SAFEGUARDS SYSTEMSCONSIDERATIONS (a)

MASTER

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SAFEGUARDS SYSTEMS CONSIDERATIONS

Presented By

R. A. Schneider and D. P. Granquist

A. INTRODUCTION

Fortunately, this presentation was preceded by three excellent presentations. These included the: 1) objectives of nuclear material control systems, 2) general, and some very clearly presented fine points, of material balance accounting, and 3) nuclear fuel cycle or cycles to be safeguarded. My task is to consider much the same subject matter, but from a different view. The viewpoint I wish to consider is that of a safeguards system. What are its elements? What factors influence the extent and manner in which the various elements are applied? Lastly, how are these elements employed in specific cases?

A safeguards system can be thought of as a collection of techniques, methods, objects, concepts, people, etc., which are united into an organized whole for the purpose of preventing and/or detecting the diversion of nuclear materials. Such a system generally implies that there are "optimum" or "best" ways of safeguarding nuclear materials. However, my purpose this morning is not to attempt to describe an optimum strategy but rather to describe some of the elements of a safeguards system and how these various ingredients may be mixed to meet different safeguards situations. My remarks are intended to provide some of the framework for the discussions and presentations of this morning.

I will endeavor to describe some of the elements of a safeguards system. Secondly, the various factors which influence the choice of how the various elements may be mixed to provide effective safeguards. Thirdly, I will endeavor to illustrate some specific examples of system approaches to particular safeguards problems.

B. ELEMENTS OF A SAFEGUARDS SYSTEM

For purposes of exposition, the elements of a safeguards system (shown in Figure 1) can be considered as made up of the following:

1. Containment refers to those objects and/or measures which are employed to keep nuclear materials within a fixed boundary or which limit their removal to a relatively few exit points. Containment may be an inherent part of the process equipment or it may be the result of physical security measures.
2. Physical Security includes measures such as locks, seals, vaults, guards, fences, and alarms which prevent access to the material or limit or detect its direct removal.
3. Personnel Security refers to measures taken to insure the integrity of personnel who have access to nuclear materials or to the associated accounting records.
4. Material Accounting includes measurements, accounting, auditing, and inventory procedures designed to provide an accurate knowledge of quantities and locations. Material accounting detects diversion after the fact by noting that material or items are missing.
5. Independent Material Accounting refers to measurements, accounting, auditing, etc., which are independent of the facility or organization being safeguarded. Independence may be achieved when the

Figure 1

Elements of a Safeguards System

measurements and accounting are done by a different commercial corporation, political entity, or by the safeguards agency itself. Independence may also be internal to a sub-set of a larger system. For example, the internal control features of a facility system are based on the concept of independence, i.e., a given transaction involves two or more individuals each acting independently.

6. Surveillance refers to the observation or monitoring by the safeguards authority of the material, measurements, procedures, and practices. Surveillance may be by humans or by tamper-resistant instruments.
7. Administrative Controls include the measures taken by plant management or the safeguards agency to assure that safeguards procedures and practices meet certain established standards.
8. Sanctions refer to the penalties which may be imposed on those found guilty of diversion.

C. FACTORS INFLUENCING THE CHOICE OF SYSTEM STRATEGIES

Some of the factors (shown in Figure 2) which determine the way in which the elements of safeguards may be mixed to achieve the desired level of protection are:

1. Strategic Value is the weapons value of a nuclide or the number of nuclear explosives which may be obtained for a given weight of the element. Plutonium, uranium highly enriched in ^{235}U , and ^{233}U are considered to be of high strategic value. Depleted, natural, or

low enriched uranium and thorium are considered of low strategic value. Implied in the concept of strategic value is the amount of such material under safeguards at a particular part of the system.

2. Critical Amount is the amount of material an assumed diverter would require to make a single nuclear explosive. Obviously, the amount would depend on the assumed capability of the diverter in manufacturing a device.
3. Accessibility is the ease with which material may be converted to a form suitable for weapons use. Metals, pure compounds, and final product solutions rank high on the accessibility scale. Dilute solutions, waste materials, and irradiated materials rank low on the scale. Accessibility may also be a function of physical location and the capability of the diverter. An irradiated fuel element within an operating pressurized water reactor is rather inaccessible. The same fuel element located in a separation's plant dissolver is not far removed from a final product solution. Similarly, the dissolver solution is highly inaccessible to an outside diverter, but to the chemical plant, it is only a few days removed from pure product material.
4. Time for Detection is the time between when a diversion could occur and when it is detected.
5. Critical Time is the time required for an assumed diverter to convert a critical amount into a nuclear device. The period of time is a function of both the accessibility of the material diverted, and the capability of the diverter.

Figure 2

Factors Influencing System Strategies

6. Cost of Safeguards is the cost of safeguards activities to the various organizations concerned. It may include total safeguards costs, i.e., plant safeguards activities plus the costs to the safeguards agency. Safeguards costs refer to the cost of measures taken specifically to safeguard nuclear materials. More often than not, these costs are not easily separated from overall costs of activities undertaken for a number of different reasons.
7. Verifiability. Materials which can be readily measured to a high degree of certainty by independent means are termed verifiable items. These include product materials such as UNH, UO_2 , UF_6 , U metal, $\text{Pu}(\text{NO}_3)_4$, Pu metal, and PuO_2 . Non-verifiable items are those items which cannot be measured readily to a high degree of certainty by independent means. These include, at present, irradiated fuel elements, certain unirradiated elements, and certain scrap and in-process materials. As the next speaker will show this list is rapidly being reduced by modern methods of non-destructive assay.
8. Degree of Independence is the extent to which redundant measurements or accountability statements are independent by virtue of having been made by different individuals, commercial corporations, political entities or the safeguards agency itself.
9. Adversary Assumptions normally refer to the individuals or groups who are considered potential diverters or adversaries. It can also refer to the various strategies which an adversary may use to

"best" the safeguards system. Examples of adversary situations include diversion by outside (non-plant) forces, individual plant employees, key plant employees who can alter the records or measurements to mask diversion, and a highly organized collective effort which extends throughout the entire fuel cycle or nation.

10. Intrusiveness is the degree to which safeguards inspections, measurements, audits, etc., violate the privacy or proprietary information of a commercial corporation or sovereign power.

D. COMBINATION OF SAFEGUARDS ELEMENTS VERSUS EFFECTIVENESS

The task or goal of the systems planner is to mix or employ the elements of safeguards in such a way as to provide the desired level of protection at a minimum total expenditure. In general, this goal is to reduce the probability of diversion being attempted and/or being successful to a near-zero value. Admittedly, a near-zero goal is extremely difficult or even impossible at this point in time. Yet, there are specific measures which can be taken which tend to minimize the magnitude and probability of successful diversion. These measures may be illustrated by considering some of the ways in which the elements of safeguards have been or would be used to meet specific needs.

The desired qualities of a safeguards system together with the factors which influence system strategies are shown in Table I.

For purposes of allocating effort, most systems workers tend to proportion the safeguards effort according to the cross product of strategic value, amount, and accessibility. Thus, large amounts of enriched uranium, ^{233}U , and plutonium in the form of fairly pure compounds

would receive the greatest attention. This implies a higher level of safeguards effort at high enriched uranium fabrication and diffusion plants, chemical processing, and plutonium fuel fabrication than at low enriched uranium fabrication or ore refining facilities. The same general principles may be employed in allocating effort within a facility.

The requirement for promptness is dictated by the critical time. consequently, the elements or tools of safeguards such as material accounting, physical protection, and surveillance must be tuned in intensity and frequency so as to detect a loss within a critical time. Concurrent with this need, the system must be able to detect the loss of a critical amount within the critical time. Here the task is one of selecting and employing the detection elements of the system to give the desired sensitivity. Normally, one thinks of detection sensitivity in terms of the measurement uncertainties associated with materials accounting. However, it may be prudent or even necessary to supplement this element with a high degree of physical protection, surveillance, and containment.

It is also desired that the system have a deterrent quality. Since diversion is an intelligent human act, it is presumed that a rational person would be deterred from diverting material if he knew there was a high probability of being apprehended and if the resulting penalties were severe. If diversion were an inherently different task, similar to breaking into Fort Knox, it is expected that this difficulty would discourage a would be diverter. On the other hand, if the potential diverter is not rational, then formidable physical barriers may be the only effective deterrent.

TABLE I

DESIRED SYSTEM QUALITIES AND GUIDING FACTORS

<u>Desired Quality</u>	<u>System Consideration</u>	<u>Guiding Factors</u>
Cost Effective	Allocation of Effort	Strategic Amount x Accessibility
Prompt	Intensity-Frequency	Critical Time
Sensitive	Detection Capability	Critical Amount
Deterrent	Effect of Sanctions	Potential Adver- sary
Robust	Level and Intensity of Independent fea- tures	Potential Adver- sary
Practical	Constraints	Cost Intrusiveness Verifiability Measurability

Another desired quality of a safeguards system is that it be robust in the sense that it is not easily defeated. In this case, the system task is one of establishing several layers of independence in the various elements of safeguards. The aim is to weave a double or triple layered net so that successful diversion cannot be achieved by circumventing a single element or single layer within a given element.

Lastly, the system must be practical in the sense that the desired qualities can be achieved to a reasonable degree within certain political, economic, and technical constraints.

Another view of the deployment of elements in a total system is shown in Figure 3. The figure shows the elements which various levels of the safeguards hierarchy may employ. In the U.S. system, the facility has the custodial or direct responsibility to safeguard the material. Concurrent with this responsibility is the power to employ all the elements of safeguards at a facility basis. The national system is represented in the U.S. by the total of facility systems and the U.S. AEC as the national authority. The AEC has the responsibility of assuring that facility safeguards are adequate and of assuring that the national system taken as a whole is effective. In this role, it employs materials accounting from an overview position. That is, it sees data from all individual facilities and between-facility transfers. It may employ the element of surveillance in the form of inspections. It also exerts administrative controls over the individual facilities through specific safeguards requirements in the form of regulations or license

conditions. It should be noted that the national authority does not, in our case, directly employ physical protection or containment as primary elements. This is the facility's task.

● The International Safeguards Authority, the IAEA, task is to independently verify the national system. Since the IAEA has no police or direct political authority, it is limited to the use of containment devices, surveillance, and materials accounting. Its main tool is that of independent materials accounting. Containment and surveillance are used as supporting elements to materials accounting.

As a last example of a safeguards system concept, I will endeavor to illustrate the concept of independent material control by a second layer in the safeguards hierarchy. The concept is illustrated in Figure 4 which shows the components of the plant material balance being independently measured at conceptual measuring stations. In reality, the measuring stations for terminal flows such as feed or product could be shipper or receiver measurements. Inventory verification could consist of an inspection team measuring some fraction or all of the inventory. The waste and scrap independent measurement could consist of a receiver's measurement of scrap and verification by an inspector of the waste sent to irretrievable storage. Waste could also be monitored through administrative controls or by comparing stated discards to process capability. Again the form of independent control could consist of verifying a single component, random independent measurements, or any mixture of such redundant measurements. What is important is the

Figure 3

Elements of Safeguards Employed in the Hierarchy of Safeguards

Figure 4

CONCEPTUAL INDEPENDENT BALANCE

concept of independent measurement of the flow and inventory to prevent or detect the possibility of diversion being masked by falsification of the source data.

E. SUMMARY

In summary, I have endeavored to illustrate in a qualitative way some of the systems aspects of safeguards. I wish to emphasize the word qualitative. As yet, we can only speak quantitatively about safeguards effectiveness in a limited way. My hope is that this presentation has made some of the things you have read or some of the things you have heard this morning more meaningful. Thank you.