REMOTE AND UNATTENDED MONITORING TECHNIQUES

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INTRODUCTION

During the last decade there has been a tremendous increase in the number of unattended verification and monitoring systems. The use of these systems for verification and monitoring of nuclear materials have resulted in a marked increase in verification coverage and at the same time reduced on-site safeguards inspections. The systems operate in unattended mode and are based on combined surveillance and non-destructive assay techniques. They can be used to verify and to monitor nuclear material inventory in unattended mode. In addition they can verify flow of nuclear materials within a facility and transfer of materials between facilities. The advantages include:

- Reduced inspection efforts
- Reduced radiation exposure of inspectors
- Reduced level of intrusiveness to the operation of the nuclear facility.

Today, the unattended assay and monitoring technique is considered the most advantageous way to implement safeguards at complex nuclear facilities, especially in automated (remote operated) plants. The design of these unattended systems is mainly based on modular hardware and software. With this technology, the flexibility for accommodating a variety of applications was designed into the basic system architecture.

The technology for transmitting a wide variety of data to off-site locations, generally known as remote monitoring, is in widespread industrial use throughout the world. The Agency initiated research and development in the field of remote transfer of safeguards data with the initiation of the RECOVER project in the last decade. At present, the technology to transfer the collected data from the unattended systems to IAEA offices does not present a challenge; however, arrangements and infrastructure for data collection, transmission and evaluation can be time consuming.

As part of the developments for a Strengthened Safeguards System, a variety of advanced unattended systems for remote monitoring and transmission by telephone lines or satellite have been studied and approaches and instruments for each application have been developed or adapted. The instruments used in these systems include:

- Digital surveillance cameras
- Electronic seals
- Radiation monitors and sensors.

UNATTENDED VERIFICATION AND MONITORING SYSTEMS

The unattended verification and monitoring systems are based on radiation or other types of sensors combined with surveillance devices. Since the designs incorporate redundant (back up) and robust elements, the reliability of the systems are very high and the Mean Time Between Failure (MTBF) depending on the type of the system can be up to 10 years. The degree of the necessary redundancy is based on the reliability of the individual components. The analysis of individual components failures has enabled the IAEA to determine the weak links in each system and corrective measures have been taken and incorporated in the designs to extend the MTBF periods.

Surveillance is normally an integral part of each monitoring system. The systems used in the past by IAEA were based on analogue technology and could not be fully integrated with unattended verification and monitoring systems. To take advantage of the emerging developments a programme of transition to digital video was implemented in the Department of Safeguards and the following three developed systems were identified for field-testing and application in the field:

- GEMINI system developed by the Aquila Technologies in USA,
- EMOSS developed by Hymatom in France for wide commercial applications and
- VDIS system developed by the Dr. Neumann Company in Germany.

The systems are based on modular design and can provide image processing, authentication [1], encryption, storage and remote transmission. The first two systems accommodate two independent data recording modules and all systems can have the capability for remote transfer of State-of-Health and surveillance data. The future challenge will be the full integration of the surveillance systems with the installed unattended assay and monitoring system.

[1] Authentication is a system or technique which determines that genuine information is transferred by an authorized source (e.g. sensor, camera or other device) within a specified time and that the information has not been altered, removed or substituted.

The unattended assay and monitoring systems can be grouped into the following three categories:

Gamma and Neutron Monitors

Several unattended monitoring systems based on the gross gamma and neutron counting techniques have been installed within the last two decades. Examples are:

- CANDU bundle counter and core discharge monitor developed by the Canadian Support programme to the Agency for CANDU reactors,
- CONSULA system developed in France for monitoring the unloading of spent fuel; and
- Unattended monitoring systems installed in plutonium fueled reactors and on-load reactors based on GRAND electronics developed in USA.

At present about 50 units are installed in the field. All of these systems are based on installation of gamma and/or neutron detectors on the fuel transfers paths, connected to an electronics cabinet containing redundant data collection and computer storage devices. Software has been developed for data collection, retrieval and evaluation. These systems are equipped with Uninterruptible Power Supplies (UPS) to ensure increased reliability of the system in case of power failure. The authentication is ensured by application of containment measures on the detectors, electronics cabinet, applied software and monitoring of the signal cables for possible tampering.

High Level Neutron Coincidence Counters

The High Level Neutron Coincidence Counting (HLNC) technique has been the main method used by the Agency for verification of plutonium bearing materials. The application of unattended assay and monitoring systems based on high level coincidence technique was introduced in 1988 and was considered a major advancement for reduction of inspection effort and improved safeguards coverage. These unattended assay and monitoring systems have provided an improved performance on the level of verification without presence of the inspectors.

Some of the installed unattended assay and monitoring units enable unattended verification of the inventory. This is realized by unattended annunciation of randomly selected items to the facility operator using special computer software and procedures for authenticating data in unattended mode without the presence of IAEA inspectors. The installed systems also enable unattended verification of material flow within the facility for example between the process and the storage area. In addition, transfers of plutonium bulk materials between facilities are verified in unattended mode and continuity of knowledge is maintained on the transfers of bulk plutonium by the correlation of measurement results (the

Totals and Coincidence Neutrons count rates) between different systems.

At present more than 15 unattended high-level neutron coincidence neutron assay and monitoring units are in routine use. The basic design consists of:

- A neutron detector for the specific application,
- Electronics cabinet with redundant Shift Register electronics,
- Computers for unattended periodic collection of data during the entire inspection period; and
- Appropriate software to collect data, enable data retrieval by inspectors and review software to analyze the data and provide the final evaluations.

The authentication of the systems was an intrinsic part of the design of each system. The successfully implemented measures are as follow:

- Application of containment measures on the detectors;
- Application of procedures for detection of any tampering with operation of the system by periodic testing of the detector efficiency.
- Application of containment measures to the electronics cabinet containing the electronic signal processors and data collection computers;
- Authentication of the signal cables by continuous monitoring of the signals;
- Maintaining continuity of knowledge on the software for collection of data, review and analysis of the data.

OTHER MONITORING SYSTEMS

Other unattended assay and monitoring systems based on similar principles has also been considered by the Agency. Examples for the design of such systems are presented below.

Solution Monitoring Systems

The application of solution monitoring techniques for continuous monitoring of tank volume and density at conversion and reprocessing facilities has been initiated by the Agency. These systems are based on sensors introduced inside the tanks containing plutonium or high enriched uranium solutions and which are connected to electronic devices to process the signals and computers for collection and storage of data. The data are collected every a few seconds and data can be filtered to enable analysis by the inspectors. The authentication is ensured by application of containment measures on the electronics cabinet containing electronic devices and data collection computers operated with authenticated software.

179

Thermo-Hydraulic Reactor Power Monitor

Another example for unattended monitoring system, which is considered for installation, is the Thermo-Hydraulic Reactor Power Monitor for monitoring the reactor power of large research reactors. The system is based on ultrasonic technique for measurement of flow combined with temperature measurement of the inlet and outlet of the reactor coolant pipes. The ultrasonic sensors are housed inside a tamper proof containment and sealed by the inspectors. The electronic signal processors and the data collection computers are housed also in tamper proof housing which is sealed with a metal seal by the inspectors. The instrument is computer- controlled and collected data can be stored for several months. Two systems were installed in 1997.

Vibration and Motion Sensors

The vibration sensors considered for field application are based on detection of vibrations or changes in the electromagnetic fields. The sensors connected with electronic signal processor and computer to store the collected data can enable detection of tampering the containment, removal of items or operation of specific machines. Several systems were installed for maintaining continuity of knowledge in 1997.

REMOTE MONITORING TECHNIQUES

The use of Non-Destructive Assay (NDA) and Containment-Surveillance (C/S) equipment operating in an unattended mode, particularly coupled with an additional capability for remote interrogation and/or transmission, offers the possibility of reductions in the number and duration of inspections. As a step towards the objective of reducing further the inspection costs while improving safeguards efficiency, the implementation of the existing technology for the remote monitoring, through telephone line or satellite communications, of safeguards information in a facility located any where in the world has been initiated by the Safeguards Department.

The remote monitoring systems currently being considered are based on digital surveillance, radiation assay and monitors, sensors and seals data collection and transfer. The communication system can be independent of the monitoring system. Each system has sufficient internal data storage and battery power, allowing the system to store images and data for several days. This will ensure the transfer of all collected data in the event of loss of network connection and/or facility power failure.

Remote monitoring offers the possibility of replacing on-site inspection activities which involve unattended assay and monitoring systems with data collection, review and evaluation at a remote location, in essentially real time. In this context, remote monitoring does not offer any new information on which safeguards conclusions may be drawn, but rather impacts the timeliness goal attainment through more frequent data review and evaluation, and the comprehensiveness, with which existing data can be evaluated to draw conclusions. The use of Remote Monitoring System is anticipated to be in connection with a reduced number of inspections, either announced or unannounced. An unannounced inspection would mean that the State and the operator would be informed of the Agency's intention to perform such an inspection only when the IAEA inspector arrives at the entrance to the facility or shortly before. Unannounced inspections have the potential to reduce inspection frequencies significantly when applied randomly on large group of similar facilities.

It is possible to remotely monitor several types of data. Those being tested in the field are as follows:

Transmission of Equipment State-of-Health

This is a simple YES or NO to indicate any failure of a specific system component or to report a suspected tampering leading to system failure. In the case of a system failure the Agency is able to react in a more timely and comprehensive manner. The next inspection can be planned to correct the situation in time. In addition, necessary advanced arrangements can be made to repair any defective equipment. The net result should be an improvement in timeliness goal attainment. The "State-of-Health" data regarding system operation and its environment is provided to monitor equipment performance and mal-functions. The systems provide near-real-time information, depending on how images and data acquisitions are set up.

Transmission of Summary Data

These data could include the number of events recorded by the remote monitoring system, e.g. the number spent fuel assemblies passing a detector, the number of triggered video recordings, number of seals attached, etc. The transmission of the summary data provides valuable information for preparation of inspection activities and scheduling.

Transmission of Detailed Data

The transmission of detailed data from individual devices provides information which can be reconciled with the operator's declaration for deriving safeguards conclusions. In addition to the State-of-Health and Summary Data, these data could include digital pictures, electronics seals (VACOSS) or sensor status reports, NDA or other measurement results. These data allow the early detection of discrepancies or anomalies or of inconclusive results, which may then be addressed and resolved in a timely manner.

DEVELOPMENT OF INSTRUMENTS AND PROCEDURES FOR REMOTE MONITORING

As noted in the introduction to this presentation, the Agency has been involved in many feasibility and field test trials designed to help evaluate and implement remote monitoring. The objective was to test the concept of remote monitoring via satellite and telephone links in real safeguards situations. These experiments and field trials provided a solid basis simultaneously to establish safeguards approaches and criteria for various types of facilities where remote monitoring is to be implemented. Priority was given to material stores and nuclear power plants. A special Remote Monitoring Project was established in October 1996 in the Department of Safeguards to prepare, through testing and planning, for implementation of remote monitoring from1998. Since establishing an infra structure for data collection, transmission, distribution, evaluation and storage was essential, extensive efforts have been made to define the needs, design a system and acquire the necessary hardware and software. To achieve data integrity and security, the provision of credible authentication and encryption of safeguards data was incorporated in the design of the system. Data transmission based on Public Switch Telephone Network (PSTN), Integrated Service Data Network (ISDN) and Very Small Aperture Terminal Satellite (VSAT) were evaluated as part of the field trials for determining their respective performance, availability and reliability and to compare installation and operational costs.

In addition to the following demonstrations and field trials, installation of remote monitoring equipment is foreseen in Sweden, Argentina and Germany in 1998:

International Remote Monitoring Project

The International Remote Monitoring Project (IRMP) was coordinated by Sandia National Laboratories, USA. The IRMP field trials began in early 1994. The countries and organizations involved were Australia, Sweden, United States, Japan, Argentina, Germany, Finland, South Korea and EURATOM (ISPRA). In 1995, the IAEA became involved in IRMP by inviting participants to establish bilateral arrangements with the IAEA. These field trials were mainly based on transmission of radiation, motion, temperature and video monitoring data via telephone links, Internet and satellite. Subsequently, the Agency established tasks with USA, Argentina, Finland and United Kingdom under the respective support programs to the IAEA safeguards.

Field Trials in Switzerland

Installation of equipment at the Paul Scherrer Institute (PSI) Proteus vault in Switzerland began in December 1995. Two digital surveillance systems and an electronic seal were installed for transmission of data through a satellite link and ISDN to Vienna. The location under field test was a vault containing a semi-static store of direct use material. A variety of query and transmission strategies were evaluated. According to the cost comparison study made for Switzerland, the implementation of remote monitoring using the available equipment and procedures will result in significant decrease in inspection costs. At present, arrangements are being made to install the necessary instruments at all nuclear facilities in Switzerland within the next months.

Field Trials in South Africa

Additional field trial was conducted in South Africa and the remote monitoring systems installed at a high enriched uranium storage facility included surveillance, seals and several newly developed sensors and detectors. The installation of an ISDN is now in progress and will provide the capability to transfer all of the collected data in the near future. The installation of remote monitoring equipment at Light Water Reactors and other storage facilities is planned within this year.

Field Trials in Japan and Canada

To demonstrate the feasibility of remote monitoring and to prepare the necessary procedures and arrangements, remote-monitoring equipment was installed at two Light Water Reactors (BWR and PWR) in Japan and one Candu reactor in Canada. At present, safeguards data are being collected remotely and evaluated by inspectors at the IAEA Regional Offices. It is expected that upon successful results and the necessary arrangements, wide implementation of remote monitoring technology will commence at LWRs and Candu reactors in the near future.

SUMMARY

In the last years, there has been a tremendous growth in the number of unattended assay and monitoring systems in the field. These systems have enabled reduced presence of inspectors while increasing the verification coverage. As part of the Strengthen Safeguards System and in particular as part of the measures to improve the cost-effectiveness of safeguards, the possibility of remote transfer of authenticated and encrypted video surveillance, seals and radiation sensor data via telephone or special satellite links have been demonstrated and the necessary arrangements and infrastructure have been prepared. The evaluation of field trials of the remote monitoring systems have shown that the systems are effective in monitoring events of safeguards relevance in near-real-times. The systems are competitive from a cost standpoint when compared to current methods. The reduction of inspection efforts can be realized by application of remote monitoring technique with scheduled inspections and more effectively with the short notice or unannounced random inspections. It is expected that, upon completion of the necessary arrangements with the Member States authorities, the Safeguards Department will implement the technique widely before the year 2000.