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Title: **INTEGRATED MONITORING AND REVIEWING SYSTEMS FOR THE ROKKASHO SPENT FUEL RECEIPT AND STORAGE FACILITY**

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INTEGRATED MONITORING AND REVIEWING SYSTEMS FOR THE ROKKASHO SPENT FUEL RECEIPT AND STORAGE FACILITY

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Integrated Monitoring and Reviewing Systems for the Rokkasho Spent Fuel Receipt and Storage Facility

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Abstract

The Rokkasho Spent Fuel Receipt and Storage (RSFS) Facility at the Rokkasho Reprocessing Plant (RRP) in Japan is expected to begin operations in 1998. Effective safeguarding by International Atomic Energy Agency (IAEA) and Japan Atomic Energy Bureau (JAEB) inspectors requires monitoring the time of transfer, direction of movement, and number of spent fuel assemblies transferred. At peak throughput, up to 1000 spent fuel assemblies will be accepted by the facility in a 90-day period. In order for the safeguards inspector to efficiently review the resulting large amounts of inspection information, an unattended monitoring system was developed that integrates containment and surveillance (C/S) video with radiation monitors. This allows for an integrated review of the facility's radiation data, C/S video, and operator declaration data.

This paper presents an outline of the integrated unattended monitoring hardware and associated data reviewing software. The hardware consists of a multicamera optical surveillance (MOS) system, radiation monitoring gamma-ray and neutron detector (GRAND) electronics, and an intelligent local operating network (ILON). The ILON was used for time synchronization and MOS video triggers. The new software consists of a suite of tools, each one specific to a single data type: radiation data, surveillance video, and operator declarations. Each tool can be used in a stand-alone mode as a separate application or configured to communicate and match time-synchronized data with any of the other tools. A data summary and comparison application (Integrated Review System [IRS]) coordinates the use of all of the data-specific review tools under a single-user interface. It therefore automates and simplifies the importation of data and the data-specific analyses.

INTRODUCTION

The large-scale Rokkasho Spent Fuel Receipt and Storage (RSFS) Facility at the Japan Nuclear Fuel Ltd. (JNFL) Rokkasho Reprocessing Plant (RRP) will be commissioned in 1998. Effective application of safeguards at this facility by the International Atomic Energy Agency (IAEA) and Japan Atomic Energy Bureau (JAEB) requires unattended verification of spent fuel receipts, unloading, and storage. An integrated verification system consisting of networked radiation monitors and surveillance systems was designed, constructed, tested, and installed.

At peak throughput, up to 1000 spent fuel assemblies (SFAs) will be accepted by the facility in a 90-day period. In order for the safeguards inspector to efficiently review the resulting large amounts of inspection information, a new set of integrated data reviewing tools has been developed. This new system, the Integrated Review System (IRS), was developed through a cooperative effort between

the Nuclear Material Control Center (NMCC) of Japan, JAEB, JNFL, Los Alamos National Laboratory (Los Alamos), and the IAEA.

FACILITY DESCRIPTION

The RSFS[1] consists of two parallel-fuel unloading pits and three storage pools as shown in Fig. 1. During fuel receipt operations, approximately one cask will be received per day or approximately 1000 fuel assemblies in a three-month period. After preparation for unloading, a loaded cask is submerged into a fuel unloading pit on one of the two parallel lines. Each SFA is unloaded one-at-a-time by a fuel-handling machine and placed into a temporary storage pit by passage through a narrow canal. The unloading operation is observed by the two multicamera optical surveillance (MOS) systems and the passage through the narrow canal is monitored by the Integrated Spent Fuel Assembly Verification and Containment/Surveillance System (ISFVS). The SFA is then transferred to the entrance of a storage pool by an underwater cart through a fuel transfer canal. The SFA is then loaded into its allocated position in the rack by a fuel-handling machine where it is stored awaiting future reprocessing in the RRP. The total capacity of the three pools (for boiling-water reactor [BWR], pressurized water reactor [PWR], and mixed BWR/PWR assemblies) is about 3,000 tons or 12,000 assemblies.

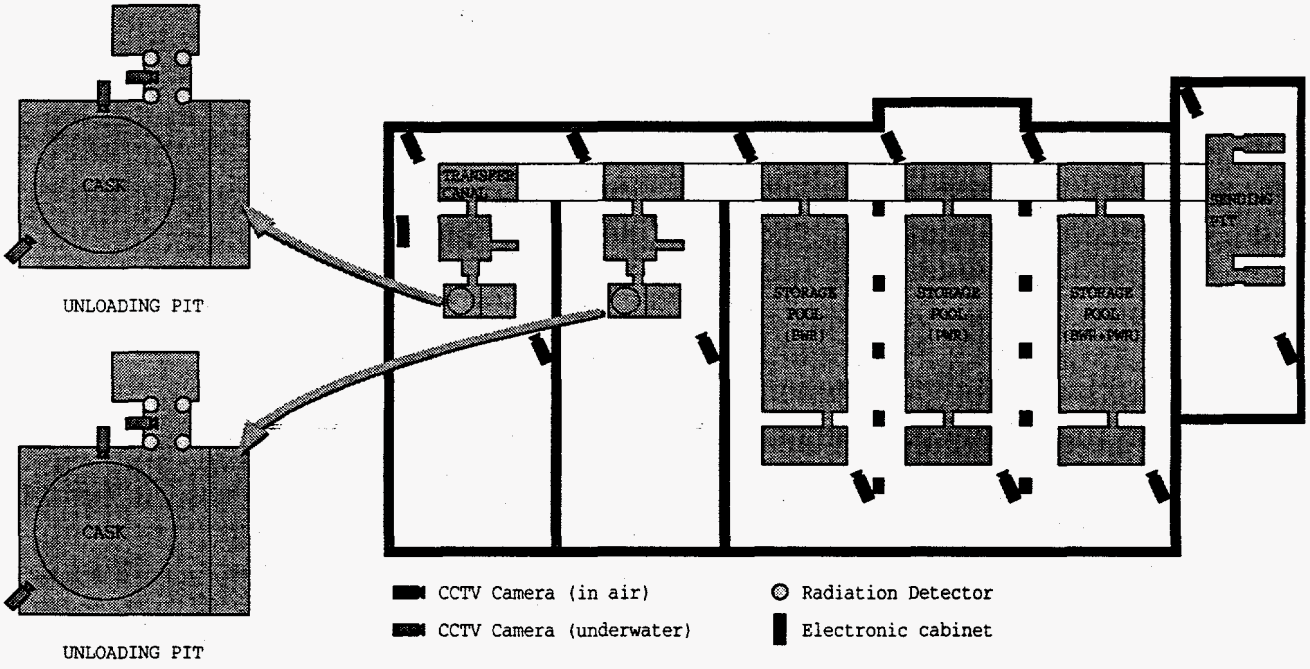

Fig. 1. Overview of the RSFS Facility.

INTEGRATED SPENT FUEL ASSEMBLY VERIFICATION AND CONTAINMENT/SURVEILLANCE SYSTEM

The ISFVS is composed of a MOS system, a radiation monitoring system, and a review station consisting of the video review (MORE) system and IRS software. The radiation monitoring system

provides a trigger signal to the MOS system when a SFA passes through the narrow canal. This trigger causes the MOS system to record images with an underwater camera of the SFA and the passage. All components are time synchronized to the master clock in the MOS system. The time synchronization and trigger signals are transferred through an intelligent network. The layout of the safeguards sensors is illustrated in Fig. 1, and a schematic representation of the system is shown in Fig. 2.

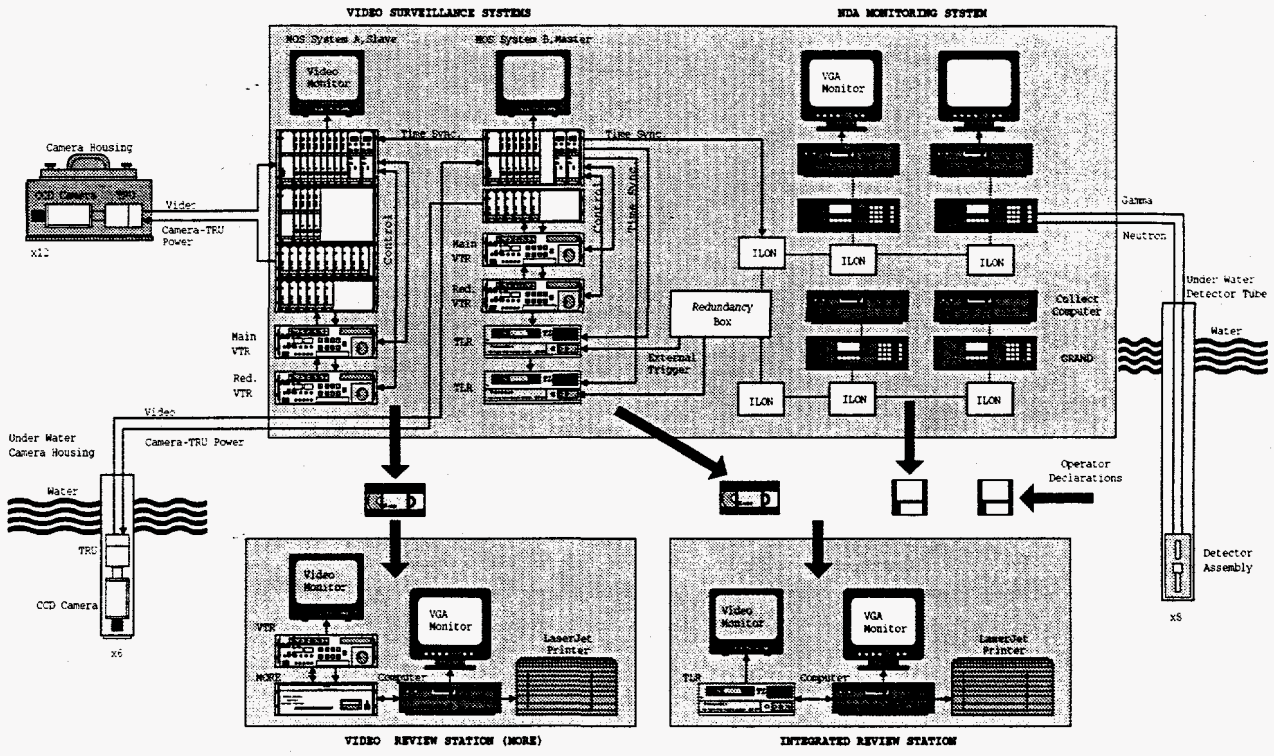

Fig. 2. Schematic diagram of the ISFVS.

Optical Surveillance (MOS) System

Twelve area surveillance cameras and six underwater cameras are connected to two MOS[2] systems. Two cameras with overlapping views always cover an objective area from opposite sides of each surveillance area. Two underwater surveillance cameras are located in each cask-unloading pit and one underwater camera is located in each narrow transfer canal. The surveillance camera located in the canal is for surveillance of the SFA transfer and radiation detector tubes. This camera records scenes of the SFA transfer in coordination with the radiation monitoring system.

The following modifications to the MOS system were made for integration with the radiation monitoring system:

- The recording capacity was increased from 200,000 to 340,000 scenes.

- Software modifications were made to allow the MOS clock to time synchronize the radiation monitor and the time-lapse recorders (TLRs) through a serial connection. The clocks of all ISFVS components are adjusted once per day.

- Two TLRs were added for triggering by the radiation monitoring system.

Almost all surveillance data are recorded by two redundant Video Cassette Recorders (VCRs) with a fixed time interval. In addition, the video from two underwater canal cameras are recorded by TLRs. Time-lapse video is recorded at a high rate (five frames per second) when triggered by the radiation monitoring system and at a periodic rate (one frame per three minutes) when not triggered by the radiation monitoring system. The TLRs encode the date, time, and alarm number (trigger number) on the video tape which allows the video reviewing software to quickly retrieve a specific video frame.

The video surveillance data are primarily collected at a fixed time interval by the MOS system. It is reviewed away from the pool by a MORE^3 system at a separate review station. The MORE system is the primary method to review surveillance video throughout the RSFS.

The additional surveillance video which is recorded by the TLRs and triggered by the radiation monitoring system was added to supplement the MOS and MORE systems. The TLRs provide a guaranteed recording of the SFAs as they pass the detector assemblies. The resulting two video systems and therefore two sets of video data are separately reviewed.

Radiation Monitoring System

The radiation monitoring system is comprised of eight detector assemblies inside water-tight tubes attached to the two narrow transfer canals. Each detector assembly consists of a gamma detector (high-pressure Xenon ion chamber), a neutron detector (4 atm. ^{3}He detector), a pre-amplifier, and shielding. A photograph of the top of the detector tubes taken during system installation in March 1997 is shown in Fig. 3. The design of the water-tight tubes permits application of IAEA and JAEB seals for integrity assurance. Two detector assemblies are located along each side of the canal. This provides redundancy for improved system reliability and facilitates the detection of the SFA direction of movement (into the temporary storage pit or returning from the temporary storage pit back to the unloading pit).

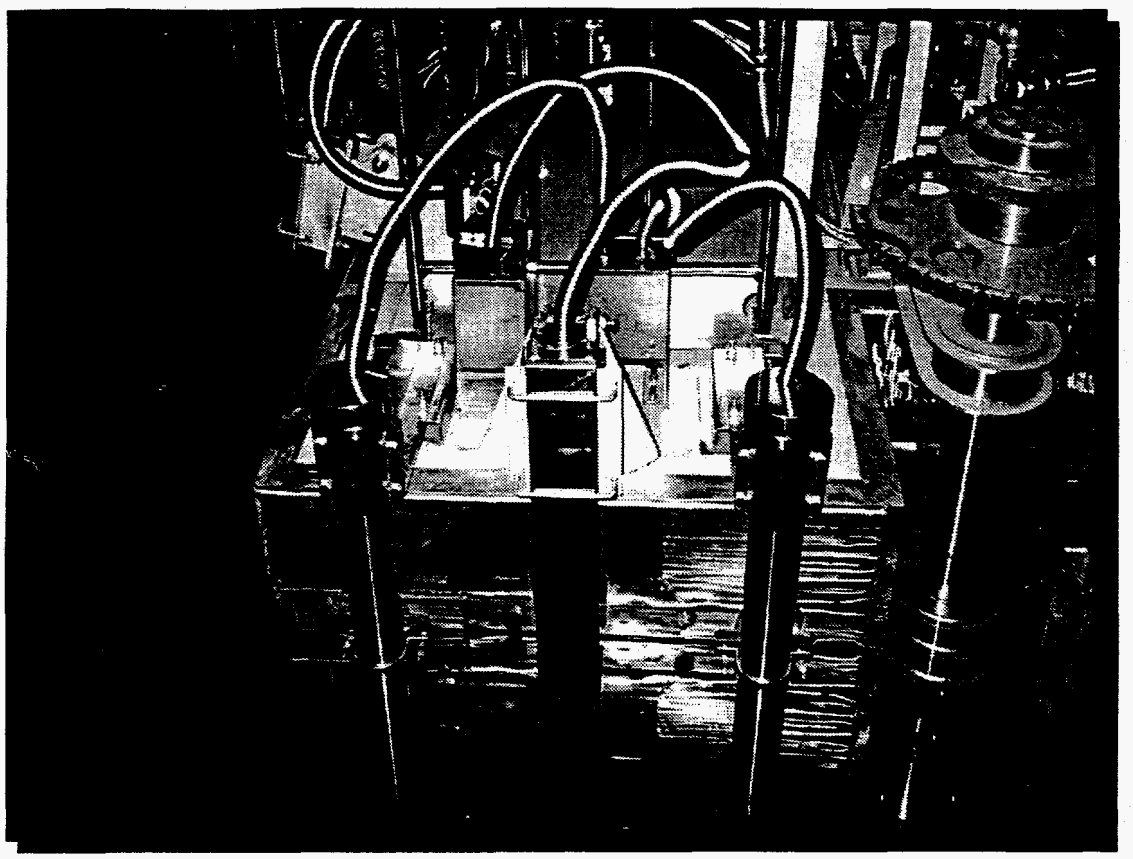

Fig. 3. The top of the detector tubes (March 1997).

The electronics for the radiation monitor consists of four gamma-ray and neutron detector (GRAND) units configured with dual ion chamber boards and triple neutron counter boards. The input circuit to the neutron counter boards was modified to improve performance for the very long cable runs (~140 m) needed in the facility. Each GRAND runs GRAND monitor firmware which was modified to provide time-synchronization capabilities. Data collection computers running GRAND Collect software connect to each GRAND unit. The GRAND Collect software was also modified for time synchronization. The electronics are configured such that failure of any component is compensated by redundant components. This therefore minimizes the risk of total data loss.

When the signal level in any of the detectors exceeds a threshold value, a trigger signal is sent to the MOS system through an intelligent local operating network (ILON). Each ILON module contains a microprocessor with logic embedded in the firmware to issue triggers. Each ILON module can limit the length of time of the triggers to prevent any failures or static radiation sources from using up the TLR videotape. The ILON also is used to transfer the time-synchronization signals between all of the components.

Integrated Review System

Significant enhancements to the past data reviewing capabilities were required to efficiently review the large amounts of data collected during an inspection period. The ability to review

multiple types of data at a high level and in a quick and easily understandable manner was needed. A new set of software tools was developed to efficiently integrate the review of the radiation data, operator declarations, and triggered TLR video. This new set of software review tools is called the IRS.

The IRS consists of multiple-data reviewing tools designed with common qualities:

- Each review tool reviews a single type of data.
- Each review tool can be used in a stand-alone mode as a separate application.
- Each review tool can be configured together with any of the other review tools to act as a single application for a complete inspection solution.

The IRS consists of several applications. A brief description of the applications used within the RSFS follows.

Detailed Review Tools–All review tools contain a common high layer of communication which allows each tool to match time-synchronized data within another review tool. Listed below are the detailed review tools.

- **Radiation Review (RAD)**: This tool reviews radiation data. It expands on the first generation of radiation review programs. Some of its features include importing the radiation data from multiple instruments into a single database, checking the imported data for integrity (missing data, out of order data, data acquired when there was no AC power, etc.), using one of three algorithms to search data channels for radiation events (peaks), determining the direction of radiation motion (using peak offsets), and graphically displaying channels of data. Currently these features are implemented for GRAND and shift register data, but all radiation types will be covered by this single program.
- **Operator Review (OP):** This tool reviews facility declarations. It converts facility-specific declarations into a facility-independent format and displays them within a table. The user can highlight and label declarations within the table. The software design separates the facility-specific conversion process from the main application in order to allow different facilities to integrate the same OP interface into their existing software.
- **TLR Review (TLR):** This tool reviews analog images recorded by a TLR. Normally images are taken periodically until an external trigger (possibly from radiation detection) causes images to be recorded at a faster rate. During the video import process, the analog tape is scanned and a list of the externally triggered events is created. The interface provides video reviewing capabilities similar to a VCR (play, pause, stop, fast forward, rewind, etc.). In addition, it provides the ability to quickly position the analog tape at any of the externally triggered events. The process of locating an event very quickly is accomplished through an algorithm which predicts the required time to fast forward or rewind to reach the destination frame.

Higher Level Review - The IRS software provides a higher level of integration than the detailed review tools. Instead of providing a single interface to a single data type, it provides

a way to import, view, and/or compare the more important summary information from multiple data types.

- **Integrated Review** - This application provides a common starting, importing, comparison, and interaction interface for all of the detailed review tools. Including this tool as part of the review software allows all of the detailed review tools to be perceived as a single, integrated data-reviewing application. This greatly simplifies the software for the user. For a typical application, IRS reviews summary data from the other more specific data-reviewing tools. Normally, the review begins by IRS automatically importing all data through the other detailed review tools. A user-configurable set of summary data from the import processes is then displayed within a table. IRS's most noteworthy strengths are its ability to compare this summary data and report the results (Fig. 4). The comparison algorithm is data unique and is completely user configurable. It also reports partial matches within the data and resynchronizes the comparison process to account for noisy data. The results are indicated in the summary table by both color and text (R = Reconciled, P = Partially reconciled, U = Unreconciled). The inspector then has the ability to display subsets of the summary data, review the summary data in detail through the other detailed review tools, manually reconcile data, highlight data, enter comments, and print the table.

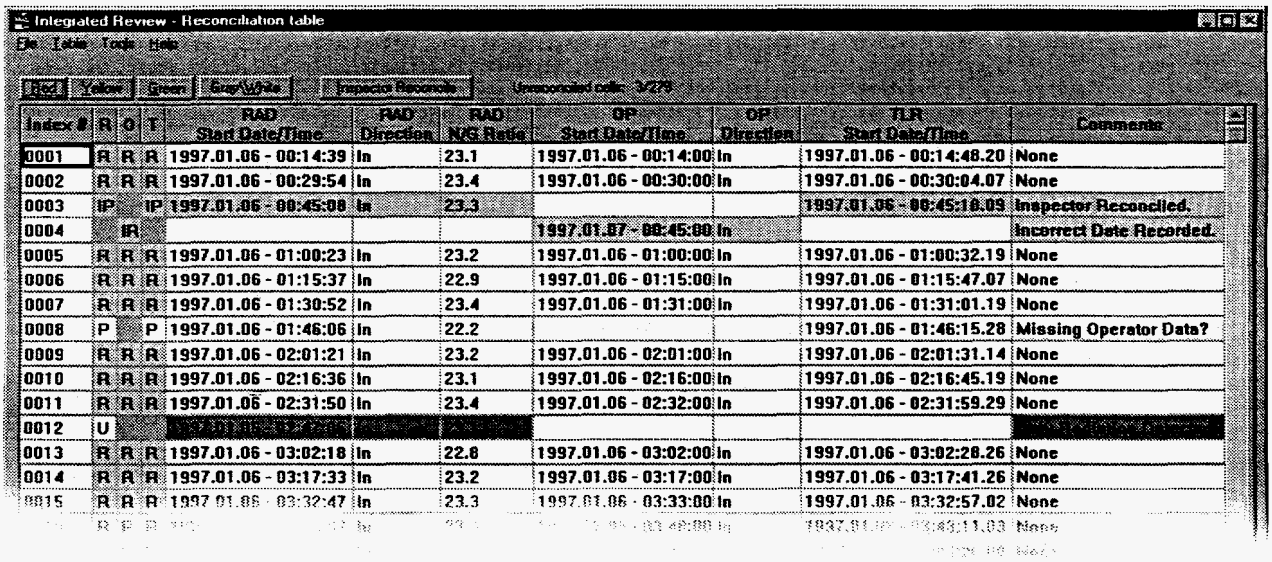

Fig. 4. Reconciliation Table–IRS comparison results reported in the summary table.

Within the RSFS, IRS is configured to compare radiation (RAD) data, operator (OP) data, and TLR data (as can be seen in Fig. 4). Date and time comparison against a configurable uncertainty compares the time at which radiation was detected, the time at which the operator declared the movement of a SFA, and the time at which video was recorded. In addition, the operator-declared SFA direction of movement is compared against the Radiation Review-determined SFA direction of movement (determined by peak offsets between separated detectors). Both of these conditions must be met in order for IRS to report a row of data to be reconciled.

A noteworthy strength provided within each review tool is the ability to automatically match and display different types of time-synchronized data between the different review tools. The user needs to simply select data within the review tool and then select the destination review tool name. For example, to display matching Radiation Review data from IRS, the user would select a cell within the IRS summary table and then select Radiation Review from its menu. Radiation Review will then automatically display its graph with the matching data highlighted. This process can be used to display data between any two review tools and to investigate in detail any data type within the IRS summary table (including the miss-matched data reported by the comparison algorithm). Figure 5 illustrates the data-matching process and interaction between four different review tools.

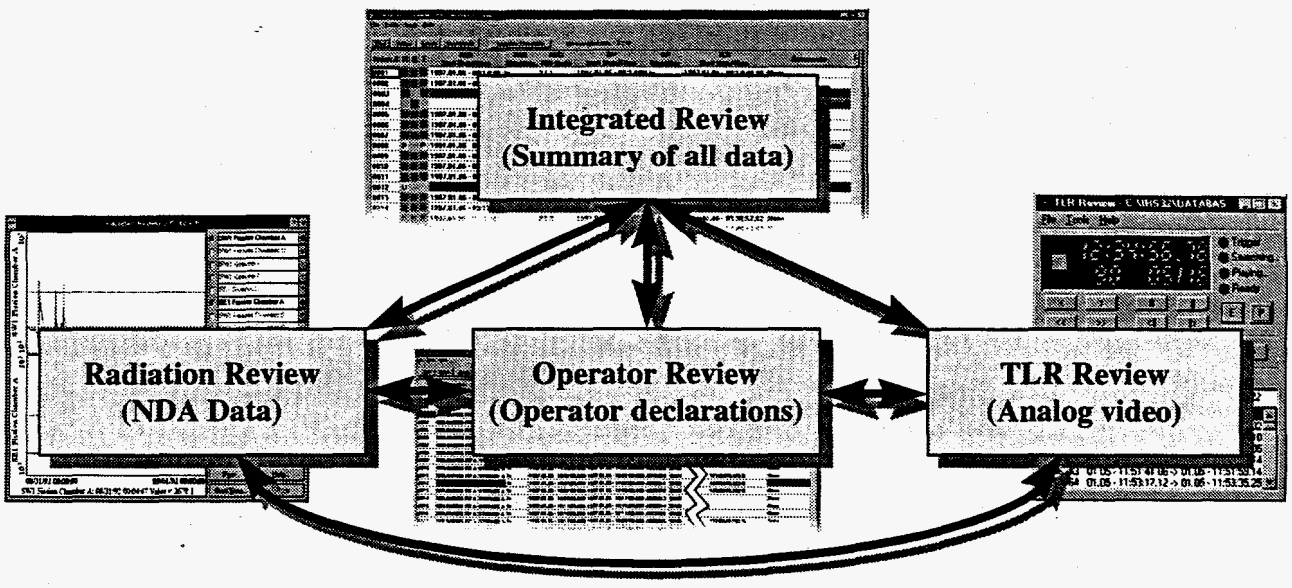

Fig. 5. Matching Data–This diagram displays four review tools configured with IRS as the inspection focus and using detailed data from Radiation Review, Operator Review, and TLR review. The arrows illustrate how messages can be sent between review tools to display matching data.

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