The modular integrated video system (MIVS): A new generation of video surveillance equipment

New video units are going to be deployed in safeguarded nuclear facilities around the world

by K.-J. Gärtner and E.W. Dawes

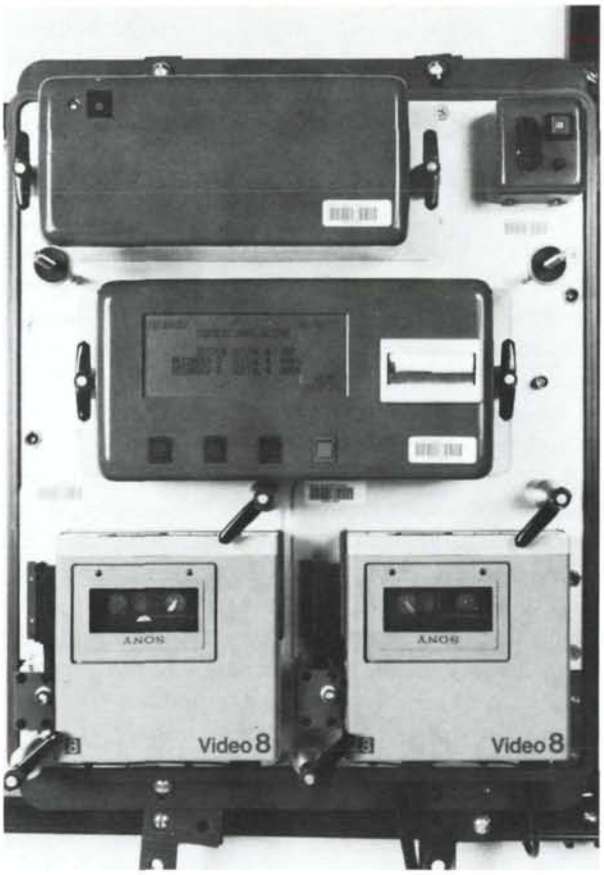
Over the years, one of the "workhorses" of the IAEA's safeguards system has been an 8-mm film camera used for surveillance purposes at many safeguarded nuclear facilities around the world.* Recently, however, the Agency has been moving away from the use of these units in favour of advanced video systems that today have taken over the market. Production of 8-mm film and cameras has been virtually discontinued worldwide. The Agency's transition to modern video systems, and the replacement of aging 8-mm cameras in some 290 nuclear facilities, has proven to be a challenging and difficult effort in terms of technology, quality assurance, cost effectiveness, and scheduling.

This article describes the development of three alternate video systems to replace the 8-mm film camera being developed through IAEA safeguards support programmes with Japan, the Federal Republic of Germany, and the United States. It reviews the progress made in various areas, and describes the features and advantages of one system — the modular integrated video system (MIVS) — which is going to be deployed as a primary safeguards tool through the 1990s.

Development of alternate video systems

The availability of alternate video systems being developed under the safeguards supports programmes is becoming an increasingly important factor. Presently, the readiness of each of the three countries' systems varies, reflecting both different conceptual approaches and starting times for research and development:

- MIVS is the United States entry which began development in the mid-1980s under an agreement between the IAEA and the United States; Sandia National Laboratories (SNL), in Albuquerque, New Mexico, was the prime design contractor. MIVS uses 8-mm video recorder technology and an innovative video authentication system. After intensive testing and enhancement, the IAEA recently placed an order for 50 production units. Units are about to be deployed in nuclear facilities throughout the world.



The MIVS, shown here without its protective cover, features modules that can be easily maintained. Shown from top to bottom are the control module, the display module, and two modules for video tape recorders.

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* The camera system was manufactured by Minolta.

- The Japanese entry is called COSMOS, which stands for compact surveillance and monitoring system. Production units are expected to be available in 1991 following completion of development evaluations now being done.
- The Federal Republic of Germany has almost finished development of a system called the Tamper Resistant TV-link (TRTL). This is a multi-camera system with video signal authentication for each video channel and a single console.

The Agency is considering all three entries but is moving ahead with MIVS deployment based upon its features, reliability, and the availability of production units. In view of this, the remainder of this article reviews the MIVS.

Mission and requirements

During the 18 years of experience with the application of 8-mm film cameras for safeguards surveillance purposes, the camera unit matured into a highly reliable, economic, and user friendly system.* Many years of technical effort and a continuous improvement of the logistics for the product were necessary to accomplish this.

Since 1976 the IAEA has also gained experience with compact closed circuit television systems (CCTV).** These offer several advantages over 8-mm film cameras, including higher picture capacity and quality, higher light sensitivity, date and time annotation, and lower sensitivity against radiation.*** Moreover, CCTV facilitates immediate on-site review of the recorded information without burdensome film processing.

MIVS will become one of the primary safeguards surveillance tools through the late 1990s. Recognizing the importance of this new equipment, personnel from the IAEA and SNL embarked on a joint effort to assure success in all phases of the MIVS project. These included design development, test verification, selection of a manufacturer, and the use of advanced field logistics and replacement practices to guarantee that a high level of reliability would be maintained. *(See box for a summary of major activities.)*

Organizing for success

Because of the importance of the film camera replacement activity, a special temporary working group was established in July 1988. This group had to develop recommendations for the co-ordination of activities required for the replacement process, which started in 1989 and will end in 1994. The group was composed of staff experienced in system development, safeguards operations, quality assurance, and procurement. Necessarily, substantial cross-functional and inter-organizational activities were involved in the initiative.

The group had direct responsibility for all the actions required to define and develop recommendations covering project tasks, resource requirements, project schedules, and allocation of responsibilities. In January 1989, the overall programme for implementation was approved. All activities to execute the programme are now being conducted through normal line management. The group's chairman continues to monitor and report on progress and specific issues as necessary.

The complexity of the programme required the application of an advanced personal computer software package to achieve a well-structured and responsive project plan which now covers more than 200 tasks.* The software contains proven and successful project management techniques. It can effectively and efficiently develop dependencies between tasks, i.e., the precedence relationships (links) of tasks, which make the project structure responsive to any critical delays in the programme.

MIVS programme plan

In 1986 the Agency adopted an SNL-proposed programme plan which reflected 10 specific steps to move MIVS all the way through successful field implementation. The specific steps were initially defined by a 1982 advisory group as general activities required for successful development and implementation of safeguards equipment. As applied to MIVS, these 10 steps were broadly categorized as follows: identification of the need; assessment of State/facility operator requirements; formulation and approval of system specification; formulation and approval of performance and reliability;certification test programme; prototype development, testing, and demonstration; selection of a commercial supplier to manufacture 16 field evaluation units; performance and reliability certification tests, including field evaluation; production ordering; and implementation.**

MIVS has now successfully advanced through these stages and the first production unit has been installed on-site.

* "IAEA Film Camera Surveillance Development and Practice", by D.E. Rundquist and R.E. Kerr, *ESARDA Proceedings* (1980).

** "Future Trends in Compact TV Surveillance Systems", by K.-J. Gärtner, B. Heaysman, and P. Vodrazka, *INMM Proceedings* (1985).

*** "Transition to CCTV Surveillance for Safeguards", by K.-J. Gärtner, B. Heaysman, R.E. Kerr, and D.E. Rundquist, *INMM Proceedings* (1987).

* "Replacement Programme Safeguards Surveillance Units", by K.-J. Gärtner, *INMM Proceedings* (1989).

** "Program Plan for the Modular Integrated Video System", by K.-J. Gärtner, B. Heaysman, R. Holt, and C.S. Sonnier, *INMM Proceedings* (1986); and "The Modular Integrated Video System (MIVS) Program in Perspective", by S.L. Schneider, C.S. Sonnier, and K.-J. Gärtner, *INMM Proceedings* (1988).

MIVS programme history, 1985–90: Summary of major activities

October 1985: An IAEA request is made for an MIVS programme task under the United States Support Programme.

February 1986: A proposal from Sandia National Laboratories (SNL) is submitted covering design and performance specifications.

June 1986: A meeting at SNL finalizes the specifications.

July 1986: The IAEA's Deputy Director General for Safeguards formally accepts the specifications.

December 1986: An SNL proposed Certification Test Plan is accepted by IAEA.

February 1987: An MIVS development prototype unit is demonstrated at IAEA.

July 1987: An SNL contract for 16 units is signed with a contractor. The units are to be used for reliability demonstration and field test. Independent consultant planning begins for an MIVS low-risk transition system.

August 1987: SNL undertakes extensive VTR (Video Tape Recorder) testing.

March 1988: Sixteen MIVS units successfully pass the 168-hour acceptance tests.

April 1988: A 5-month reliability test for 10 MIVS units starts at IAEA.

July 1988: The IAEA convenes a working group concerning the replacement of existing film cameras with the new video system.

August 1988: MIVS computerized project planning is initiated.

September 1988: The MIVS 5-month reliability test is concluded with successful results. A joint reliability statement is issued by IAEA and SNL.

November 1988: MIVS training for the IAEA inspectorate begins.

December 1988: SNL/IAEA begin preparation of a request for bid document for MIVS production. SNL initiates MIVS design enhancements, and completes environmental testing of two MIVS units. A field commissioning test begins with the first MIVS field installation.

February 1989: Field commissioning tests and inspector training continue.

April 1989: Request for bids for production of the MIVS are issued. The document includes special quality requirements.

June 1989: An SNL support function under the United States Support Programme is defined and approved.

July 1989: IAEA evaluation of prospective suppliers begins. An MIVS production contract is awarded.

August 1989: Further MIVS changes are made to enhance producibility.

September 1989: An initial "production prototype" unit is received by the contractor. Initial manufacturing and quality plans are reviewed.

November 1989: The planning continues and includes spare parts logistics, projections of field reliability, IAEA test acceptance, and field installation practices.

December 1989: The first production unit is reviewed by IAEA at the contractor and shipped to the IAEA.

January 1990: The second and third production units are prepared for the preplanned environmental test.

February 1990: The first production unit is installed on site.

March 1990: The final version of the contractor's manufacturing and quality plans are reviewed.

The MIVS was built by a team under contract to the IAEA at Aquila Technologies Group Inc. in the USA.

MIVS Low-Risk Transition System (LRTS)

As previously indicated, the importance and cost of the MIVS programme required that the Agency be confident that low-risk had been achieved in MIVS transitional phases (transitional phases can be thought of as the 10 steps outlined earlier).

In April 1987, a consultant was contracted under the US safeguards support programme to work with IAEA staff to draft such an LRTS*. The planning necessitated an in-depth assessment of the risks associated with each transitional phase. In turn, this required the application of an existing best practice (or, if absent, the creation of a new practice and application) until the risk was minimized.

Use of this planning tool resulted in the identification of 73 potential risks for the MIVS project, many of which were already effectively covered by applied best practices and could therefore be discounted. Others required the development of new and better practices for MIVS. These are in place and, with the exception of some residual work to be done on documentation and verification of the LRTS, this phase of the MIVS project is considered complete.

Use of the LRTS tool proved to be invaluable, especially as it applied to the production and implementation phases. The Agency is therefore planning to selectively apply the LRTS methodology to future equipment development and implementation.

The MIVS production contractor

Before awarding the contract, the Agency's Departments of Safeguards and Administration, assisted by design and quality assurance personnel from SNL, drafted a request for bid proposal. It included detailed requirements for engineering services and maintenance of high quality levels during MIVS manufacture. Requests for bids were then sent to several US and European companies.

A major milestone was reached on 27 July 1989, when the Agency placed an order for production of the MIVS with Aquila Technologies Group Incorporated, Albuquerque, New Mexico. Selection of this company was based on three factors: its major thrust was in the development of advanced video technology systems employing video disk and tape approaches; it had unqualifiedly accepted the IAEA requirements for manufacturing, engineering, and quality controls as detailed in the Agency's request for proposal and supporting quality documents; its bid price was highly competitive.

In support of the selected contractor, SNL was appointed as the engineering and quality assurance oversight body for the Agency at the production site. This effort was administered under the US support programme and further maintained through visits to the selected contractor by IAEA Department of Safeguards personnel. In turn, the contractor's senior management have visited the Agency twice since the contract was awarded.

These efforts will continue for a substantial part of the decade as further MIVS and spare parts are produced. In retrospect, these communication and co-ordination meetings have proven vital due to the complexity of the MIVS project.

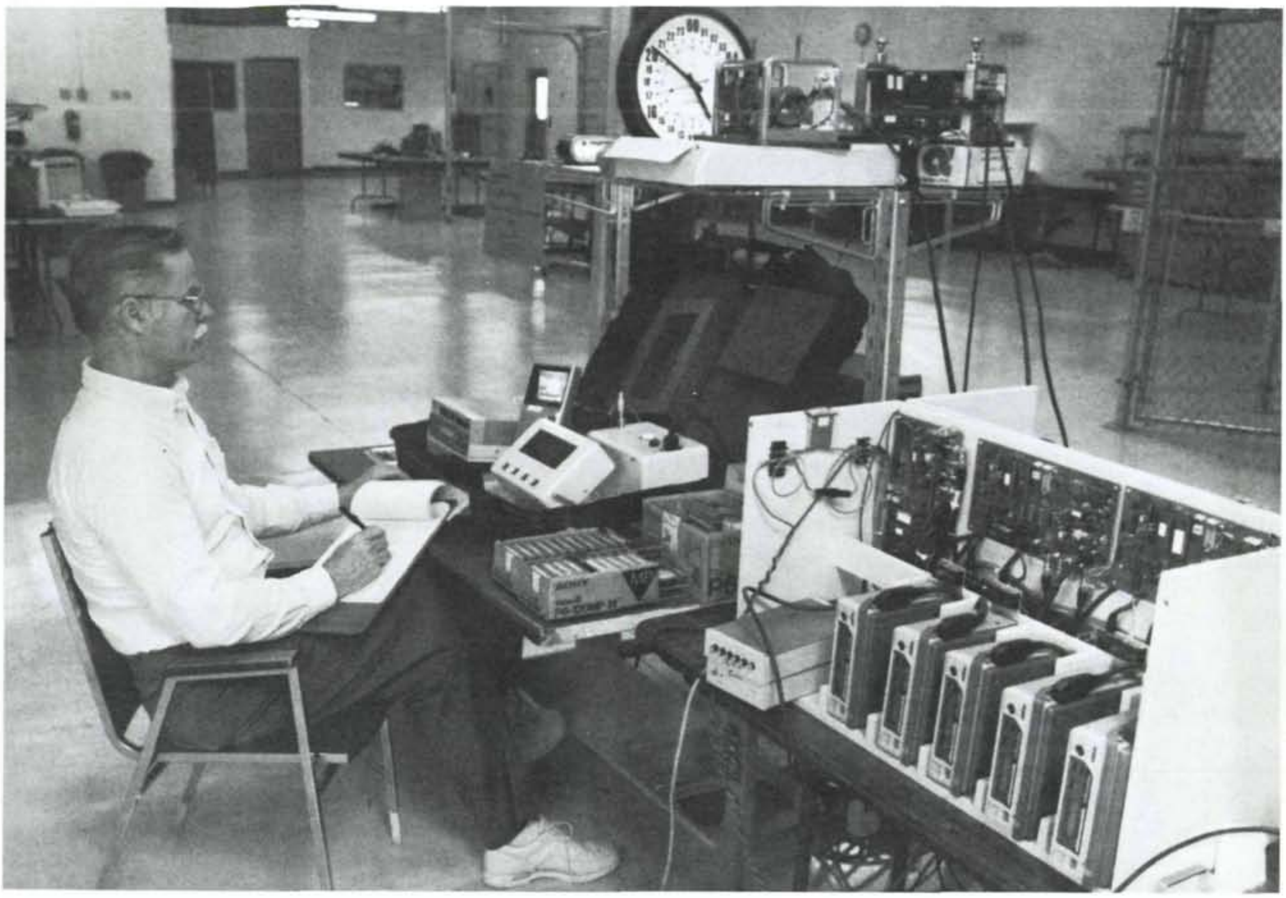
Equipment design

MIVS is a microprocessor-controlled CCTV system designed to operate at 5-minute intervals in an unattended surveillance mode over a 3-month inspection

Comparison of MIVS and 8-mm camera system

Characteristics	8-mm camera (twin Minolta)	MIVS
Recording principle	Two 8-mm film cameras	Two 8-mm TV recorders
Recorded scenes per single unit of media	7200 (monochrome) 3600 (colour)	26 000 (monochrome)
Inspection service interval	25 days at a 5-minute scene interval	90 days at a 5-minute scene interval
Light sensitivity	Approximately 25 lux	Approximately 0.05 lux
Time/date annotation	No	Yes
Camera location	Fixed with recording/control in single console	Can be up to 60 m from recording/ control console
Power supply	2 dry-cell batteries AA-size	AC power, 100–240 volt AC with 3-hour battery backup
Field repair strategy	Replace complete system	Snap-in modules for display, power, and video tape recorder functions
Reliability	0.98 at 90% confidence level at 7000 scenes	Over 0.98 at 90% confidence level at 26 000 scenes
Investment costs	About US $2300	About US $13 000
Running costs film-tape/90 days	US $10 (unprocessed)	US $20
Size (L × W × H) (mm^2)	330 × 200 × 230	Control unit: 640 × 500 × 160 Camera: 300 × 200 × 230
Operational weight	6.5 kg	28 kg total

* "Development of a Plan for Ensuring a Low-Risk Transition of the MIV System for Design, Test, Production into IAEA Implementation", by E. Karlin, Report POTAS, Task D.60 (May 1989).



The MIVS went through extensive testing. Shown here is a technician testing the video tape recorder. (Credit: Aquila Technologies Group Inc.)

period.* It can be installed in those safeguarded facilities where main system power is readily available, and in situations where it is desirable to have the TV camera separate from the recording and control equipment. In case of a power failure, the system is equipped with a backup battery lasting at least 3 hours. (*See accompanying table for the features and advantages of the MIVS over the 8-mm camera system.*)

Modular concept and logistics. MIVS has a modular hardware structure to simplify maintenance and service. The two basic components of the MIVS are the camera module and the recording control unit. Both are contained in tamper-resistant housings which are kept under Agency seals.

The camera module consists of a CCD (charge coupled device) TV-camera and video authentication circuitry. The recording control unit includes four modules which can easily be replaced during normal inspection. These consist of one power supply module, one display module, and two identical recorder modules. The power supply module includes a universal AC/DC power supply, a backup battery, and a paper printer for event recording, such as the number of recordings within the inspection period and tamper events. The display module incorporates the complete system control, a liquid crystal display (LCD) to support system set-up and inspection, and the receiving part of the authentication circuitry.

Video authentication. The camera module and recording control unit are connected through a hybrid cable (coaxial cable and a pair of copper wires) with a maximum length of 60 metres. The cable is assumed to be accessible to third parties. Therefore, to assure that the video signals generated by IAEA TV cameras are recorded without falsification, a sophisticated authentication system is an integral part of MIVS.* Detected events that indicate tampering are recorded in a non-volatile memory and on video tape together with the video signal. All memory data are transferred to a paper printer at each inspection visit.

Surveillance and redundant recorders. An important contributor to MIVS overall system reliability is its video tape recorders (VTR) subsystem. Early in the design effort, it was recognized that these hard working VTRs would require redundancy to assure maintenance of MIVS surveillance.

* "A Video Authentication Technique", by C.S. Johnson, *INMM Proceedings* (1987).

* "The Modular Integrated Video System (MIVS)", by S.L. Schneider and C.S. Sonnier, *INMM Proceedings* (1987).

The definition of surveillance maintenance is rigorous: the two VTRs alternately (and independently) record scenes and the requirement is that two successive scenes cannot be lost. Redundancy virtually assures that this will not occur from VTR mechanical or electronic failure.

Conformance with this requirement was thoroughly evaluated during the IAEA/SNL reliability tests of over three million scenes recorded between April and September 1988. Surveillance was never lost during this test. An additional 10 million scenes were recorded with 165 VTRs by SNL in the 1986–89 period while assessing the recorder's mechanical durability.

The analysis of this data, as well as that from VTR environmental tests, led to Agency development of a maintenance replacement policy of 2 years for VTRs in MIVS units deployed in the field. This policy also took into consideration issues of cost effectiveness.*

Surveillance record and review station. As an important part of the MIVS system, SNL developed a review station to evaluate MIVS surveillance activities.** MIVS can record video scenes at any interval between 1-to-99 minutes. Each recorded scene is annotated by time and date, the scene number, and tamper events.

Four tamper events are defined: opening of the MIVS console; loss of electric power; video authentication failure; and trigger event recording.

The review station can process this information for the inspector. It can summarize missed scenes, any tamper events, as well as any video loss exceeding 15 seconds. The system can also be set up to automatically stop upon detecting one of these conditions, and to allow for manual verification, or it may update counts of the detected conditions without stopping.

As previously mentioned, all event data are also stored in electronic memory. At the time of an inspection visit, data is transferred to a paper printer to become part of the inspection report.

Summary

MIVS represents an important new surveillance system which is about to be deployed by the IAEA Department of Safeguards. Its development represents a collaborative, successful effort of government, private firms, and the Department of Safeguards.

Development and success were bolstered through the use of tried and proven project and programme management techniques as well as application of the appropriate engineering and quality assurance tools.

As MIVS enters its deployment and implementation phase, there will be no slackening of these efforts.

* "Video Tape Recorder Reliability Requirements for the Modular Integrated Video System (MIVS)", by E. Dawes, *INMM Proceedings* (1989).

** "Modular Integrated Video System (MIVS) Review Station", by M.L. Garcia, *INMM Proceedings* (1989).