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CONTAINMENT AND SURVEILLANCE - A PRINCIPAL IAEA SAFEGUARDS MEASURE

Darryl D. Drayer
Sandia National Laboratories
Albuquerque, New Mexico

Cecil S. Sonnier
DOE Consultant
Jupiter Corporation
Albuquerque, New Mexico

DISCLAIMER

CONTAINMENT AND SURVEILLANCE: PAST, PRESENT, FUTURE

Darryl D. Drayer
Stephen A. Dupree
Sandia National Laboratories
Albuquerque, New Mexico

Cecil S. Sonnier
DOE Consultant
Jupiter Corporation
Albuquerque, New Mexico

ABSTRACT

The growth of the safeguards inspectorate of the Agency, spanning more than 40 years, has produced a variety of interesting subjects (legal, technical, political, etc.) for recollection, discussion, and study. Although the Agency was established in 1957, the first practical inspections did not occur until the early 1960s. In the early inspections, there was little C/S equipment available, and no optical surveillance was used. However, by the third decade of the IAEA, the 1980s, many technology advances were made, and the level of C/S equipment activities increased. By the late 1980s, some 200 Twin Minolta film camera systems were deployed by the Agency for safeguards use. At the present time, the Agency is evaluating and beginning to implement remote monitoring as part of the Strengthened Safeguards System. However, adoption of remote monitoring by international agencies cannot occur rapidly because of the many technical and policy issues associated with this activity. A glimpse into the future indicates that an important element of safeguards instrumentation will be the merging of C/S and NDA equipment into integrated systems. The use of modern interior area monitors in International Safeguards also offers a great potential for advancing C/S measures. The research in microsensors is in its infancy, and the opportunities for their reducing the cost, increasing the life time, and increasing the reliability of sensors for safeguards applications are manifold. We may be approaching a period in time in which the terminology of C/S will no longer have its original meaning, as integrated systems combining NDA instruments and C/S instruments are already in use and are expected to be the norm in the near future.

1. INTRODUCTION

In October 1954, the Statute of the International Atomic Energy Agency (IAEA) had been signed by seventy nations. The Agency was established in 1957, and at the end of its first year of operation 130 professionals were employed in all departments. One of the unique features of the IAEA is that it has direct interface with Member States through the medium of on-site inspections. By the end of 1996, the number of professionals in the Safeguards Department had increased to about 270, over 200 of whom were inspectors. This growth of the safeguards inspectorate of the Agency, spanning more than forty years, has produced a variety of interesting subjects (legal, technical, political, etc.) for recollection, discussion, and study. This paper addresses the specific subject of technical means for maintaining continuity of knowledge between inspection intervals - classically referred to as Containment and Surveillance (C/S).

Profound events over the past five years have significantly altered the prospects for International Safeguards. It is generally recognized that it will take some time for all elements of the new Strengthened Safeguards System (SSS) to be implemented. However, it seems worthwhile to review where we have been, where we are, and where we are likely to be going in the area of C/S. In fact, we may be approaching a period in time where the terminology of C/S will no longer have its original meaning. Integrated systems combining Non-Destructive Assay (NDA) instruments along with C/S instruments are already in use and are expected to become the norm in the near future.

2. THE FOUNDATION OF CONTAINMENT AND SURVEILLANCE

From the beginning, the fundamental element of International Safeguards has been material accountancy; that is, accounting for nuclear material subject to safeguards. This is achieved through inspections, examination of records and reports, material measurements, and other means. In INFCIRC/66, one of the basic safeguards documents, C/S was not specifically identified as a means to be used, but neither was its use excluded. However, the recognition of C/S was a slow process, arranged on a case-by-case basis. In the mid-1970s, with the emergence of INFCIRC/153,[1] C/S was specifically incorporated as "important complementary measures" to material accountancy, and was specifically identified as measures that should be used for the purpose of fulfilling inspection responsibilities.

The First Three Decades: 1957-1987.[2] Although the Agency was established in 1957, the first practical inspections did not occur until the early 1960s. During this interim period, a functional operations organization was established. In the early inspections, there was little C/S equipment available, and no optical surveillance was used. The inspections were expanded in 1962 to include several power reactors. It was in this time frame that the first use of C/S began. Several commercially available seals began to be used on an experimental basis. In the fall of 1966, the IAEA began to make use of a seal developed for the U.S. Internal Revenue Service. This seal was termed the "Type E" seal. Today, after several modifications, it remains the most widely used seal in the Agency's arsenal.

In its second decade, the IAEA evaluated and, in a number of cases, implemented a wide variety of C/S equipment. There was, and of course still is, a direct relationship between C/S equipment availability and the development of similar technology for the commercial market. Adhesive paper seals were introduced, principally for short-term sealing applications. The first fiber optic seal, termed Fiber Lock, was developed in the U.S. and offered for evaluation by the U.S. Arms Control and Disarmament Agency (ACDA). Also, electronic seals were developed in Germany and the U.S.

The rapidly expanding commercial and home movie camera industry made available to the Agency a wide variety of surveillance systems for possible C/S application. By early 1976, the IAEA had approximately sixty optical surveillance systems in use, including single-frame 35mm, 16mm, 8mm, and Super 8mm cameras, plus several custom units. These systems included Minolta XL-400 and XL-401 Super 8mm Cameras. By 1978, this camera system, with a number of timer modifications, became the primary IAEA optical surveillance device. Under an

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1 "The Structure and Content of Agreements Between the Agency and States," INFCIRC/153, IAEA, June 1972.

2 For more detail on the development activities prior to 1991, the reader is referred to the Proceedings of the 1991 INMM Annual Meeting and the paper of C.S. Sonnier, "Containment and Surveillance in International Safeguards - The Past - The Present - The Future."

Agency contract, Psychotronic Electronicsche Grate, an Austrian vendor, produced the first IAEA video system, the Psychotronic System. In its second decade, the IAEA introduced the use of monitors and sensors in safeguards, albeit not on a wide-scale basis. Some of these devices included: Reactor Thermal Power Monitor, Electrical Power Monitor, Track Etch Monitor, and Bundle Counters.

In the third decade of the IAEA, the 1980s, many technology advances were made and the level of C/S equipment activities increased. Equally important, a number of Member State Support Programs were established and several of these programs began significant activities in the area of C/S technology development. In this decade as in the previous, many understood "C/S" to mean "Cameras and Seals." Indeed, considerable effort was devoted to the development of film camera systems with increased film capacity, video systems utilizing video cassettes and discs, electronic seals, and a variety of other C/S equipment. These systems included the Variable Coded Sealing System (VACOSS) electronic seal, the COBRA Seal System, Passive Environmental Monitors, multiplex video systems, ultrasonic sealing systems, and reactor power monitors.

During this third decade, the first Integrated Monitoring System was developed and fielded. This system combined radiation detectors, crane monitors, and a data collection module into a functioning whole and provided for sensor triggering of optical surveillance cameras. Also, in this decade, ACDA developed the RECOVER System. RECOVER was designed to monitor the status of C/S devices from a remote location by retrieving data from these devices over commercial telephone lines. This system was extensively tested on a worldwide basis and demonstrated the basic feasibility of remote monitoring. Concurrent with the RECOVER activities, a system called LOVER (which was an acronym for "Local Verification") was developed and tested in Germany. This system involved an integrated monitoring system for use within a complex of facilities in the same local area. Following the RECOVER and LOVER system tests, in Japan the development of remote monitoring equipment continued with application to monitor shipments of nuclear materials.

The Fourth Decade - 1987 Onward. By the late 1980s, some 200 Twin Minolta film camera systems were deployed by the Agency for safeguards use. At this time, it became evident that the film-camera technology would soon be replaced by video-tape technology. Steps were, therefore, necessary to insure that when that time came the IAEA would be prepared to replace the film cameras with tape recorders. Both Japan and the US addressed this problem. The Japan Atomic Energy Research Institute developed the Compact Surveillance Monitoring System (COSMOS), and Sandia National Laboratories developed the Modular Integrated Video System (MIVS). Both of these systems are now in routine safeguards use.

In this fourth decade, a wide variety of C/S equipment was developed by organizations in Australia, Canada, France, Germany, Japan, UK, U.S., and other IAEA Member States, as well as by the JRC-Ispra laboratory of EURATOM. The products developed included seals, video surveillance and video review stations, and various integrated systems. The total effort devoted to C/S equipment during this period is far too great to describe in detail in this paper.

In the early 1990s, digital video and low-cost computer network technology came into widespread industrial use. In France, Germany, and the U.S., development of the EMOSS, Neumann, Gemini, and Image Compression and Authentication Module digital video systems commenced. At the present time, these systems are in various stages of field test or approval for safeguards use. Work on advanced seals was also pursued.

3. FUTURE OF C/S

At the present time, the Agency is evaluating and beginning to implement remote monitoring as part of the SSS. With this technology, it is possible to retrieve data collected by on-site instruments through a communication link with the site from a remote location. This communication link can be made secure, if required, by means of access passwords and data encryption. Remote monitoring of nuclear facilities is not a new concept and does not entail a severe technical challenge. However, the use of remote monitoring in safeguards applications raises a number of issues, such as cost savings, facility impact, and acceptability by both the facility and the national entity involved. Ultimately, acceptance will depend on the benefits accruing to both the monitoring and the monitored parties, balanced against the costs to each.

Adoption of remote monitoring by international agencies cannot occur rapidly because of the many technical and policy issues associated with this activity. Experience with these systems is essential before the stakeholders in International Safeguards - the State regulatory organizations, the international monitoring organizations, the inspectors, the facility operators, and the developers of the technology - can develop and approve the policy guidance necessary for routine acceptance of remote monitoring.

In order to gain this experience, in 1993 the US Department of Energy (DOE) and its international partners initiated the International Remote Monitoring Project (IRMP). The purpose of the IRMP was to conduct field trials of the technology to demonstrate it to the international safeguards stakeholders. The project promoted the exchange of monitoring, data handling, and communication technology; the installation and testing of such technology in various types of nuclear facilities; and the collection and assessment of data obtained from the trial systems. In September 1995, the U.S. Secretary of Energy conducted a remote monitoring demonstration for the IAEA General Conference in Vienna using the IRMP technology.

By 1997, the IRMP field trials had shown that remote monitoring offered a viable option for improving monitoring efficiency. It is generally expected that fully operational remote monitoring systems will be implemented by the Agency by 1998. These systems will be associated with a variety of associated openness and transparency measures. Openness and transparency, including some form of short-notice inspections, are prerequisites to the effective implementation of remote monitoring in any State.

There are numerous organizations in the U.S. and around the world currently working on remote monitoring technology for International Safeguards. The technology is advancing rapidly. It is now necessary to seek agreement on standards that will allow each development organization to use their resources as they wish but still present a useable product for safeguards use. The World Wide Web provides a good example of how standardization can work to the advantage of all users.

When considering the use of remote monitoring, there are critical elements of physical protection and proprietary information that must be addressed. Virtually all elements of physical protection directed at the security of facilities are sensitive and there often are processes or equipment within nuclear facilities that are proprietary. With remote monitoring, there exists the possibility of having a wide variety of data available to the IAEA, and protection of sensitive information becomes all the more important in such a case. In particular, the transmission of video data off-site may be quite sensitive to the facility operator or State authority.

Remote monitoring systems are expected to become routine, with transmission of a variety of safeguards data to IAEA Headquarters and to regional offices. Remote monitoring technology will be progressively updated to take advantage of rapid technology advances. The World Wide Web offers the possibility of drastically reducing the cost-of-data transmission. However, use of this technology for safeguards purposes will require careful consideration of security issues. Acceptance of certain openness and transparency measures is also expected. Such measures may include some form of short notice inspections, perhaps on an allocation basis. Other measures may include joint sharing of data from safeguards systems, joint resolution of discrepancies in the data, and sharing of site process and audit data. All of this is expected to have a profound affect on the entire regime of International Safeguards.

More About the Future. A glimpse into the future indicates that an important element of safeguards instrumentation will be the merging of C/S and NDA equipment into integrated systems. This would include seals, video systems, and a wide range of detectors and analytical processes. In some cases, the detectors used may be similar or identical to detectors used in domestic physical protection. One can envision an increased interaction between International Safeguards and Domestic Safeguards. Of course, any consideration of the use of Domestic Safeguards elements in International Safeguards will require avoidance of all issues related to sensitive data. State peculiar measures are not relevant to International Safeguards.

In the aftermath of the 1972 terrorist attack at the Munich Olympic Games, a large effort was instituted to increase the level of Domestic Safeguards, particularly regarding acts of terrorism. A significant part of that activity was concentrated on the development of interior sensors for fixed-site applications, an effort which continues to this day. The use of modern interior area monitors in International Safeguards offers a great potential for advancing C/S measures. Of particular importance, is the application of these sensors in areas of declared inactivity; for example, in nuclear material storage areas that are entered infrequently.

Interior monitoring sensors include motion sensors designed to detect the motion of an intruder within a confined interior protected area. These instruments may make use of ultrasonic, microwave, infrared, audio, electric-field, active sonic, light level, and video motion phenomena. Boundary penetration sensors are designed to detect penetration of the boundary of a protected area. These include vibration, door and window, capacitance proximity, passive audio, ultrasonic, wire grid, metal foil, glass-break, continuity, infrasonic, light-beam, magnetic switch (balanced and simple), passive sonic, passive ultrasonic, and seismic sensors. Point sensors include capacitance monitors, proximity instruments, pressure switches, and strain gauges. Basic detection phenomena for these sensors include portal opening; breaking through an exterior boundary such as a wall, floor, or ceiling; radial or traverse motion; and physical contact with a monitored item.

These monitoring instruments are all subject to nuisance alarms; i.e., triggering of the sensors by activities unrelated to the events or items being monitored. Major sources of nuisance alarms are: radiofrequency transmitters, animals, ambient acoustic noise such as thunder, vibration of sensor mounting structures, loose-fitting doors, flickering of fluorescent lights, movements exterior to the area being monitored, and localized air movement from heating, cooling, humidity, or wind. Physical and environmental conditions affecting interior monitoring systems include electromagnetic, radioactive, acoustic, thermal, optical, seismic, and meteorological phenomena.

Two physical conditions of importance to interior motion sensors are the specifics of the building or room construction and the various equipment or objects that occupy the area or room to be monitored. A careful review or survey of the area to be monitored is necessary to choose a particular sensor technology or a combination of interior monitoring systems. It should be recognized that each area in which an interior monitoring system is to be used will have its own unique physical and environmental conditions that will affect the choice of the types of sensors to be used. Each area should be analyzed as a separate entity. The conditions encountered for

International Safeguards will be, for the most part, in controlled environments; i.e., the environments will usually be predictable and measurable. However, they still may present problems to the proper operation of interior detection systems. It may be necessary to employ a combination of sensors in order to achieve an adequate monitoring capability.

There is much technology available to support the use of interior monitoring equipment, and extensive experience has been accumulated in their use. Effective utilization of this technology is not just an "out of the box" operation, but application of this equipment to International Safeguards appears to have considerable merit. Prior to implementing any of this equipment, however, it may be useful for the IAEA to consider assembling a small team of experts to assist in facility evaluations and to produce system designs that lead to optimum utilization of the interior monitoring systems.

Additional areas of synergy between Domestic and International Safeguards might include the evaluation and certification of domestic measurement equipment for IAEA use, the authentication of Domestic Safeguards data for IAEA use, and the international monitoring agencies taking credit for domestic inventories to lengthen inspection intervals. Improved materials accounting capabilities at a site can support more efficient reporting of inventory as well as material balance and transactions data, both for domestic agencies and the IAEA. One example of this is the Local Area Network Materials Accounting System (LANMAS), a next generation PC-based database system that is being developed under DOE sponsorship.

There is active research underway in the area of microsensors for use in a variety of applications. Such sensors are inexpensive, reliable, and extremely low power. Microsensors, when produced in quantity, may be considered "throw-away" and be used in both temporary and quasi-permanent applications. Their small size and low power requirements may make them amenable to high levels of redundancy, which could greatly increase coverage of both area monitor systems and item monitoring. Microsensors include applications to chemical detection which could assist future Agency activities in environmental monitoring. Small, inexpensive radiation sensors are under development and might be useful for a variety of Agency applications. The research in microsensors is in its infancy, and the opportunities for their reducing the cost, increasing the life time, and increasing the reliability of sensors for safeguards applications are manifold.

From the beginning, equipment to support IAEA Safeguards could be characterized as that used to measure nuclear material (Destructive and Non-Destructive Assay) and that used to provide continuity of knowledge (Containment & Surveillance). C/S equipment has often been thought of as Cameras and Seals; however, in recent years technology has advanced to the point at which a wide variety of sensors are now available for, and relevant to, the C/S mission. The traditional film cameras have been replaced by video equipment, and fiber optic and electronic seals have come into rather widespread use. Many more changes will occur in future years.

Perhaps the most interesting aspect of the evolution of C/S instrumentation, and that which indicates the wave of the future, is the integration of video surveillance and electronic seals with a variety of sensors and NDA equipment. Combinations of this type are illustrated by safeguards systems currently in place in several nuclear facilities in France, Germany, Japan, the UK, the U.S., and elsewhere. The terminology of Integrated Monitoring Systems has emerged with the employment of network technology capable of interconnecting all desired monitoring elements. Also, the technology for transmission of a wide variety of information to off-site locations, termed Remote Monitoring, is in widespread industrial use.

Use of C/S technology reduces requirements for reinventory of safeguarded material. With the addition of remote monitoring, there should be a reduction in the cost of safeguards programs and a reduction in the required handling of materials by monitored facilities compared with current practice. Furthermore, these results should be achieved without reduction in the effectiveness of the overall Safeguards Program. This paper has demonstrated the evolution of C/S equipment and has indicated the large amount of effort devoted to the improvement of C/S. Further progress is anticipated including the advent of new sensor types and technology, implementation of remote retrieval of data, and incorporation of openness and transparency measures. These developments should further improve the efficiency of safeguards operations, freeing the inspectors from certain routine tasks and providing them with improved data in a timely manner.

Programs that address future technology needs for remote monitoring systems are planned or are underway. These needs include analysis and development work related to system and component vulnerability assessment, equipment reliability, improved interactive display of data, authentication and encryption key management, technical comparisons among alternate communications modes, information management, data format standards, information screening for decision making, advanced data and sensor integration, advanced communications methods, and increased network architecture flexibility. Products in each of these areas should become available for use in C/S in the near future.

Data management, including presentation of data and imagery for analysis and reporting, will present a significant technical challenge when a large number of facilities are monitored. In the data-rich environment that will exist from the extensive use of integrated monitoring systems, inspector analysis of the data must be based on sophisticated screening and effective presentation of the data. Methods for converting the monitoring data into knowledge for making decisions and reaching conclusions exists only in rudimentary form at present but will become essential in the future.

4. CONCLUSION

It would be beneficial to have more frequent meetings and workshops among International Safeguards and domestic nuclear facility security and materials protection experts to discuss specific issues. The meetings of the Institute for Nuclear Material Management, the European Safeguards Research and Development Association, the IAEA Physical Protection Conference, and the IAEA Safeguards Symposium are examples of good opportunities for meeting and discussing these and other specific topical areas.

Events over the past five years have significantly altered past thinking about International Safeguards. It is generally recognized that it will take some time for all elements of the SSS to be implemented. In fact, we may be approaching a period in time in which the terminology of C/S will no longer have its original meaning. Integrated systems combining NDA instruments and C/S instruments are already in use and are expected to be the norm in the near future.

In light of the significant changes in International Safeguards of the past several years, and their effect on the expectations for future International Safeguards, it is desirable to reflect on the direction the development of safeguards should take and the implications of that direction on safeguards policy and practice. The time-proven monitoring techniques, based on quantitative factors and demonstrated universal application, have shown their merit. However, new expectations regarding increased efficiency, detection of undeclared facilities, early warning of proliferation activities, etc., suggest the possibility that a future IAEA safeguards system could rely more heavily on the value of a comprehensive, transparent, and open implementation regime. Most certainly, a very large reliance on qualitative data will be necessary in order to gain the many benefits of the emerging advanced C/S technology.

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