ALARA FOR CASK MRS BY REMOTE OPERATIONS

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Abstract

Radiation dose rates in a monitored retrievable storage (MRS) facility are high enough to warrant the evaluation of robotic systems to achieve personnel dose reductions. Robots with sufficient mobility and dexterity to perform Health Physics surveys and maintenance are currently in use. The addition of artificial intelligence computer methods to the robot removes the need for a human operator for normal surveillance activities. Use of an Expert System creates a robot with sufficient flexibility to recognize and respond to off-normal conditions such as radiation leaks.

Radiation doses in a monitored retrievable storage facility (MRS) can be reduced by remote operations using robotic systems enhanced by artificial intelligence techniques. The dose rates within a cask storage array will be over 100 mrem/hr on contact in normal circumstances and over one rem/hr in abnormal conditions, as shown in Table I. This is with 35,000 MWD/MTU burnup fuel cooled 5 years, and dose rates will be substantially higher for fuel with extended burnups of 45,000 MWD/MTU or more. The large volumes of the casks cause the radiation field to be relatively uniform and thus insensitive to distance (as shown in Fig. 1), making auxiliary shielding cumbersome, so options for dose reduction for workers are reduced to short occupancy times. Times required to maintain or repair casks are not well known at present because of lack of operating history, but substantial dose reductions are likely if remote methods are applied to operations.

Table I

Dose Rates for Storage Casks (mrem/hr)
(31 Assemblies burned to 35,000 MWD/MTU and cooled for 5 years)

Condition	Number of Casks in Array: 1	4	10 or more
Normal	100.	160.	188.
Abnormal	711.	1140.	1350.

Applications currently envisioned are remote sensing and alarming of cask parameters such as fuel cavity pressure, and robotic dose rate surveillance and repair of a damaged cask array. Periodic survey by robotic television and dose rate meters is feasible, and normal maintenance functions such as replacing a malfunctioning pressure sensor are within the current state-of-the-art. The stereoscopic visual system acuity and manual dexterity required for such maintenance tasks are no greater than those required for current applications such as machining aircraft components.

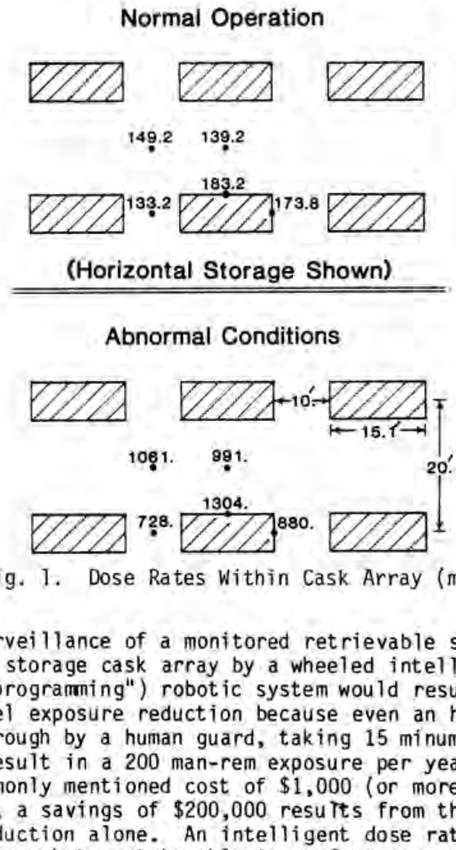

Fig. 1. Dose Rates Within Cask Array (mrem/hr).

Surveillance of a monitored retrievable storage site or storage cask array by a wheeled intelligent ("self-programming") robotic system would result in personnel exposure reduction because even an hourly walk-through by a human guard, taking 15 minumtes, could result in a 200 man-rem exposure per year. At the commonly mentioned cost of $1,000 (or more) per man-rem, a savings of $200,000 results from the exposure reduction alone. An intelligent dose rate surveillance robot must be able to perform several interrelated tasks to perform its function:

1. Interpretation of data from the dose rate sensors.
2. Path planning to allow navigation within the MRS.
3. Alteration of behavior under abnormal conditions.

A robot that can interpret data to recognize false alarms can be configured using an artificial intelligence Expert System. For instance, human knowledge about the probable failure modes for cask storage could be used in an expert system to guide the robot's actions. The radiation leaks associated with misplaced auxiliary shielding, loss of liquid shielding and gaseous leaks all demand different behavior in performing a dose rate survey. This type of knowledge is taken for granted by human experts but is difficult to implement with conventional programming methods. Expert Systems were developed as a means of representing such knowledge so that a computer could "reason".

Two kinds of Expert Systems that can use knowledge of nuclear physics are rule-based systems and causal model systems. Rule-based systems store their knowledge in the form of "IF (CONDITION) THEN (ACTION)" statements which a computer can apply to data from its sensors to determine the optimum course of action.[1] Causal model systems store knowledge in the form of cause-and-effect networks that represent the actual physical processes that govern the world-view that the robot must work in.[2,3]

Data interpretation is enhanced by operating the robot in two modes: Patrol mode, in which the robot follows a preplanned survey route through the MRS, and Seek mode, activated when higher than normal dose rates are encountered during the patrol. Interpretation of dose rate data and robot position by the Expert System is used by the robot in its planning process and also results in a dose rate map that will assist Health Physics personnel in their assessment of an off-normal situation. A form of path planning could be applied to construct a surveillance plan for the local area (Fig. 2), based on information from the vision sensors and knowledge about the radioactive material storage method.

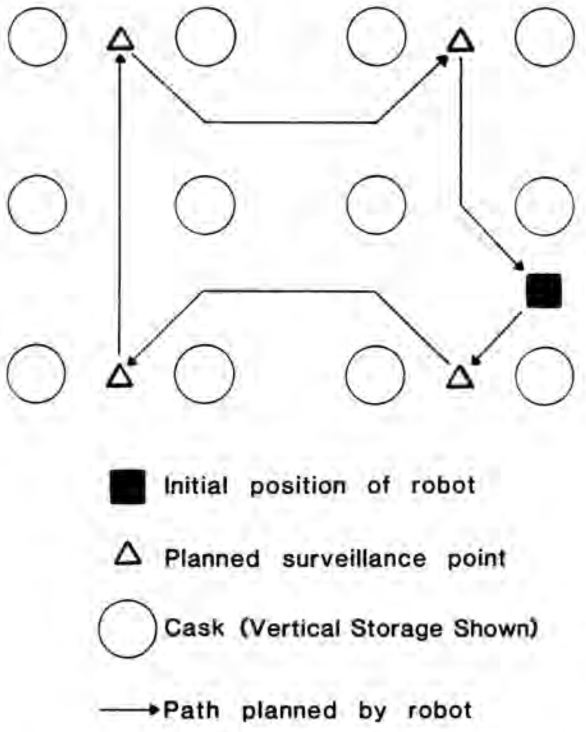

Fig. 2. Path Planning for Surveillance.

The value of potential dose reduction for maintenance tasks is more difficult to estimate since it depends on the duration and frequency of such tasks. For example, assuming a mean-time-between-failures (MTBF) of 10,000 hours, an array of 100 storage casks would require 90 sensor replacements per year. If it takes five minutes to replace a sensor, and the dose rate is over 1 rem/hr, the expected dose rate reduction would be at lease 7 man-rem/yr, or $7,000 for this maintenance task. Such maintenance operations would likely be performed by teleoperated robots under human direction.

The use of robots to repair casks within an array damaged by storms would result in substantial dose reductions because robotic systems could be used for preliminary damage assessment and to remove debris and emplace temporary shields within a planned work area. Robotic welding to reseal a leaking cask and robotic application of shielding materials where the cask shielding has been compromised could return the cask array to a semblance of normal operation before human presence is required. Mobility of a robot within an array cluttered with debris is more difficult than it would be for a maintenance robot, but tracked robots and legged robots have already been designed. Intelligent robots that can recognize objects and plan their movements via Expert Systems already exist,[4] and their added flexibility could be very useful in off-normal operations. A more sophisticated form of path-planning is required in this scenario because of the need to adjust the robot's behavior when a pre-planned path is blocked. An intelligent robot can automatically adjust to such conditions because it considers obstacles as part of the environment (as shown in Fig. 3).

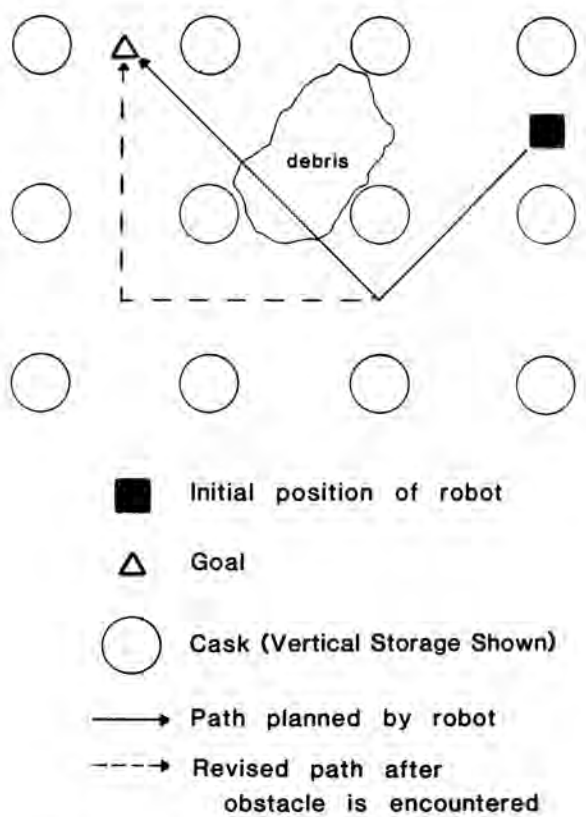

Fig. 3. Adaptive Path Planning.

The considerations discussed above indicate that remote operations in an MRS offer substantial dose reductions and associated cost savings. Robots could perform patrols and dose rate surveys without human attention by the use of artificial intelligence Expert Systems in the control computer. The required mobility and dexterity in robotic hardware already exist, and the advanced computer systems needed are being proven in current R&D programs.

References

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