

STRENGTHENING OF SAFEGUARDS - REMOTE MONITORING IN SOUTH AFRICA

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Abstract

South Africa voluntarily removed its nuclear capability before acceding to the Non-Proliferation Treaty (NPT) in 1991. The Safeguards Agreement between South Africa and the IAEA (INFCIRC/394) was signed in 1991 and the Convention on Physical Protection (INFCIRC/225) was signed in 1981. Following the 37th Regular Session of the General Conference of the IAEA in 1993, South Africa informed the Director General by letter, dated 20 December 1993, of its preparedness to consider proposals from the IAEA on the further strengthening of Safeguards for High Enriched Uranium (HEU). This was intended to provide additional confidence building measures and enhance transparency. Remote Monitoring (RM) as a Safeguards tool was being actively developed and tested on an international level during this time.

Clearance to build an RM system in South Africa was obtained in August 1996. User specifications and technical specifications were drawn up and co-operation established between Sandia National Laboratory (SNL), Aquila Technology Group (ATG), US Department of Energy (DoE), IAEA and the South African National Safeguards Authority, which until February 2000 was the Atomic Energy Corporation of South Africa Ltd (AEC) and since March 2000 it was delegated to the South African Nuclear Energy Corporation Limited (NECSA). Equipment was procured from items available on the industrial market. Installation was completed during April 1997 and a testing phase was started. An extension of the Remote Monitoring System (RMS) to Koeberg Nuclear Power Station (2 Pressurized Water Reactor (PWR) units) and the Thabana pipe store (Safari Reactor spent fuel storage) was accepted by NECSA. Data transmission (encryption, transmission line, electronic hardware and software) problems were resolved over a period of time. Equipment related problems included neutron induced failures of the digital processing part of the camera hardware. A key success factor in resolving these technical problems with the RMS was the good communication between NECSA and IAEA technical staff and the competent and speedy reaction. This good co-operation enabled completion of the test phase, initiation of normal remote monitoring operation with IAEA review and the start of the final phase of pioneering a new safeguards approach for the facilities with RMS.

1. REMOTE MONITORING OBJECTIVES

The initial objectives for a remote monitoring system were:

- (a) To institute additional confidence building measures regarding South Africa's HEU material through continuous real time monitoring, improve openness and transparency, show commitment to safeguards agreements and demonstrate trust in order that safeguards goal attainment was assured,
- (b) To increase effectiveness and strengthen safeguards implementation,
- (c) To collect experience on the effectiveness, reliability and functionality of RMS as part of the IAEA safeguards system, and
- (d) To lower the cost of safeguards processes by reduction in the inspection effort (e.g. frequency of inspections).

Additional benefits would be that the RMS could reduce worker radiation exposure and be less intrusive on facility operations. The national output from the RMS could also be integrated into the physical protection surveillance system in order to enhance the detection capability through health or motion pictures.

2. INTERNATIONAL DEVELOPMENTS IN RMS

The US Department of Energy, through bilateral agreements with international partners, had initiated the International Remote Monitoring Project [1] by placing demonstration systems in various nuclear facilities to conduct field trials during 1994 and 1995. The RMS was tested in dry spent fuel storage facilities, light water reactor facilities and laboratories.

With experience gained from these projects, RMS is presently being field tested with the IAEA in:

- (a) Seven countries with Safeguards Agreements in force,
- (b) Nineteen facilities (five of these facilities in South Africa),
- (c) Thirty-nine camera systems (twelve of these cameras are installed in South Africa: four in the HEU storage vault, two in Thabana pipe store, two each in the two units of the Koeberg Nuclear Power Station (KNPS) and two in the Koeberg spent fuel cask storage facility).

3. RMS IN SOUTH AFRICA

3.1. Installation and Configuration

Development of the unattended RMS for timeliness purposes was initiated for field testing (with reference to the implementation of Programme 93+2), using a land based communication network between the IAEA Headquarters in Vienna and Pelindaba site in South Africa.

The RMS made use of cameras with motion detection and unattended remotely monitored sensors such as magnetic vault door switch and a network of "seismic" sensors along the walls and individual vault contact surfaces in the HEU storage vault at Pelindaba. User and technical requirements were jointly resolved between SNL, ATG, US DoE, IAEA and NECSA. The user requirements included review stations at both IAEA Headquarters in Vienna and at the Pelindaba field office, authentication of data, encryption of data, traceability through file number, date and time identification, motion and trigger events to initiate alarm signals and images and sufficient storage space at the camera and server in case of transmission failure. The present RMS configuration is given in Table 1.

TABLE 1: PRESENT RMS CONFIGURATION

IAEA/National Authority	Site	Facility	Equipment		
			Server (SDIS)	Camera (DCM-14)	External Sensors
IAEA: In field office at Pelindaba - Frame relay gateway server In Vienna: - Review Station - Archive National Authority: Review station in offices at Pelindaba	Pelindaba	HEU storage vault	1	4	Magnetic door switch Wall containment
		Thabana Pipe Store		2	Wall containment
	Koeberg	PWR Unit 1: - Spent fuel pond - Core vessel PWR Unit 2: - Spent fuel pond - Core vessel Castor spent fuel store	1	1 1 1 2	

The Pelindaba facility operator provided emergency power in the vault, access to the vault for installation and maintenance of the camera/sensor system and ad hoc access for fault diagnostic purposes. In addition, the National Safeguards Authority provided technical staff for the initial testing of RMS outside the vault and installation and operational support throughout the testing phase. The RMS was integrated with the normal safeguards processes and routine monitoring of system integrity was done by the National Authority.

The RMS was installed in facilities that were under safeguards and where all safeguards processes were operational and functioning well. The history of RMS installations, extensions to include the present five facilities and current operational status is contained in Table 2. The good co-operation, fast communication and availability of competent IAEA and NECSA technical personnel contributed greatly to the successful installation and testing phases of the RMS.

TABLE 2: TIMELINE OF RMS INSTALLATION AND OPERATIONAL STATUS

Date	History and Status
July 1991	South Africa (SA) accedes to NPT
September 1991	SA signs Comprehensive Safeguards Agreement
December 1993	SA accepts RMS field tests to strengthen safeguards
August 1996	IAEA clearance to install RMS in SA
February 1997	RMS installed with commercial server connected to 4 Gemini camera systems.
	Data transmitted using SA encryption units
1998	Commercial server replaced by prototype SDIS server with electrical/lightning protection.
	PSTN replaced by ISDN to increase data transfer speed
	RMS added to Thabana Pipe Store and connected to existing SDIS server
Late 1998	SA agrees to use IAEA encryption
Early 1999	Frame relay hub installed in IAEA field office at Pelindaba
February 1999	RM communication reliable. Occasional 1 to 3 day communication failures due to Pelindaba phone system.
	Cameras work without problems since this date except for operator outages or set-up error
Mid 1999	RMS installed in KOEBERG NPS Units 1 and 2 and Castor spent fuel store
	No communication problems since installation
	Both spent fuel pond cameras had no problems since installation
	Camera problems in core vessels and castor store:
	(a) Operator turned off lights in reactor hall
	(b) Several neutron induced failures occurred in four cameras (in reactor vessel and castor store)
2000	Cameras in castor store upgraded. Now works satisfactorily
May 2000	Camera in KOEBERG NPS unit 1 replaced
June 2000	Routine Safeguard Reviews initiated for all five facilities
February 2001	Camera in KOEBERG NPS unit 2 replaced
April 2001	All camera software in KOEBERG NPS units 1 and 2 and Pelindaba upgraded
June 2001	New IAEA Safeguards approach for discussion
July 2001	Camera in KNPS unit 2 replaced
September 2001	Camera in KNPS unit 1 replaced

3.2 Authentication

Each image is authenticated by the DCM-14 and stored on a PCMCIA card inside the camera housing (which is under IAEA seal). The images are then transferred to the hard drives of the SDIS server and ultimately (via ISDN) to the field office at Pelindaba and via frame relay to IAEA Headquarters in

Vienna. Authentication ensures the transferred images are genuine. The PCMCIA cards in the cameras are removable in event of transmission failure.

3.3 Encryption

Remotely monitored images are transferred across local lines, national telephone lines and state boundaries to the IAEA's Headquarters in Vienna. The need for encryption is both a South African and IAEA requirement. Encryption technology developed by local South African suppliers was used initially, but the slow transfer speeds of PSTN lines and the reliability of ISDN encryption units prompted a switch to IAEA approved encryption technology.

Encryption is used as follows:

- (a) Individual DCM-14 images are encrypted in each camera for the entire transfer process, and
- (b) Hardware encryption of the frame relay link is used to further protect images during transfer from the IAEA Pelindaba field offices to IAEA Headquarters in Vienna.

Plans are in progress to replace the frame relay link with virtual private network encryption over the internet. Taking advantage of this recent advance in encryption technology will lower transmission costs by an order of magnitude.

4. REVIEW OF REMOTE MONITORING

Presently, during the test phase, the IAEA and National Authority share RMS images. The primary objectives for the NECSA Safeguards Function were:

- (a) A daily check of each RMS camera to ensure that a health picture was taken. (On many occasions, this check has enabled a quick response by NECSA Safeguards staff to rectify problems with the vault camera, server or sensor system and ISDN transmission line. Because images are only relayed to Vienna once per day, NECSA Safeguards has often attended to problems before IAEA staff in Vienna became aware of them.)
- (b) A quick download and review of alarm file images soon after the triggering event to ensure that any access was authorised,
- (c) Review of specific historical events (e.g. verification of object which was moved using a crane in the spent fuel area of Koeberg Nuclear Power Station) by NECSA Safeguards in order to verify safeguards activities.

A systematic review and assessment of images will be incorporated by NECSA Safeguards once the RMS is formally approved as an additional safeguards tool.

The IAEA initiated routine Safeguards reviews of installed RM systems in all five facilities in June 2000. Formal approval for all parts of the RM system is currently underway, pending technical review.

4.1 RM timeliness requirements for Safeguards

The image intervals are set remotely by the IAEA for:

- (a) Routine health images, which range from one to sixty minutes depending on the facility (HEU storage vault, spent fuel pipe store, reactor or cask store) and the type of operation in progress (e.g. a smaller interval was used during the spent fuel re-racking activities),
- (b) Motion and alarm images, which can be set to one minute or smaller intervals to capture activities of interest in greater detail. (In fact, the camera takes a picture every few seconds, but only selected pictures are saved.)

During the testing phase of the RMS in the HEU storage vault, the following results were obtained:

- (a) According to the image time interval set by the IAEA for HEU storage vault cameras, all health pictures for the entire period could be obtained, except during period of camera maintenance by IAEA technicians,
- (b) Motion images for all authorized access to the vault were recorded for the full period of access by each relevant camera.

It can be concluded that the safeguards timeliness component (monthly verification) for the HEU storage vault could be successfully verified by the RMS for the period since June 2000.

For the Thabana pipe store a similar result was obtained. However, the timeliness component could not be attained for RMS in the two reactor units of the Koeberg Nuclear Power Station due to a neutron-induced failure, over time, of the camera digital converter components (DCM-14s).

4.2 RM as a Safeguards Tool

In mid-2000, the IAEA approved the RMS in all South African facilities for use as a complementary safeguards tool, but did not change the traditional safeguards approach.

Presently a proposal is being investigated by the IAEA to use RMS with a new Safeguards approach, which would entail the following:

- (a) Formalising data sharing between IAEA and National Authority for:
 - (i) Fixed time health images, and
 - (ii) Motion triggered images during authorised access.

These images have been shared since the start of the RMS testing phase in South Africa, but new arrangements need to be negotiated for motion triggered events during the implementation phase.

The National Authority will still not have access to image data generated:

- (iii) During power failure,
 - (iv) By tampering events, and
 - (v) By triggered events based on possible attempts to compromise the system.
- (b) Monthly evaluations of RMS surveillance at the HEU storage vault used in lieu of seal changes to satisfy timeliness requirements. Routine monthly inspections would be reduced to eight short notice inspections per year and eventually replaced by two or three short notice random inspections per year. (Note that this scheme benefits physical protection as well, since fewer vault entries are required.)
 - (c) At the Thabana pipe store, meeting timeliness requirements through RMS surveillance review and reducing inspection effort from four regular scheduled quarterly inspections to one short notice random inspection.
 - (d) At Koeberg Nuclear Power Station (Units 1 and 2) meeting the timeliness requirement with RMS surveillance and then conducting only one PIV each year and one or two semi-random, short notice interim inspections. It is considered that at the Koeberg spent fuel cask storage facility, one PIV and one short notice inspection each year would suffice with RMS surveillance.
 - (e) Reducing travel costs by scheduling interim inspections at Koeberg Nuclear Power Station just after or prior to the normal monthly inspections to Pelindaba.

The new safeguards approach, once approved by the IAEA, would be implemented as soon as possible.

5.1 Benefit to South Africa

The following benefits can be assigned to Remote Monitoring in South Africa:

- (a) A "safeguards tool" which gives a direct visual demonstration of safeguards control and builds confidence with all interested parties (International community, National Authority, Department of Minerals and Energy, NECSA Board of Directors and Top Management, etc.)
- (b) Enhancement of physical security for the HEU storage vault,
- (c) Additional source of data to assist with safeguards verification (e.g. number of racks without spent fuel assemblies passing camera at specific time and date for further operations during the reracking process in KNPS), and
- (d) Transfer of technical know how with respect to remote monitoring to state technical staff.

5.2 Benefit to IAEA

The IAEA achieved the following objectives during the Remote Monitoring project:

- (a) Field demonstration of the reliability, functionality and maintainability of RM,
- (b) Identification and resolution of technical problems encountered in an operational environment,
- (c) Development of operational experience and procedures for routine RM review and use,
- (d) Implementation of a strengthened safeguards regime in South Africa which provides additional assurance of compliance with safeguards agreements, especially on highly sensitive HEU material,
- (e) Improvement of surveillance quality and more rapid identification of surveillance failures (in fact, data from one RM unit at the Koeberg Nuclear Power Station was used in the 2000 Safeguards Implementation Report (SIR) to compensate for a MIVS failure, saving the timeliness goal for the facility),
- (f) Possible future reductions in inspection effort and associated costs.

It is worth mentioning, now that the technical problems encountered during development and testing have been mostly solved, that the current RM system provides higher quality images with greater reliability than the analog systems it has replaced. Routine review is performed on a monthly basis, and problems such as loss of lighting or power are identified and corrected within days instead of months. The system has the added benefit that the standard interval is remotely adjustable and supplemented with motion triggered images to provide greater detail during periods of interest, such as reactor refuelling or cask loading and shipment.

Improvements over traditional surveillance measures are also realised with regard to the efficiency of inspections and timeliness of follow-up actions. By reviewing surveillance prior to an inspection rather than afterwards, the inspector already knows whether the surveillance is conclusive. Thus, he or she is prepared to perform any additional verifications required by the surveillance review, avoiding follow-up visits. Additionally, the inspector is better prepared to investigate shipments, receipts, and activities such as vault entries.

Finally, RM systems eliminate the need for in field service, making inspections shorter. This is a mutual benefit for operators and inspectors. Shorter inspections are less intrusive, and radiation exposure is reduced for all involved.

5.3 Cost benefit

The cost for IAEA funded hardware, software, data transmission and all relevant labour could exceed one million US dollars for the present RMS installed, operated and tested over the last four years. The cost to the operator and the National Authority (e.g. for installation, labour, office space and

operations) is an order of magnitude lower than the IAEA cost. Recouping this cost or offsetting the current operational costs of RMS with a reduction in the inspection effort is not expected or feasible. However these costs should be viewed against the fact that in South Africa RM provides an additional confidence building measure and an additional tool to strengthen Safeguards on highly sensitive material in the HEU storage vault.

Using remote monitoring to satisfy timeliness requirements at other key facilities handling HEU at Pelindaba it is technically not feasible. Thus, for the foreseeable future monthly inspection of other facilities at the Pelindaba site will still be required. Since inspection costs are governed mostly by the cost of air travel, the savings from RM implementation in South Africa will not be as substantial as they might be elsewhere.

6. CONCLUSION

In the five years since installation and testing of remote monitoring began at Pelindaba, South Africa and the IAEA, working together, have succeeded in developing a reliable and robust surveillance system that delivers high quality images directly to the inspector's desk in almost real time. With this surveillance data, it is typically possible to achieve verification for timeliness purposes without conducting an on-site inspection. The potential benefits include: a reduction of inspection cost and effort, a less intrusive inspection regime, shorter inspections, reduced radiation exposures, more rapid response to problems, improved physical protection (at direct-use vault stores), and higher quality on-site inspections (due to better prepared inspectors). In summary, experience with RMS in South Africa has demonstrated that remote surveillance can actually provide better assurance of non-diversion with improved timeliness than traditional surveillance systems serviced during on-site inspections.

The continued requirement for monthly inspections at other HEU facilities at Pelindaba means that the cost and manpower savings from RMS in South Africa will be small. However, the potential savings at facilities in other Member States could be substantial. In particular, RMS could be used to eliminate all interim inspections at many power reactors. The pioneering work done in South Africa has identified and solved many technical problems, and the experience gained will ensure that the installation of future systems is largely problem free.

ACKNOWLEDGEMENT

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REFERENCE

- [1] Dupree S.A. et al. "Remote Monitoring in International Safeguards", JNMM, January 1996