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Telepresence and Virtual Environment Applications on the Light Duty Utility Arm System

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TELEPRESENCE AND VIRTUAL ENVIRONMENT APPLICATIONS ON THE LIGHT DUTY UTILITY ARM SYSTEM *

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ABSTRACT

The Tri-Party Agreement was initiated in 1989 to provide a thirty-year clean-up plan for the United States Department of Energy's (DOE) Hanford Site. This plan addresses the remediation of hazardous chemical and radioactive wastes with a major emphasis on the characterization of Hanford's underground waste storage tanks. To assist in this task the DOE is funding the development of a light duty robotic arm capable of deploying various tools which can inspect and characterize the interior of DOE waste tanks. Current development includes two new technologies — stereoscopic telepresence, which will allow three-dimensional viewing of the waste tank interior; and "virtual environments" (or "virtual reality"), which will provide computer-simulated world wherein operators can practice inspections and other activities prior to performing actual operations in real waste tanks.

INTRODUCTION

The United States Department of Energy (DOE) created the Office of Technology Development to assist in the environmental restoration of waste sites across the DOE complex. To complete this task, several major new technology demonstration efforts were initiated. One such effort is the Underground Storage Tank Integrated Demonstration (USTID). This program concentrates on the characterization and remediation of underground radioactive waste storage tanks, and is funding the development of a Light Duty Utility Arm (LDUA) system at the Hanford Site located in southeastern Washington state.

The LDUA system consists of a robotic arm that will function as a deployment platform for various surveillance, inspection, and characterization end effectors, and a mobile deployment vehicle to maneuver the system to various waste tanks. End effectors that will assist in these tasks will be developed by DOE laboratories, industry, and academia.

This paper describes the development and implementation of new telepresence and computer-based virtual environment technologies as parts of the USTID. Stereoscopic telepresence can effectively put the eyes of the inspector into the waste tanks to examine tank walls and in-tank structures. Three dual-camera stereoscopic imaging systems are currently being developed for use with the LDUA to provide the inspector with true depth perception in real time as he or she manipulates the LDUA in the underground tank from the deployment vehicle aboveground nearby. The virtual environment is a complementary technology. Using sophisticated three-dimensional modeling software, programmers are creating

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"virtual waste tank" environments. The virtual waste tanks and accompanying models of the LDUA and its end effectors will be used to train LDUA operators both in the full range of normal tasks during tank characterization (and later, remediation), and in simulations of a number of "unplanned events." The virtual tank and LDUA environments will be displayed stereoscopically to give the operators a sense of immersion and true depth perception while they practice in-tank operations.

Figure 1 shows the LDUA system deployed at an underground waste storage tank. The LDUA and related equipment to be used in the tanks will be deployed through riser pipes leading from ground level into the tanks.

TELEPRESENCE

One of the technologies that is currently being developed as an inspection tool is stereoscopic telepresence. The intent is to, in effect, put the eyes of the inspector into the waste tanks to examine tank walls and in-tank structures. All of the remotely controlled operations to be performed in the waste tanks are complex and require precise control. Real-time stereoscopy will give the LDUA operator more natural, realistic views of a tank's interior with true depth perception, allowing him or her to guide the LDUA more intuitively and accurately. This assertion has been verified by testing of stereoscopic viewing systems by operators of remote manipulators at Hanford, under the

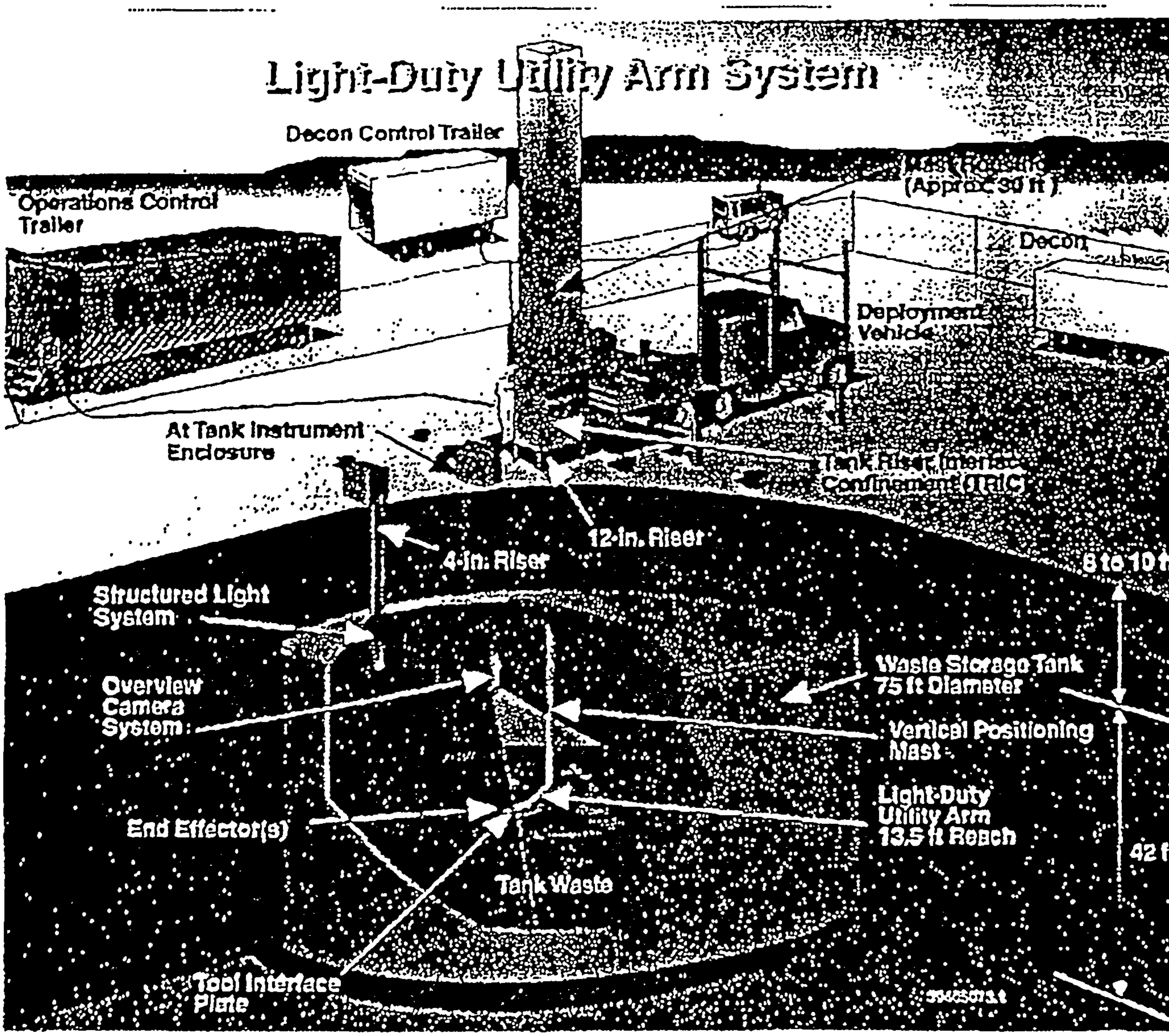

Figure 1. The Light Duty Utility Arm system deployed at an underground waste storage tank

lenses mounted on a rotatable disk can be seen. These lens pairs provide three zoom levels, from wide angle to telephoto. Lighting is provided by a general purpose source lowered into the tank separately from the OSVS.

High Resolution Stereoscopic Videocamera System

The high resolution stereoscopic videocamera system (HRSVS) is being developed to provide closeup stereoscopic viewing of in-tank structures. The HRSVS is mounted on the end of the LDUA as an end effector and will be positioned near the interior tank walls and piping to inspect for anomalies such as cracking and corrosion. Figure 4 shows the cylindrical casing and the inner workings of the HRSVS. The outer diameter is limited to 26.7 cm (10.5 inches) to fit down a 30.5-cm (12-inch) riser on the end of the LDUA. The module contains a pair of cameras for stereoscopic imaging, rotatable objective lenses for three levels of magnification, a single pre-objective lens for focusing, and an integral lighting source. In this application, real-time stereoscopic video-imaging will be used by inspectors both to navigate the HRSVS inside the tank and to enhance the appearance of three-dimensional features of in-tank structures (e.g., sediment deposits, shallow surface imperfections, etc.). The view/record feature of the StereoGraphics' processing system allows both for real-time viewing of the image and for recording onto standard-format videotape for later playback.

Still Stereoscopic Photographic System

The Still Stereoscopic Photographic System (SSPS) is being developed to record high resolution still digital photographs of the entire interior of the waste tanks. The complete stereoscopic documentation of tank structures will be a major source of data from which it will be possible to make accurate three-dimensional measurements of tank features. The combined photographic and dimensional information will be used both in the early characterization work and, later, in planning the remediation of the waste tanks. The SSPS prototype is shown in Figure 5, though this is not is final configuration. The actual SSPS will be redesigned with a maximum diameter of about 26.7 cm (10.5 inches) to fit through a 30.5-cm (12-inch) riser on the end of the LDUA. The SSPS includes a pair of high resolution digital still cameras and an integral lighting source. The inspector will be able to monitor the current stereoscopic image on a monitor, maneuver the SSPS to the desired location and capture stereoscopic image pairs at will.

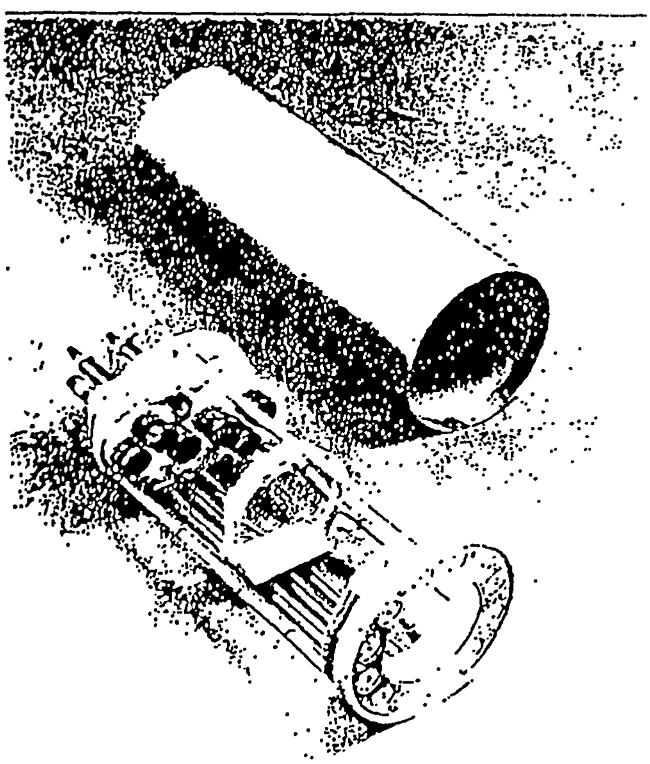

Figure 4. High resolution stereoscopic videocamera

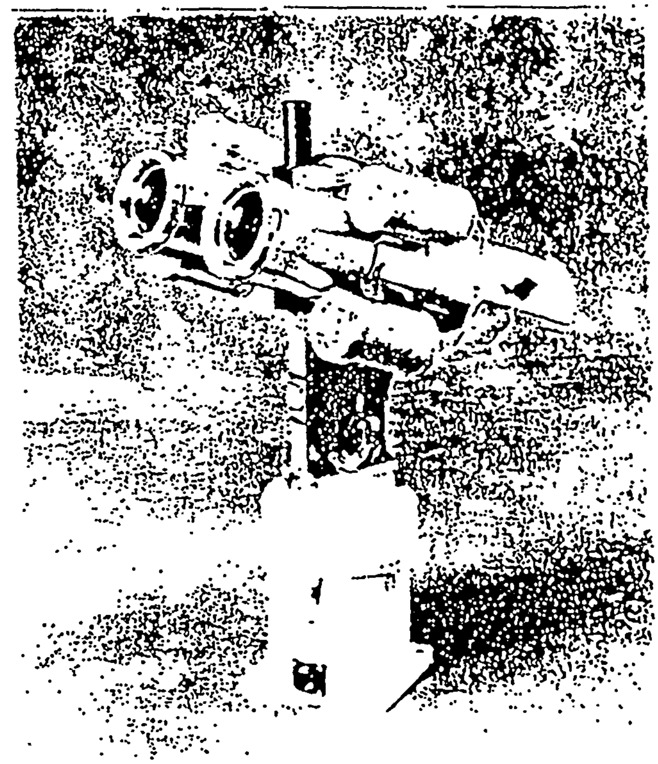

Figure 5. Still stereoscopic photographic system

VIRTUAL ENVIRONMENTS

Another technological innovation in the USTID is the use of virtual environments to conceptualize, plan, and practice various in-tank operations. Nearly all of the equipment that will be deployed in the underground waste tanks is unique and new. LDUA operators will need considerable training on all of the end effectors to be used on the LDUA as well as on several other sensors to be deployed in the tanks. The use of virtual environments as training tools offers an economical supplement to the use of mock-ups and real equipment. The same interactive models can also be used in an "exploratory" mode to help design and "test" new equipment and plan new in-tank operations.

Using three-dimensional modeling software, robotic control software and steroscopic virtual reality modeling software, programmers are creating a variety of "virtual waste tank" environments. The virtual waste tanks and accompanying models of the LDUA and its end effectors will be used both to plan and test the feasibility of proposed in-tank procedures and to train LDUA operators. Operators will practice performing normal tasks exactly the way they will perform them during real waste tank characterization activities. A number of "unplanned events" can also be programmed to provide accident scenarios which can test both the procedures for recovery and the operator's ability to implement them.

Figure 6 shows a realistic scene taken from one of the virtual tank environments already created. The interactive model from which this picture was taken is three-dimensional and, in practice, is viewed stereoscopically to closely mimic the experience of operating the real stereoscopic equipment to be used in the tanks. Realism is further enhanced by incorporating actual images of in-tank structures, as can be seen in the figure. In this case, preliminary inspection photographs of a tank's walls and some solidified waste were digitized

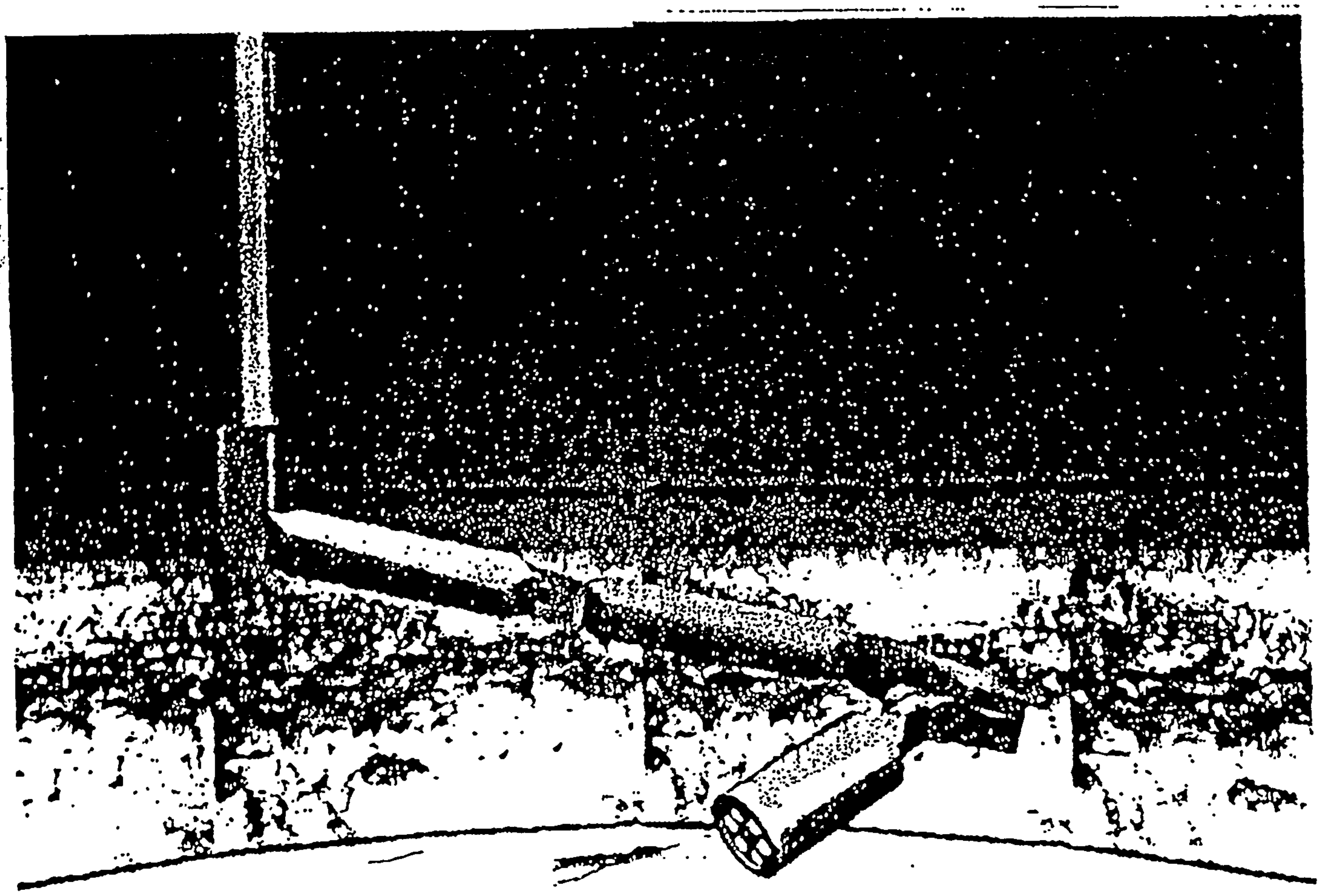

Figure 6. Scene from a virtual environment of an underground storage tank with the light duty utility arm deployed

and included in the virtual environment. Throughout the USTID, tank models will be updated from operational data as it is gathered. The revised virtual environments will in turn be used to help plan future operations.

Demonstrations of the prototypes of the stereoscopic telepresence and virtual environment technologies were included in the initial USTID on-site demonstration conducted in June, 1994 at the Hanford Reservation. All of the prototypes performed as designed. Figure 7 shows the audience viewing a stereoscopic simulation of LDUA deployment projected onto a 2.9-meter (10-foot) screen. The next milestone in the USTID will be cold testing of the LDUA, its end effectors, and the other in-tank sensors and equipment in 1995. Concurrently, the virtual waste tank simulation and training system will be developed and specific interactive training models for the end effectors will be implemented.

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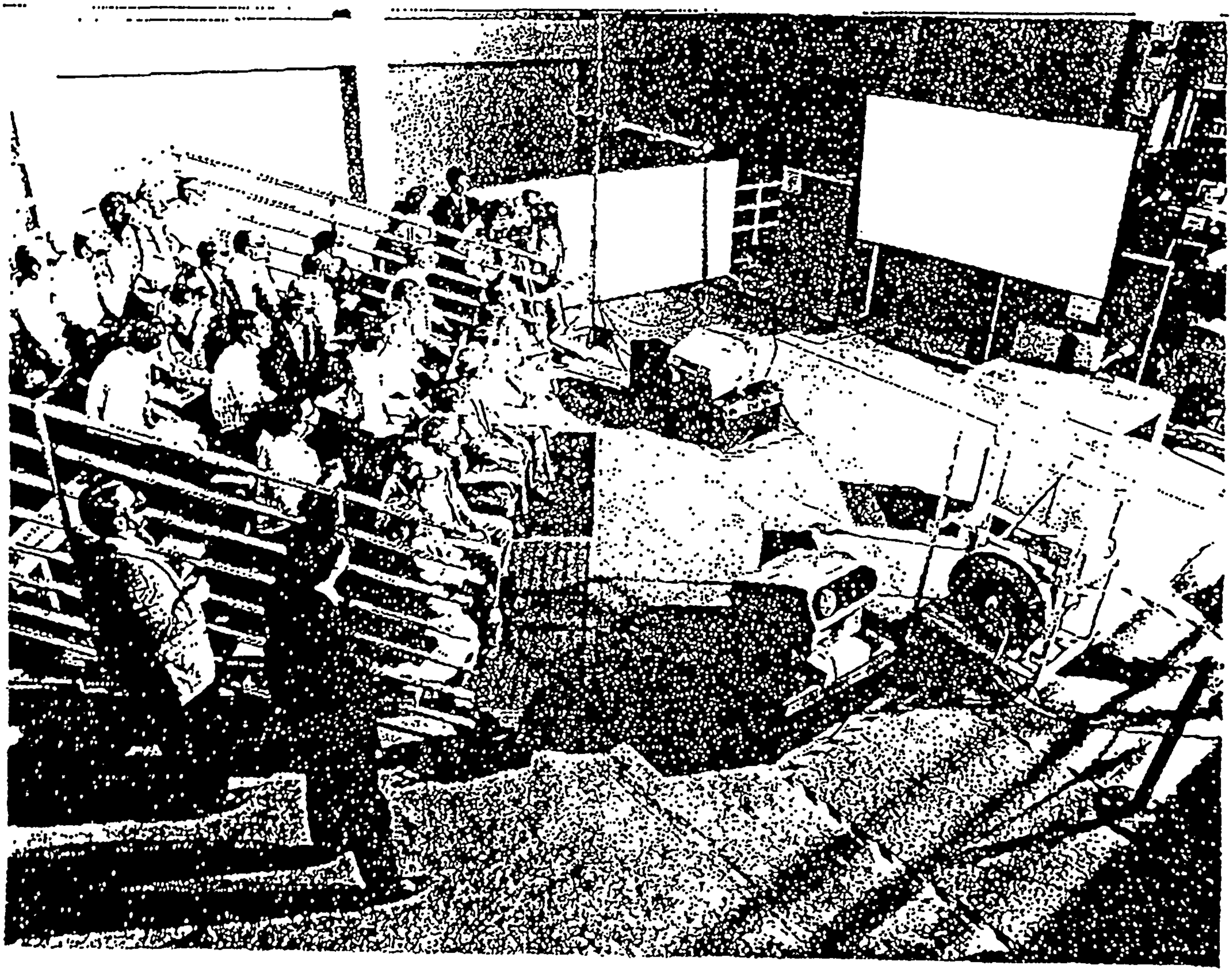

Figure 7. Stereoscopic viewing at the Underground Storage Tank Integrated Demonstration at Hanford in June, 1994