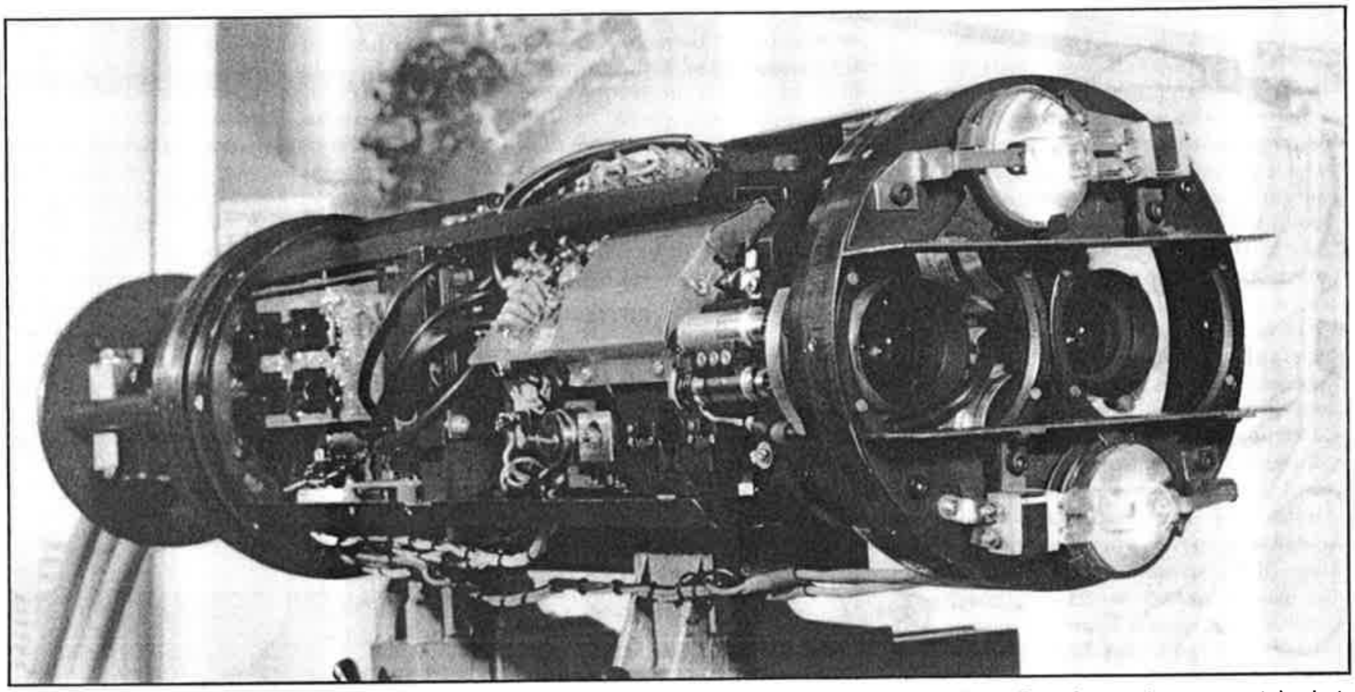
3D TV — looking forward in depth

By E Abel and A A Dumbreck

AEA Technology's 3D TV equipment shows performance benefits over conventional television — it is quicker and easier to use, requiring less precision and less camera deployment manipulators. Operators have taken to the new system very quickly.



▲ The latest, third generation 3D TV camera can be used in many different nuclear applications. Requirements were matched at different nuclear facilities in the UK and the most stringent values adopted. This approach placed extreme constraints on the camera design, but the result is a versatile and robust camera which will also be suitable for many applications beyond those foreseen at present.

Direct viewing of remote handling tasks in decommissioning, operation, inspection and repair of nuclear facilities is constrained by the need to contain the workspace and to provide adequate shielding for operators and other staff. Improvements in camera design and display technology, and an understanding of radiation tolerance and human factors, have been brought together at AEA Technology to provide a range of stereoscopic or 3D TV viewing systems. These allow operators to assess conditions accurately in a remote environment, and can be used either to observe or inspect, and to help in completing complex manipulations and tool deployment.

DEVELOPING 3D TV

The concept of producing 3D TV as a useful tool for remote handling has existed for some time. Experiments at Harwell in the late 1970s began to quantify the benefits that could be obtained by using simple orthogonal TV configurations (separate TV cameras viewing a workplace from 90°-apart positions), high definition TV, and prototype stereoscopic systems. In 1983 the programme of work was focused onto the objective of producing practical, easy-to-use and reliable 3D TV systems for the nuclear industry.

The development programme has gone through the following stages:

- Determining the design criteria for comfortable-to-view, useful 3D TV systems.
- Building engineered prototype cameras and displays.
- Evaluating prototype systems in cold mock-ups.
- Building second generation systems, and evaluating them.
- Building third generation, radiation-tolerant black and white systems.
- Evaluating and deploying these third generation systems in radioactive environments.

Alongside this programme, work has been carried out on the videotape recording of 3D television pictures, which is useful for referencing and archiving facility equipment and for training operators in new techniques. Extensive human factors studies carried out during the evaluation of the 3D TV systems have confirmed the adequacy of the design criteria and allowed guidelines to be set which can be practically achieved in the manufacture of 3D TV systems.

CAMERAS AND DISPLAYS

Successful engineering of a 3D TV system requires attention both to the cameras and to the display technique. The principle is to arrange two separate (left and right) images from the cameras in a display. The images are naturally similar but present slight horizontal disparities, providing depth information when viewed correctly. The display method

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that has been chosen for current work uses two monitors, each with polarizing filters at their faces, set together at right angles. The two polarized images representing left and right camera views are combined through a semi-reflective mirror, and then viewed with polarized spectacles similar in appearance to ordinary sunglasses.

There is no time difference between the display's left and right images. The mechanical design embodied in the camera mounting and control, with the precise assembly of the monitors, ensures that the design criteria can be met. The observer can accept size scaling of images easily, but attempts to reproduce scenes with excessive depth, or ones with either vertical disparities or inconsistent matches of images, result in discomfort and a resistance to using the system. Controls for picture shape and adjustment of parameters such as colour and grey level are available for setting-up, but in practice, the pictures remain stable over long periods of time without the need for recalibration.

Other designs for black-and-white displays, smaller displays and built-in workstations have been produced and built. The method of display using polarizing light was chosen after assessing all the reported methods of 3D TV display; it gives the best pictures. It is worth mentioning briefly two alternatives. Time division displays produce noticeable time differences between left and right images. Simple versions show flicker, which we believe is unacceptable, and these versions should be avoided because of operator discomfort. Higher quality time division systems are feasible but would be expensive because of the need for non-standard equipment. Prototype autostereoscopic TV displays have been demonstrated at Harwell. These systems do not require the observer to wear viewing aids and show promise for some future applications.

The first two prototype black-and-white 3D TV cameras used four solid-state cameras with a wide-angle pair stacked on top of a narrow angle pair, replicating the extremes of a zoom lens arrangement. The camera optics were designed so that focus and convergence were coincident for each camera pair. The appropriate camera pairs were selected at the display control panel.

Colour 3D cameras used pairs of repackaged single sensor solid-state cameras, and improvements in the lens carriage mechanism meant that it could accommodate other sensors. The operator could select automatic or manual iris control, and the position feedback of focus gave data from which range information could be calculated.

Third generation. The latest development is a third generation 3D TV camera that can be used in many different nuclear applications. The specification was derived by matching requirements at different nuclear facilities in the UK and adopting the most stringent values. This approach placed extreme constraints on the camera design, but the result is a versatile and robust camera which will also be suitable for many applications beyond those foreseen at present. In particular, the long cable length and slim diameter of the camera make it ideal for reactor inspection and in-cell viewing of manipulative or decommissioning-type tasks. A target radiation tolerance is 10^6Gy, with dose rates up to 10^3Gy/h. Individual components have been irradiated at Harwell and shown to perform well, but specific applications may require extensions to these confirmatory experiments.

Computer control of focus and convergence (which are not mechanically linked in this camera) allows a skilled operator to further enhance performance of the system if required. The computer is used to provide information on lens status (wide or narrow-angle pairs), coolant flow, temperature, and convergence distance — which can be used for measuring distances with accuracy.

EVALUATING THE SYSTEM

During the development programme, evaluations and operating experience has accumulated. It is apparent that for effective teleoperation, visual feedback is as, if not more important than force or position feedback from a manipulator, and this should be reflected in the budgetary process in specifying equipment. Initial simple comparisons of performance of high definition and 3D TV systems were supplemented by more complex applications of TV involving some form of manipulative task. Comparisons have been made using force reflecting manipulators, a variety of task boxes, and sorting tasks, where depth information is vital in avoiding uncertainty in unstructured environments. Trials at AEA Technology's Windscale Nuclear Laboratory have compared performance benefits of 3D TV over orthogonal TV in operations such as remotely cropping reinforcing bars using an industrial robot carrying a hydraulic tool. Another experiment, also at Windscale, confirmed the benefit of 3D TV in handling and accurately relocating samples of cut reactor pressure vessel using a crane.

Tangible benefits. Some of the major conclusions to come out of these evaluations are that 3D TV gives tangible and significant benefits, including:

- A general reduction in the number of views (and hence cameras and support structures) required.
- Faster operational times, with greater improvements for task elements requiring alignment.
- Fewer manipulator movements for a given task, which implies fewer errors and less collisions.
- Less critical camera positioning.
- Operator preference for 3D.

The last point is significant in that no ill effects have been noticed in trials of the prototype and engineered systems. The fact that new and untrained operators appear to be at ease with a task more quickly using 3D TV implies that the complexity of the task could be increased, or conversely, that less skilled operators could be used. The results of human factors and experimental trials have been used to refine the design of the 3D TV system hardware and operational procedures. □

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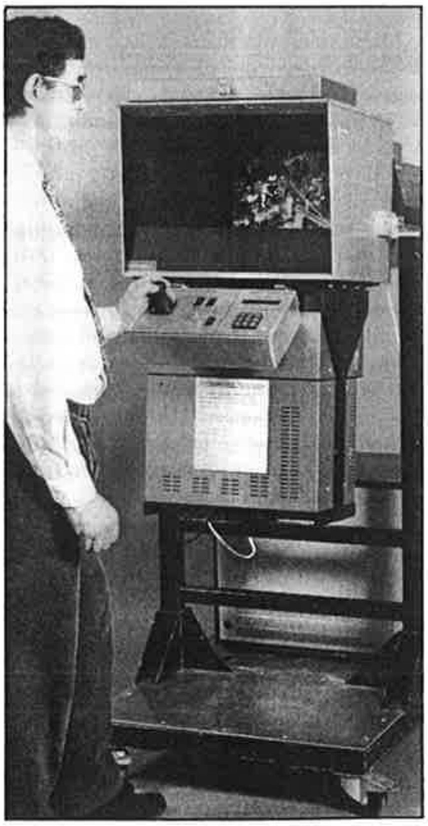

▲ **Using the colour 3D display. Designed to be moved into position alongside a manipulator control station, it is larger than a built-in display.**