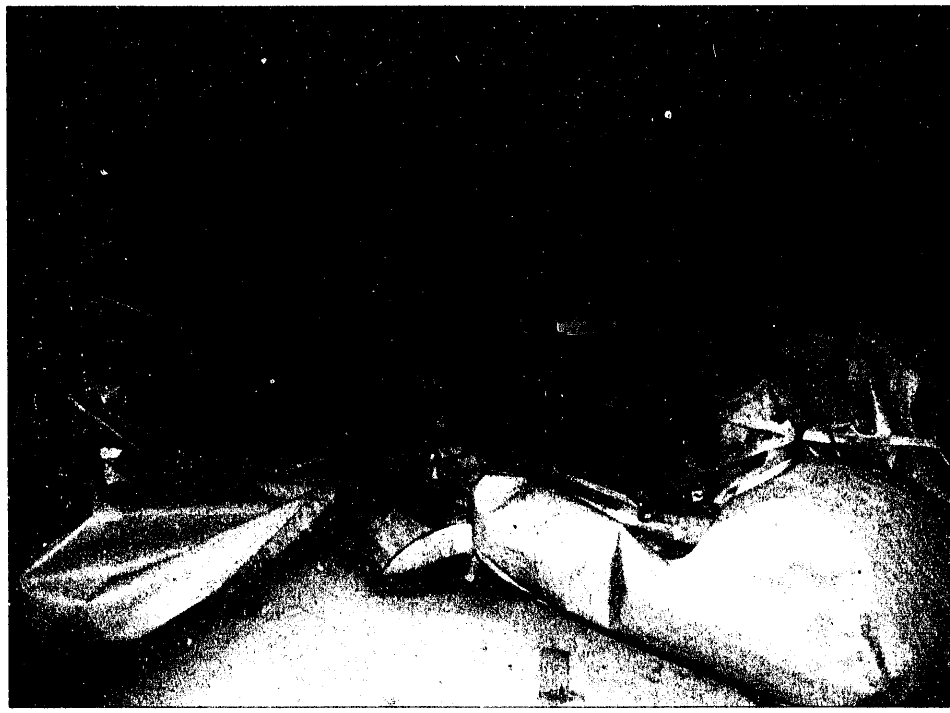
Ultrahigh velocity reached by .17 caliber rifle

The Terminal Ballistics Laboratory set a Sandia velocity record for a projectile launched from a gunpowder rifle. Steel and tungsten carbide balls were launched to speeds over 2,300 meters per second from a .17 caliber smoothbore rifle in a series of barrier penetration tests. Ultra-high-speed framing cameras, operating at 660,000 frames per second, showed that the balls separated from a plastic sabot and remained intact after penetrating a two-element barrier. (Rod penetrators used earlier had unacceptable yaw problems.) The test setup used inexpensive commercial hardware, including an unrifled barrel blank, to perform four high-velocity experiments in a single afternoon.

Karl Svensson, *Org. 2761-6, (505) 845-3163, FAX 844-3151*

When the Mars Pathfinder Lander sets down on the Martian surface in 1997, the landing will not be cushioned by expensive, heavy retrorockets, but by a cheaper impact attenuation (airbag) system designed and tested by Sandia National Laboratories. Scientists at the Jet Propulsion Laboratory in California conceived of the system, and JPL and Sandia researchers worked together closely as Sandians designed and fabricated the hardware.

"Basically, we had to demonstrate that the system would cushion the lander's impact on the surface of Mars to less than 50 g," says Don Waye, of Sandia's Parachute Technology and Unsteady Aerodynamics Department. As part of that demonstration, one series of tests verified a computer simulation of airbag performance and lander deceleration, while another series of tests demonstrated the structural integrity of the landing system's construction and materials.



The simulated, scale-model lander surrounded by deflated airbags. The tetrahedral lander is shown with its sides open and flat to the ground, in the post-landing position. The central panel holds the impact test instrumentation.

Sandia's Parachute Laboratory staff fabricated the airbag system. Constructed of coated Kevlar cloth with fusion-welded seams, the airbag system was designed to decelerate the lander during impacts up to 35 meters per second vertically and in winds estimated to exceed 35 meters per second horizontally. JPL supplied a 38 percent scale model of the tetrahedral lander, and Sandians mounted the four tri-lobed airbags on the four faces of the vehicle.

During testing, Sandia's High Altitude Chamber simulated Mars's atmospheric pressure (1 percent of Earth's sea-level pressure). To compensate for the restrictions of the chamber, researchers installed the model lander upside down and accelerated an impact plate into it using bungee cords. Instrumentation designed at Sandia measured airbag pressure and temperature and impact plate velocity and deceleration. The results of 18 tests of the airbags were compared to the computer simulation. The simulation and the test data correlated well, and the computer model was improved.

The second series of five tests, at Sandia's Coyote Canyon Cable Facility, demonstrated the structural integrity of the design and materials under simulated impact conditions. The same 38-percent scale-model airbag and prototype lander used in the High Altitude Chamber tests landed with both vertical and horizontal motion on a simulated Martian surface, which included rocks on the last test. An onboard instrumentation package measured airbag pressure and lander decelerations during impact and subsequent bouncing and rolling.

The success of both of these test series demonstrated the feasibility of airbag impact attenuation for the Mars lander. Tom Rivellini, the JPL Pathfinder airbag team member, summarizes the success: "Thanks to the test program work, and all of the learning we (JPL and Sandia) did during the program, I was able to convince the Pathfinder Review Panel that airbags were indeed the way to go."

For more information, call
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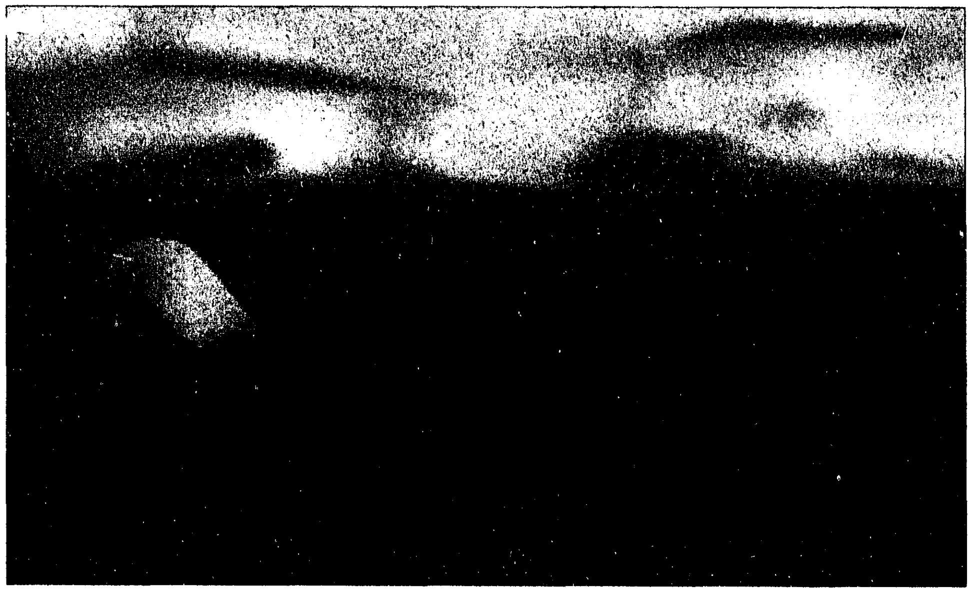
Real results from an unreal lab

Virtual test environments to improve testing operations



A sled track test as it might be simulated in a Virtual Test Environment. The VTE allows researchers to "observe" a test that occurs only within a computer program's algorithms and evaluate both the test design and the virtual results.

Researchers at Sandia are taking the first steps in developing a new concept in laboratory testing. The Virtual Test Environment is an icon-based computer simulation system that will enable engineers to model a complete testing environment. The VTE will provide testing organizations with a unique analysis and visualization capability to simulate test hardware and testing conditions. Eventually, a simulated test object could be tested in a VTE and observed on a computer screen before a single piece of hardware was constructed or a test system assembled.

"Right now, our focus is on developing a structural response testing environment," says Scott Klenke, of Sandia's Experimental Structural Dynamics Department. The structural response environment (for vibration and modal testing, for example) will include computer models of both test equipment and test objects. The development team is using MATLAB and Simulink software tools to create the icons and the algorithms behind the icons for test instruments. "We've already designed a number of icons to represent parts of the test environment," says Klenke.

The definition of a virtual test object is as important as the definition of virtual instruments. The first simulated test object will be a scale model of an earth penetrator weapon. This is a useful test object because there is an existing finite element model of the penetrator, as well as available experimental structural response data. For the structural response test environment, VTE developers will define more and more complex test objects, until they can generate a model for any desired test.

Developing the VTE requires a real team approach, with contributions from the Development Testing Center and the Computational/Computer Sciences & Math Center within Sandia, and from Virginia Polytechnic Institute. VPI researchers have worked on the visual representation of a laser vibrometer and of the test set-up as a whole. Gradually, the VTE will become a mirror of a complete structural response laboratory, including excitation sources, transducers, signal-conditioning electronics, and data acquisition systems.

The VTE is a Laboratory-Directed Research and Development project. LDRD projects permit Sandia staff to explore innovative scientific and technological opportunities that have high potential for useful applications.

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- ❑ to scout opportunities for technology transfer
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4. What is your general impression of this issue?

Choice of topics:	❑ excellent	❑ good	❑ fair	❑ poor
Newsbriefs (page 2):	❑ excellent	❑ good	❑ fair	❑ poor
Clarity of writing:	❑ excellent	❑ good	❑ fair	❑ poor
Quality of photographs:	❑ excellent	❑ good	❑ fair	❑ poor
Quality of illustrations:	❑ excellent	❑ good	❑ fair	❑ poor
Timeliness:	❑ excellent	❑ good	❑ fair	❑ poor
Technical depth:	❑ just right	❑ reasonable	❑ too technical	❑ too shallow

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Landing on mars . . .	❑ good	❑ fair	❑ could have been omitted	❑ no opinion
TT news in brief . . .	❑ good	❑ fair	❑ could have been omitted	❑ no opinion
Real results . . .	❑ good	❑ fair	❑ could have been omitted	❑ no opinion
Cheaper, better, smaller . . .	❑ good	❑ fair	❑ could have been omitted	❑ no opinion
Don't touch, just measure . . .	❑ good	❑ fair	❑ could have been omitted	❑ no opinion

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"We want to help other organizations learn how to build their own virtual test environments," Klenke says. The VTE team envisions a time when all parts of the Development Testing Center will be able to utilize VTEs for their testing. That time is several years in the future, but the development and implementation of VTEs will have an important impact on design, as well as testing, at Sandia. The use of VTEs fits right into Sandia's goals for developing agile processes for the Labs' work, including the research, design, development, and production of weapon components. When researchers can design and assemble a component or subsystem as a computer model, and then test it in a VTE, design flaws can be discovered early, proper functioning can be confirmed, and, when hardware is produced, it will be right the first time. This expertise can also be transferred to U.S. industry for the same advantages, improving U.S. economic competitiveness.

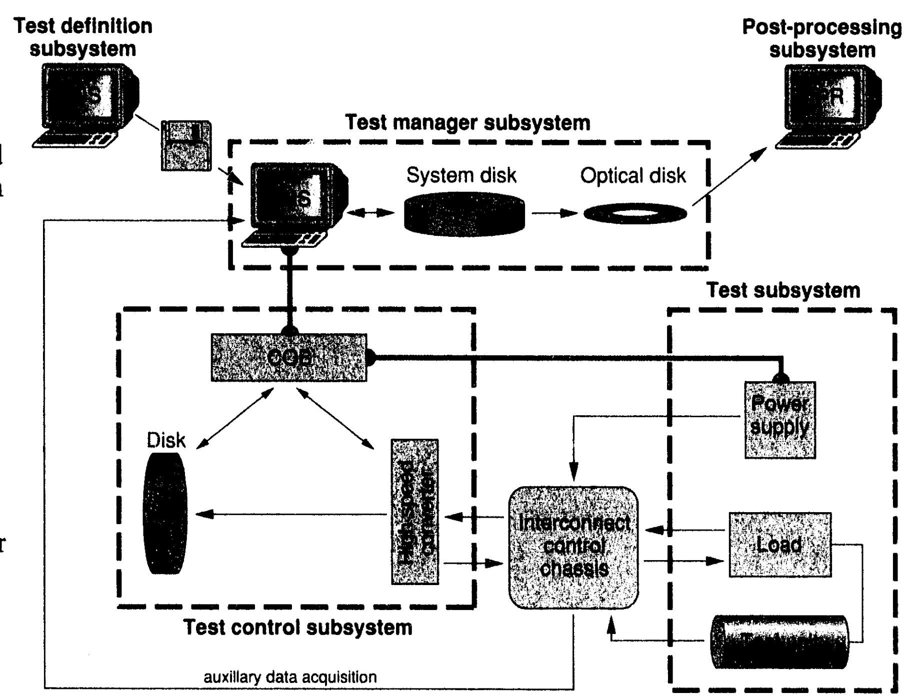
For more information, call
Scott Klenke, *Org. 2741, (505) 844-9034, FAX 844-0078, or*
Scott Gray, *Org. 2900, (215) 758-6117, FAX (215) 694-0542.*

Cheaper, better, smaller

New power sources tester answers need for in-plant quality testing

Its predecessor took up three full equipment racks and cost $300,000. Now a $40,000, single-rack unit can provide a wide range of tests for double-layer capacitors, batteries, and other power sources. One of the main uses of the new tester is to qualify power sources at production plants. "In-plant testing of weapons-quality double-layer capacitors and batteries is a lot more efficient than shipping units to an acceptance point, like DOE's Pinellas facility," says Garth Corey, of Sandia's Storage Batteries Department. "Corrective action and communication are much faster and more effective when the quality tester is on-site."

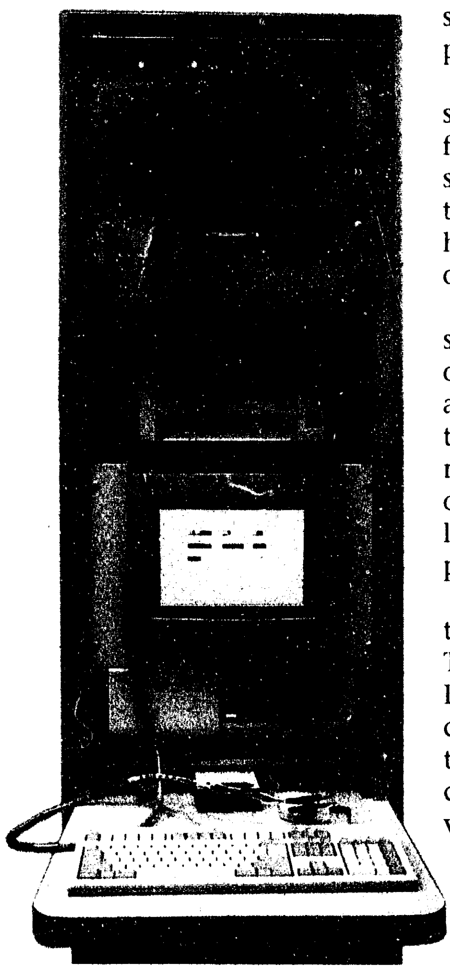
Tester developers wanted to build a less-expensive, easy-to-use system that would supply secure (i.e., independent) results for power source



How it works

The chart above shows the process for implementing test instructions, starting at Sandia, where the Test Definition Subsystem generates a set of test instructions and writes them onto the TDS diskette. The TDS diskette, sent to the testing site, will talk only to the COB (computer-on-a-board in the tester) and the COB will take instructions only from the TDS diskette. The COB controls the test through the interconnect control chassis, which manages the loading devices, power supply, and other electrical conditioning equipment that may be attached to the power source. The ICC sends the analog measurements from the test back to the analog-digital converting system, part of the test controller rack, which ships digital data back to the COB and/or the COB's hard disk. The COB changes the raw digital data into engineering units for later analysis. The engineering data is written directly to the system disk of the Test Manager Subsystem; the TMS can also write the data to the optical disk, which is returned to Sandia for post-test processing.

A single-rack power sources tester. The top portion of the rack contains the resistive loads that test the power source. The test instructions are loaded into an on-board computer (located below the keyboard) from a secure diskette.



acceptance testing. To do this, they selected DOS-based microprocessors to manage the tests and control test equipment. The heart of the system is a rack-mounted "computer-on-a-board." This COB, which is built around a 386 microprocessor, loads its test format and operating system from a password-secure disk sent from Sandia to the test site. The test operator uses another DOS-based computer to load the test information into the COB and to monitor the test. The operator can't interfere with the test or modify the test definition, but can abort the test for safety reasons. "We developed a system that ensures the integrity of the test data no matter where the test is performed," says Corey.

Not only is the test procedure secure, new test definitions can easily be sent from Sandia on diskette to the test site, making the system much more flexible than earlier testers. Corey says, "We've convinced our users that the software will not change the calibration of the test equipment. The only time we have to do an unscheduled calibration of the system is when the hardware changes, such as when we change the electrical loading system or other components."

In fact, the electrical loads are an important aspect of the flexibility of the system. The tester developers searched out a commercially available family of electrical loads that covered a broad range of voltages and currents and allowed a wide variety of load profiles. This means that the tester can check the functioning of a selected power source under a variety of conditions that match the specified or expected use conditions of the double-layer capacitor or battery. While most tests involve rapid discharge or draw down of double-layer capacitors, the tester can also cycle rechargeable batteries over longer periods of time, up to several weeks or hundreds of cycles.

The first testers produced at Sandia using the secure tester design are now testing thermal batteries and double-layer capacitors for weapons systems. Testers are already in place at Pinellas, for acceptance testing, and at an Eagle-Picher plant, for production testing. An Evans company plant in Providence, Rhode Island, will soon receive a next-generation tester for production work. The system allows both development testing, in which developers can modify test parameters more easily, and production testing, which provides secure data for quality control functions. The work on the testers is sponsored by DOE's Defense Programs organization. With its relatively low cost, flexible test set-up, and more compact installation, the new tester will soon find more applications as a power sources tester.

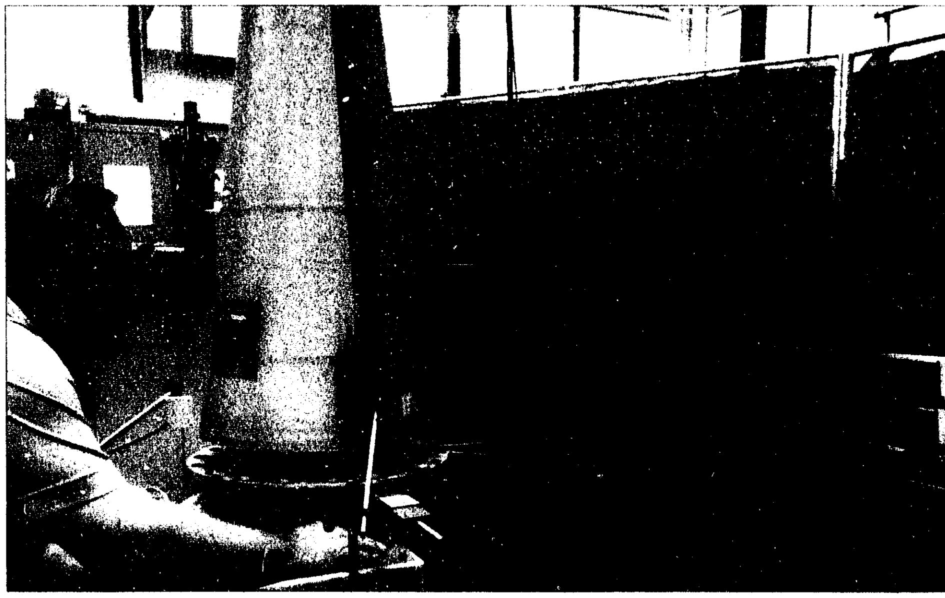
For more information, call

Garth Corey, *Org. 2525, (505) 845-4596, FAX 844-6972.*

Don't touch, just measure

Noncontact precise measurement system finds the right axis for many objects

Recently, Sandia researchers needed to dynamically balance lightweight reentry vehicles for a United States Army Space and Strategic Defense Command program. Dynamic balancing is a pretty common procedure for automobile tires — most drivers recognize that their tires will wear better and steer more accurately if the forces applied to the tires are distributed evenly. The same concepts can be applied to objects in flight — balancing is essential for stability. In the case of the USASSDC reentry vehicles, a straightforward procedure was made difficult by the extremely lightweight, deformable materials and non-symmetrical shape that characterized the vehicles.



Bob Varga adjusts the alignment of the test object to within thousandths of an inch based on measurements from noncontacting transducers. The reference axis of the test object can be found with fewer iterations of this improved procedure.

"We couldn't just put an RV on the spin balancing machine and set up the usual contact sensors to define its position and find a reference axis," says George James, of Sandia's Experimental Mechanics Department. "These RVs are long and very light; contact sensors would tear them up."

The flight vehicles are about 1.5 meters long and 0.5 meters in diameter at the base, yet they weigh only 1 to 4.5 kilograms.

The deformable and asymmetric nature of the reentry vehicles required a noncontacting alignment system that would locate a vehicle's reference axis so that it could be aligned with the balancing machine's spin axis. The reference axis is the axis about which the reentry vehicle will rotate without tumbling; the new technique defines the axis using two planes through the test object (one at the top of the vehicle and one near the bottom). Mechanics researchers developed a method for determining a reference axis using a reference target and digital video analysis at the top plane and laser triangulation sensors focused on the vehicle's surface at the bottom plane.

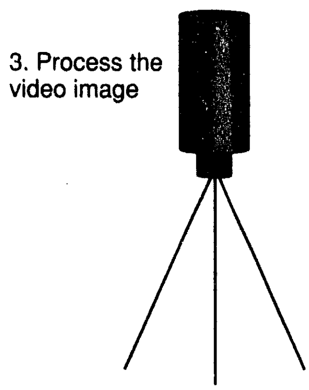
The reference axis at the top plane is defined at the center of the reference target, while a second target, called an angle target, is offset from the reference target to determine angular orientation. As the reentry vehicle slowly rotates on the balancing machine, the reference target orbits the machine spin axis and video data are recorded.

"Video information does not usually yield quantitative data," notes James, "but this technique does." Edge-detecting software links up with specialized algorithms to calculate target positions, angular orientation, and the reference axis offset at the upper plane.

For calculations at the lower plane, noncontacting laser triangulation sensors measure the variation of the surface of the object, during rotation, at a plane near the base of the test object. The data describing these variations are processed to calculate the center of the best-fit circle defined at this plane. The reference axis of the vehicle is defined as passing through the best-fit circle's center.

The top plane video data and the bottom plane laser triangulation data are linked with a common time measurement to allow an angular interpretation of the bottom plane measurements. This allows the reference axis to be defined using the top and bottom offsets from the machine spin axis. The process also defines two tilt and translation adjustments required to align the vehicle's reference axis with the machine spin axis.

This new technique provides several improvements over conventional alignment methods. First, conventional methods with contact sensors can require several iterations over four (or even eight) hours, while the new process requires two to three iterations and less than two hours. Second, the alignment is far more accurate, since several hundred data points are measured on the circumference of the object, compared to four points on the object in conventional practice. The new alignment technique is also much more robust, since the test object does not need to be perfectly symmetrical. Errors in angular orientation have been substantially reduced, and the entire process is highly



automated, reducing operator training and providing a record of all measurements and alignment parameters.

The new approach may have several applications in testing or characterization. One development project will balance objects based on their observed motion while being spun about one fixed point. This technique allows balancing of large, lightweight objects that cannot be constrained for traditional balancing procedures. Other applications include noncontact measurements of rigid-body motions for rocket systems following pyrotechnic separation events; trajectory measurements following rotating separation events; and vibration data analysis in a region of high electromagnetic fields. Similar applications have been proposed for rotating modal testing, noncontact static testing, 3D robot trajectory analysis, and measurement of micromachine motion.

The hardware and processes developed for noncontact alignment open up a new realm of balancing and testing of very large lightweight objects. As a result of these developments, efficient and precise alignment measurements of rotating machinery can be obtained through noncontact methods. This technology has already been extended to testing in new and unusual environments and may have more applications in the near future.

For more information, call
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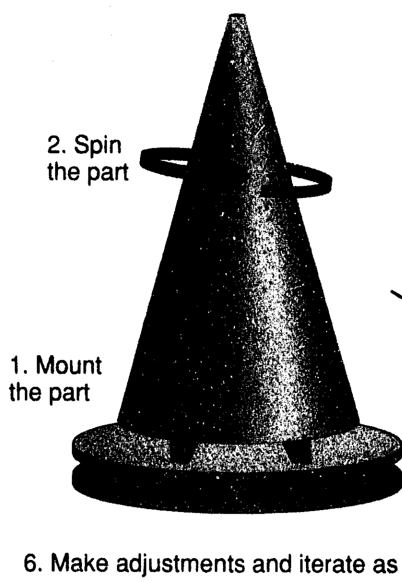
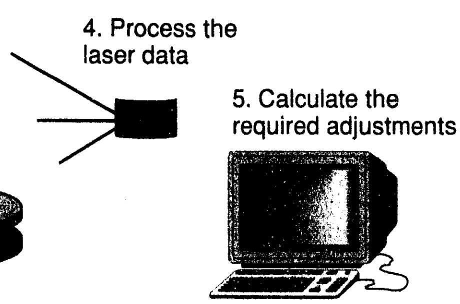
José E. Suazo, *Org. 9811, (505) 845-8507, FAX 844-0094.*





An overview of the improved process for defining the reference axis of flight objects and other test items. The non-contacting procedure permits analysis of fragile and non-symmetrical objects. Special video image processing, linked to laser positioning data and computer analysis, results in quick turnaround of data and fewer test iterations.

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