PREFERRED
RELIABILITY
PRACTICES

ADVANCED COMPUTED X-RAY TOMOGRAPHY

Practice:

Use advanced computed X-ray tomography as a precision method of materials characterization and defect location to ensure high reliability of aerospace hardware and conformance to design requirements. Employ this sophisticated and proven technology for nondestructive evaluation (NDE) of materials and structures. Assure the adherence to established precautionary measures during tomography operations.

Benefits:

Advanced computed X-ray tomography can be used to produce both two-dimensional and three-dimensional images of structures, materials, parts, and components. These images are providing information that is useful for inspection, evaluation, and diagnostics of complex hardware.

Programs That Certified Usage:

Solid Rocket Motor (SRM), Space Shuttle Main Engine (SSME), Solid Propulsion Integrity Program (SPIP), Modified NASA Motor Program, Sub-Scale Solid Rocket Combustion Simulator, other aerospace and aerospace-related applications.

Center to Contact for More Information:

Marshall Space Flight Center (MSFC)

Implementation Method:

1. General Description of the Process:
   Advanced computed X-ray tomography uses high intensity X-ray sources, sensitive electronic detectors, sophisticated computer control and analysis techniques, and automated manipulation systems capable of translating and rotating test objects, to produce cross-sectional images of precision aerospace components. A system block diagram is shown on Figure 1. This test method can be used to verify tolerances, to determine relative material densities, to locate inclusions or defects, and to measure the extent of erosion and ablation in composite materials. The equipment and procedure is applicable to metals (up to 10 inches thick) composites, or combination metal/composite structures varying from 2 inches to 50 inches in diameter (depending on the material density) and weighing up to 3700 pounds.

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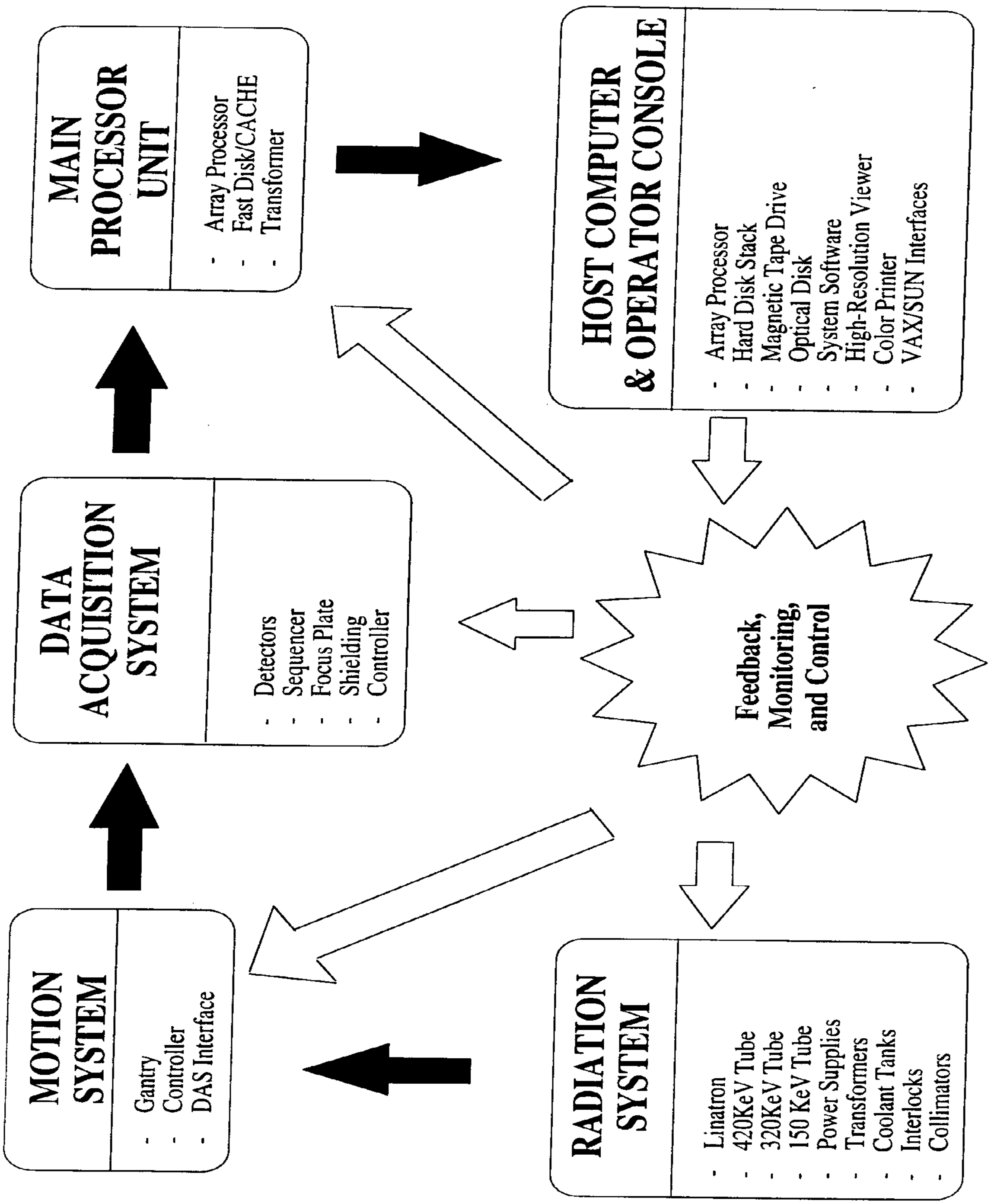

Figure 1. Advanced Computed X-ray Tomography Basic System Block Diagram

Cross-sectional images, generated by rotating and translating test objects slowly in an X-ray source, produce accurate representations of thin slices of the test object. It takes 20 minutes to produce an image of a thin slice for a typical SRM nozzle. To form a three-dimensional image of the internal structure of the nozzle, 150 to 250 slice images are acquired and stacked. The

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entire process is controlled remotely by computer. Operational personnel are located external to the test cell. To prevent personnel contact with harmful X-radiation sources or environment, there are safety precautions that include constant dosage monitoring of stray/exposure radiation.

A principal use of advanced computed X-ray tomography at MSFC has been evaluation of solid propellant rocket motor nozzles. The technique has been used for verification of nozzle integrity, thermocouple location determination, and post-fire char depth evaluation. The procedure can locate high or low density inclusions, delaminations, or debonds, and profound material density variations. The images can be observed in near real time as they are generated, and are archived for future detailed analysis and evaluation.

2. Safety Precautions:

   To ensure maximum safety to personnel, equipment, test objects, and the environment, safety precautions for tomography facilities should be established and enforced. Flammable or explosive materials are not permitted in the facility. The minimum personnel required for operation of X-ray sources should be a radiation protection supervisor and an operator. Both should be trained in the principles of radiation protection and safety. Personnel are not permitted in the exposure bay during the activation of the X-ray sources. A key-lock system is installed to prevent activation by unauthorized persons. An electronically controlled safety interlock switch is located on the exposure bay doors to shut down system operation when the doors are opened. Further, manual emergency shutdown switches are located at operator consoles and inside the exposure bay. Radiation meters are used to monitor the control room and adjacent work areas. These switches and meters should be tested and calibrated on a periodic basis. Thermoluminescent dosimeter badges and pocket dosimeters are used to monitor exposure to radiation of the personnel. Detailed operating schedules, access control, and sign-in logs should be used to prevent or limit unauthorized persons from entering the facility during operation and to record those who visit during non-operation periods. Warning lights are used to warn personnel of impending or ongoing operations. Video surveillance cameras are used to monitor critical areas to prevent access by unauthorized personnel.

Technical Rationale:

The MSFC has operated its computed X-ray tomography facility since 1988 with significant benefit to product reliability and with no injury to the personnel or facility. X-ray sources used include a two million electron volts (ev) accelerator, and 420, 320, and 150 Kev X-ray tubes. Computer control of high energy X-ray sources with remote video viewing along with the proper precautions and warnings have been proved to provide a safe and effective inspection procedure.

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Impact of Nonpractice:

Failure to apply computed X-ray tomography methods for investigations of appropriate hardware may lead to the use of flawed structures. Further, failure to implement safety precautions may result in injury to exposed personnel.

Related Practices:

PT-TE-1423, "Radiographic Testing of x-ray Materials."

References:

1. Hediger Lisa: "Reliability Improvement for the Advanced Computed Tomography Inspection System (ACTIS)," Marshall Space Flight Center, AL, August 1992.

2. Lawson, Seth et. al.: "Modified NASA Motor Process Procedure," M&P-M-NASA-027, Marshall Space Flight Center, July 1993.

3. Hediger, Lisa et. al: "Standard Operating and Safety Procedures for the Advanced Computed Tomography Inspection System (ACTIS) Facility," EH13P-88-01-Revision A, Marshall Space Flight Center, AL, February 1988.

4. Lee, T.J.: "Radiation Safety Manual," MM 1860.2D, Marshall Space Flight Center, AL, December 26, 1991.