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THIRD ANNUAL SAFEGUARDS ROUNDTABLE
WITH DIXY LEE RAY

INTEGRATED SAFEGUARDS

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On the Cover:
Former Atomic Energy Commission Chairman Dixy Lee Ray participates in the Institute of Nuclear Materials Management's Third Annual Safeguards Roundtable.

Integrating Safeguards Fills The Gaps

This issue includes an interview with Dr. Dixy Lee Ray, and a number of papers on integrated safeguards.

Dr. Ray was the featured speaker at the INMM Annual Meeting last June. She served as Chairman of the Atomic Energy Commission from 1972-1974, and is perhaps the most capable and dedicated advocate of nuclear energy today. Here she explains how we, as individuals and as an organization, could and should be more effective in explaining the importance of nuclear energy.

The Institute sponsored a workshop on Integrated Safeguards in Albuquerque, N.M. Oct 17-20, 1988. At a workshop, discussions are at least as important as the papers presented. Although the discussions were not recorded, some of those who presented papers were persuaded to edit them for this issue of the Journal. These papers are of general interest.

Ivan Waddoups of Sandia National Laboratories and Jack Markin of Los Alamos National Laboratory organized the workshop, and they have contributed a summary to the Journal. The workshop was excellent, the program well-planned and organized. Summaries of most of the papers were printed with the program and distributed on-site. The papers were relevant and the discussions lively. There was a reception Monday evening, a luncheon Tuesday, and a banquet Wednesday night at which Nick Roberts of Los Alamos spun a modern-day fairy tale.

More than 100 participants took part, including 20 from the Department of Energy (DOE) headquarters and field offices. The rest were from DOE contractor facilities, with the notable exception of Mr. Kaseda Noboru, Nuclear Material Control Center, Tokyo, a member of our Japan Chapter.

Although the participants were primarily concerned with the safeguards system of the DOE and its particular facilities, the subject of integration of domestic safeguards is universal. The paper by Robert Carlson is a general analysis of why integration is important and how it might be implemented. He also explains, tactfully, why it has not been widely implemented at the DOE facilities. The other papers describe alternative approaches which have been or are being implemented at various facilities.

The subject is even broader than indicated here, as I'm sure the authors would agree. The papers tend to emphasize how such activities as materials control and accounting, physical protection, production, and safety generate and use overlapping information. Other important functions at a government or private facility that generate overlapping information include fiscal management, personnel management, payroll, purchasing, environmental protection, and protection of proprietary or otherwise sensitive information. Not only do the sources and uses of information overlap, but the responsibilities for performing and evaluating different functions duplicate each other as well. Additionally, management must pay attention to the morale of its employees and public perception of its performance. Policies and procedures which may seem desirable for one of the many functions may interfere with the performance of another.

We must also consider redundancy along with integration. No single protective measure can be perfect. Several less-than-perfect measures in a series, however, should be highly effective. A domestic safeguards system should have the following components: a protected area; one or more material access areas; control of access to the above; a personnel assurance program; authorization to handle or move materials; portal monitors; surveillance of the materials or personnel (both is overkill); accounting to provide assurance or to identify what may be missing; responses to alarms; guards; secure links to local police; pursuit; recovery; and plans to mitigate the consequences should all of the above fail. This combination should provide several layers of redundancy.

Safeguards should be planned, operated and evaluated as a complete system. Any alternative is costly and may leave gaps between measures separately designed and operated.

William A. Higinbotham
Brookhaven National Laboratory
Upton, New York

The Road To Success

Members and friends of INMM: Best wishes for the New Year!

As I am drafting these notes it is a dreary, gray winter day in Ohio. The kind of day that is perfect for napping, planning a new garden, dreaming of the INMM Annual Meeting, or maybe mapping out a course for the Institute over the next year.

By the way, the Annual Meeting will be held at the Orlando Stouffer Hotel July 9-12, 1989. The Orlando Stouffer is a beautiful facility in an outstanding location. The meeting technical program is strong and full, so plan to come early or stay late to take advantage of all the local attractions. This is one meeting you cannot afford to miss.

But on to more serious thoughts than sunshine and swimming pools. During the coming year all of us will face exciting challenges. Some that we have anticipated and are ready to accept and some we have no way of knowing about in advance. Your officers, executive committee members, and standing committees have been working to develop a roadmap and set of milestones as we strive for continuous improvement in the INMM. Today, at least, I see our challenges in the fields of professional development, membership, communications, and a review of our management structure.

Ken Sanders, U.S. Department of Energy, is the executive committee member with oversight responsibilities for the new Professional Development Committee. Terry Olascoaga, Sandia National Laboratories, is the chair for the Committee and is developing a charter which will consider both educational development and recognition.

Nick Roberts, Los Alamos National Laboratory, is our membership chair. The INMM seems to have reached a plateau of approximately 800 members. I think there must be at least 1,000 professionals who are concerned about Nuclear Material Safeguards and support the goals of the Institute. It should be a goal for each of us to at least ask one potential member to join.

Communications has always been a challenge for the nuclear industry. In particular, we now see increasing concern about science education for young people. Several years back the Institute had a viable award for a student safeguards paper. Unfortunately, interest in the award has unaccountably vanished and no papers have been submitted. Laura Thomas, Eagle Research Group, Inc., as chair of the Communications Committee, has agreed to consider this problem while maintaining the high standards for the INMM *Journal.*

Two ad hoc committees have been established to review the management needs of the Institute and the methods for funding Institute activities. Denny Mangan, Sandia National Laboratories, and Nancy Trahey, U.S. Department of Energy, are leading these efforts. I am sure they would welcome your input.

Time to go back to dreaming about the Annual Meeting. I hope to see you there.

John F. Lemming
Monsanto Research Corporation
Miamisburg, Ohio

The INMM Workshop on Integrated Safeguards

The INMM Workshop on Integrated Safeguards, held October 18-20, 1988, in Albuquerque, NM, provided attendees with a broad spectrum of subjects including integration philosophy, the relationship between integration and safeguards policy, technology development, and current safeguards practice at DOE facilities.

The following six papers in this issue are representative of some of the major topics covered at the workshop. Some additional topics and points of interest discussed are included in this summary paper.

Bill Bartels, DOE/OSS, presented the opening remarks in which he surveyed some of the current OSS activities related to development of integrated safeguards systems at DOE facilities. These include the promulgation of performance-based MC&A orders and guides that encourage a systems approach to implementing safeguards and technology development initiatives that focus research and development on integrated systems.

The definition of an integrated system included in his paper follows:

"An integrated nuclear material protection system includes physical protection, material control and accounting, and security of information and computers. The system also receives and digests information on production plans and process operations, including criticality control operations. The system evaluates possible occurrence of theft, diversion, and bypassing or defeating the protective measures included in the system. The system presents the results of its evaluation to plant management and other approved users in ways designed to flag conditions requiring attention and facilitate decision on possible actions."

His conclusion indicated that DOE would like to 1) identify and set priorities on the practical ways that might improve protective measures for existing and near-term DOE facilities through better integration, and 2) identify promising ideas on how to gain the full advantages of integration in new or modernized facilities over the next 20 years.

The session devoted to the use of evaluation tools and their relationship to integrated safeguards included a discussion of the tools and their use in the real world. The general consensus following this session was that the tools available have provided a great deal of assistance in evaluating integrated systems but more tool development is needed. John Murphy from ERC International summarized the needs as follows:

"We have found several areas where the models as written have limitations that have prevented us from moving ahead easily. The issuance of DOE order 5633.3, Control and Accountability of Nuclear Materials, is providing us with the "opportunity" to develop methods of using the subject models to truly integrate the physical protection and MC&A areas. Currently this integration is generally limited to the immediate detection that can be developed from the material control or material accountability programs when analyzing abrupt theft scenarios. Future analysis will require that systematic, quantifiable evaluations be performed that can only be met by well integrated safeguards systems. In order to perform these analyses effectively, or possibly at all, we will need fully integrated modeling tools."

On this same subject, Mr. Bartels emphasized:

"Our existing vulnerability assessment tools are not complete. They do not give proper credit for important, less tangible protective measures such as the DOE personnel security assurance program, the quality of material accounting and control, the clearance program, the probability of accidents or human errors made by opponents forced to face a series of choices, the ongoing performance of surveys of protecting system effectiveness by DOE operations offices, or the ongoing inspection and evaluation of existing protection performance by the DOE Defense Programs Office of Security Evaluations."

The other major subjects covered revolved around DOE and its role relative to integrated safeguards. The subject of integration of orders, inspection, and organization stimulated much widely varied but interesting discussion. The written word cannot capture the full essence of these discussions. It is sufficient to say that the attendees all gained an increased understanding of the potential advantanges/disadvantages, ease/difficulties, and political implications associated with integrating at the bureaucratic level.

Ideas were solicited near the end of the workshop as to what could and should be done to gain the potential benefits available from increased integration. A summary of these ideas follows:

1. Make a more concerted effort to improve communications between MC&A, physical protection, operations, safety, and site management. Increased communications will help in identifying and then implementing integration where it makes sense.
2. Involve individuals in the vulnerability analysis activities from all areas which could be effected by safeguards upgrades.
3. Develop design aids to enhance integrated system design.
4. More synergism than is presently being obtained is available now if we strive to capitalize on it.
5. Integrate audits, surveys, orders, and inspections.
6. Resource integration between the developers of new concepts and implementation is necessary.

In summary, the workshop demonstrated great interest in integration even if there isn't agreement on all the details. Much technology exists to allow us to do considerably more than is presently done at many sites. There are many examples of successful integration which have improved safeguards and operations. The challenge is, as always, to do the right things in the right place for the right reasons.

Jack Markin
Los Alamos National Laboratory
Los Alamos, New Mexico

Ivan Waddoups
Sandia National Laboratories
Albuquerque, New Mexico
Workshop Co-Chairs

Fellows

Like many professional organizations, the INMM has established a membership grade of Fellow. The requirements for attaining this level of recognition are spelled out in Article I, Section 4 of the Bylaws. In Article II, Section 5, the procedures for attaining the grade of Fellow are specified. This section is as follows:

Section 5. Fellows

A. The grade of Fellow may be attained only by advancement from the grade of Senior Member, and may not be attained by application. A proposal for the advancement of a Senior Member to the grade of Fellow shall be originated by five (5) or more Members of the Institute who shall provide data sufficient in their judgment to substantiate the qualifications of their candidate with respect to the requirements of Article I, Section 4 of these Bylaws. Such proposals shall be submitted to the Secretary who shall refer them to the Fellows Committee for its consideration.

B. If the Fellows Committee finds such candidate fully qualified for the grade of Fellow, and that such advancement to that grade would be in the best interest of the Institute, it shall so certify the nomination and forward its recommendation to the Executive Committee. If the nomination receives the favorable vote of two-thirds of the members of the Executive Committee, the candidate shall be made a Fellow of the Institute.

Each year, Chapter Chairman are contacted by the Fellows Committee Chairman to solicit nominations for the grade of Fellow. Note that the nomination procedure does not require that the nomination be made through a Chapter. If you as an INMM member want to sponsor a member, you may do so by writing a letter of nomination to the Fellows Committee Chairman. Such letters must fully describe the qualifications of the nominee and be signed by five INMM members in good standing.

Please insure that the nominee meets the minimum requirements as given in Article II, Section 5. Briefly, nominees must be Senior Members of INMM actively engaged in nuclear materials management or in a closely allied field. They must have distinguished records of sustained contributions to their profession in the development or exposition of theory, principles, and/or techniques, and must have a minimum of fifteen years experience in the field. The number of Fellows in the INMM is limited by the Bylaws to five percent of the total membership. A single nomination letter should be signed by all recommendors if possible. If this is difficult because of the location of some, short letters endorsing the original letter signed by one or more additional members and sent directly to the Fellows Chairman will be honored and made a part of the main nominating letter.

The Fellows Chairman for 1989 is John L. Jaech. Nominations may be mailed to the following address:

John L. Jaech
Department of Safeguards—IAEA
Wagramerstrasse 5, P.O. Box 200
A-1400 Vienna, Austria, Europe

Pacific Northwest

The winter meeting of the Pacific Northwest Chapter of INMM was held January 19, 1989. Barbara Fecht, Battelle, Pacific Northwest Laboratory (PNL) gave a presentation on "Manny," a life-size computer controlled mannequin. The anthropomorphic robot was developed at PNL for use by the U.S. Army to test protective clothing. During the business portion of the meeting, the 1989 officers were introduced and the gavel was passed to Chairman Obie Amacker, Jr. The following officers were elected for 1989:

Chairman
Obie P. Amacker, Jr.

Vice-Chairman
Don E. Six

Secretary/Treasurer
Debbie A. Dickman

Executive Committee
F. Gary Fetterolf
Bonnie J. Johnson
Vicki K. Locati
Dean W. Engel (Past Chairman)

Debbie Dickman
Secretary/Treasurer
INMM Pacific Northwest Chapter
Richland, Washington U.S.A.

Nuclear Fear:
A History of Images
by Spencer R. Weart
Harvard University Press
Cambridge Mass.
535 pages, $29.50 (clothbound)

There was once a brilliant scientist who, while seeking hidden knowledge, discovers "the most prodigious secret of physics — the release of vast energy from within atoms." He has an "ugly, mad streak within him," but is also a visionary who sees, stemming from his discovery, a city of "white towers rising from gardens, a peaceful and prosperous future city centering upon gleaming atomic power plants." He builds an atomic ray projector and finds that it can cure cancer and other ills, but that it can also cause cancer, genetic monstrosities, and ulcerated flesh. Recognizing that its destructive power offers a defense against his country's enemies, he goes down to his laboratory, deep in the earth, and constructs a powerful robot armed with the new ray projector. While he is preparing his robot his lover finds him, and in a fit of madness, hoping to make her immortal, he turns the ray on her. When the terrified woman flees, the enraged scientist climbs into his machine, rides it to the surface, attacks his enemies with its weapons, and lays waste the earth, but in the process the robot is destroyed. When his lover, emerging from her hiding place, tries to lift the blackened ruin of the machine, it suddenly cracks open and the scientist, purged of his madness, crawls out. They join hands. Perhaps a new world would rise from the old ... a white city, and the human race would be redeemed.

With this fable, paraphrased above, Spencer Weart, s physicist who is Director of the Center for the History of Physics at the American Institute of Physics, begins his highly original and impressive exploration of the sources of nuclear fear. In the process he delves not only into ancient and medieval writings and scholarly works of the more immediate past, but also into fairy tales, novels, science fiction, films, newspapers, comic books, psychological and anthropological works, religious tracts, Congressional hearings, and virtually every kind of record of human thinking bearing on his central thesis. Stated in its simplest terms, this is that the fear of things nuclear, both military and peaceful, is so powerful, pervasive, and often seemingly irrational because it resonates with a teeming host of images from man's past, some explicit and some deeply hidden in a kind of racial memory. Common elements in many of these images are the themes of secret knowledge with the power for doing good or evil, arrogant and possibly mad but visionary savants, transforming rays, transmutation of base materials into noble ones, death, destruction, suffering, and, ultimately, redemption through purifying fire.

One intellectual embodiment of these deep-seated beliefs was medieval alchemy, whose imagery, as Weart shows, has permeated the writings about nuclear energy from the start. He goes further, attributing some of the reactions to nuclear images to underlying sexual fears (and you thought this was a family magazine!)

The remarkable thing about Weart's book is that it analyzes nuclear fear at several different levels of understanding — as a reaction against technology and a yearning for simpler, more idyllic times (the small-is-beautiful movement), as a conjuring up of apocalyptic images from the distant past, and as a stirring up of hidden but powerful sexual fears of domination and victimization — and relates them to each other. You don't have to accept all aspects of his reasoning (in particular, I found the sexual symbolism arguments rather far-fetched — after all, as Freud, an inveterate cigar smoker, once said, sometimes a cigar is just a cigar), but the depth of his scholarship, his perceptiveness about the motivations of both pro- and anti-nukes, and his eloquence are most impressive.

He has also done a wonderful job of digging up early nuggets about energy that we tend to associate with the nuclear-energy controversy of today. Thus, he traces fears of the depletion of fossil fuels to the warnings of an English economist in 1865 about the consequences of an exhaustion of domestic coal resources. In response, scientists of the day assured the public that other sources of energy — wind, the tides, geothermal energy, and sunlight — would be found. Shades of the alternative-energy movement of the 1970s.

Then there is that old chestnut that makes us wince when we hear it, about nuclear power eventually becoming too cheap to meter. That fanciful prediction, it turns out, originated not with Admiral Strauss, of the Atomic Energy Commission, but in the early 1900's with General Electric's chief engineer, Charles Steinmetz, and he was talking not about nuclear power but about electrical energy in general. And the cliche about a golf-ball sized piece of uranium having enough energy to drive the Queen Mary across the Atlantic, far from being a 1950s invention had its origin in a 1904 calculation by the English chemist and collaborator of Lord Rutherford, Frederick Soddy, who concluded that the energy in a pint of uranium (rather larger than a golf ball) could propel an ocean liner from London to Australia and back. Finally, coming closer to modern times, Weart cites a 1940 American film, "Murder in the Air," about a secret ray projector that could knock enemy bombers out of the sky. And who was the actor who played the role of the guardian of this filmic precursor of Star Wars? You guessed it — Ronald Reagan.

Of course, for many people nuclear power is inextricably associated with nuclear weapons, and Weart explores this connection in the public mind at length. It is indeed striking that in the 1920s and 1930s, before the advent of the atomic bomb, the public seemed unconcerned about the dangers of radioactivity, although they had been amply demonstrated in the medical literature. One example of this apparent indifference cited by Weart was a 1929 European pharmacopoeia that listed eighty patent medicines containing radioactive ingredients as their active element. Some medicines were advertised falsely as radioactive, but others actually did contain radium, and the first proven death from radiation poisoning was caused by one such, which, among other things, was advertised as a sexual rejuvenant. Those were also the days when women workers in a New Jersey plant painting watch dials with radium to make them luminescent pointed their brushes by moistening them with their lips. Five of them died of what was described as "jaw rot." And studies about that time found the incidence of lung cancer in Czechoslovakian uranium miners to be 50%. The public seemed to take all this in stride — the few publicized incidents seemed unremarkable in comparison with the thousands of lives lost each year in industrial accidents.

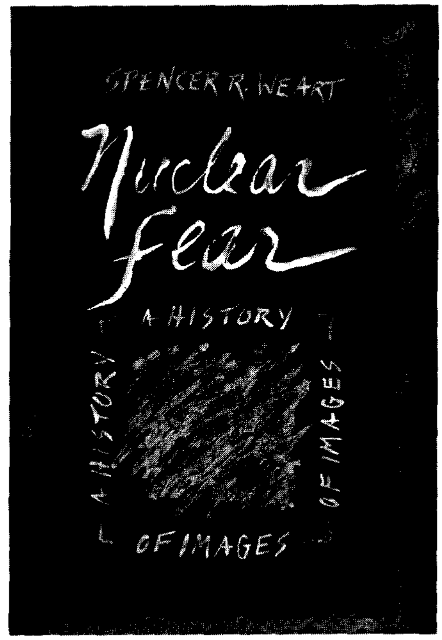
During World War II, however, there was a growing appreciation among scientists in the Manhattan Project of the dangers of radiation, especially from a possible release of the huge amount of fission products that would accumulate in the planned production reactors. To guard against this possibility the Hanford reactors were spaced at least six miles apart and workers' housing was located several times this distance away, while daily exposures were limited to 0.1 rem per day.

These fears were naturally confined to the scientists and workers in the highly secret wartime projects. All this changed, however, with the bombings of Hiroshima and Nagasaki, the development of the even more fearful thermonuclear weapons, the accidental exposure of Japanese fishermen to fall-out from the test of one such device, and the frantic Cold-War buildup of nuclear arsenals. The release of films of the first hydrogen-bomb test in 1952, showing the immense fireball superimposed on and engulfing the entire island of Manhattan, sent fears of Armageddon — literally, for many fundamentalist Christians — shuddering down the spines of viewers. But even then these fears did not extend to the peaceful uses of nuclear energy, touted by the scientists, politicians, and journalists of the day as virtually capable of bringing about a new Eden — the white city of Weart's fable. In fact, it was partly to distract people from the menace of nuclear weapons and to legitimize their continued development and deployment that President Eisenhower fashioned his Atoms-for-Peace proposal that led to the establishment of the International Atomic Energy Agency.

What then, caused public attitudes towards nuclear power to change? Weart traces the first seeds of doubt to the controversy in the 1950s over the Fermi-I reactor, a demonstration-size fast breeder that proponents wanted to build near Detroit, contrary to the then-prevailing philosophy of siting reactors far from large population centers and to the advice of the AEC's own Advisory Committee on Reactor Safeguards. What might have been, however, merely a local dispute was given national prominence by becoming embroiled in the brewing controversy over whether atomic energy should be privately developed or remain a government monopoly. The reactor's proponents, including most prominently an engineer and chief executive of the Detroit Edison Company, were determined to break that monopoly, but committed to its preservation were a powerful senator on the Joint Committee on Atomic Energy, Clinton Anderson of New Mexico, and the head of the United Automobile Workers, Walter Reuther. When Anderson released the ACRS report opposing the proposed siting on the basis of a postulated "maximum credible accident" — a meltdown and explosion breaking the containment and allowing the escaping fission products to blow towards Detroit — the UAW brought suit, initiating four years of litigation which the AEC finally won, but at a heavy price in terms of adverse publicity and the precedent that had been set.

There were other consequences of Fermi-I. In 1957, in an attempt to ease public concern and deal with the reluctance of commercial insurors to insure power reactors, Congress passed the Price-Anderson Act, which guaranteed coverage of roughly half a billion dollars for the damages resulting from the nuclear disaster. Ultimately, this official endorsement of the view that a single industrial accident could cause so much damage was trumpeted by the opposition as evidence of the unacceptable dangers of nuclear power.

Even more damaging was an AEC-requested study by Brookhaven National Laboratory that calculated the consequences of a maximum credible accident (without estimating the probability of such an accident). The results, published in the famous (or infamous, depending on your point of view) WASH-740 report, were enough to give anyone pause: up to 3000 immediate deaths and 1½ billion dollars' worth of damage. What more could the anti-nukes ask for? Avidly seizing on the report, they broadcast its worst-case scenario at every opportunity, and the situation wasn't helped by a remark by Edward Teller (who invented the concept of the maximum credible accident as the benchmark against which all



reactor designs were to be tested) that the report "understates the actual dangers."

Meanwhile, Senator Anderson, intending to reassure the public by making the Commission more responsive to its concerns, forced the AEC into public hearings before licensing any new reactor. Unfortunately, the AEC's manner of conducting these hearings impressed some as "arrogant and secretive," and their effect was opposite to the one intended.

A succession of events further crystallized public opposition. A proposal by the Consolidated Edison Company of New York to build a power reactor at Ravenwood, "in the shadows of the towers of Manhattan," aroused a storm of protest, including that of an ex-chairman of the AEC, David Lilienthal. An earlier attempt to site a plant on the scenic coast north of San Francisco, at Bodega Bay, had run into similar opposition from those afraid of the potential despoiling and contamination of an area of great natural beauty. Eventually both projects were abandoned, not only because of local hostility but because of the doubts about their safety by nuclear experts themselves, doubts that were reinforced in the case of Bodega Bay the discovery of a small geological fault running through the site. Additional impetus was added to the growing anti-nuclear movement by an accident in Fermi-I in which a piece of metal came loose during start-up tests and blocked the flow of coolant to one fuel channel, causing a small amount of fuel to melt. Although the reactor was safely shut down and there was no significant release of radioactivity, the incident touched off speculation about what *might* have happened if only circumstances had been a little different (in each of a long chain of events, of course), and eventually inspired the publication of a sensational and unreliable book with the inflammatory title, "We Almost Lost Detroit".

I will not go into the events, culminating in the Three Mile Island accident of 1979, that brought the anti-nuclear movement to its eventual full flower. Suffice to say, Weart covers this history in meticulous and fascinating detail. Nor will I try to summarize the arguments relating the dread of things nuclear to apocalyptic images and deep-lying sexual fears. Concerning the former, it does not seem to me to be necessary to go beyond the obvious association of nuclear power with images of fireballs, vaporized people, and deadly, drifting clouds of fallout for an explanation of public apprehension, and the latter theory I do not find very convincing. Instead, I'd like to concentrate on what seems to me a sufficient basis for understanding the fury and (to pro-nukes) the irrationality of the opposition to nuclear power. This, as Weart argues in the most eloquent and superbly written chapter in the entire book ("Civilization or Liberation?") can be found in the dichotomies, or bi-polarities, as he calls them, of *authority* versus *victim*, *logic* versus *feelings*, and *culture* (or civilization) versus *nature*.

The argument starts out with the observation, based on surveys, that the most important single factor determining which side of the nuclear debate a person will take is the degree of confidence that person has in basic social institutions. Those who strongly trust those institutions tend to align themselves unequivocally on the pro-nuclear side. Conversely, those who distrust them tend to form the core of the opposition. Trust in social institutions is, of course, closely related to whether one accepts authority as a legitimate and necessary exercise of organized society or regards it as a tool for political oppression — i.e., for victimization.

Also closely related to these attitudes is the value one places on reason vis-a-vis feelings as a guide to action. Scientists, engineers, and government officials like to think of themselves as swayed more by cool logic than by unruly, subjective feelings. Artists, creative writers, media people, and social activists tend to elevate intuition — i.e., feelings — above dry factual considerations. With the exception of media people (who, however, often view themselves as spokesmen for the disenfranchised), they also are prone to visualize themselves as a victims of an increasingly mechanistic society. Such people are predominantly found in the anti-nuclear camp.

But ever since the Industrial Revolution the rationalist mode of thinking has most influenced the course of civilization, a hallmark of which has been the subduing of nature and the transformation of the Earth. In the process, a host of new problems has appeared: environmental pollution, complex social relationships, and the tensions and disatisfactions of an increasingly materialistic life. In the view of some, these ills far outweigh the benefits of modern technology, and man can overcome them only by reducing both the scope and scale of industrial civilization and restoring the earlier, supposedly healthier, balance with nature. For these people, nuclear power is the most visible and potent symbol of a technological society gone amok, and must be destroyed.

Of course, in a society that emphasizes feelings over logic, participatory democracy (another rallying cry of the anti-nukes) over representative government with all its structural forms and procedural safeguards, and a pristine and benign nature over technology, power will gravitate towards those most skilled at the arts of communication — that is, towards those very same artists, creative writers, media people, and social activists. So in the end the motivation underlying all the lofty sentiments, the propagandizing, the appeals to reason and conscience, and the evocation of emotion, may be nothing more than that good old-fashioned lust for power.

This review can give only the skimpiest idea of the riches of this book. It is eloquent, probing, and highly original. It is also at times irritatingly repetitious and insistent, and places undue reliance on the anecdotal evidence of psychologists and social researchers. Nevertheless, Weart (who, by the way, is no anti-nuke) has performed a monumental labor in producing this extraordinary analysis of nuclear fear and exploring the nuclear controversy in unprecedented ways. No matter which side you're on, you'll find this a provocative and stimulating work.

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Integrated Safeguards: A 1988 Perspective

Robert L. Carlson
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ABSTRACT

The forces resisting integration and those promoting it are explored to explain why progress has been so slow. Those constraining integration include inertia, terminology, regulations and funding. Forces promoting it consist of the growing cost of protection, declining budgets, and the emergence of the insider threat. Changes to the approach for preparing Regulations, redefinition of organizational responsibilities, and development of automated methods for data exchange, all offer new opportunities for integration. An integrated solution to the insider problem is described, and an example of integration in an advanced fuels plant is presented.

INTRODUCTION

Integrated Safeguards has been a topic of interest for over a decade. The earliest references in the literature were in 1976 when four papers were presented on the subject at the Seventeenth Annual Meeting of the Institute of Nuclear Materials Management. Since that time, the subject has been discussed and debated in the literature to the present date. Although there has been some progress towards integration, there is general agreement that a considerable amount remains to be accomplished. Kelley (1986) summarized the situation as follows:

"Historically, it has been common practice to divide safeguards activities into two general classes, one security and the other material control and accounting (MC&A). This division has been reflected not only in the safeguards organizations at Headquarters and Operations Offices, but also in the way programs have been planned, safeguards funds have been allocated, and facility systems have been evaluated. While perhaps resulting from ineffective communication between separate organizations, lack of coordination of their activities, and poor integration of facility material control and accounting and physical security subsystems."

These inefficiencies have long been recognized and have prompted the U.S. Department of Energy (DOE) to perform several studies to find ways to promote the integration of these two factions in an effort to reduce the overall costs associated with the protection of nuclear material. Success has been mixed. A few notable examples of successful integration have been accomplished, and will be discussed below; but, in general, progress has been slow or nonexistent.

FORCES RESISTING INTEGRATION

With the emphasis that has been placed upon integration, the question remains: 'Why has progress been so slow'? To answer that question, one needs to examine the forces that resist integration. These include: inertia, regulations, terminology, and funding.

Inertia

Even though there may be forces promoting change, most organizations will resist until the forces become overpowering. This is particularly true in bureaucratic organizations, that have defined charters and are performing their function with some degree of success. Within these organizations, the resistance to change is directly related to the internal perception of success. There is an understandable reluctance to modify something that is working well. Therefore, in a stable organization, all members have clearly defined their participative role and are content in performing those roles. In such an organization, the internal forces promoting change are small or absent. Any changes that do occur tend to be technological improvements that enable the same job to be performed more easily. Examples include copy machines replacing carbon paper, and word processors replacing improvements, but do little to change the job function. While specialized computer packages have largely replaced older manual technologies such as drafting tables and ledger books, the function that is performed remains the same.

In bureaucratic organizations, the major external force that promotes change is the funding level. These organizations produce services, and when funding is reduced, the level of service is reduced correspondingly. When funding levels are increased, the amount of services are generally also increased. However, only drastic changes in funding level have a major influence on organization structure or group function. Very large funding increases result in organization expansion and restructure. Likewise, severe budget cuts require staff reduction and realignment of duties for the remaining staff. The opportunity exists during these times to modify the function of the organization. During these times, integration is possible, in one case from expansion of responsibilities, and in the other from consolidation of organizations. When these organizations stabilize, the window of opportunity is often lost, and resistance to change again sets in.

Terminology

Integrated safeguards is a term that has taken on several meanings over the years. In 1976, Brenner and McDowell described integrated safeguards as the integration of Security and Material Control & Accountability (MC&A). They envisioned a three part program that had personnel control, material operations control, and material accountability. The personnel control portion contained the elements of physical security, and the material operations control had the material control portion of safeguards. Bray and Kendrick (1976) supported this concept, as did Bambas and Barnes (1980), Reynolds (1981), and Miyoshi, et al. (1984).

However, others have used the term 'Integrated Safeguards' to describe systems that combine the traditional MC&A activities with Process Control. Shipley (1977) used that definition in his study of the safeguards system for the Anderson plant. Vaughan (1980) also used it in the description of the system developed for the GE Wilmington plant. Barnes (1985) expanded the scope to included personnel information, safety and work planning. The recommendations of deMontmollin and Walton (1976) included both the integration of physical security and the process.

The problem of separation of MC&A and Physical Security due to traditional terminology was recognized and addressed by Tape, et al. (1987). They proposed a new system in which 'Authorization', 'Enforcement', and 'Verification' were used to describe a new organization of traditional activities. They proposed that new organizations be constructed to align with these new sets of activities. It is unclear, however, how this restructuring would solve the problem. New barriers would quickly be erected to protect the new organization from encroachment of duties by the other organizations. Thus, while the approach is novel, it may not solve the problem.

The definition of Safeguards in the U.S. Department of Defense (DOD) is not always consistent with its use in the DOE and the U.S. Nuclear Regulatory Commission (NRC) communities. For example, when Bruckner (1986) spoke of "Integrating Safeguards and Security with Operational Requirements at DOD Facilities in Europe", the term 'Safeguards and Security' was used to describe what is normally referred to as 'Physical Security' in the DOE.

Without a firm definition of the meaning of Integrated Safeguards, the end product becomes unclear; and without a good understanding of the final goal, the means of achieving it become difficult if not impossible. Thus the lack of standardization in the terminology of integrated safeguards has been a factor in delaying its achievement.

Regulations

From the U.S. Atomic Energy Commission, through the Energy Research and Development Administration, to DOE, the requirements for safeguards and for security have always been kept in separate orders. This division continues to the present day. Physical security is currently governed by DOE Order 5632.2A, MC&A by DOE Order 5633.3. As is often the case when orders are revised on differing schedules, there have been conflicts in the requirements. For example, the term 'category' is used to determine both protection and reporting requirements, and has had slightly different definitions in the two sets of orders. Until DOE Order 5632.2A was issued on February 9, 1988, the Physical Security requirements had not recognized a category IV quantity of nuclear material, although it has been present in the past several versions of MC&A orders. Currently both DOE Order 5632.2A and DOE Order 5633.3 have redefined the quantities in each of the categories to reflect material attractiveness, and are using the same table of definitions. These changes to the nuclear material quantities in each category have been in the process of formulation for several years, and finally reflect complete agreement in category definition. Although the guides to implement these regulations are still being formulated, this closer alignment of regulatory definitions should promote more rapid integration.

In the private sector, the situation was and is even more dichotomous. Bishop, et al. (1976), recognized that licensees were governed by two different parts of the law: 10CFR70 defining material accounting requirements, and 10CFR73 containing requirements for physical security. These requirements were prescriptive in nature with little latitude to develop cost-effective graded systems in either discipline.

Al-Ayat, et al. (1981), recommended to NRC that a single rule be developed that covered both physical protection and MC&A, citing the major benefit as enhancing the uniformity of protection and reduction of the possible gaps that result from two separate rules. They recommended a single performance-based rule that would allow the Licensee to choose the elements of physical protection, materials control, and materials accounting that best suited the process; they also recommended that inspections become a test of the overall system in which all elements would contribute successful levels of protection.

Apparently, that advice was not accepted. Today, the situation is worse. The current Code of Federal Regulations has the traditional activities of Material Control and Accountability in two separate parts of the law; 10CFR part 70 and part 74. Both of these parts have sections entitled "Material Status Reports" (70.53 and 74.13), and "Nuclear Material Transfer Reports" (70.54 and 74.15). Although the headings are in both parts of the laws, only part 74 contains the actual requirements, with part 70 referencing the applicable parts of 74. However, part 70 contains "Measurement Control Program for Special Nuclear Materials Control and Accounting" (70.57), and "Fundamental Nuclear Material Controls" (70.58), while part 74 contains "Nuclear Material Control and Accounting for Strategic Nuclear Material" (74.51) as well as the reporting requirements. Physical Security requirements remain in 10CFR73. Thus, in the private sector, the direction is not to consolidate the requirements for Safeguards and Security which could promote integration, but to divide them even further.

Funding

As described by Kelley (1986), Safeguards and Security have traditionally been supported by different sources of funding. This tended to focus the direction of attention inward towards internal needs, rather than outward towards the overall needs of the facility. The emphasis was on projects that would solve problems only within the one discipline, with little regard to the needs of other organizations. This naturally evolved from the phenomenon that integrated projects have many more requirements than projects addressing a single interest. This, in turn, makes them more expensive and thus harder to fund.

Integrated projects are difficult to fund from a single source. Accountability projects normally have difficulty justifying and fulfilling Security needs; and the same is true of Security projects meeting MC&A needs. Combining several funding sources is difficult due to the differences in the approval cycles of the separate funding agencies. In the instances where a construction project includes funding for Safeguards and Security, as well as the process, the opportunity exists for integration. An example where substantial cost savings were realized due to this arrangement was the Fuels and Materials Examination Facility (FMEF) built at Hanford.

FORCES PROMOTING INTEGRATION

The major force promoting integration is the growing cost of protection and the shrinking budget for the nuclear industry. With the increased level of terrorist activities throughout the world, DOE's re-evaluations of facilities once thought secure have revealed vulnerabilities to a dedicated attack. This has brought about more stringent requirements, more frequent tests and more critical inspections. All of these factors have combined to dramatically increase the cost of protection. There is a strong interest by DOE/HQ to reduce these soaring costs where it can be done without creating vulnerabilities. Where integration would either enhance the level of protection effectiveness or eliminate duplication, it should be pursued vigorously.

The increased attention being paid to the insider threat mandates a change in the traditional focus of Safeguards and Security activities. Previous attitudes that background investigations conducted for a "Q" clearance would weed out potential undesirable insiders has recently proven to be untrue. The Walker Case is a prime example. Therefore new solutions need to be found. These solutions must be balanced with the needs of production. One of the major DOE missions is to produce weapons for National Defense, and the goal of the domestic programs is to produce cost-effective peace time nuclear uses. Therefore, any Safeguards and Security solutions that intrude significantly on the production mission or the cost-effectiveness goal are unacceptable. Fortunately, several emerging technologies may aid in developing new solutions. These will be discussed in succeeding sections.

The insider threat poses a problem that crosses the traditional boundaries of Accountability, Material Control, and Physical Security. Since most facilities have processes that allow hands-on access to nuclear materials, it is almost impossible to eliminate the opportunity for an authorized insider to divert or steal nuclear material. When routine handling of nuclear material is part of an individual's job function, the opportunity for access to that material cannot be prevented. The major problem, then, is to ensure that all the activities of the individual are legal and authorized. To perform this function administratively becomes burdensome to the process, especially if colluding insiders are considered.

OPPORTUNITIES FOR INTEGRATION

There are a variety of opportunities for integration. Some of these are in the elimination of the barriers described in previous sections. Inertia in an organization and the separate sources of funding are probably the most difficult to overcome, as they cannot be attacked directly. However, as the other barriers are eliminated and further opportunities arise, these may cease to be problems.

Integration of Regulations

When regulations are prescriptive, managers of facilities are reluctant to avoid literal compliance. For example, if the regulations state that response must be within a specified time, managers facing inspection will ensure that the response meets that time, even though the inherent delays built into the facility may allow a reaction that is less rapid and still provides adequate protection. Prescriptive regulations do not permit flexibility.

Although the trend is away from prescriptive regulations to laws that are more performance oriented, inspections still tend to focus on a discipline or a portion of that discipline without regard to the effectiveness of the rest of the system. Thus an inspection of Accountability ignores how well the material is controlled or physically protected. When inspections stem from different orders, whether they be prescriptive or performance oriented, there is little latitude to pick and choose safeguards measures that are cost effective for a particular facility. The solution is to produce a single performance-based regulation that would become the basis for performance tests and inspections.

Integration of Responsibility

Normally it is difficult to integrate responsibilities except in concept. When a job is broken into smaller tasks, assigning responsibility for a specific task to more than one individual or group does not work. Under these circumstances, either no-one accepts full responsibility, or there is overlap, conflict, and subsequently wasted resources. Two organizations can have responsibility for a job if each group has well defined tasks. An example, can be found in the nuclear material movement procedures used by Sandia National Laboratory. There the material handlers, which are part of the operations department, and the guard force, which is part of the Security department, share the responsibility for SNM movement. However, each group has separate, well defined functions that they must perform as part of the overall job. So, while the job is shared, the tasks are not. This arrangement allows each group oversight over the other's activities; and theoretically, provides a stronger Safeguards system as there is little opportunity for collusion.

This approach can and has been applied to many areas of Safeguards and Security. At the highest level, protection of nuclear material is the responsibility of the United States Government. This responsibility has been delegated to the Department of Energy, Office of Safeguards and Security; from there to the Field Offices; and finally to the contractors. At the contractor level, the responsibility has been divided into security, materials control, and accountability, although in many cases the latter two functions have been combined into a single department.

In most contractor operations, the security function has been split into two organizations: Security and Patrol. Security has the responsibility for interpreting policy establishing guidelines, and is primarily an administrative organization. The Protective Forces are charged with the responsibility of implementing the policies and guidelines. This type of organization seems to work well, with one group providing the planning and direction while the other performs the function.

This division between supervision and implementation has not been as apparent in materials control and accountability. In some contractor organizations the MC&A job has been split between the MC&A organization and the Process organization, with each faction having well defined duties. The Process organization has the responsibility for the material handling, and Safeguards provides an oversight and reporting function. However, Safeguards often retains some of the MC&A implementation functions, so that the division between administration and execution is not well defined.

One opportunity for integration would be to clearly separate the administration and implementation functions in MC&A, and then to combine the administrative portion with the similar organization in Security. This would provide an integrated Safeguards and Security managerial group, Patrol which executes the physical protection function, and an MC&A implementation organization. Some integration would be achieved, while maintaining separate performing organizations.

Integration of Data

Probably the major opportunity for integration is with data. In the past, the philosophy has been to generate Safeguards data separately from other organizations. This separation assured independence of the data, but doubled the cost for data collection and handling. Under the current economic conditions, it is no longer feasible to pursue that philosophy. The data should be generated once and then shared. Where possible, the transfer of information should be automatic and electronic. This means developing online computing systems so that the information can be used by each individual group as soon as it is available. This type of integration is possible with today's technology, and does not perturb the organizational structure or current functional responsibilities.

As shown in Figure 1 and Table 1, a considerable amount of data needs to be shared. Most information needed by an organization to perform its function is needed by at least one more group. For example, Material Quantity, Chemical Composition, and Measurement information are needed by Accountability, Process, Quality Control, and Material Control; while Specific Location and TID data are only needed by Material Control and Process. Although each organization has data needs that overlap with others, the interactions are extremely complex.

To analyze these relationships, a pair-wise comparison was made of the 27 generalized information elements for the various disciplines. The results of this comparison are shown in Table 2. From the totals, it can be seen that the greatest number of interactions with other groups is by the Process with 39, and the fewest is in Security. As expected, the Process has the greatest interchange with Materials Control and Quality Control at 13 data elements each. The overlap of the Security information needs is poorest with Accountability and Quality Control.

From Figure 1, it can be seen that the disciplines of Security, Accountability and Quality Control form three poles in the diagram. The information overlap between these three, if only these three are considered, is low enough not to warrant the building of an integrated data interchange. The disciplines of Process and Materials Control, however, overlay the intersection of these poles. Thus the building of an integrated data system should start with Materials Control and the Process. Not only do these two have a large number of common data elements, but together, they contain all but four of the data types in the matrix. If data integration started with Material Control and the Process,

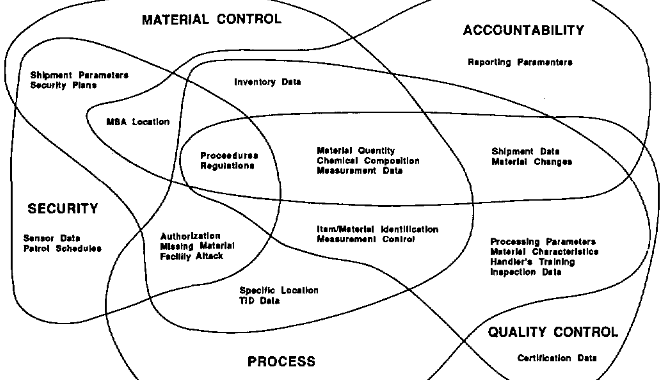

Figure 1. Data Needs for Materials Control Accountability, Quality Control, Process and Security

the addition of the remaining disciplines of Security, Accountability and Quality Control would be relatively simple.

INTEGRATED SOLUTIONS TO THE INSIDER PROBLEM

A discussion of integrated safeguards is not complete without an examination of the insider problem. The insider has been a threat for many years, but little has been done in the way of finding solutions due to the difficulty of the problem. With today's technology, perhaps some solutions are at hand.

The insider adversary who has routine access to nuclear material has an advantage that the outsider lacks. When an outsider attacks a facility, his actions relay his intentions. However, an insider's intentions are not known until the act of a theft or diversion is in progress. Therefore, with the insider, there is much less time to respond. Thus, detection of an adversarial act needs to occur when it starts.

To provide this early detection, there are three necessary functions that must be performed: Tracking nuclear material, controlling personnel, and assessing authorization.

Material Tracking

Traditional techniques of material control which indicate that material has moved are not sufficiently timely to prevent theft or diversion. These methods can only detect a diversion after it has happened, and may act as a deterrent if the probability of detection is high and the discovery time is sufficiently short, but they rarely can detect the act and cannot prompt a response in time to curtail it. The needed system is one which alerts the authorities when material starts to move.

There are several ways to perform the tracking function. The WATCH system described by Sanderson (1987) tracks items by means of a transmitted signal. It is a device that attaches to a container or part and emits a radio frequency signal when it senses motion. The item that is moving is identified from all the other items that have WATCH units. It does not yet have the capability to track movement, although that capability would exist with further development.

Another method under investigation to track material is called "Ntrack". This system is designed to track bulk nuclear material movement by sensing the change in radiation that occurs over time when a quantity of SNM is moving. It does so by triangulation. It also promises to trace material movement and determine approximate quantity. It cannot, however, differentiate between items unless their precise beginning location is known, and it is not expected to function well under conditions where simultaneous movements occur. While still only in the initial testing stages, this method shows considerable promise.

Los Alamos National Laboratory is developing a system to detect movement and/or tampering of containers in a storage area. The system uses video images and compares these to previously stored images of the same location. Very small changes in item location and orientation can

Table 1
Integrated Data Matrix

Data Element	M.C.	Acc	Q.C.	Process	Sec
Shipment Parameters Date, time, locations	x				x
Security Plans VA's, MSSA's, upgrades	x				x
Inventory Data Beginning, ending, changes	x	x		x	
Reporting Parameters Project No., COEI, Material Type Code		x			
MBA Location Quantity by MBA	x	x			x
Procedures Operating instructions	x	x	x	x	x
Regulations Orders, directives	x	x	x	x	x
Material Quantity Element, net and gross weights	x	x	x	x	
Chemical Composition Element and isotope ratios, impurities	x	x	x	x	
Measurement Data Chemistry and NDA	x	x	x	x	
Shipment Data Quantity, composition, identifications		x	x	x	
Material Changes ID's, decay, production, burnup		x	x	x	
Sensor Data Alarms, tests, maintenance					x
Patrol Schedules Deployment, staffing, armament					x
Authorization Access, material handling	x			x	x
Missing Material Loss of item of quantity	x			x	x
Facility Attack Confirmed alarm	x			x	x
Item/Material Identification Facility identifications for discrete quantities	x		x	x	
Measurement Control Calibrations, standards, errors	x		x	x	
Processing Parameters Temperatures, pressures, times			x	x	
Material Characteristics Form, grain size, pH, flowability			x	x	
Handler's Training Training records			x	x	
Inspection Data Feed, in-process, product			x	x	
Specific Location Position by identification and quantity	x			x	
TID Data Records of TID Seals	x			x	
Certification Data Process, measurement technique, vendor parts			x		
Process Trends Efficiency, throughput rates, reject rates				x	

be detected. It appears to be useful for storage locations where a large number of movements are not expected; and it can be activated by a motion detector so that it only needs to be operated when someone is present. Although the algorithm alarms when something is moved, human assessment and intervention are still needed to determine the legality of the movement.

Another method of tracking is to utilize a method similar to the process used in an automated system. This consists of weighing and identifying an item before it leaves the source, comparing the elapsed travel time against an expected time, and verifying weight and identity upon arrival. This method is not as timely as those previously described, as it can only alarm after a diversion or theft has occurred, and there is some possibility of substitution if the individuals making the move are colluding insiders. On the other hand, it can be rapidly implemented by any facility having a real-time accountability or process control system.

Authorizing Movement

If the nuclear material were in a permanent storage where no movement was allowed, the function just described would provide sufficient protection. However, most facilities have processes where material is not only moved on a routine basis, but is changed in composition, quantity, and/or form as a result of the process. In these facilities, real-time tracking of the nuclear material may not provide enough information to determine if diversion or normal processing is occurring. Therefore, an additional piece of data is needed: is that material supposed to be moving? To obtain this information requires the cooperation of the Process, the Accountability system or both. To be timely, either the process must have an on-line production plan that provides data on material movement by item and time, or the Accountability system must be real-time as well as on-line. Either system must be able to provide the information about the sending location, the destination, and the item or quantity that is to be moved or processed.

Table 2
Data Element Matrix Analysis

Discipline	M.C.	Acc	Q.C.	Process	Sec
Materials Control (M.C.)	—	7	7	13	8
Accountability (Acc)	7	—	7	8	3
Quality Control (Q.C.)	7	7	—	13	2
Process	13	8	13	—	5
Security (Sec)	8	3	2	5	—
Total	35	25	29	39	18

Integration between either the process control or the accountability system and the on-line material control tracking system is needed to provide an exchange of data rapidly enough to determine if the item or material movement is authorized. When material movement is sensed, the materials tracking system must obtain information about the authorization of that movement within seconds to decide whether or not to generate an alarm. If the movement is authorized, the tracking system must follow the material to its destination to ensure that diversion en route has not occurred.

Controlling Personnel

One additional function is needed to supplement the material tracking and movement authorization systems. The material tracking system indicates when an event is happening, the process control or accountability system confirms whether it is a legal move, but it is still unknown whether the person or persons involved are authorized to make the move. This information is vital if a diversion or theft does occur. Two things need to be considered: (1) Whether the individuals attempting the activity are who they say they are, and (2) if they are authorized for that activity. Control at portals allows entry to an area by authorized individuals, but not all of these persons are permitted to handle nuclear materials. Maintenance personnel, supervision, and members of the protective force are examples of individuals that have routine access, but no handling authority, but may have or obtain the knowledge that a movement is pending. If one or more of these persons takes the correct material, during the correct time frame, and in the appropriate direction, the system will not alarm unless there is some indication that those individuals are not authorized. Therefore, it is important that the integrated system provide both the identification of the individuals and the establishment of their authority to act.

Again, there are several ways to establish identity. There are commercially available devices which utilize some physical characteristic to verify identity. These personnel identity verification (PIV) devices include hand geometry, fingerprint scan, retina scan, handwriting analysis and voice print verification. When used in conjunction with the movement request, these devices will positively identify the individual. Waddoups (1987) described a new personnel monitoring device being developed that can be attached to an individual to identify those persons that pass through a specially designed portal. While some method is still needed to link the individual to the identification, this method offers an advantage over the PIV in its ability to provide some tracking of individuals in real-time. The more numerous the portals are, the more effective is the tracking.

Identifying the individuals still does not establish their authority for the act being performed. Some other link must be established to perform that function. A table of authorization, protected from tampering, needs to be available to the tracking system. This table can either be resident in the subsystem for personnel tracking, or be obtained from the process control or accountability system.

DEVELOPING AN INTEGRATED SYSTEM

As can be seen from the foregoing descriptions, a considerable number of pieces of information that come from a variety of sources are needed to make a real-time alarm decision. There are generally two approaches: build a single system that contains all of the required data, or develop an integrated system. The single system approach requires maintenance of a database that contains information often duplicated elsewhere. It has the advantage that it can perform its function independently, without assistance of other systems; but has the disadvantage that any data changes (movement information, or access authorization, for example) need to be independently performed in several systems. This duplication makes data maintenance more complicated and more prone to error.

The integrated system coordinates the information that resides in other systems as necessary to perform a specific function or to make a decision. Updates of information such as location of material, or access authorization levels, need only be changed once and can be performed at their source. A disadvantage is that a variety of systems must be operational to obtain all the necessary data.

AN EXAMPLE OF INTEGRATION

The Fuels and Materials Examination Facility (FMEF) at the Hanford Site is an example of a facility where integrated Safeguards concepts were included in the early design phases. Not only were attempts made to integrate the functions of security, materials control and accountability, but integration with the process, quality control and building functions were also planned.

The FMEF was designed and built as a remote and automated facility that at times during its construction had the various missions of fuel fabrication, reprocessing, and post-irradiation examination. Since the building was designed to handle irradiated materials, high burnup plutonium, and Uranium 233 spiked with Uranium 232, heavy shielding and remote handling were required. The decision was made early in the design that, where possible, the processes should be automated and computer controlled. In addition, the computer control was to be at the local level, with CPU's that were dedicated to segments of the process. This was an ideal setting for data integration. Although the computer processing was distributed, each individual unit needed information that was produced by a computer somewhere else. Thus a network for information flow was designed to provide the information when and where it was needed.

The FMEF was divided into four major computer centers for control of the various disciplines and for information exchange: Process Control, Security, Accountability, and Building Control. Each of these centers was structured internally in a hierarchial manner for information and data transmission, while data was transmitted between the centers over a dedicated link. The philosophy was that only information and not control would be exchanged. Thus one computer could not shut down another computer in a different control center. The control function was retained in each computer center, and the decision about what action to take was dependent upon the information received and the current conditions.

Building services such as inert gasses, cooling water, electricity, and air balance are monitored by a building control computer. Some of these services are critical to safe operation of the various processes, and information about the failure of a particular service needed to be transmitted so that the process could be safely shut down if that service was needed for continued operation. An example is the continuous flow of chilled water that was needed for air conditioning in the various computer rooms. Notification of a failure in the chilled water system would enable orderly shut down of the computer systems before they "crashed" due to an over temperature condition. An example of a security interface is in the air balance monitoring. Drastic changes in air balance could be due to equipment malfunction, sabotage, or intrusion into the ducting. During off-shift hours, the security system requires notification to enable investigation and response.

The Process Control computer center performed two functions: control of the various processes, and collection of Quality Control data. It also collected data for the Accountability System and transmitted internally generated alarms to the Security system. During the initial design of the process equipment and control system, it was decided to use only one set of measurement instrumentation, rather than separate instruments for process, accountability and quality control. Thus instrumentation was selected that would meet the strictest requirements for that portion of the process, and control for those instruments was assigned to the Process Control subsystem. The process control computers gather the measurement data, convert it to engineering units, use it for process monitoring, store it for Quality Control, and transmit it to the accountability system as appropriate.

The Process Control also performs an on-line nuclear materials control and criticality safety functions. Continuous monitoring of the process equipment and material movement is necessary to ensure that the process is functioning properly and that material is not accumulating above safety limits. For example, a can of plutonium oxide is weighed and identified before it is placed on a conveyor belt to be transported to the next process segment, and a timer is activated. If the container does not arrive at the destination within a preset time, an alarm is raised. Upon receipt, the can identification is rechecked to ensure that no material was lost during transport. Thus, any action that would indicate diversion of SNM is rapidly discovered by the process control computers, and an alarm is generated. In addition, the same procedure is observed during manual transfers that result from cleanout or an upset condition. The container is weighed and identified at each end of the transfer, as well as the whole operation being timed. Since two-man control is required during any manual transfer for both Safeguards and Safety reasons, the computer provides an additional check that essentially constitutes three-man control. Any deviation from the expected conditions is investigated and alarms are automatically generated if warranted.

The Accountability Control center tracks nuclear material from entry into the facility until it leaves as product, waste or scrap. As part of its hierarchial structure, it contains the Receiving and Vault subsystems. The Receiving subsystem contains the receiving and waste nondestructive assay (NDA), and controls the automated handling equipment that interfaces with the vault. The FMEF vault is completely automated. Plutonium is contained in Central Research Laboratory canisters that mechanically mate with the process equipment and enclosures. Within the vault, these are stored in special concrete filled pallets. The pallets are moved between storage locations and the transfer station by an automated stacker/retriever. The canisters are moved between the pallet and the Vertical Reciprocating Conveyer (VRC) by a computer controlled electrical robot. The VRC moves the canister between floors of the building, interfacing with the receiving and assay area, the NDA laboratory, and the process. As within the process, each canister is weighed and identified as it enters or leaves the vault, and comparisons are made with the information about that canister as it is received or stored. If the comparison fails for any reason, the transfer is suspended, an alarm is generated, and the container is placed in a secure position until an investigation is conducted.

Since the vault is in an automated mode during normal operation, there are several illegal operations that generate alarms directly to the Security Control center. If the controllers are switched to manual mode, an alarm is immediately generated, as this is an indication that an insider is attempting to move material in an unauthorized manner. Differences between control state and sensor status also generate alarms. An example is on the VRC doors, where the control state is closed and a sensor indicating open might be the first indication of an individual attempting to force the door.

The Security Control center monitors both the external and interior intrusion sensors, and controls building access. The alarm subsystem operates like most modern security systems. When an alarm is generated by a sensor, the controller brings up a pre-determined camera for protective force assessment. In the design of the FMEF systems, if the alarm is indeed an intrusion, that information is sent to the other control centers. These individually take action that is deemed appropriate. In the Accountability Control center, for example, all transfers from the vault are suspended, and any material in transit is put into storage. Then the stacker/retriever and the robot are moved into positions where they become most effective as barriers and are powered down to prevent their possible use by the adversary. In addition, the Accountability computer can be logically disconnected to protect its classified information. In the Process Control center, similar actions can be taken to get the SNM inside equipment where it is better protected from forcible removal.

The security computer also controls building access. The building is divided into floors and areas that are entered by means of a keycard. As people enter the facility, they are provided a keycard that is assigned to the individual whose identity is verified with hand geometry. The security computer contains the hand geometry profile for each individual along with an access authorization list for floors and rooms. The computer then permits access where authorized, alarms when unauthorized access is attempted, and tracks each individual throughout the facility. This latter capability provides an integrated sharing of knowledge with Safety. In the event of an emergency, the location of all building occupants is available at a remote terminal. Individuals can be inventoried from this list. The locations of missing persons and probable routes of exit can be determined in case of an accident.

An additional area of integration is between the Security Control center and the Accountability Control center. The security computer contains the hand geometry profile for all persons that are authorized access to the facility. This information is used by the accountability computer when access to the classified database is requested. Rather than two lists being maintained and updated, the security computer retains the master list and the accountability computer requests that information when it is needed.

CONCLUSIONS

Evidence suggests that Integrated Safeguards should be pursued where it is cost-effective to do so. However, the barriers towards its achievement need to be eliminated, and the first barrier that needs to be tackled is terminology. Bartels (1988) in his address to the INMM Technical Workshop on Integrated Safeguards, used the term: "Integrated Nuclear Materials Protection System". It is suggested that this term be adopted, and that it include the information integration from Security, Materials Accountability, Materials Control, Process Control, Quality Control, and Safety. Then a system that shares the data shown in Figure 1, and makes it available to all those disciplines that need it becomes the goal of a Integrated Nuclear Materials Protection System.

The next barrier to eliminate is differences between the regulations. The most efficient way to do this would be to develop a single, performance-based order for the DOE community that covers both Security and MC&A; and to perform a similar consolidation of requirements in 10CFR for the Licensees. This will tend to reduce the inconsistencies and conflicts between regulations that have been present in the past. While it is outside the scope of this study to implement this consolidation, the recommendation is made that policy makers move in that direction.

The development and use of technology described earlier to track nuclear material and identify individuals needs to be accomplished to protect against the insider. These methods are relatively non-intrusive on process operations. They merely force compliance procedures already in existence.

Where possible with automated methods similar to those presented in the preceding section need to be utilized to remove personnel from areas containing SNM. Not only do they improve the Safeguards posture of the facility, they reduce radiation exposure and contribute to improved product quality.

Finally, automated methods of data exchange need to be developed and incorporated into plant operations to form an Integrated Nuclear Materials Protection System.

ACKNOWLEDGEMENTS

This was an integrated safeguards project. It involved the cooperative efforts of Sandia National Laboratory, Los Alamos National Laboratory, and Westinghouse Hanford Company. Guidance and funding were provided by Ivan G. Waddoups of Sandia. Jack T. Markin of Los Alamos provided assistance and review. G.W. Riedeman of the Westinghouse Hanford Company served as a sounding board for ideas.

The Integrated Data Matrix, Table 1, was developed with the help of a large number of individuals from the three sites. I wish to acknowledge the help of Gene Bentley, Dave Bouse, Wayne Delvin, Kay Ondracek, Dave Rasmusssen, and Marjory Serier of Westinghouse Hanford; Russell Curtis, Byron Gardner, James Kaiser, and Art Trujillo of Sandia; and Bob Kellam, Bob Marshall, Bob Pogna, and Nick Roberts of Los Alamos.

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Argonne National Laboratory-West Integrated Safeguards

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ABSTRACT

This paper describes the key features of safeguards integration that have been developed over the last few years at Argonne National Laboratory-West (ANL-W). The areas discussed are Physical Protection (PP), Material Control (MC) and Material Accountability (MA). The information will conclude with a brief discussion of experimental concepts that have been tested or are in progress.

PHYSICAL PROTECTION (PP)

Physical protection elements have been introduced at ANL-W through the integrated effort of management, safety, safeguards and security. The result has been to upgrade physical barriers, alarm and assessment systems, interlock systems, to provide for controlled evacuations, and to consolidate key areas.

Physical Barriers

One of the important physical protection developments at ANL-W is the "hardening" of Material Access Areas (MAA). This has included such steps as installing multiple barriers to all entry points, which not only delay an adversary trying to gain forced entry, but also adds layers of difficulty for the insider trying to remove material. Another significant effort has been to provide overburden to protect walls, floors and ceilings from forced entry.

Interlocks

Interlock systems have been implemented to enforce a "one-door-at-a-time" concept. This prevents a clear path for attack from the outside, while also providing alarm and assessment of the potential insider threat. This concept is further used to prevent the unauthorized removal of special materials (SNM) through monitored access points.

Safe Haven Concept

The safe haven concept is applied at ANL-W to prevent the "grab and run" scenario that would potentially allow rapid removal of material during an evacuation of a facility. The concept is simply to control all emergency escape routes, within the constraints of safety. This can be done through fences, gates, monitoring points; with the evacuees directed to a controlled and monitored collection area.

Consolidation of Areas

Past inspections and evacuations resulted in a clear need to consolidate facilities and functional areas in order to utilize protective forces to the best advantage. Scattered functional areas, such as process, radiography, testing, assembly, and non-destructive assay led to numerous transfers, multiple targets, and complex response plans. Through consolidation, the number and frequency of material transfers is minimized. Security response plans are greatly simplified and lead to economies in manpower and supervision.

Rapid Response to Emergencies

ANL-W takes advantage of a small, compact site to provide rapid response to emergencies. A state-of-the-art central station alarm system allows timely assessment and evaluation of emergency conditions with resulting immediate response.

Other factors that have contributed to a strong physical security posture are the implementation of a human reliability program and an aggressive security inspector training and qualification program.

Another area of integrated effort has been the development of vulnerability analyses. This effort has been punctuated by strong, aggressive management involvement as well as excellent facility participation. Figure 1 is illustrative of the process. It shows security engineering as the conduit or "funnel" for integration of various interests and concerns. Input from management, security operations, material control and accountability, facility management and operations, safety, quality and peer groups all combine to form a unified, coherent approach to vulnerability assessment.

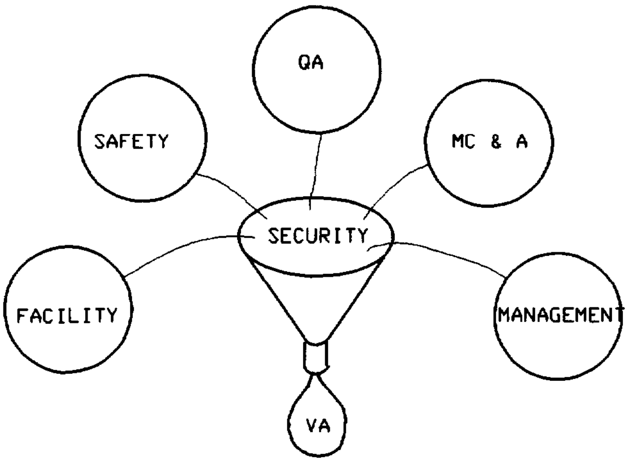

Figure 1. VA Integration

MATERIAL ACCOUNTABILITY (MA) AND MATERIAL CONTROL (MC)

Proven material accountability and control practices are employed at ANL-W. For example, access lists are established, updated and maintained for all material access areas. These access areas are located within a well-defined protected area and have the combined strength of delay, alarm and assessment. Material surveillance procedures are in force for appropriate transfers. Loss and apparent losses, if such should occur, would be promptly reported to management and security.

Vault openings and closings are coordinated with material control, facility and security personnel. On-site and off-site transfers are closely coordinated according to written plans and procedures, which include written notifications.

Vault and safe combinations are registered and maintained by security. Multiple key holders from various groups enhance the control and usage of keys and combinations. Emergency evacuations are pre-planned and practiced according to written procedures. Also, normal and after-hours working conditions are planned for and scheduled in writing well in advance of the activity.

Current work in the area of integrated materials control and accountability at the ANL-W Fuels Manufacturing Facility (FMF) was initiated with the development of a PC based Materials Accountability System. System software was developed by Los Alamos National Laboratory (LANL). This system, known as PC-DYMAC (Dynamic Materials Accounting), operates on a number of personal computers and is currently in use in the ANL-W FMF. Subsequent to this development, ANL-W personnel worked with Sandia National Laboratories (SNL) Albuquerque who were performing developmental work in the area of integrated safeguards. In August 1987 SNL demonstrated a system in the FMF which integrated materials and personnel tracking aspects of materials control into a single operational system (Ref. 1). This previous demonstration together with LANL's PC-DYMAC has grown into the current effort, initially known as the Integrated Materials Control System (IMAC), which is now being called the Argonne Unified Safeguard (ARGUS) System. The ARGUS system consists of the materials tracking portion of the SNL demonstration integrated with a new version of the LANL PC-DYMAC.

The basic purpose of the earlier demonstration by SNL was to provide a working test and evaluation of a developmental system. This system demonstration was instrumental in formulation of the current project. The ARGUS system currently under development is made up of three major components. These components perform the separate functions of (a) observing all containers for movement or tamper either authorized or unauthorized, (b) authorized access approval or denial, initiation and receipt of material transfer with update of materials accounting data base, and finally (c) the performing of materials accounting for the facility. Both functions (a) and (b) are coordinated through a single computer which is known as the Computer Augmented Materials Access (CAMA) system.

The CAMA system, as depicted in Figure 2, receives input from the two "subsystems" to facilitate execution of functions (a) and (b). With function (a) being provided by the Wireless Alarm Transmission of Container Handling (WATCH), and function (b) being performed by the Mobile Accountability Verification Inspection Station (MAVIS). To conduct function (a) the WATCH system provides electronic surveillance of containers, for both access and tamper. This is provided by electronic motion-sensing devices that have been attached to all SNM containers which communicate via RF to the WATCH controller which in turn communicates with the CAMA system, again using a RF data link. Thus any motion of a "WATCHed" container,

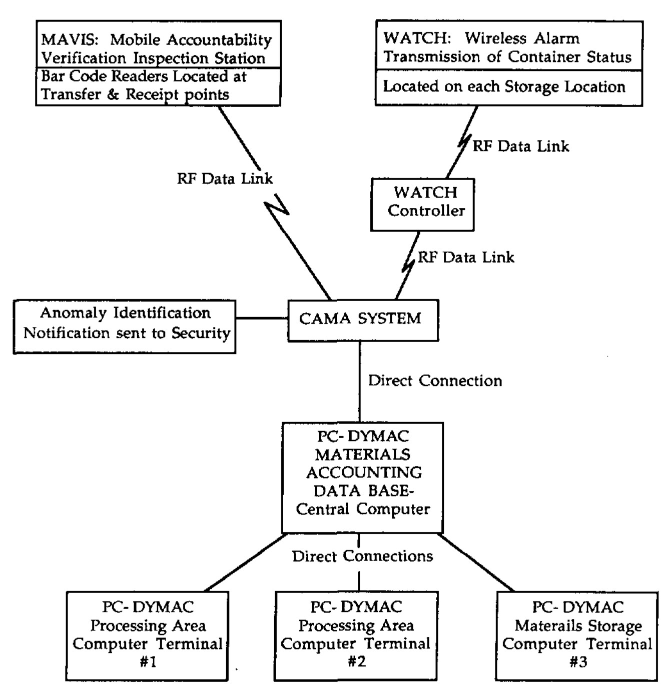

Figure 2. Basic Schematic of the ARGUS System

i.e., tampering or access, either authorized or unauthorized, is continuously monitored on a 24-hour basis with all detected motions recorded by hard copy for further investigation. A significant benefit of the WATCH system is that electronic surveillance of material is provided on a full-time basis. By analogy, this is far superior to a conventional tamper-indicating device in providing continuous surveillance. Access to a container that is "WATCHed" is accomplished by informing the CAMA system that a specific WATCH and therefore the specific container to which the WATCH is attached is going to be moved or opened. This notification is provided to the CAMA system with access authorization and electronic confirmation of Materials Surveillance Procedures (MSP) through the MAVIS system. In addition the CAMA system will report identified anomalies directly to security for immediate action.

The MAVIS system consists of a remote user-interactive bar code reader that communicates with the CAMA system computer via a RF data link. The interactive nature of the MAVIS software provides the user adequate questions and feedback, in the form of confirmatory questions, to make its use straight forward. A typical interaction with the MAVIS involves a brief initial period of question answering, the majority of which are answerable by reading a provided bar code, e.g., for destination and transfer type, followed by personnel identification accomplished by the reading of a bar code for the employee's identification credentials. The SNM container identification, transfer type, destination, and personnel authorization are all known at this point and have been communicated to the CAMA system. A more detailed schematic of the MAVIS, WATCH, and CAMA systems interactions is shown in Figure 3. If the CAMA system has received prior knowledge of authorized access or movement of SNM no alarm will be reported. In addition, "time outs" are provided which will cause the system to alarm if, for example, material access takes too long or a material transfer is not completed in a predetermined length of time. In all instances, e.g., container changes, material transfers etc., the session with the MAVIS is ended with a final required bar code read reconfirming the participating personnel, thus confirming MSP during material access. All material transfers are receipted in a similar fashion using the MAVIS, updating the materials accounting data base and again confirming MSP during the actual transfer and receipting process. All identified anomalies are reported and recorded. Actions by security are currently under development. In summary, most of the interactions with the materials accounting system are provided through the reading of bar codes using the MAVIS system.

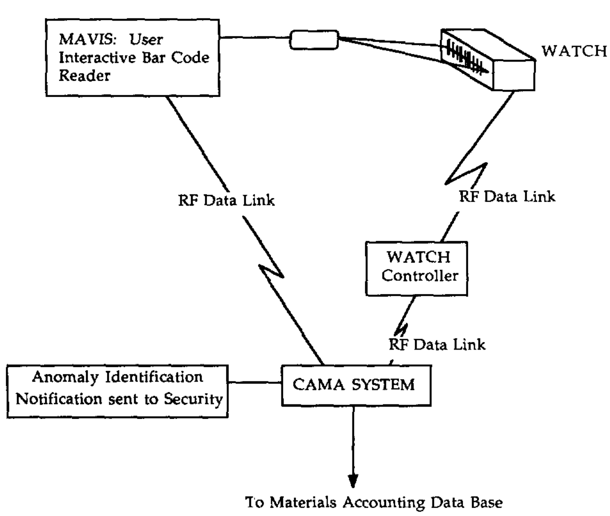

Figure 3. Schematic showing MAVIS, WATCH, and CAMA System Interactions

The CAMA system capabilities can be summarized in saying that it interfaces with both the MAVIS, WATCH, and PC-DYMAC. In addition to handling MAVIS interactions, reporting WATCH movements, and maintaining a state of health for each individual WATCH, the CAMA system also:

- updates PC-DYMAC with respect to what containers are being accessed, who is accessing the containers, and the destination of transfers or changes in location within the same room,
- provides electronic confirmation of MSP during material access, material transfer, and material receipt,
- provides approval for personnel who are attempting to access and/or transfer material,
- provides alarms to local security when an anomaly occurs such as disapproval of material access.

The final component in the ARGUS system is the materials accounting data base, PC-DYMAC. For specific details with respect to PC-DYMAC the reader is referred to Reference 2. PC-DYMAC, currently in use in the ANL-W FMF, has proven itself over time to be sound accountability software. Currently PC-DYMAC is being reconfigured for its part of the ARGUS system. As indicated in Figure 1, PC-DYMAC will consist of 4 personal computers, a central unit that is directly connected to the remaining three. All communications that are required between peripherals is through the central computer station. In this way, all inventory updates of peripheral computers, as well as communications between the CAMA system and PC-DYMAC, take place via the central computer.

The overall integration of these systems represents a level of integrated safeguards not before seen at the ANL-W site. It is believed that this integration will provide ANL-W with significant benefits. ARGUS system benefits can be summarized through system capabilities as follows: near real time accountability, full traceability of material access and transfer without the current hand written generation of paper work, enforcement of approved personnel accessing material, electronic confirmation of MSP during material access and transfers, continuous 24-hour surveillance of all vault stored material, personnel tracking through knowledge of material access, transfer initiation and receipt, and automatic notification to security for identified anomalies. Since this is a developmental program, the goal of which is a test and evaluation of this system is an operational environment, some of the listed benefits may not prove to be less advantageous while others, not yet identified, may be recognized. At a minimum, this system is a promising safeguards system which can be built upon in the future.

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The Idaho Chemical Processing Plant Process Monitoring Computer System

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ABSTRACT

The use of the Process Monitoring Computer System(PMCS) at the Idaho Chemical Processing Plant (ICPP) relative to Safeguards and Operations concerns is discussed. Measures which have been taken to assure the reliability of the system data are outlined along with the measures taken to assure the continuous availability of that data for use within the ICPP. The integration of process and safeguards information for use by the differing operating staff levels is discussed. The PMCS successfully demonstrates the concept of remote Safeguards surveillance and the need for common information between different support organizations for an operating plant.

SYSTEM DESCRIPTION

The Process Monitoring Computer System (PMCS) at the Idaho Chemical Processing Plant (ICPP) is a set of data acquisition devices which transmit process data to a computer for data processing and storage. These signals are in the form of analog (continuous) and digital (discrete) data from the plant instruments and special sensors installed on the plant equipment. This system began as an experiment in remote Safeguards surveillance of an operating plant. The system today is used by Safeguards, Support, and Operations staff to assure the controlled operation of the facility through on-line analysis of process data in a quick, convenient manner. Figure 1 illustrates the current scope of this system throughout the ICPP. The heart of the system is a set of VAX 11/780 and MicroVax II minicomputers.

Data is acquired by the system through the following:

1. Scanivalve controllers—These controllers gather data from the pneumatic plant instruments and convert it to an electronic signal for processing by the computers.
2. 4 Analog Multiplexers—These devices gather electronic data signals and feed them into the system. Electronic instrumentation is rapidly replacing the older pneumatic instrumentation within the ICPP process areas. These and the scanivalve units discussed above gather 395 analog signals from the plant.
3. 4 Digital Controllers—These devices gather the 484 digital state (on/off) signals from various devices throughout the facility such as pumps, jets, airlifts and samplers to determine whether they are actuated or not.

Variables are computed from combinations of the acquired data by the computer. All of this data is scanned once per minute and stored in on-line mass storage for 1 year.

Access to the system is controlled with both VAX-VMS password control and the dedication of terminals. Six terminals with dedicated printers from this system are currently located within the fuel processing areas of the ICPP for use by Operations personnel. A single dedicated terminal with a printer is located within the offices of the Safeguards staff for use in analyzing the process data. Other terminals on the system are for general purpose computing and access is controlled by password.

OPERATIONAL USE OF THE SYSTEM

The PMCS monitors the ICPP fuel process operations which consist of various headend dissolutions, one cycle of TBP solvent extraction, two cycles of hexone extraction,

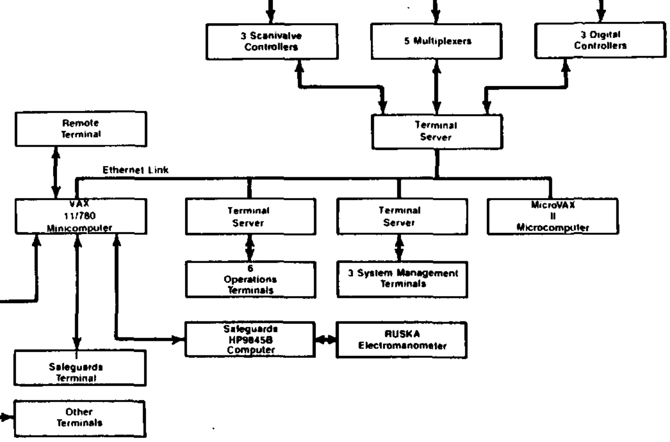

Figure 1. PMCS Block Diagram

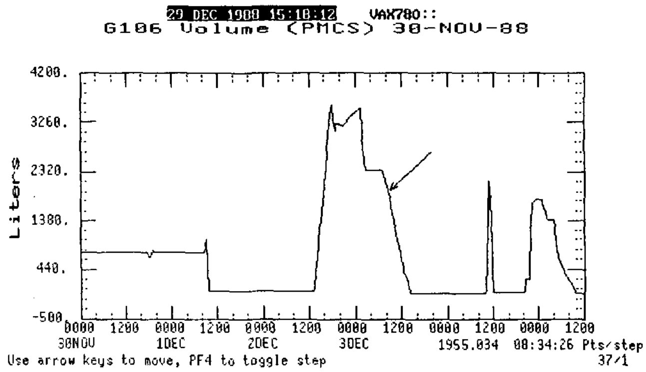

Figure 2. An Example Plot

```
***** Listing of common equipment in other currently active transfers *****

        Possible causes for this discrepency report:
             A currently active transfer indicates a certain valve
               must be Closed and the requested transfer says to
               Open the same valve.
             Both transfers indicate the same valve must be Open.
             Two transfers into or out of same tank, or attempt to
               fill an emptying tank, or empty a filling tank.

             This report does not take into account the actual
             status of the device as monitored by the PMCS.

Requested Transfer:   U129 to TANKFARM      Starting time: 17-SEP-1987 12:51
Transfer Number:     5188

Device              Conflicting Transfer          Reason
------              --------------------          ------
U129                U129 to TANKFARM  (5187)      Second Transfer From Tank

TANKFARM            U129 to TANKFARM  (5187)      Second Transfer into Tank

RCV-U-10            U129 to TANKFARM  (5187)      Both Open
```

Figure 3. A Conflict Printout

and a denitration step. The goal of the system is to gather the highest quality process information available and make that information usefully available to the Production, Safeguards, and Supporting staff. The PMCS provides a convenient means of monitoring the process to look for unusual happenings and flag those happenings for further investigation by appropriate plant personnel.

The largest single use of the system is interactive analysis of process operation using the stored data. All of the stored process information is readily retrievable through a set of interactive programs designed for that purpose. Each of the groups interested in analyzing the ICPP operation has differing uses for the process information, but the different uses all involve analysis of the same information. The information is therefore retrievable in the form of tables, graphs, calculations, and pre-printed forms designed to aid the operation of the facility.

Plots of all process data are available with total flexibility of scale specification. Digital signals may be plotted as well as Analog signals and computed process variables. The time span of these graphs may be as little as 1 hour or as long as 30 days. Figure 2 illustrates an Analog signal plot. Shown in the figure is the option called "FIND" which places a crosshair on the plot and displays the value of the variable in the lower corner of the plot. A second plot can be added to this graph and both variables may be read in the lower corner.

A useful feature of the plots is the ability to scroll through the time axis with a one keystroke command, allowing the frame of the plot to be moved back and forth through time. Also, both scales of the plot may be easily changed. This flexibility greatly increases the power of the system to track down problems within the process, contrasting sharply with the traditional methods of looking at tracings on plant instruments and analyzing information contained on them.

A significant operating concern addressed by the system is the reduction of inadvertent transfers. This is accomplished through several programs on the system. The first of these calculates available headroom within a receiving vessel and the target instrument readings for both the sending and receiving vessels when the transfer is complete. These desired readings provide guidance to let the operators know when the end of a transfer is approaching. The system uses current process data for this calculation, limiting the amount which may be transferred to that which the receiving vessel is able to hold.

Inadvertent transfers are also reduced by the generation of operating sheets which delineate the status of equipment to be used in a given transfer. These sheets are retrievable by vessel name. When it is desired to start a transfer, the system checks the route of that particular transfer against the route of currently active transfers to assure that there are no conflicts in required equipment states between the transfers. If there is such a conflict a printout, illustrated in Figure 3, is generated which lists the equipment with the conflict and the active transfer that is generating the conflict. The system then asks for verification that the Operator wishes to continue with the transfer. The conflicting states are flagged under the following conditions:

1. If a device, such as a valve, needs to be open for both transfers.
2. If a device needs to be open for one transfer and closed for another transfer.
3. If one of the vessels used in the transfer is being used in another transfer.

The conflict report does not take into account whether or not the device is physically actuated at that particular time. It is designed to flag conflicting requirements between two transfers which it has been told will be going simultaneously. At this time there is no decision capability placed within the computer. Operational decisions are still the responsibility of assigned personnel. The PMCS is only used to provide information required for those decisions.

If the decision to proceed with the transfer is made, or if there are no conflicts with other transfers, the system then compares the list of devices in that transfer with a database maintained for the purpose of validating the digital signals of the system. If the PMCS sensors of the devices used in a particular transfer have not been verified as being correctly operable within a given time, the system asks the Operator to verify the current state of the first five devices in the list. If all device sensors in a given list have been verified, this part of the program is bypassed.

At this point, a Pre-Transfer Form is printed out for the Operator to use while performing the transfer. This form lists the vessels used in the transfer, administrative preconditions to the transfer, and the equipment state required to perform the transfer. Also listed on the form is the current sensed status of the devices involved in the transfer. A listing of possible inadvertent destinations is provided to allow easier tracking of where the solution may be going in the case of a mistaken transfer.

The system maintains a table of transfers while it is told that the transfers are ongoing. This table is easily retrievable at any time and is printed out at the beginning of each shift to provide the incoming crew a better picture of the condition of the plant operation.

A form is also generated for the closeout of a transfer, requested in the same manner as a Pre-Transfer Form. The steps followed in the process are the same as with the Pre-Transfer Forms with the exception that the system does not look for conflicts with existing transfers. In this case, the system performs a volume balance to provide an added assurance that all of the solution transferred did indeed arrive at the intended destination.

A feature implemented on the system in an effort to upgrade the quality and efficiency of the ICPP operation is placement of the plant calibration equations in the computer. The equations, generated from a combination of instrument data and known volume equations, are contained in the system and used by the computer. By making the computer the source of the controlled calibration equations, it is assured that any changes to the equations automatically cause the system to begin using the new equations. Only one data base currently exists for the vessel calibrations where before there were three. This assures the continuity and quality of the information. Vessel volumes are displayed on the system in many ways. One of interest is a listing of current instrument readings and the resulting volumes from those readings for a typical plant instrument. Included in this display are the calibration equations, overflow volumes and operating volume limits. A calibration curve, illustrated in Figure 4, plots volume against level in the vessel, includes lines to show the overflow and operating volumes, and places a mark at the current volume of the vessel. These same equations

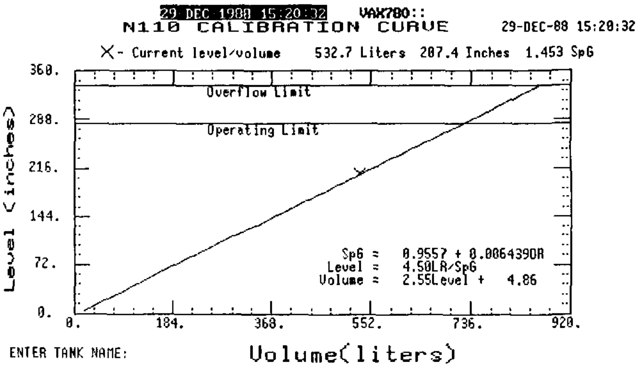

Figure 4. A Calibration Curve

are also used in the Pre-Transfer calculations discussed previously.

Flowrate measurement at the ICPP has been difficult. The low, by industrial standards, flows used combined with the fact that high radiation fields demand remote operation has rendered most systems unsuitable for flow measurement. Because of this, flow is calculated based on differences in vessel volumes over time, as shown through the process level/density instrumentation. This method of flow measurement is known as tank depletion.

The PMCS has been programmed to calculate tank depletion flowrates in real time for any given stream within the ICPP. The calculated rate is updated once a minute and is used to watch the effects of adjustments to the flow. Adjustments are visible within one minute on the screen providing an indication of the correctness of the adjustment while the overall average for longer time intervals is still shown. This feature frees the process Operator to concentrate on the effects of the process change rather than the mechanics of variable computation.

Often, solution is added to feed vessels from makeup vessels to allow continuous processing in the facility. During this type of transfer a standard tank depletion calculation cannot be performed since the apparent level in the tank will change based on inlet flow and outlet flow rather than just outlet flow. The tank flowrate program corrects such calculations through a material balance around the system.

SAFEGUARDS APPLICATIONS OF THE SYSTEM

Process information is needed by the Safeguards staff in tracking SNM through the ICPP facility. Historically, much of this tracking has been performed manually. However, manual tracking is becoming increasingly difficult due to the complexity of the facility, the length of the process runs, and the shorter analysis times desired. The PMCS is therefore playing an increasingly vital role in the analysis of the facility. The system capabilities discussed thus far were all initially developed to enhance the reliability of the system for the Safeguards function. It must be recognized, however, that at the ICPP it is difficult to separate the information needs of Safeguards from the needs of Process Operation and Analysis. What is different is the analysis of the information. The requirement for the validity of the information is shared by the two organizations.

The difficulty of the Safeguards analysis may be appreciated through realizing that the ICPP process is divided, for the sake of Safeguards, into 5 process Sub-Material Balance Areas (Sub-MBAs). These areas, one of which is illustrated in Figure 5, are fenced by sensors to allow the system to completely monitor transfers through the vessels that define the boundaries of these areas. This information is assembled within the computer system and stored in proper format for on-line retrieval and analysis of that data. Further, the data is analyzed and reports are generated each day for transfers across the Sub-MBA boundaries.

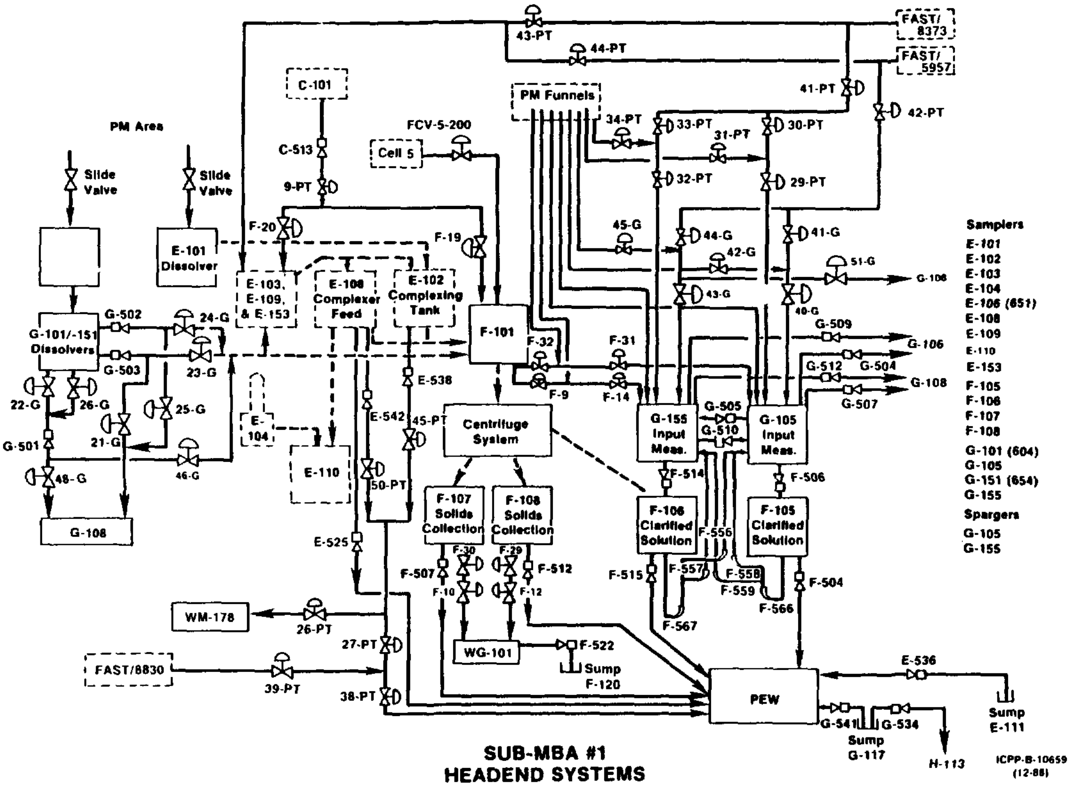

Figure 5. An Example MBA

The Safeguards reports generated daily by the system in addition to the use of all of the previously discussed features, are in two forms:

1. The Sub-MBA Report
2. The System Status Report

The Sub-MBA report is the result of analysis of all defined transfer routes within the process which cross Sub-MBA boundaries. The report lists the route of interest and plots a 24 hour time line across the top of the page. The computer then places an asterisk in the line corresponding to the time that a combination of digital state devices actuated on the transfer route, indicating that some event did occur. This report is obtained daily by the Safeguards staff.

Another report generated by the system on a daily basis is the system summary of the status of the data acquisition devices on the system.

If any of the devices lose contact with the computer system a series of question marks is printed for the appropriate device during the appropriate time span. These reports together provide a daily analysis of events within the facility.

This information is a part of the larger Safeguards effort which maintains SNM control at the ICPP.

DEVELOPMENT PLANS

With the availability and integrity of the system data assured, it is possible to foresee the future development of a system that will become an Expert System on transfers within the facility. A program will be undertaken to arrive at real-time or near-real-time accountability measurement validity analysis through the following items:

1. A complete analysis will be made of all transfers over the previous 24 hour period to assure that all of the transfer requirements were met.
2. Ultimately, analysis such as the above will be performed just prior to initiating a transfer out of a vessel and appropriate warnings will be printed if the prerequisite conditions are not met.

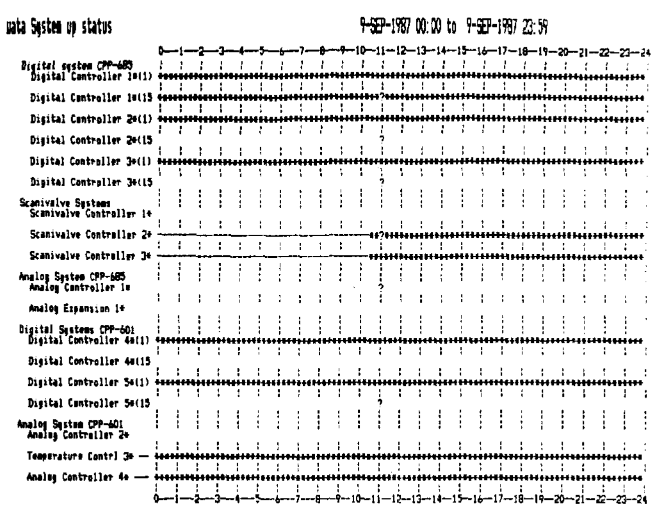

Figure 6. System Status Report

3. Through the use of the transfer data base on the system, it will be possible to warn of an impending incorrect transfer through the sensing of the motivating devices on a transfer line. If a signal that the device is actuated comes in, the routes will be scanned to determine where that transfer is going. At that point, an analysis similar to the above will be automatically performed to determine if it is permissible to make that transfer. Warnings will be printed as needed. This system will need to make use of techniques to enhance the current Expert System for these types of transfers. Also, the system will review transfers that are reported as closed to assure that they were indeed correctly closed out and some device was not left actuated.

CONCLUSION

The PMCS has been shown to be a valuable tool for analysis of the ICPP fuel processes and provides the Safeguards staff with a source of information to independently verify procedural compliance. The PMCS has also demonstrated that Safeguards and Production goals do not have to be in an antagonistic relationship. Material benefits from the system are enjoyed by all parties.

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Neil A. Liester received his B.S. in Electronics Technology from Brigham Young University, Provo, Utah, in 1979. Liester is the Senior Program Analyst in the Engineering Department of Westinghouse Idaho Nuclear Co., Idaho Falls. He works as the lead programmer and assistant manager of the process monitoring computer system.

Planned Integration of MC&A, Physical Protection and Process Information at a Plutonium Reclamation Facility

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ABSTRACT

The plutonium recovery plant will have two material access areas: one containing the reclamation and plutonium finishing processes and the control laboratories, the other containing the storage vaults, shipping and receiving activities. It is planned to integrate the MC&A and physical protection data systems for the facility as a whole and to integrate the safeguards and the process control data systems for the operations in the processing area. The general approach adopted is described.

PLANNED INTEGRATION OF MC&A, AND PHYSICAL PROTECTION DATA

Westinghouse Hanford Company (Westinghouse Hanford), the Hanford Site Operations and Engineering Contractor for the U.S. Department of Energy, plans a series of projects to improve and integrate, where feasible, the physical protection and nuclear material control and accountability (MC&A) systems in the Plutonium Finishing Plant (PFP). The PFP performs a mission of plutonium reclamation and conversion to a finished product. Associated with these chemical processes are a number of support laboratories and storage vaults.

The PFP will be organized into two Material Access Areas (MAA). The first MAA will include the laboratory and plutonium reclamation and finishing portions of the plant complex. The second MAA will include the shipping/receiving and storage portions of the plant complex. The MAAs will be subdivided into several zones, and control will be established for the zones.

Improvements to the physical protection system will add Positive Personal Identification Verification (PPIV) and Card Access Authorization (CAA) to selected zones within the facility. Data available from these modifications will be managed by an existing physical protection computer. Because of the nature of this computer system network at the Hanford Site, it is necessary for the network to be unclassified. Current plans call for the physical protection computer to report to the classified MC&A computer certain protection data related to presence and authorization of individuals who are requesting access to the classified MC&A computer.

Improvements to the existing MC&A system will provide modernized material-movement control and material accounting. Material control will be improved via a three-step material-movement procedure: preauthorized plan step, movement initiation step, and completion step. The material-movement procedure and associated authorizations and communications will be managed by the upgraded MC&A computer system. The upgraded material accounting system will build onto the concepts developed in the Safeguards Active-Response Inventory System (SARIS). Safeguards-required process and accounting data will be input to the software program like "Wisdom and Sense," developed by Los Alamos, is being considered for use in checking all input data before being accepted into the accounting data base records.

In order to successfully integrate the unclassified laboratory and process data with the classified MC&A data, it is necessary to develop a data filtering device that will permit the transmission of unclassified data to a classified computer and at the same time prohibit the transmission of classified data to the unclassified computer. Such a data filtering device has been developed recently by the Westinghouse Hanford Security Applications Center (SAC). This device is called the Restricted Data Transmission Controller (RDTC) and is currently undergoing accreditation tests.

Integration of selected security and safeguards data has become possible through the combination of selected data within the safeguards and security computing systems and the development of the RDTC. In this era of security and safeguards integration, security and safeguards will continue to execute their functions independently or in combination, as appropriate, using new tools that permit improved performance. Integration of data and common reporting between security and safeguards does not mean the integration of function is desirable or required.

PLANNED INTEGRATION OF PROCESS AND SAFEGUARDS DATA

Westinghouse Hanford Company (Westinghouse Hanford), the Hanford Site Operations and Engineering Contractor for the U.S. Department of Energy, plans a series of projects to improve and integrate, where possible, process control, laboratory analysis, and nuclear material control and accountability (MC&A) systems in the 200 Area.

Improvements to the process control system of the Plutonium Reclamation Facility (PRF) will route electronic data signals from process control instruments to computers in the central control room. The process will be segmented into various unit operations where process material balances can be kept using appropriate process data. Selected unclassified process or laboratory data will be made available to the MC&A computer system, which is classified, where calculations and data analyses will be performed. Since the MC&A system will contain larger data bases and provide more computing power than the process control computer, material balance indicators can be quickly monitored, calculated, and reported to custodians, operators, and safeguards personnel. Examples of materials balance indicators are inventory differences and process losses (leaks, misroutings) or data anomalies that might be considered potential diversions.

Improvements to MC&A system, which take the graded safeguards concepts into account, will be designed to fit the unique needs of the operations and safeguards users via distributed data input terminals. The control of nuclear material movements will be accomplished through the following three-step method: custodial authorization, movement initiation, and movement completion. The software will be based on the concepts in the Safeguards Active-Response Inventory System (SARIS) and will be structured to account for the nuclear material in the smallest feasible portion of the process. The data maintained in the MC&A system is classified.

In order to successfully integrate the unclassified laboratory and process data with the classified MC&A data, it is necessary to develop a data filtering device that will permit the transmission of unclassified data to a classified computer and at the same time prohibit the transmission of classified data to the unclassified computer. Such a data filtering device has been developed recently by the Westinghouse Hanford Security Applications Center (SAC). This device is called the Restricted Data Transmission Controller (RDTC) and is currently undergoing accreditation tests.

Integration of certain process, laboratory, and safeguards data has become possible through the combination of selected data within the safeguards, process, and laboratory computing systems and the development of the RDTC. When these planned improvements become available in the 200 Area, a closer link will develop between the process and safeguards functions. The ability of the plant to perform its safeguards responsibilities will be greatly improved.

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Material Surveillance Procedures

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ABSTRACT

A recent Department of Energy regulation specified that the two man rule should be employed at a plutonium conversion facility. Analysis showed that more effective protection of the material could be provided in a more efficient manner. The solution chosen in this particular case is described along with the added benefits achieved. The regulation was subsequently modified to permit such alternatives.

INTRODUCTION

DOE Order 5632.4 required that procedures be in place which assured the observation of an area containing special nuclear material (SNM) by at least two "Q" cleared persons. The FB-Line facility, which converts plutonium solution to plutonium metal, was not in compliance with this requirement due to the amount of manpower required and therefore cost involved as well as the increase in radiation exposure to personnel. A task team, formed in late 1985, developed a unique way to meet the intent of this and other DOE Order requirements.

BACKGROUND

Savannah River Plant (SRP) was designed and built primarily for the production of tritium and plutonium. The plutonium is produced by irradiation of depleted uranium slugs in on-site heavy water moderated reactors. After irradiation the depleted uranium slugs are shipped to the F-Area chemical Separations Area canyon building for processing. The actual separation of the plutonium from uranium and fission products is accomplished in the canyon facility. The FB-Line facility which is located on the south end of the canyon facility receives plutonium solution from the canyon facility for conversion into plutonium metal. The FB-Line facility contains category IB quantities of SNM (pure products). The canyon and FB-Line facilities are enclosed in a Limited Area. The FB-Line facility processing areas are inside a material access area (MAA).

DISCUSSION

SRP had recognized that the FB-Line facility did not comply with all of the DOE Order requirements. Manpower and operating budget resources did not support compliance with material surveillance procedures (MSP), also called the two man rule, as defined in the DOE Orders. Adherence to this requirement is also in direct conflict with the radiation exposure reduction philosophy of ALARA—as low as reasonably achievable. It was also felt that unless the two man rule was a dedicated two man rule, i.e. the second person could not be performing additional work while observing the first, the procedure would not be very effective.

The task team formed in 1985 was charged with resolving all practices and procedures in the FB-Line facility that were not in compliance with the DOE Orders. Guidance from management directed them to look for innovative, cost effective solutions that integrated physical security with material control and accountability (MC&A) measures. Their first step was to look at what material surveillance procedures were intended to accomplish.

The overall goal of an insider protection system is to ensure that attractive SNM cannot be removed from a facility or diverted within the facility by either a single insider or a colluding pair of insiders. Typically a safeguards system includes layers of defense such as a protected area boundary, material access area boundary, and material acquisition locations (Figure 1). Each line of defense must provide a portion of the necessary protection. The first line of defense, the material acquisition location, must provide protection from removal of material from the material acquisition location by a single insider. In addition, each specific protection system must ensure that due to its design it does not render another system at a different line of defense ineffective for a particular pair of colluding insiders.

With this in mind the task team proposed the Boundary Enforcement Technique or BET as an alternative to the two man rule. The BET is based on the concept that material within a processing area will be protected against theft

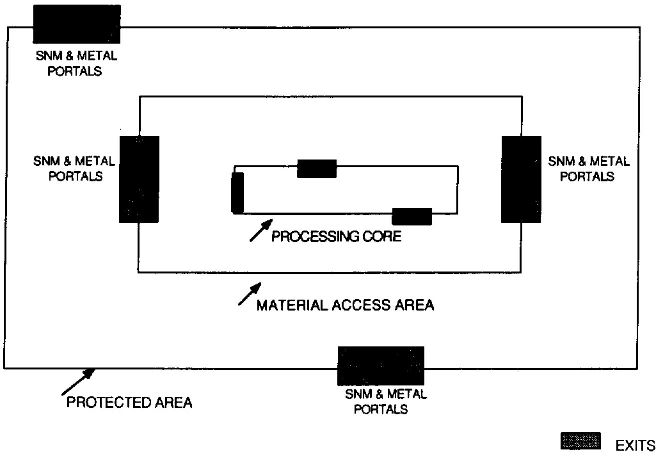

Figure 1. Boundary Enforcement Technique

or diversion from the processing core. A Security inspector is located at strategic points within the processing area. His responsibility is to monitor all personnel and non-SNM material leaving the processing facility with an SNM monitor (gamma and neutron sensitive). You could say that the security inspector serves as the second half of the two man rule. The BET provides a line of defense internal to the MAA boundary by ensuring that category I quantities of material can only be removed from the processing area when under the two man rule; however, routine operations may be conducted in the processing area by single individuals.

There are three primary goals for the BET.

- The BET must provide protection against removal of material from the processing core by a single insider. The level of protection must be equal to or better than that provided by the two man rule.

  A detailed analysis in 1987 supported use of the BET over the two man rule because a higher probability of detection was assigned to the BET. It was agreed that enforcement of MS by means other than administrative or procedural measures, such as security inspectors, card readers, and so forth provide a higher level of detection and; therefore, a lower level of risk. In addition, it provided substantial improvement to the outsider safeguards position because the increase in security inspector staffing provides additional delay.
- The technique must not render the MAA boundary protection system ineffective to any of the same pairs of colluding insiders.

  To prevent the technique from rendering the MAA boundary protection system ineffective against an operator and a security inspector in collusion, security inspectors that are assigned to the BET posts should not be allowed to be assigned to the MAA boundary posts during the same inventory period. This prevents the colluding pair from removing material from the processing core and then, when the security inspector moves to an MAA post, removing the material through the MAA boundary.
- The technique must be cost effective.

  Since 104 additional operators would be required to implement a dedicated two man rule in the FB-Line facility, the BET provides an annual cost savings of $4.7 million. This in turn relates to avoidance of an additional 200 rem/year in radiation exposure to facility personnel.

SUMMARY

Under the new DOE Orders, material control requirements are contained in MC&A Order 5633.3. This order does not define MS as the two man rule allowing facilities such as FB-Line to propose alternate methods of meeting the MSP requirement. Just prior to issuance of DOE Order 5633.3 the Office of Safeguards & Security assessed the BET independent of the MSP requirement in DOE Order 5632.4. It was judged to meet the intent of the MSP.

SRP supports the direction of the new DOE Orders to integrate material control and accountability systems with physical security systems to provide cost effective solutions to threats posed by insiders and outsiders. Alternate means of equivalent protection designed for facility specific applications, like the BET, will lead to a reduction in the number of exceptions (which can be misinterpreted as system weaknesses or vulnerabilities) and more cost effective solutions.

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The Role of Plutonium as a Resource Now and in the Future

Keynote Address
29th Annual Meeting
Institute of Nuclear Materials Management
June 27, 1988
Las Vegas, Nevada U.S.A.

Dixy Lee Ray
Institute for Regulatory Science
Alexandria, Virginia U.S.A.

To appreciate the role of plutonium as a resource now and in the future, we need to examine this remarkable element in the context of three separate and different applications. These involve three of the several isotopes of plutonium, ^{238}Pu, ^{239}Pu and ^{240}Pu. All of these are alpha-emitters with half-lives of approximately 89 years for 238, roughly 24,000 years for 239, and about 6,500 years for 240. ^{239}Pu is the fissionable isotope preferred for weapons use; 240 is a strong neutron-emitter and predominates in reactor-grade plutonium.

Considering ^{238}Pu first, it is used in radiothermal generators (RTG), especially those designed for operation in space. Providing reliable, independent, long-term power in multi-watt amounts, ^{238}Pu has figured in a number of satellites including those used for navigation, for lunar landings, the Nimbus weather satellite, the Viking probe to Mars, and the Pioneer series of data gathering units, launched in 1972 and 1973. Pioneer is still operating, its sturdy ^{238}Pu fueled RTG still functioning after 15 years, and still sending useful signals with data from far deeper in outer space than was ever imagined when the program began. When it was launched, the guaranteed generator life was three years! In all the publicity and rejoicing about Pioneer's performance—why doesn't someone give some credit to Plutonium-238?!

When our space probing program revives, as it surely will, RTG's will continue to provide reliable power, with ^{238}Pu continuing its role as an important resource in the quest for basic knowledge about the universe. Plutonium will supply the power to get data from way out there back to us mere humans on our little planet.

Of course, RTG's also serve on earth, providing reliable power for instruments in remote regions, but these are generally fueled by radionuclides other than plutonium.

Second, isotope 239 is the plutonium of military fame. Together with the other fissionable element, Uranium-235, ^{239}Pu is an indispensable component of most of our nuclear warheads. Uncomfortable as acknowledgement of the military role of plutonium may make some members of the civilian nuclear power and nuclear materials industry, this side of the plutonium coin is also a significant resource in our own national security, and in the defense of Western civilization. I will return to this subject later to examine some of the vexing questions about weapons plutonium, after looking at our third area, the one that involves plutonium-239 and 240 in the production of electricity.

Considering electricity, have we become so used to it that we forget sometimes where it comes from and how utterly dependent on it we are? There are people still alive, and I am one of them, who remember that having electricity in your home meant a single, naked 15 or 25 watt light bulb hanging from a wire in the center of a room. No matter where you stood or what you did, you were always in your own shadow! There are still people living in rural America who recall when electricity—just 50 years ago in the 1930s ushered in the modern agriculture and began to relive the farmer (and his wife and children) from hard manual labor and sheer drudgery. With the very modern problem of agricultural surpluses in this country, we forget that in the 6,000 years of known human history, such food surpluses are new and unique. It doesn't hurt to remember for a moment how it was ... In 1910, 25 percent of the land had to be used to raise feed for farm animals. With their help, one farmer could feed 7.1 persons. (I have often wondered about that 0.1 person—but now having spent some years in Washington, D.C. and more recently having been active in the political arena I've met plenty of them!) Now one farmer feeds 59 people. In 1910, one farmer with a team of horses could plow one acre per day, now with tractors, he plows 35. In 1910, one acre yielded 26 bushels of corn, today that same acre yields 97. To produce today's crops without fuel and electricity and with 1910's technology would require 27 million more farm workers (there are only 4 million now), and 61 million more horses and mules. And it would take 20 years to breed them, since there are only 3 million now alive! How's that? Why not speed up the breeding? Because biology works by its own clock. With humans it takes 9 months to make a baby. Not better nutrition, nor better doctors, nor spending more money, nor mighty wishing can reduce that time—it still takes 9 months. You can't even make 9 women pregnant and get a baby in one month— it just won't work.

There might be more important commodities than energy and especially electricity in the modern world, but it would be hard to make the case. Energy is societies' lifeblood. With it, in sufficient amounts and at affordable cost from reliable dependable sources, we can literally do anything. That is not an idle boast. The knowledge of materials and processes is vast and growing; the sheer technological genius that abounds, both present and potential knows no limits. I used to point out that knowledge is unique in that it is our only resource that increases with use—the more we use it, the more we have. But now I must add plutonium to that unique category! And we're not taking advantage of this priceless feature!

Here we are, approaching the last decade of the 20th century, a once buoyant nation with unbounded faith in the future and in our ability to make it better, now so possessed by self-doubt and recrimination, so frightened that something might go wrong, that we're unwilling to accept even minute amounts of personal or environmental risk. Too afraid to accept what's really very good, we demand a guaranteed perfection, even while knowing that a 100 percent risk-free society is unobtainable.

Remember that electricity is the cleanest, safest, cheapest and most flexible form of energy yet known—but it's not perfect, it's dangerous. Yet it is so common and so useful that its ready availability at reasonable cost is considered a right, a basic human requirement. (At least that's the way State Utility Commissions behave.) But electricity is a commodity like any other, manufactured, distributed and sold to all customers—yet uniquely, a utility cannot refuse to sell electricity (at least in the domestic market) and uniquely electricity is almost the only item that we use before we pay! Strange how accepted a part of modern life electricity has become. Who remembers now the fear, often bordering on hysteria that accompanied its introduction? Who recalls that the world's most eminent body of scientists, the Royal Society of London, met in special session to oppose its use? Declaring that Edison's ideas to electrify cities "defied scientific principle" and "wouldn't work," the Royal Society made a last-ditch effort to prevent electrification by passing a resolution that electricity is ... "too powerful to put into the hands of common men." And who now remembers the bitter feud between Thomas Edison and George Westinghouse as to whether alternating or direct current should be used!

Let me emphasize once again that knowledge of and use of electricity is the hallmark of our time. Electricity makes the technological age possible. Everything we identify as "high-tech" is electricity-dependent. As Thomas Edison once said of the light globe is equally true of the computer ... "It works better," he said, "if you plug it in." Electricity powers the computers and word processors and business machines, financial transactions and robotics and advanced industrial processes; it powers telephones and television, the entire communications industry, commercial and domestic life. In the electricity-dependent, industrial, technological nations, people live longer and healthier lives, have greater relief from drudgery and hard manual labor, enjoy a greater choice of goods and services, have more mobility and more personal liberty than in any other society. Ours is not a perfect society—it is only better than all the others. Given an average life expectancy exceeding three quarters of a century, we've got to be doing something right, junk food, nuclear waste, and all.

And what we are doing right is using more and more electricity, gradually replacing the burning of fossil fuel and direct use of thermal energy. In the past 15 years, since the 1973 OPEC oil embargo, efficiencies and conservation measures have reduced much waste. But our oil imports have grown, reaching as many as 7 million barrels per day in 1987, when foreign oil cost $40 billion. That is nearly one quarter—actually 25 percent of our trade deficit. All along, the demand for the use of electricity has continued to climb by 17 percent since 1973 and is moving ahead by rates of 2-5 percent annually. With a healthy economy, this trend will continue. And with growing concern for the problems of air pollution, including CO_2 buildup, the technologies for generating electricity are once again coming under scrutiny. No matter what advances are made in clean coal burning technology, the use of any fossil fuel, whether coal, oil, wood chips, garbage, natural gas in a thermal power plant will release tons per day of CO_2 into the atmosphere. The rate for a nuclear power plant is zero.

There is still uncertainty and considerable debate about CO_2 accumulation, the greenhouse phenomenon and the effect upon climate, but there are those who believe that the current heat wave throughout much of our country, and the drought in the midwest and southeast are related to CO_2. Just last week, on June 23, James E. Hansen, Chief of NASA's Goddard Institute for Space Studies, in testimony before the U.S. Senate Committee on Energy and Natural Resources said, "The greenhouse effect has been detected and is changing our climate now." He also pointed out that the earth has warmed at a record pace in the past two decades, and that the four warmest years of this century have been in the 1980s. The current heat wave has already caused some brownouts in the mid Atlantic states (utilities do not like to talk about this) and institutions such as the National Bureau of Standards have been warned on occasion in the past few weeks to stop using their computers. Already, there are rumors of some compressor burnouts from voltage reduction.

No matter from what perspective the situation is examined, the conclusion is inescapable, more electricity will be needed. Recent studies from the Gas Research Institute report that 150 GW of new capacity by the year 2000 must be added to sustain even a meager 1.6 percent annual growth. None of that is under construction.

Whatever are the projections and the realities, it is not too soon to think seriously of how electricity will be generated in the future. Either we will expand our use of nuclear power or we will not. When the years of experience and the performance record of the 108 operating nuclear power plants is examined and compared to other means of generating electricity—nuclear is the clear choice. Environmentally benign, safe, reliable, even the cost of nuclear power is far more favorable than the public has been led to believe. When lifetime costs are calculated over a 30 year cycle and compared, for example, to oil burning facilities, all nuclear plants average 4.7 cents per kilowatt hour, whereas at the lowest oil prices, the best oil burners average nearly double that—8.2 cents per kilowatt hour. If one selects only recent, more costly nuclear plants, those going on line in 1984-87, they average 7.6 cents per kilowatt hour—still less than the lowest cost oil burners.

Of course critics claim that uranium, like oil or coal, is a finite resource—true, and that is why extending it with plutonium is so important. And of course, the same critics also oppose plutonium recycling and breeder reactors by pointing to the present so-called glut of uranium, both mined and enriched. Not to worry—time will prove them wrong on both counts. Because, as Bernard Cohen has so clearly enunciated, "the existence of plutonium is the only guarantee we have that this world can obtain all the energy it will ever need forever—at a reasonable price." Note this use of the word "guarantee." Now we may think of fusion as promising unlimited power in the future, but great as the potential is, there is certainly no guarantee. Plutonium use is a present and known technology. Conversely, we will lose that guarantee with plutonium if our nuclear power program continues along its present track. The stupidity of foreclosing on the reprocessing of spent fuel, viewing it instead as waste to be disposed of in deep geological formations, is beyond belief. Should we turn our backs on the use of plutonium as a fuel for generating electricity, we will deny abundant energy, not only to ourselves, but to coming generations as well.

How does plutonium function as a resource in power production? Fuel in light water reactors is a mixture of ^{235}U and ^{238}U, enriched to about 3 percent in the fissionable isotope. As the reactor operates, some of the ^{238}U, which cannot burn, is converted into plutonium. This occurs by a series of 3 simple steps, starting with absorption of a neutron, which converts ^{238}U into ^{239}U. The ^{239}U then undergoes beta decay to form Neptunium-239, which in turn then beta decays to form ^{239}Pu. This process is automatic—according to natural law, it happens inevitably, and in all LWRs. The Plutonium-239 can then undergo fission and thus serve as a nuclear fuel. Some of it does in fact burn in power reactors, enough to account for about 1.3 percent of the reactor's total energy production. The rest remains and can be recovered from spent fuel by reprocessing. The reprocessed plutonium can be returned as fuel for present power reactors. This is plutonium recycle. It is a logical, sensible and efficient way to take a byproduct and turn it into a useful resource.

Additionally, the plutonium can be used in a breeder reactor, whose fuel is a mixture of plutonium and ^{238}U. Much more of the ^{238}U is converted to Pu than in present reactors, more than enough to replace all the Pu that is burned. In a breeder, nearly all of the ^{238}U—not less than 1 percent as in present reactors is eventually used to produce energy. About 100 times as much energy is thus derived from the same initial quantity. To say that we do not need this efficiency and can afford to waste 99 percent of our uranium because there is at the moment plenty on hand is a kind of twisted logic that in any other field would be treated with the derision that it deserves.

Of course the breeder technology is sophisticated and, as with everything else in the nuclear area, must be developed with intelligence and care. France, England, the U.S.S.R., Germany, and Japan all have reprocessing and breeder programs. Japan's first experimental breeder reactor went critical in 1977 and began using recycled plutonium in 1981. The American program was vigorous 15 years ago, but years of political fighting have succeeded in scrapping it. Why? Fear is the apparent answer. Fear of diversion of plutonium from reactors to military programs, fear of terrorism, fear of plutonium itself. Since fear generally feeds on ignorance, let us briefly examine the proliferation potential for successful terrorist acts and toxicity of plutonium. It was the belief that reactor plutonium in the hands of unscrupulous persons or renegade nations could be diverted to bombs that led President Carter to stop reprocessing. He apparently believed that if the U.S. should deny itself the use of such plutonium, then the rest of the world would follow suit, thus minimizing the amount of the material in the civilian economy. He has, of course been proven wrong. But how realistic was his fear?

In his lucid and excellent book, *Before It's Too Late; A Scientist's Case for Nuclear Energy*, Dr. Bernard L. Cohen has so clearly put the case about nuclear weapons, proliferation, and terrorism, that in what follows, I shall quote liberally from his outstanding book (Plenum Press, New York and London 1983).

To see the shallowness of President Carter's policy, it is necessary to know how a plutonium bomb works. There are two stages in its operation; first, there is an implosion in which the plutonium is blown together and powerfully compressed by chemical explosives which surround it, and then there is the explosion in which neutrons are introduced to start a rapidly escalating chain reaction of fission processes which release an enormous amount of energy very rapidly to blow the system apart. All of this takes place within a millionth of a second, and the timing must be precise—if the explosion phase starts much before the implosion process is completed, the power of the bomb is greatly reduced. In fact, one of the principal methods that has been considered for defending against nuclear bombs is to shower them with neutrons to start the explosion early in the implosion process, thereby causing the bomb to fizzle. For the bomb to work properly, it is important that no neutrons come upon the scene until the implosion process approaches completion.

Now plutonium fuel, plutonium-239, as we know, is produced in a reactor from uranium-238, but as it remains in the reactor it may be converted into plutonium-240 which happens to be a prolific emitter of neutrons. In a power plant, the fuel typically remains in the reactor for three years, as a consequence of something like 30 percent of the plutonium produced comes out as plutonium-240. If this material is used in a bomb, the plutonium-240 produces a steady shower of two million neutrons per second, which on an average would reduce the power of the explosion tenfold, but might cause a much worse fizzle. In short, a bomb made of this material, known as "reactor grade plutonium," has a relatively low explosive power and is highly unreliable. It is also more difficult to design and construct.

A much better bomb fuel is "weapons grade plutonium," produced by leaving the material in a reactor for only about 30 days. This reduces the amount of plutonium-240 and hence the number of neutrons showering the bomb tenfold.

One might consider trying to use a power reactor to produce weapons grade plutonium by removing the fuel for reprocessing every 30 days, but this would be highly impractical because fuel removal requires about a 30-day shutdown. Moreover, the fuel for a power reactor is very expensive to fabricate because it must operate in a very compact geometry at high temperature and pressure to produce the high-temperature, high-pressure steam needed to generate electricity.

That is why it is much more practical to build a separate plutonium production reactor designed not to generate electricity but rather to provide easy and rapid fuel removal in a spread out geometry with fuel that is cheap to fabricate because it operates at low temperature and normal pressure. Moreover it can use natural uranium rather than the very expensive enriched uranium needed to power reactors.

Another alternative would be to use a research reactor, designed to provide radiation for research applications rather than to generate electricity. At least 45 nations now have research reactors, and in at least 25 of these there is a capability of producing enough plutonium to make one or more bombs every two years. Research reactors are usually designed with lots of flexibility and space, so it would not be difficult to use them for plutonium production. Whereas it is difficult to use power reactors.

A plant for generating nuclear electricity is large and highly complex with most of the size and complexity due to reactor operation at very high temperature and pressure, the production and handling of steam and the equipment for generation and distribution of electricity. It would be impossible to keep construction or operation of such a plant secret. Moreover, only a very few of the most technologically advanced nations are capable of constructing one. A production or research reactor, on the other hand, can be small and unobtrusive. It has no high pressure or temperature, no steam, and no electricity generation or distribution equipment. Almost any nation has, or could easily acquire, the capability for constructing one, and it probably could carry out the entire project in secret. There would be no compulsion to submit to outside inspection.

In view of the above considerations, it would be completely illogical for a nation bent on making nuclear weapons to obtain a power reactor for that purpose. It would be much cheaper, faster, and easier to obtain a plutonium production reactor; the plutonium it produces would make much more powerful and reliable bombs with much less effort and expense.

But obtaining plutonium from fuel is not the only way to get nuclear weapons. Another principal method is to develop isotope separation capability. Nine nations now have facilities for isotope separation, and others would have little difficulty in acquiring it. A plant for this purpose, costing $20-200 million could provide the fuel for 2-20 bombs per year, and could be constructed and put into operation in 3-5 years. The product material would be very easy to convert into excellent bombs, much easier than making a plutonium bomb even with weapons grade plutonium. Finally, the easiest way is to steal or buy one.

The main point here is that the U.S. position of denying reprocessing and subsequent use of the plutonium resource to ourselves in no way affects either weapons proliferation or decisions by other countries to reprocess for their own fuel benefit.

Now what about terrorists stealing plutonium—for whatever purpose? First, we are really dealing with relatively small amounts of material. Can we protect it?

If all of our electricity were derived from breeder reactors fueled by plutonium, the quantities of plutonium involved would not be very large. All of the plutonium in a breeder reactor would fit inside a household refrigerator and all of the plutonium existing at any one time in the United States would fit into a home living room. The great majority of it would be inside reactors or in spent fuel where the intense radiation would preclude the possibility of a theft. As in the case of radioactive waste, the small quantities involved make very elaborate security measures practical.

There have been charges that all these security measures with armed guards would turn this country into a police state. However, the total number of people required to safeguard plutonium would be only a small fraction of the number now used for security checking in airports to prevent hijacking of airplanes. That force has hardly given our country a police state character.

And what about terrorists using an armed attack against a power plant? Security measures make a direct onslaught most unlikely to succeed and should terrorists gain entrance how could they make off with the highly radioactive fuel? Perhaps, say the critics, they could use sophisticated weaponry from a hilltop and rupture the entire pressure vessel so as to "release this radioactivity."

The containment building is made of concrete 3.5 ft thick, with the steel reinforcement mesh so tightly woven that vibrators must be used to force the concrete through it before it hardens. That makes the walls much stronger than, for example, the rooms of the German submarine bases on the French Atlantic coast, which were bombed round the clock by the allied air forces with "blockbuster" bombs, but withstood even direct hits. But suppose this imaginary supersaboteur did have some mysterious missile that managed to blow a hole into the containment building. What next? Would he have a second missile to make the hole larger, and a third to penetrate the remaining concrete structures inside the building, and a fourth to begin working on the steel pressure vessel? Would he wait until the weather is just right so that the fruits of his labors are not dispersed harmlessly in the atmosphere? This does not yet ask all the questions but the whole idea is too absurd to waste more space on.

Plutonium is often called "the most toxic substance known to man," "toxic beyond human experience," the "fearsome fuel," and other such melodramatic nonsense.

Of course plutonium is toxic. Of course it must be handled with care. But the rest is just horror propaganda. Plutonium is primarily an alpha emitter, which means that its radiation is absorbed in the air after a few inches, and a sheet of paper is sufficient to shield oneself against its radiation at close quarters. It is far from being the most toxic substance known to man. When eaten or absorbed in the blood stream, it is ten times less toxic than lead arsenate and hundreds of thousands of times less toxic than some biological poisons such as diphtheria or botulism toxin.

However, though ingestion of plutonium or its absorption through the skin is dangerous, the real danger of plutonium is breathing it in the form of fine dust particles. Plutonium is essentially insoluble in water, and fine particles may stay long in the lung, with the possibility of causing lung cancer. This has been extensively investigated.

And the experimental evidence is overwhelming. Not a single human cancer has ever been positively associated with exposure to plutonium. During the national emergency conditions of the early nuclear weapons industry, the exposures to plutonium far exceeded the present maximum permissible limits. Yet, of 17,000 plutonium workers, including those associated with the Manhattan Project, not one has died of or developed plutonium-related health problems.

Included in this figure are 25 plutonium workers from Los Alamos (1944-45) who had 25 times the presently permissible amount of plutonium deposited in their lungs. According to critics' estimates of lung damage, these 25 workers should have developed 1,500 individual lung cancers. In fact, out of the 25 workers, 23 are alive and in good health, and 2 died recently, one in an automobile accident, and the other from a heart condition.

Of all the materials that have emerged since the dawn of the nuclear age, it is probable that none has been subject to so much controversy as that 95th element in the periodic table, the transuranic metal plutonium. From those who claim that it is the most toxic substance known, to those who see only its military use in warheads, and the many opponents who would like nothing better than to have it stuffed back into some Genie's bottle, plutonium has suffered something of an image problem. Perhaps its name also contributes to its bad press. But it was not named for Pluto the God of the underworld or Hades, but for Pluto, the second planet beyond Uranus in the heavenly firmament. It is an extraordinary resource, like no other. It's promise, it's guarantee, is essentially unlimited energy; but will we use it?

When I think of this question, I'm reminded of what Thomas B. Macaulay, one of the great English writers of the last century, said in a letter to an American friend dated May 23, 1857. He wrote: "A democracy cannot survive as a permanent form of government. It can last only until the voters discover that they can vote themselves largess from the public treasury. From that moment on the majority will always cast their ballots for the candidates promising most benefits from the public purse with the result that a democracy always collapses from loose fiscal policies, always followed by a dictatorship."

"The average age of the world's greatest democratic nations and societies has been 200 years. Each has gone through the following sequence:

- from bondage to spiritual faith
- from spiritual faith to great courage
- from courage to liberty
- from liberty to abundance
- from abundance to complacency
- from complacency to selfishness
- from selfishness to apathy
- from apathy to dependency, and
- from dependency back again into bondage."

Can we escape this fate? Fortunately the record shows that a free people can regain their faith, understanding, and courage. They can again become persons responsible for their own well being. The record shows that people can, by their own intelligent actions, regain their liberty any time they want to! Will we have the intelligence and the courage to use plutonium wisely and with care so that we can assure our liberty through an abundance of affordable energy? I believe we can—and we will.

Dixy Lee Ray is a Senior Scholar with the Institute for Regulatory Science, located in Alexandria, Virginia. The Institute is dedicated to the proposition that laws, regulations and judicial decisions should be based upon best available scientific data; it is also deeply involved in the question of who speaks for science.

Dr. Ray has held several elected and appointed positions. She was elected as the Governor of the State of Washington after she had served as a Commissioner and Chairman of the Atomic Energy Commission. She was also an Assistant Secretary of State, responsible for international science and the environment. Dr. Ray was also the Director of the Pacific Science Center and a professor.

Dr. Ray has an earned Ph.D. from Stanford University and has been awarded 22 honorary doctorate degrees. She divides her time between writing, consulting and indulging in her wood carving hobby.

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William A. Higinbotham: What is it that the Institute of Nuclear Materials Management, as a professional organization, should be doing in your mind in order to help media to get a better understanding of what really ought to be said and done in the field of nuclear energy?

Dixy Lee Ray: The first thing, and this has been done in quite a few places around the country, is to set up a speaker's bureau. Local community groups like Rotary, Chambers of Commerce and League of Women Voters or Altrusa are always looking for speakers. It never hurts to have somebody available who can write out a basic speech and present it. That's a grass roots thing that will always be effective. But more specifically I believe that the Institute itself should take the responsibility of responding to publicity. In the beginning, at any rate, we can't generate any publicity because only bad news gets out. That we'd just as soon avoid. To say that 108 plants are operating and they're doing just fine is not going to get you headlines. But when something negative comes up, the response needs to be made as quickly as possible. It must be polite, even deferential, and accurate. Above all, accurate.

WH: It is very difficult to get the public to look at all the risks. We tend to take for granted all the day-to-day risks associated, for example, with coal. You undoubtedly have some numbers in the back of your head as to what the risks of coal are as compared to nuclear. How do we present a balanced case?

DLR: We can do that, of course, in these talks to local groups. For example, recently a train carrying chlorine derailed in New England and there was a refinery fire in Mexico. In both cases many people had to be evacuated. When these sort of catastrophes happen, write a letter to the editor pointing out that these are some of the risks to society. Identify yourself as being from a nuclear group, and remind the public that these things do not happen with nuclear. Point out that these are the sorts of risks that, unfortunately, society must accept.

By doing it that way — even though many letters to the editor won't get a response or be printed — at least they get read. They have a system for reading them, and somebody in the organization is going to become accustomed to hearing from you. That means that when something nuclear does turn up, they're just as apt to turn to you as to Sternglass, [Dr. Ernest Sternglass is a controversial statistician on the faculty of Pennsylvania State College. He has been frequently quoted in the popular press.] say, or somebody else. In other words, you need to establish your expertise, and that can only be done by taking advantage of these other actions and commenting about them. The other thing is, whenever something positive happens, like when there was a lot of talk on radio about the Pioneer [satellite], and how Pioneer was sending back these little signals from many miles away. Not one word was said about how the signals got here. If somebody were to keep talking about it, that's going to picque somebody's attention and next time they produce any pictures of Saturn or any of the other planets, they'll say "we have all these photographs because of the power that was supplied by plutonium 238." We just have to keep plugging.

Alan Moghissi: In the same vein, about a year ago, there was an accident in Pennsylvania, and 60,000 people had to be evacuated. . .

DLR: The evacuation was no trouble because the plan had already been drawn up for the Three Mile Island Nuclear Plant. They were able to evacuate without a hitch. Didn't require anything at all; did it instantaneously. Fifty thousand people had been evacuated only because they had the plan in place, they had practiced it and knew exactly what to do. It was only because the nuclear power plant was there.

Charles Pietri: Dixy, you mentioned chemical and biological threats. As a marine biologist, you probably have all these facts. Could you give us a feeling of the magnitude of the risk involved between, say, nuclear versus biological or chemical weapons?

Charles Pietri

DLR: I don't think I can give you numbers but let me just make a comment: Chemical and biological toxins, weapons if you like — their effect is almost instantaneous, within seconds. Or, in the case of certain biological agents like Anthrax, they affect within days. There is, at the present time, certainly in our nation, no plan of any kind in existence to protect the civilian population. Nobody's got that particular responsibility. It would fall at the present time, in our governmental system, under FEMA.

Chemical and biological materials are easily available, and can be acquired by anybody. Even though the postal service is just now talking about refusing to send biological toxins through the mail, they've been doing it for years and years. There are cases on record where people have sent in for pathogenic organisms where there's a high degree of suspicion that they intend to use them as a weapon, and they have been intercepted. If you want to get case histories, there is a book published called *America The Vulnerable [America the Vulnerable: The Threat of Chemical and Biological Warfare,* Joseph Douglass, Lexington Books, 1987]. It is about the realities of chemical and biological warfare. When you compare the toxicity of plutonium with many chemical or biological materials, the latter are clearly more hazardous.

Here's an interesting sideline: There is an island off the northern part of Scotland that was used in the early days of World War II as a biological warfare experimental area. It was sprayed with Anthrax. It is still totally off limits. Nobody can go there and must not go there because it is still contaminated with Anthrax. The spores remain active for at least 40 years and probably much longer than that. The horror of various types of nerve toxins and the so-called nerve gases and chemical weapons is great. Their danger is that some of them are easy to make, you can do it essentially in the bathtub with the chemicals that you can buy in the open market and they take effect within minutes, if not seconds.

Whereas, you could take plutonium outside and put it in the ventilation system of a building. You could turn off the ventilation system. Plenty of time to evacuate the people; blow it out, disperse it in the atmosphere. Cleanup is easy. Anybody who got even a negligible amount of it could be detected, and the cleanup procedures we know from the Los Alamos people. If there is any affect, it's going to be more than 25 years into the future. If that were nerve gas, you'd all be dead in two minutes.

WH: The Institute of Nuclear Materials Management is an international organization. You probably have seen that we have a number from Japan and Europe today.

DLR: I was very much impressed.

WH: This presents some particular opportunities — certainly from the point of view of exchanging technical information, it's extremely useful. We also share our problems to some degree.

DLR: That's right. For so long, sharing information in this field was "we give it to you guys," essentially, not entirely. That was the attitude. It certainly was the attitude that [President] Carter had, "If we do it, everybody will follow our example."

Right now we need information from other countries on reprocessing, the plutonium recycle and so on. The Japanese particularly would be a great source of information. Certainly all the countries that are reprocessing or planning to use plutonium recycle should get together. An opportunity took place just a few weeks ago with all the talk about the treaty with Japan as to whether "we would permit the reprocessed plutonium in our air space" and so on.

Somebody ought to write a book about that. In the first place, it was a direct violation of the Non-Proliferation Treaty. It would have been (and could still be) an opportunity to present some information about the usefulness of plutonium recycle and how this is a resource that should not be dispensed with.

CP: But we're speaking about technical expertise and that's really not the issue ...

DLR: It's not the issue, but it is our tool. And even though the issue is an emotional one, we cannot fight it or combat it on emotional grounds. No matter how strongly we may feel, we have to counter the emotionalism.

William A. Higinbotham

CP: Do you think that's an effective approach?

DLR: No, but it's all we've got. We can't do it any other way. I think that the current problems we've got with carbon dioxide and heat are giving us an opportunity ...

Fritz Seiler: A corollary to what Dixy is saying is what's going on right now in the Physics Society. The Health Physics Society, by its statute, cannot speak out on issues as a Society. The President-elect, Bob Alexander, is now traveling the country, from chapter to chapter trying to convince people: "We've got to change the statute so that the society can speak out on issues, can release statements to the press to contradict falsehoods." The Institute can do the same thing in its area of expertise. It could say: "We, the technical people in this area, have the following statement to make on what was said in the press." State your position. Also, the Health Physics Society and the Society for Risk Analysis have consulted specialists in communication who have said that the way we communicate among ourselves is not the way in which we should communicate with journalists. We have to adapt our style of thinking and talking to other people.

DLR: That gives me an idea. When an organization does take a stand: "We, the members of INMM take this stand on this issue in which have experience and can speak," that should be circulated to the professional societies. Get their mailing lists. Then at least you're beginning to flood the scientific community and things will develop from there.

WH: I think that you see the Health Physics Society as rather similar to our Institute. Safeguards is just one area associated with nuclear energy, whereas the American Nuclear Society, for example, is broad-based. I have a feeling that the narrower groups tend to leave big jobs to the broader-based groups.

DLR: The American Nuclear Society typically has had all the strength of a wet noodle. Many of these societies began as non-profit organizations and they're afraid for their tax standing. They're nervous about offering a position on issues. . .

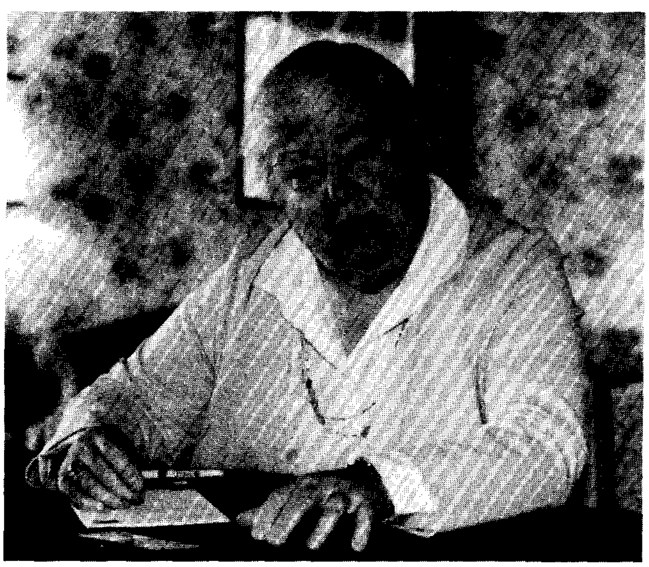
AM: I chair one of the committees for the American Association of Engineering Societies (AAES). They have an excellent mechanism for presenting position statements. If you were to come up with a statement dealing with nuclear, the public may perceive that because there is a "Nuclear" in your organization's name, there is a self-interest in it. But the moment that you go to the AAES, that goes away because they represent about three-quarters of a million individuals. That is no longer a small group. The AAES is working with the American Medical Association on presenting statements on some issues. We are currently involved in two issues, one of which relates to nuclear. Suddenly there is a powerful coalition to express views. But you see, somebody has to start that. When it comes to safeguards, no one is more qualified than your organization to work up the details, the nitty-gritties, and to present a statement that is acceptable to the rest of the profession.

The mechanism would be: you come up with a well-documented statement. The statement passes through your regular field review, and then goes to the AAES and passes theirs. There are plenty of people, including myself, who would be glad to foster it, to shepherd it, and bring it through. The statement is then released as a position of the engineering profession.

Alan Moghissi

Eugene V. Weinstock: People are afraid even to talk about ordinary light-water reactors. And coming from Long Island, we've had quite a lesson in that. How realistic is it to expect that the public can be persuaded to accept plutonium use?

DLR: I think you're coming from the bottom end of the scale. There are plenty of places around the country where there are operating reactors, and a great many of them have been operating for quite a while and are thoroughly appreciated. The opponents keep trying — two or three times in Maine already they have had an issue on the ballot to get rid of the plants. In a lot of instances, for example around the Trojan Nuclear Plant in Oregon, the people that live within the effective radius of the plant, that are affected by the taxes that the plant pays, are fully aware of the fact that their real estate taxes are substantially lower than the rest of the state of Oregon. They pay no school taxes and so on. Trojan supplies all that. They are willing to go down the road and fight to keep Trojan open.



Dixy Lee Ray

So it all depends upon the experience that a particular community may have had. I think you can find widespread support in North Carolina. North Carolina Power and Duke have done a terrific job down there. As the problems develop, as Brookhaven is unable to operate its computers because there isn't enough electricity or the voltage has been reduced, maybe even some of the scientists there will begin to say "where's our electricity?"

Public perception is an obstacle and a very big hurdle because the public has been so thoroughly brainwashed. There's only one way to get over it and that is by careful and conscientious presentation of the facts, which will then all get taken into consideration.

EW: One of the objections that people often raise to plutonium use is the existence of unstable regimes in the world. They point particularly to the Iran/Iraq War. They say: "Now what would have happened if those people had been able to get their hands on nuclear weapons?"

DLR: Nothing nearly as bad as what has happened as a result of their being able to get their hands on chemical weapons.

FS: I can very well appreciate what has been going on. My former superior in the Swiss military was the president of the international commission that went to the Persian Gulf to investigate the situation. These weapons were far more devastating than, say, five or 10 tactical nuclear weapons fired in that critical situation. Chemical weapons are point weapons. They are locally very effective, and do not destroy the roads and material.

CP: The IAEA and the Non-Proliferation Treaty are being looked upon as models for an inspectorate for chemical weapons.

EW: In view of the present economics of reprocessing, is plutonium recycle, in the United States at least, viable?

DLR: I don't think that the economics take into account the value of the use. I'd like to see a real economic analysis to take into account what it does to extend the uranium, the amount of and the value of the energy that is manufactured and so on, and not just the cost of the reprocessing and what you can sell it for. But the entire life cycle cost.

We have to use economic costs in a lot of different ways, and often, just to support a position. Let's take the handling of nuclear waste. If you count up all the costs, including the research and development cost of boring holes into deep geological formations, whether you use them or not, plus all the costs of packaging and transporting and placing the stuff there, and then compare that to the costs of reprocessing — I have a hunch that reprocessing will come out looking like a rose. If you reprocess, then you remove not just the plutonium and the unburned uranium but also the cesium and strontium for which there are also very good uses. Then you are removing 98 percent of the thermal burden and 97 percent of the gamma flux and the stuff that remains can be a lot easier to handle and much less costly to handle. So when it comes to economics, I think you have to look at the whole picture.

EW: But in the U.S. at least, reprocessing was to have been a private commercial venture. Is it realistic to expect that companies going into this would look not at what would be the immediate return on their investment but at the return 30 years or 40 years hence?

DLR: We have to recognize that any company working on this is going to look at what did happen to AGNS [Allied-General Spent Fuel Reprocessing Plant, Barnwell, S.C.]. They are going to recognize that without certain government guarantees, economic or not, it can't be done. So far the government has been unwilling to give those guarantees.

EW: People talk about privatizing the enrichment industry. Is it really a viable commercial enterprise in the United States?

DLR: Under present circumstances, in this country, no. And not because of the technical aspects of it at all, or because of the difficulties of negotiating with the DOE to take over what has been a government monopoly. The real problem is that this country is not a reliable supplier of enrichment services and therefore won't have any international customers. I hate myself for saying that but it's


Fritz Seiler

true. The turnaround began in 1975. We have lost our credibility. There's no country in the world that will buy from us if they can buy anyplace else.

As long as the Atomic Energy Commission was in existence there was never a contract that wasn't fulfilled. AEC had a reputation worldwide as being a reliable supplier. So the answer is a practical one, under the present circumstances: The market for enrichment services has shrunk. Besides, look what we've got. We've got an aging diffusion plant that may or may not be working well. I don't really know what's happening at Oak Ridge. They abandoned the Portsmouth centrifuge plant after investing a billion dollars. The DOE has selected an isotope separation process that is not proven. And they've turned their backs on a couple of other projects. They're putting all their eggs into laser isotope separation. There has not been a kilogram separated that way yet.


Eugene V. Weinstock

CP: Can we talk about advanced reactor concepts? What are your thoughts on the IFR [Integrated Fast Reactor] and the new generation of reactors?

DLR: I'm very enthusiastic about them. One of the things that this lull in commercial activity has given us is the opportunity for a lot of people with very good minds, particularly at the national labs, to put their ideas to work and develop them; taking advantage of technology that's already on the shelf and saying: "How can we do the job in a way that we can put something together that will essentially, well, let's just put it bluntly, be even safer than the present generation of light water reactors, which is not to say they're not safe when properly constructed, operated and maintained." But it is possible to take advantage of the natural laws governing many phenomena so that if a situation arises that could lead to some kind of an accident, whether that be a lost coolant or a runaway fission or whatever, then as surely as water runs downhill, the reactor is so designed that the natural law acts as the stopping mechanism.

This has been achieved in several different designs. Let's mention the slowpoke reactor in Canada which presently is used only for isotope production. The Canadians have developed it into an operating reactor to be a competitor to the TRIGA. They have been, for the last few years, active in modifying it so that it can be used as a producer of small amounts of power, say in the 10 to 100 MWe range. That reactor is so designed that it essentially operates itself. It requires one operator and all the operator has to do is to read the dials every once in a while. It can shut itself down and does if there is any problem.

Then there's the reactor that has been developed in Switzerland called the Geyser [a Swiss design for an "inherently safe" reactor]. That's a small reactor which is meant especially for space heating. This is something we've overlooked in this country. But I think it's very important. It is designed to be able to provide home heating and building and office heating in a radius of about 20 miles. It operates entirely on hydrostatic principles and shuts itself off completely if there is any problem. I have seen a working model in which the fuel is electrical heat rather than nuclear but the principle is the same. It's really quite extraordinary the way it operates. Somebody looks in on it about once a week just to read some records.

Then there's the little reactor that was designed and a prototype built at Los Alamos. It was designed to answer a need on the North American warning system to have a reactor in the small kilowatt energy production range that could provide power for operating radars on the early warning system. This had to be with some Canadian cooperation since 80 percent of those sites are on Canadian soil. I could briefly describe it: Picture a tub, perhaps as big around as this side of the table, probably eight or nine feet high. Fill it with graphite and put the holes in the right configuration for HTGR fuel. Then you have additional holes in which you place heat pipes. On top of the heat pipe you have a thermoelectric converter. You put that whole thinking in a hole in the ground, cover it over with a cement cap and the only thing coming out of the ground is the plug from the thermoelectrics. It will deliver reliable power up to 10 KWe for a period of 20 years. If more power is needed, the thermoelectrics could be replaced with a Rankine cycle. We have lots of experience with those, not only in hazardous locations, such as along the Alaska pipeline, but in outer space as well. So we know they operate without attention. Excess heat dissipates into the ground.

This little reactor has not been deployed because the DOE was unable to agree on the wording of a memorandum of understanding with the Canadians and managed to extend the discussion for a period of five years, and even the military got tired of waiting.

Now we come to IFR. Remember that the first electricity produced by any nuclear reactor in this country was at EBR 1 [Experimental Breeder Reactor Number One]. That was Wally Zinn's baby at Argonne National Laboratory. It produced about 45 KWe. EBR 2, which is a follow-up, a research breeder reactor, has been operating continuously for nearly 40 years. It has been used for all kinds of experiments.

It was Wally Zinn's original idea that the best fuel for the nuclear reactor was metal, not oxide, but metal has a problem, metal expands with heat. That expansion created all kinds of cladding problems that they were unable to overcome, so that the preferred fuel for present generation reactors is, and probably will continue to be, oxide fuels. In the past 20 years there has been a lot of fine basic research on metals, not only in this country, but especially in England.

Fuel rods have now been designed that provide for linear expansion of the fuel and a means of fabricating the metallic pellets so that the expansion is in one direction. This makes the use of metal fuel possible. For the past 20 years, Argonne has been doing experiments with the metallic fuel. They do not have plutonium facilities so it's with uranium fuel, but plutonium would be essentially the same thing. They have not only perfected and tried it out as fuel in EBR 2 in Idaho, but have done a lot of experiments with it where all controls are turned off, and the reactor operates itself, shuts itself down just as soon as the temperature reaches a point which is some 150 to 200 degrees below the melting point. It can operate totally without an operator, although one wouldn't want to do it that way, but it can in terms of safety. It is liquid-metal cooled, and that of course has its own problem; it has to be very carefully handled and kept fully away from any contact with water. But anyhow, all the component parts of a reactor, based on metallic fuel and based on these physical principles that have come to be called "passive safety," have been tested without a prototype actually being constructed so far.

This reactor concept is called the "Integrated Fast Reactor." It has enormous promise. Not only does the metal fuel offer the advantages of being able to breed because it's a fast reactor—not necessarily a breeder but a fast reactor—but it operates at a relatively low temperature, about 900 degrees, and at ambient pressure. That brings a couple of things in that contribute to safety.

There's another aspect which particularly appeals to me: With metal fuel, you can use electro-refining methods to reprocess. That means that instead of having a big reprocessing plant, you can do it in a crucible — maybe a big crucible. It means that instead of having to transport spent fuel from the reactor to another facility someplace, you could take the fuel out of the reactor and run it into the reprocessing place, electro-refine it, refabricate it, and recycle it right back into the reactor. The whole fuel cycle can be on the same site. It can be done that way because you're dealing with small amounts of material and not large amounts of chemicals. So I just think it has tremendous potential for the future.

There is some industry interest in these concepts, and both General Electric and Rockwell International have been engaged, for the last three years, in a kind of competition supported by grants by the Advanced Reactor Group in DOE. They have each designed a metal-fueled, liquid-metal-cooled reactor based on the many of the IFR concepts: one called SAFR, that's the Rockwell unit, and PRISM is the other by General Electric. They're both good designs. One is designed to be operated with the reactor totally underground, that's the GE unit. The other one would be above ground. They're both designed as modular units, with each module being able to put out about 350 MWe. They incorporate all these concepts of automatic operation and central processing with controls and shutdowns, based upon experiments that have been done at Argonne and Idaho Falls, on the response of metal fuel to abnormal circumstances.

EW: Should a strict barrier be maintained between civilian and military uses of nuclear power? I'm thinking of a proposal that surfaces periodically to do isotopically enrich reactor grade plutonium in order to upgrade it for weapons use. This proposal was made few years ago and caused quite a furor.

DLR: That strict separation of civilian and military is purely artificial, one of the kinds of things that I've never been able to understand. It sounds so very noble. The electricity that operates every military establishment in this country comes off the commercial grid. It is intermingled and indistinguishable from civilian electricity. It's made by a civilian utility. Is that dirty electricity? The military uses many of the same kinds of equipment, trucks airplanes, everything else, as in the civilian economy. The civilian economy has benefited enormously from military programs not only in the present day but dating back to Leonardo da Vinci. I was interested recently to go back and read some more about Galileo and I was impressed by how many of his experiments and how much of his thinking was stimulated by military needs. It was the development of a mechanized military that led Galileo to almost all of his work on the motion of bodies, on fluid mechanics, almost everything except the movement of the heavenly bodies in the firmament. It's amazing, but all throughout history, there is no question but that there has been a close correlation between civilian and military activity. It was the "civilian aspect of military needs" that led to the field of what we call civil engineering. Roads, bridges and so on were, in the beginning, for military purposes. I think that's quite right, because what is the military except the special part of society that protects the rest of it.

EW: I'd like to ask one question, totally unrelated to this, but one on which I would expect you to have strong opinions. What is your view on the proposal to transform the NRC from a commission to an agency administered by a single administrator?

DLR: It'll never function smoothly until they do. The Chairman was considered the head of the AEC, and so treated by the President and by the Congress and all the other agencies. In statute, there were five commissioners and they were equal, but one of them was a lot more equal. In practicality the chairman was the head of agency. We've got to be able to put administrative responsibility in the hands of one person.

WH: The other reason for the commission was because we were dealing with a new subject which was going to require development and understanding and development of policy. For that, it's nice to have some guarantee. But once you come to a well defined position, which is what the NRC as a regulatory commission is, then it really doesn't make any more sense.

DLR: No it doesn't. And it can cause a lot of mischief. One person on a Commission can really cause a lot of mischief.

EW: In view of the present climate concerning nuclear energy, how would you encourage young people to go into the nuclear field?

DLR: Anyone who has an interest in that direction should enter the field, by all means. Regardless of what happens in the nuclear power industry — and I have a lot of faith that its going to become much more viable and important in the years ahead — there's still a vast area of interest in the whole of nuclear science. There are plenty of opportunities and always will be. We're never going to give up nuclear propulsion for our navy, and it's going to include some increase on the surface ships. That's a big field.

There are going to be a lot more nuclear things taking place in the space field, regardless of what people get emotional about. There just is no other way to provide the power. That's going to go beyond RTGs to newly designed, special kinds of reactors both for power and propulsion.

Of course, a big field we always forget about is Medicine. There are millions of medical procedures annually using nuclear materials. I visited the University of Missouri about a year and a half ago. They have probably one of the most effective and now one of the largest nuclear graduate programs, training nuclear physicists and engineers, in the country. They have a TRIGA reactor which they have been using constantly and is now being upgraded to 100 MWth. That's really something for a TRIGA. Some of the advances that they were discussing are fabulous. Let me mention just one: liver cancer, which at the present time is just not treatable. They've developed a technique there of taking radioactive yttrium, encapsulating it in little glass balls or spheres of the proper size, and injecting it into the bloodstream. These circulate around and get stuck in the liver in those capillaries that are in the cancerous area, where it bombards those cancer cells. The treatment is in very early stages of development, but it looks promising. As a treatment, it's another step forward. These kinds of things are happening and it's just marvelous.

CP: You know that it's amazing that we have to fight to bring something like that out into the public domain. Yet, another example, neutron and proton therapy for cancer, is totally accepted as a by-product.

DLR: Then we get a wonderful new instrument for nuclear magnetic imaging and they drop off the word "nuclear." Another thing: blue topaz is becoming a very popular gemstone. It's quite expensive. All the blue stones are color-enhanced. That means that they have been irradiated with neutrons they come out a sapphire blue. I have read advertisements in magazines about "color-enhanced" blue topaz that don't say anything at all about nuclear radiation. . .

I think there's life in the nuclear industry yet, and that's going to be very important. Maybe sooner than we think.

Posts Vacant in the IAEA

The Department of State, the U.S. Arms Control and Disarmament Agency and the Department of Energy have initiated a program to improve recruitment of U.S. nationals for employment in the IAEA.

In an effort to support this program, *JNMM* will publish IAEA vacancies.

Department of Nuclear Energy and Safety

Division: Nuclear Safety *Section:* Radiation Protection *Position:* Transportation Safety Specialist *Grade:* P-5 *Vacancy* #88/065 *Opened:* 29 Nov 1988 *Closing:* 29 March 1989

Division: Nuclear Safety *Section:* Radiation Protection Service *Position:* Radiation Protection Service Officer *Grade:* P-3 *Vacancy* #88/064 *Opened:* 22 Nov 1988 *Closing:* 22 March 1989

Division: Nuclear Fuel Cycle *Section:* Nuclear Materials and Fuel Cycle Technology *Position:* Nuclear Fuel Specialist *Grade:* P-4 *Vacancy* #88/062 *Opened:* 8 Nov 1988 *Closing:* 8 March 1989

Division: Nuclear Fuel Cycle *Section:* Waste Management *Position:* Chemical/Nuclear Engineer *Grade:* P-5 *Vacancy* #88/059 *Opened:* 8 Nov 1988 *Closing:* 8 March 1989

Division: Scientific and Technical Information *Section:* Computer *Position:* Data Communications Officer *Grade:* P-3 *Vacancy* #88/058 *Opened:* 8 Nov 1988 *Closing:* 8 March 1989

Department of Research and Isotopes

Division: Life Sciences *Section:* Nuclear Medicine *Position:* Radioimmunoassayist *Grade:* P-4 *Vacancy* #88/066 *Opened:* 29 Nov 1988 *Closing:* 29 March 1989

Division: Physical and Chemical Sciences *Section:* Industrial Applications and Chemistry *Position:* Chemist *Grade:* P-4 *Vacancy* #88/060 *Opened:* 8 Nov 1988 *Closing:* 8 March 1989

Department of Safeguards

Division: Safeguards Information Treatment *Section:* Data Processing Services *Position:* Operations Unit Leader *Grade:* P-4 *Vacancy* #88/069 *Opened:* 20 Dec 1988 *Closing:* 20 April 1989

Division: Development and Technical Support *Section:* System Studies *Position:* Senior Safeguards Analyst *Grade:* P-5 *Vacancy* #88/068 *Opened:* 20 Dec 1988 *Closing:* 20 April 1989

Division: Development and Technical Support *Section:* Systems Studies *Position:* Safeguards Analyst *Grade:* P-4 *Vacancy* #88/061 *Opened:* 8 Nov 1988 *Closing:* 8 March 1989

Department of Technical Co-operation

Division: Technical Assistance and Co-operation *Section:* Training Courses *Position:* Training Courses Officer *Grade:* P-4 *Vacancy* #88/067 *Opened:* 29 Nov 1988 *Closing:* 29 March 1989

Division: Technical Assistance and Co-operation *Section:* Experts *Position:* Experts Recruitment Officer *Grade:* P-3 *Vacancy* #88/063 *Opened:* 22 Nov 1988 *Closing:* 22 March 1989

How to Apply

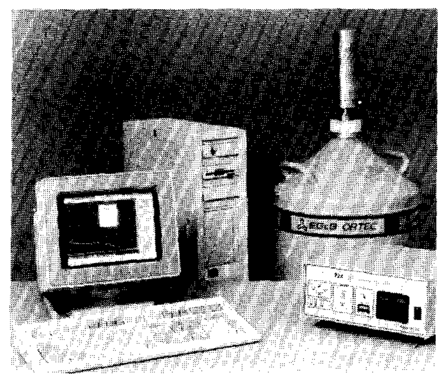
Applications must include a vacancy notice number, and should be mailed to the United States Mission to the International Atomic Energy Agency, Kundmanngasse 21, 1030 Vienna, Austria (Attention Ronald Bartell). After U.S. Government endorsement is given, the Mission will forward the application to the Division of Personnel at the IAEA.

U.S. Candidates must also send a photocopy of the original application to: (for positions in the Department of Safeguards) P.O. Box 650, Brookhaven National Laboratory, Upton, NY 11973, (for all other positions) IO/T/SCT, Rm. 5336, Department of State, Washington, D.C. 20520.

For more information contact Mr. W. Porter, Department of Energy, (202) 586-8253, FTS 586-8253. Potential applicants should leave their name, address, and position in which they are interested. DOE will then forward a package of information on the IAEA and the position for which they applied.

EG&G Introduces a New MC&A Family

EG&G ORTEC has announced the personal-computer based Spectrum Master family of data acquisition products for nuclear spectroscopy. The 92X Spectrum Master is a computer-controlled integrated Gamma spectroscopy system for use with germanium detectors. The functions of amplifier, bias supply, digital spectrum stabilizer, sample changer control, ADC, and memory are provided in a single package.



The accompanying Multichannel Analyzer Emulation software, Maestro II, provides live spectral display, control of hardware and features such as Nuclide Identification/Peak Search, and "Job Streams." The software is menu-driven.

The 919 Spectrum Master is a NIM module providing the functions of a digital stabilizer, ADC, and memory. The integral four-input, high-speed multiplexer and 64K-channel data memory is optimal for both ultra-high count-rate or multiple-detector applications.

The MCA-on-a-card family member, called the Spectrum Ace, consists of an ADC, data memory, and microprocessor, Available in 2K, 4K and 8K memory versions, the card fits inside any IBM-compatible PC. For information contact EG&G ORTEC, (615) 482-4411.

New Microwave Detection System from Racon

Racon has introduced an addition to its line of Intrusion Detection Systems, the Model 16000. The Model 16000 is a perimeter microwave detection system featuring the advanced microwave radar technology coupled with field interchangeable printed array antenna elements for short (100 foot), medium (350 foot), and long range (600) volumetric detection patterns.

The system can be combined with battery, solar panel and radio links for completely self-contained, wireless operation and alarm reporting. The unit includes six field selectable operating channels with high adjacent channel rejection to allow multiple radar operation in a highly congested RFI environment. The unit also features an audio sidetone output which simplifies system set-up and can be used in operation to determine relative target size and velocity.

For information contact Greg Baxter, RIDS Sales Manager, (206) 241-1110 or (800) 426-5245.

Ultrasonic Inspection System Offered

The TOMASCAN, offered by Tecrad International Corp., is an ultrasonic inspection system featuring high data acquisition speed and real-time digital signal processing. The system is fitted with programmable motor controllers allowing transducer movements along up to six axis.

The instrument presents scan information in real-time, on a color screen, in A, B, and C-scan. The multi-tasking system allows simultaneous presentation of the different scan types, along with control windows. Data acquisition is performed at 80 Mhz rate on up to 16 sequential channels.

Raw or processed data may be stored in real-time, on either the 40 MB hard disk, the floppy disk, or on the optional 800 MB WORM optical disk system. An optional printer is available.

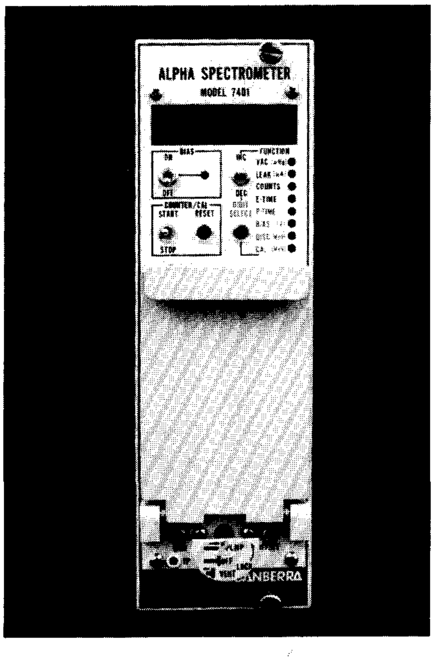
For information contact Tecrad, (203) 342-4972.

Canberra Introduces New Spectrometer

Canberra Industries has introduced the Model 7401, a NIM-based Alpha Spectrometer that combines all of the instrumentation needed for alpha spectroscopy in a single package. With the addition of a detector and a vacuum pump, the user is ready to perform alpha spec.

The unit includes a built-in counter/timer and a stainless steel vacuum chamber. Essential parameters such as chamber pressure, detector bias and leakage current are shown to the user through a front panel display. Counts, elapsed time and preset time are also displayed.

The Model 7401 is equipped to handle detectors up to 900 mm² in size, and can accommodate 2″ diameter samples. For information contact Canberra, (203) 238-2351.



April 3-5, 1989
The Use of Computers in Security, Oak Ridge, Tenn. USA *Sponsor:* Institute of Nuclear Materials *Contact:* Barbara Scott, INMM Headquarters, 60 Revere Dr., Suite 500, Northbrook IL 60062 USA, (312) 480-9573.

April 17-23, 1989
8th Symposium on the Training of Nuclear Facility Personnel, Gatlinburg, Tenn. *Sponsor:* Oak Ridge National Laboratory and Reactor Operations Division of the American Nuclear Society *Contact:* W.E. Eldridge, Co-chairman, 8th Symposium on the Training of Nuclear Facility Personnel, Oak Ridge National Laboratory, P.O. Box 2008, Bldg. 3042, Oak Ridge, TN 37831-6060.

May 1-June 1, 1989 (Call for Papers)
11th Symposium on Safeguards and Nuclear Material Management, Luxembourg *Sponsor:* European Safeguards Research and Development Association (ESARDA) *Contact:* L. Stanchi, CEC-JRC, 1-21020 Ispra (Verese) Italy.

June 4-8, 1989
Annual Meeting of the American Nuclear Society, Atlanta, Ga. USA *Sponsor:* American Nuclear Society *Contact:* Meetings Dept., American Nuclear Society, 555 North Kensington Ave., La Grange Park, IL 60525 USA.

June 11-16, 1989
9th International Symposium on the Packaging and Transportation of Radioactive Materials (PATRAM '89), Washington, D.C. USA. *Sponsor:* U.S. Department of Energy and the International Atomic Energy Agency *Contact:* Judith Gale, (301) 986-4870, 7101 Wisconsin Ave., Suite 610, Bethesda, MD 20814

July 9-12, 1989
30th Annual Meeting of the Institute of Nuclear Materials Management, Stouffer Orlando Hotel, Orlando, Fla. USA *Sponsor:* Institute of Nuclear Materials Management *Contact:* Barbara Scott, INMM Headquarters, 60 Revere Dr., Suite 500, Northbrook IL 60062 USA, (312) 480-9573.

July 10-14, 1989
Management & Disposal of Radioactive Wastes *Sponsor:* Harvard School of Public Health *Contact:* Sharon E. Block, Office of Continuing Education, Harvard School of Public Health, 667 Huntington Ave., L-23, Boston MA 02115 USA, (617) 732-1171.

October 23-28, 1989
1989 Joint International Waste Management Conference, Kyoto, Japan *Sponsor:* ASME, JSME, AESJ *Contact:* To submit papers on high-level waste contact S.C. Slate, (509) 376-1867, Battelle, P.O. Box 999, Richland, WA 99352; to submit papers on low-level waste contact F. Fiezollahi, (415) 768-1234, Bethtel National, 50 Beale St., P.O. Box 3965, San Francisco, CA 94119 USA

The events listed in this calendar were provided by Institute members or taken from widely available public listings. We urge INMM members, especially those from countries outside the United States, to send notices of other meetings, workshops or courses to INMM headquarters.

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