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SYSTEM DESIGN AND EVALUATION FOR NATIONAL SAFEGUARDS SYSTEMS*

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I. INTRODUCTION

Most national safeguards systems reflect similar internal concerns. Earlier emphasis on the effective management of a valuable economic resource and protection of the public against accidental loss or release which might constitute a health hazard have been supplemented by an increased emphasis on the protection of the public against the consequences of deliberate destructive events involving nuclear materials and nuclear facilities. The concept of "safeguards," as opposed to nuclear materials accounting or nuclear materials management, arose first in connection with a specific concern over the diversion of special nuclear materials from "peaceful" to "military" uses. The growth of the private nuclear industry under government regulation and the transition in the U. S. and other countries to private ownership of nuclear materials has brought to the forefront the concomitant need for assurance that

* This paper is based on a study by the authors for the Division of Safeguards & Security, U. S. Energy Research and Development Administration, reported in reference [1].

DISCLAIMER

"nuclear material is not diverted from civilian industry to an illicit use." [2, p. 121] The basic distinction between "safeguards" and "safety" seems now to be the concern, both national and international, for protecting the public against willful acts, as opposed to accidents, involving nuclear facilities or materials

An extensive U.S. study [3] has used the concept of "societal risk" to examine the effectiveness of reactor safety systems in terms of their ability to achieve an acceptable level of protection against accidental malfunctions of a reactor. The study on which this paper is based [1] has used this concept to develop a comprehensive rationale for safeguards design and evaluation and a framework for continuing systematic assessment of the effectiveness of the system and the allocation of safeguards resources. This use of societal risk as a basis for systems analysis is consistent with the stated objective of a national safeguards system as

> "achieving a level of protection against ... [willful actions involving the possession of nuclear materials or the sabotage of nuclear facilities] that insures against a significant increase in the overall risk of death, injury, or property damage to the public from other causes beyond the control of the individual." [1]

This definition extends the more usual statement of the aim and objective of safeguards as the prevention, detection, and/or deterrence of the diversion of nuclear materials to unauthorized purposes to include both a concern over the threat and the consequences to the public of such diversion or misuse as well as the specific capability for prevention and detection. The need to be concerned with the threat, or frequency, has been stated earlier by one of the authors [4]. The notion of potential consequences has been implicit to the concept of "graded" safeguards.

This paper presents a structure of the safeguards problem which puts into context all of these changes in the objective and scope of a national safeguards system. Within the objective of reducing societal risk the allocation of resources to safeguards will be commensurate with the national priorities of a nation. The priority which a nation gives its safeguards efforts reflects the level of perceived threat, the perception of the resulting consequences, as well as the nature of competing areas for utilization of national resources. A nation's ultimate selection of the safeguards mechanisms which will achieve a required or desired level of protection will be influenced by the legal and cultural norms of the nation, the relative cost of employing the various mechanisms, and the effectiveness of the mechanisms in the context of the national environment.

The structure presented permits all these factors to be taken into account in the design and implementation of a cost-effective safeguards system. The approach is comprehensive in that it considers the full range of incidents which could be of concern, as well as all the safeguards mechanisms which could be applied to protect against the occurrence of those incidents. The safeguards mechanisms include those actions taken to reduce the risk to the public through reductions in the frequency of attempt, in the probability of success, and in the consequences resulting from a successful perpetration.

The design of the national safeguards system involves the matching of appropriate protective mechanisms to all feasible adversary action sequences, where an adversary action sequence is an ordered set of steps which would be required for the perpetration of an anti-social event. The total set of mechanisms legally, culturally and technically available to a nation need to be evaluated against these required actions, to determine the system which provides the desired degree of protection at the minimum cost. Given the fact that the relative costs of labor, materials and technology differ for each nation, and that the effectiveness of the mechanisms is affected by the environment of application, the choices for different nations will probably differ. The underlying rationale is one of attaining an equilibrium of risk for all the adversary action sequences which could affect the nation. This basis of resource allocation involves consideration of the likelihood of the sequence being attempted as well as consideration of the consequences resulting from its completion.

2. THE SOCIETAL RISK APPROACH[1]

2.1 Definition of Risk

The basic safeguards management problems of system design, resource allocation, and evaluation of performance require some degree of quantification of the effectiveness of the safeguards system. The ultimate capability for quantitative assessment would be the ability to measure objectively the societal risk associated with a given level of safeguards effort, and the relationship of this risk to that which society finds acceptable.

To achieve these goals in terms of the safeguards objective, societal risk was chosen as the basis for designing and evaluating the safeguards system. Even given severe limitations on the capability to quantify the risk, a more systematic and effective approach to safeguards design can be provided by a structure which focusses the safeguards effort on those immediate and long-range steps which are more directly related to the reduction of societal risk.

1 - The material in this section is largely abstracted from, and more completely considered in, reference [1].

A dictionary definition of risk is "the possibility of loss or injury to people or property." A more quantifiable definition is "the expected loss due to a given unit of activity or due to the conduct of that activity over a given period of time." The technical definition of risk is frequently given as:

$$\text{Risk}\left(\frac{\text{consequence}}{\text{unit time}}\right) = \text{Frequency}\left(\frac{\text{event}}{\text{unit time}}\right) \times \text{Magnitude}\left(\frac{\text{consequence}}{\text{event}}\right).$$

To use this definition it is necessary to specify:

1) the unit of endeavor or activity to which the risk pertains; and
2) the consequence or outcome to be measured.

There are usually many ways in which we can define intermediate events or intermediate units of activity, in order to be able to calculate societal risk or to express differences in individual risks. For example, the societal risk of the outcome "death" from the activity "use of automobiles by residents of the U.S. for one year" is approximately 50,000 deaths/year. If this risk were spread homogeneously over a population of approximately 200,000,000 persons, then the chances that any individual would die during a year as a result of driving an automobile would be 2.5×10^{-4}, or 1 in 4,000. If, in the technical definition given above, we define "event" as an "accident involving an automobile," we can also express the societal risk, in this example, as:

$$50{,}000\ \frac{\text{deaths}}{\text{year}} = 15 \times 10^{6}\ \frac{\text{accidents}}{\text{year}} \times \frac{1\ \text{death}}{300\ \text{accidents}}\ ;$$

the expected number of accidents/year times the expected number of deaths per accident.

In the Rasmussen Study [3] the basic approach to the quantification of risk involved the definition of certain initiating "accidents" whose frequency could be estimated; the possible chain of events following these initial events; their conditional probability of occurrence in the presence of given safety measures; and the determination of the consequences of each chain of events. In contrast to these accidental events, the events of safeguards concern are the end product of willful actions on the part of an adversary. The analysis proceeds from the terminal events which are the direct cause of a given level of consequences, and not from the initiating action. The former constitute the "top event" of a tree used to analyze the possible sequences of actions which can produce the event under study. The definition of risk for a given terminal event is:

$$\left(\frac{\text{consequences}}{\text{unit time}}\right) = \left(\frac{\text{attempts}}{\text{unit time}}\right) \times \left(\frac{\text{events}}{\text{attempt}}\right) \times \left(\frac{\text{consequences}}{\text{event}}\right)$$

or, expressed in mathematical terms,

$$R = \pi p c$$

where: R = risk to society in terms of consequences/unit time

π = frequency of attempt to produce an event;

p = likelihood event can be produced if attempted; and

c = consequences of the event.

Note that if, for example, we define the action of safeguards concern as the diversion of nuclear material, this definition implies immediately that our safeguards system should be designed not only to reduce the likelihood of a successful diversion but also to reduce the frequency with which diversion might be attempted (see [4]) and the potential consequences to the public of a successful attempt.

The definition of the safeguards problem consists of a determination of the set of events within the scope of safeguards concern, and the sequences of adversary actions required to perpetrate these events. In the example above the action of diverting material does not in itself have public consequences, but is a necessary action to a whole set of events involving varying degrees of consequences which involve the possession of nuclear material. It is crucial that this set of events be complete, i.e., that it include all events within the scope of the safeguards objective. The total risk will be the sum of the risks associated with all events. Since an event can result from any one of a number of successfully attempted adversary action sequences, this total risk can be written:

$$R = \sum_{ij} \pi_{ij} p_{ij} c_i$$

where the summation not only extends over all events, but also over all sequences of actions leading to each particular event. The consequences, however, depend only on the event. It should be noted that π_{ij} and p_{ij} are not independent. Note that it is the risk that is added, not the consequences: an event with low consequences but high likelihood of attempt and success can contribute more to the total risk than an event with high consequences and a low likelihood of occurrence.

While the validity of the solution to the systems design problem depends on the completeness of the definition of the set of events and action sequences leading to the events, the ability to successfully quantify the risk depends on the degree to which individual terms in this expression can be estimated. This involves:

1. Identification of those adversary action sequences by which a given event may be perpetrated;
2. Estimation of the frequency with which these sequences will be attempted;

3. Estimation of the likelihood that the safeguards system will interrupt any action sequence; and
4. Estimation of the consequences associated with the events.

Each of these essential elements for utilizing this definition of risk for systems design and evaluation is discussed briefly in the following sections.

2.2 The Safeguards Problem

2.2.1 Classification of events

A general classification of events of safeguards concern, reflecting both the actions required to produce the events and consequences to society, must start with a consideration of the type of events. Three broad categories of willfully created events are nuclear explosions, dispersal of nuclear material, and critical incidents. Thus, the type of event relates to the physical and chemical properties utilized as the primary source for damage, and therefore relates to the materials, skills, resources, and actions required to produce the event. These event types also affect the magnitude of consequences which depend on additional factors such as the location of the event, i.e., populated area versus unpopulated area. Many other parameters will have to be considered, for a characterization of events sufficient to provide a basis for meaningful consequence estimation.

2.2.2 Adversary action sequences

An adversary action refers to any action conducted by an adversary in the course of perpetrating an event. Adversary actions may be roughly divided into three categories; preparation; access and acquisition; and utilization. The specific adversary actions involved depend on the adversary action sequence chosen by the adversary. This, in turn, depends on the skills and resources he has or can obtain, his motivations, etc.

Adversary actions commence with the decision to perpetrate an event and end with perpetration of the destructive event. Defining all action sequences that could lead to an event is difficult. However, certain actions which are necessary for perpetration of an event are relatively easy to identify. Some actions are common to several or many of the possible action sequences.

Adversary action trees are one particularly useful means of identifying the adversary action sequences associated with a given terminal event, and providing a context for identifying appropriate protective mechanisms and a basis for evaluating system effectiveness. It is vital to identify and consider the full class of adversary action sequences which lead to events of consequences, even though some of the sequences may be eliminated at an early stage of the analysis. The degree of detail pursued should be commensurate with the degree necessary to assess the effect of the protective mechanisms on each action sequence.

Figure 1 is a flow diagram showing the sequential nature of the generic adversary actions required to produce an event. A given sequence does not necessarily include actions in all of the categories. In addition, some actions can take place simultaneously and the order of general adversary actions might be modified. Each of the general adversary actions identified in Figure 1 actually represents a composite of specific action choices.

2.3 The Safeguards System

2.3.1 Protection mechanisms

A safeguards system is an aggregation of the protective mechanisms which contribute to the reduction of risk. A subsystem structure is necessary to relate these protective mechanisms to specific adversary actions in a manner enabling identification of available mechanisms and a

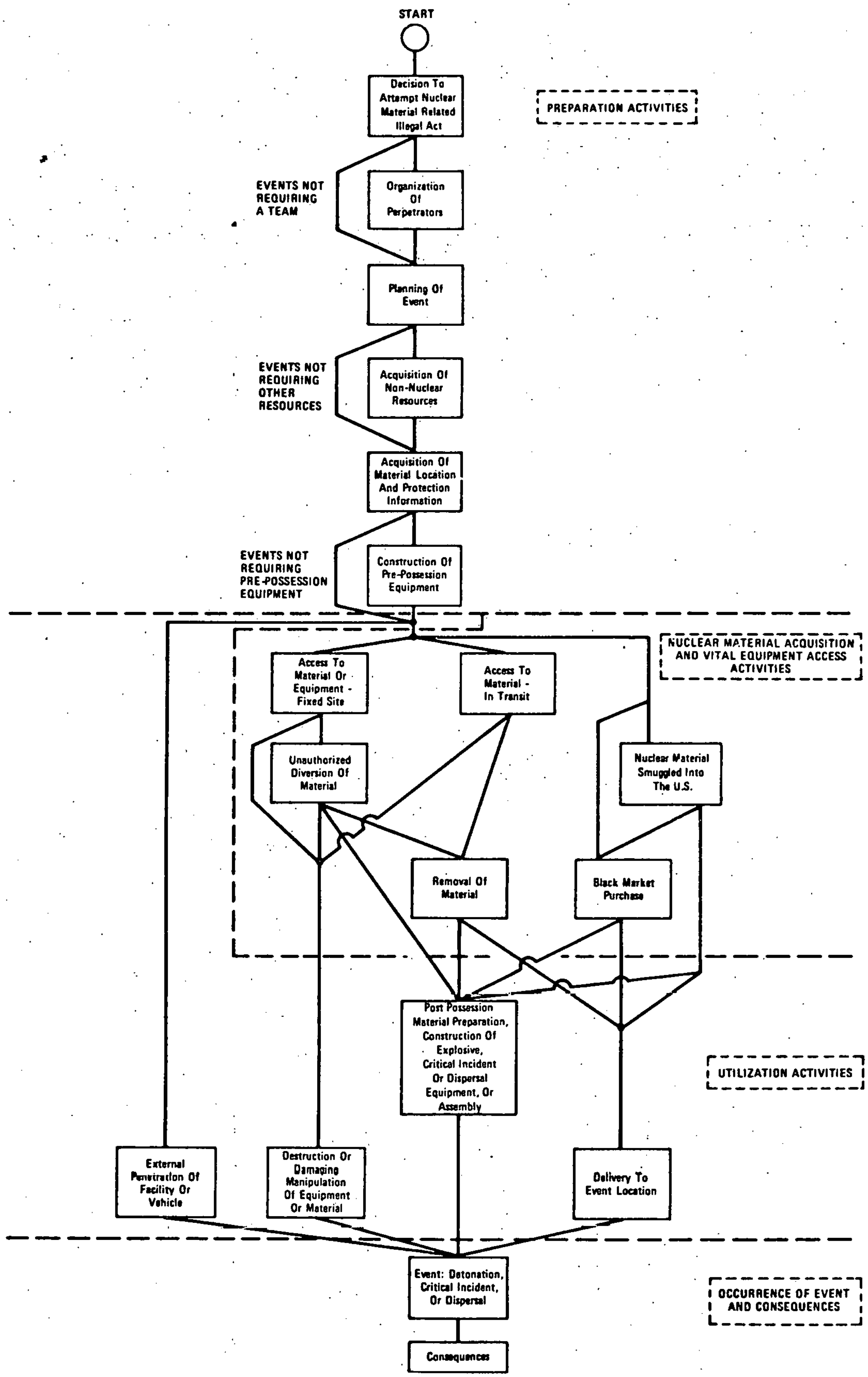

Figure 1. Adversary action flow diagram.

meaningful evaluation of the contribution to the reduction of risk.

The term "function" refers to the way a particular mechanism affects the adversary. A mechanism is "passive" if its effectiveness is not modified by the lack of detection of an adversary action in progress. In contrast, an "active" mechanism is one for whose effectiveness depends on, or is modified by, detection. In general, the effectiveness of "active" mechanisms is dependent on time of detection and the quality of information available regarding the adversary action.

Functions of protective mechanisms are deterrence, detection, defense, and consequence reduction. Deterrence affects both the frequency of attempts (π) and the probability of their success (p); defense affects (p); while consequence reduction affects (c). Detection affects the ability of active mechanisms to interrupt adversary actions or to reduce consequences. The nature of the interaction between the protective mechanisms constituting the safeguards systems and the adversary actions they are designed to interrupt is illustrated in Figure 2. It indicates the relation between the safeguards functions and a general adversary action in terms of the possible outcomes. An individual, non-specific adversary action is shown on the right side of the Figure and the safeguards protective mechanisms on the left side. The possible outcomes of any individual adversary action along the sequence are that the adversary will complete the action, or will be interrupted, possibly by being shifted to an action in a different sequence.

While evaluation of the risk associated with a postulated or existing safeguards system requires only a consideration of the protective mechanisms included in that particular system, the design of improvement of a safeguards system requires consideration of all available protective

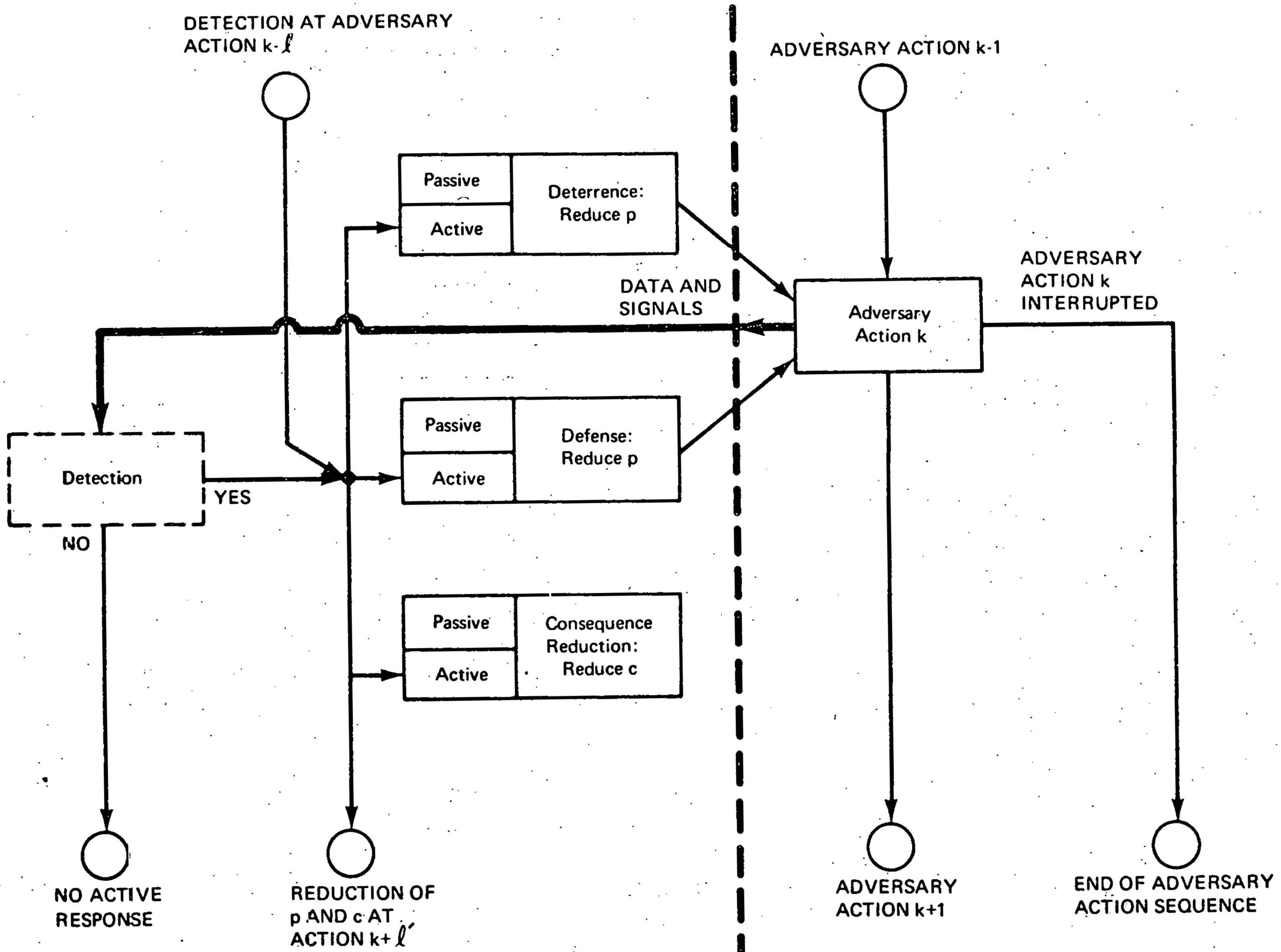

Figure 2. Adversary interaction model.

mechanisms and their associated technical and economic characteristics. In the context of societal risk, safeguards system planning requires the identification of the available protective mechanisms and the assessment of their ability to reduce the frequency of an attempt; to reduce the probability of completing a sequence given an attempt; or, to reduce the consequences of the event resulting from a successful sequence.

One strength of a safeguards program lies in the fact that the adversary must carry out an entire sequence of actions successfully, while the safeguards system need only interrupt the sequence at some one point prior to sequence completion. Furthermore, it is not necessary to rely completely on a system which must detect and react to a single adversary action before it is completed, since the detection of an adversary activity at one point in the sequence can lead to a planned reaction at that step or at some later step in the sequence. On the other hand, the adversary need choose only that sequence that best suits his purposes and capabilities, while the safeguards system must be designed to cope with all credible action sequences.

2.3.2 Subsystems of safeguards

Examples of safeguards mechanisms are guards, barriers, motion detectors, internal control procedures, measurements, response forces, etc. These may contribute to deterrence, detection, defense, or consequence reduction; may be active or passive; may influence π, p, or c, and so forth. The mechanisms of safeguards should not be considered individually, but as aggregations which make up subsystems of safeguards.

SUBSYSTEM REFERENCES	SAFEGUARDS SUBOBJECTIVE	ADVERSARY ACTION	ADVERSARY MODE
1	Reduce Frequency of Attempt		
2	Reduce Probability of Sequence Completion	Preparation Activities	
3a	" "	Unauthorized Access - Fixed Site	Force
3b	" "	" "	Stealth
3c	" "	" "	Deceit
4	" "	Diversion	
5a	" "	Unauthorized Removal - Fixed Site	Force
5b	" "	" "	Stealth
5c	" "	" "	Deceit
6a	" "	Unauthorized Access - In Transit	Force
6b	" "	" "	Stealth
6c	" "	" "	Deceit
7	" "	Unauthorized Removal - In Transit	
8	" "	Smuggling of Material	
9	" "	Black Market Acquisition	
10	" "	Destruction or Damaging Manipulation of Equipment or Material - Fixed Site	
11	" "	External Penetration - Fixed Site	
12	" "	External Penetration - In Transit	
13	" "	Post Possession Material Preparation	
14	" "	Delivery to Event Location	
15	Reduce Consequences		

Table 1. A structure of subsystems of safeguards.

The subsystems are defined so they can be related to a specific term in the risk equation and to a specific set of adversary actions. This facilitates a systematic evaluation of the subsystems in terms of the functions covered by the mechanisms. Of course, a specific mechanism may contribute to more than one subsystem. (For example, a guard may perform several different fuctions.) This fact is particularly important when considering the operation of the safeguards system under duress, when failure of one mechanism may affect several subsystems (a "common mode" failure).

Any subsystem is a hierarchical organization where the hierarchy is the explicit choice, in order of importance, of the independent parameters. Table 1 presents a structure of subsystems which has been defined with the parameters considered in the following order:

1. Relationship to the affected term in the risk equation, i.e., reduction of frequency of attempt; reduction of the probability of success; and reduction of the consequences;
2. Relationship to the affected adversary action;
3. Relationship to mode of adversary action. This is applied only to certain access and acquisition activities and certain utilization activities; and
4. Relationship to the functions of mechanisms involved, i.e., detection, deterrence, defense, and consequence reduction, either active or passive.

The subsystem boundaries are not well defined, but involve judgment and flexibility. Refinements in their definition can evolve from results of R&D on subsystem evaluation and quantification and from operational experience.

2.4 Evaluation of Risk

2.4.1 Frequency of attempt

The total societal risk was expressed in 2.1 as the sum of the expected consequences to society over all events of safeguards concern and all adversary actions required to perpetrate these events. For each combination of adversary actions so defined it is necessary to consider not only the consequences of the final event but also the frequency of attempt and the chances of success if attempted.

The frequency of attempt associated with a given combination of adversary actions can be considered to be determined by:

- the frequency with which the desire to cause consequences will result in an attempt;
- the likelihood of selecting nuclear means, given the attempt to cause consequences;
- the likelihood of selecting a specific nuclear event, given that nuclear means are selected; and
- the likelihood of selecting a specific sequence of actions for perpetrating the chosen nuclear event.

The first two of these are largely determined by the political, social, and economic environment and affect decisions at the national level as to the resources to be allocated to safeguards. Except for the overall frequency of attempts to cause societal consequences, the components of the frequency of attempt of a particular sequence are dependent on adversary characteristics. As conditions change, the population of potential adversaries changes, and may involve different objectives, motives, and capabilities. Among those events which would be sufficient to cause the desired consequences, the decision to use a nuclear event will be based on the relative resources, time, and technical capabilities required, risks of failure involved and the value placed on the event by the adversary, as well as the ability of the adversary to achieve the same value level of means other than nuclear.

The last two are directly related to the resource allocation problems within the scope of safeguards system design and evaluation. For a given adversary, the probabilities of choice of a specific sequence will be dependent on his perception of the probability of successfully completing the sequence as compared to other possibilities. Accordingly, there is a relation between frequency of attempts and probability of success. That is, if the safeguards system is modified to reduce a given probability of success of sequence completion, the sequence becomes less attractive to the adversary. Accordingly, the adversary view of the system will change and the associated frequency of attempt will also be reduced for that sequence. The frequency of other sequences may also be affected.

2.4.2 Probability of success

The interaction between the safeguards system and the actions it is designed to counteract is reflected primarily in the conditional probability that an attempted sequence of actions will be successful. This will have a secondary effect on the frequency of attempt to the extent that the adversary's choice will reflect his perception of the chances of success. The system may also have some direct effect on the frequency of attempt and the consequences.

Computation of the probability of successful completion of all action sequences leading to events of safeguards consequences in the presence of a given set of protective mechanisms requires that we be able to define both the active and passive interruptive capability of each protective mechanism with respect to every required adversary action. Computational models are derived in [1], Appendix IV. Consideration of "common mode" measures, where the combined effect of two protective mechanisms may not result in an effectiveness equivalent to the independent provision of each mechanism, are an important consideration analogous to the "common mode" failures of the typical fault tree analysis. Basically, the model developed reflects the fact that we can reduce the probability of success either through passive mechanisms designed to prevent the action or through active mechanisms designed to detect an action and provide a rapid response. Systems design should reflect cost-effective trade-offs between these two possibilities.

2.4.3 Consequences

The consequences desired and caused are a function of the motivations of the adversary. Some possible effects of nuclear events which have been used to evaluate consequences in other contexts are:

- immediate death from blast or irradiation;
- delayed death from blast, radiation damage, or chemical poisoning;
- injury from blast, radiation damage, or chemical poisioning;
- property damage from blast or contamination cleanup; and
- cost of evacuation.

In addition, there may be indirect societal consequences associated with actions other than a terminal "event" involving nuclear material. For example, the illegal possession of nuclear material could be utilized for blackmail purposes constituting a threat to national interests. Thus, a proper view of consequences as related to societal risk might include all of the social implications as well as the direct measures indicated above. In addition, a consideration of consequences should reflect the possible non-linear effect on society of loss as a function of size of loss, larger losses being more traumatic to the society than a sum of small losses of equal total magnitude.

The functional form of the model includes the possibility that the losses will be dependent on the motivations and skills of the adversary and the consequence reduction activities of the safeguards system. The magnitude of consequences desired by the adversary will vary depending on his motivations, i.e., the objective is not likely to be the creation of maximum consequences, per se, but rather, to accomplish some political or personal objective.

2.4.4 Adversary characteristics

The ability to characterize an adversary in terms of his capability and motivation to carry out given action sequences is essential. The characterization is also necessary to the assessment of the likelihood of attempt, the probability of a successful completion of a chosen action sequence, and the resulting level of consequences.

Two adversary characteristics basic to assessability are the skills and resources of the adversary. The skills include technical skills, administrative skills, and criminal skills. Examples of the skills are the adversary's capability in the use of explosives, in by-passing of electronic alarms, in recruiting and utilizing technical personnel, in determining and obtaining requisite shipping or storage information, and in effectively utilizing a given level of weapon or attack. Similarly, his resources could be characterized in terms of technical resources, financial resources, and personnel resources. For example, does he have facilities available to manufacture an aerosol which would enable a sophisticated dispersal device? Does he have the necessary financial resouces to process stolen materials to the required form for utilization, or the required resources to organize an attack?

The mathematical model as formulated ([1], Appendix IV) considers only the total risk associated with adversary action sequences of which a given adversary is capable. A more general approach would define the total or expected risk associated with an assumed population of potential adversaries. This would require the determination of the frequency distribution of attempts by this population of adversaries, and determination of the probability of successful completion for each of the various classes of potential adversaries.

2.5 Utilization of the Societal Risk Model

There are limitations on the extent to which it is feasible to use the present model to produce a numerical quantification of the societal risk associated with safeguards, or to establish a precise decision structure to arrive at optimum resource allocation decisions. The task of providing the detailed structure and necessary information will be difficult and time-consuming, particularly with regard to the frequency of attempt and the magnitude of the consequences. Similarly, there are places where the model still does not adequately reflect reality, and further conceptual development will be necessary to fill in these gaps. However, the immediate and future utility of this model does not depend on an ability to provide numerical quantification. The framework provided for a definition of the scope and objectives of safeguards and the ability to systematically consider the elements involved in an effective safeguards program should improve operating decisions even though the information base is necessarily qualitative and subjective.

In this connection use of semi-quantitative factors which reflect the risk considerations of the model can provide for an internally consistent system which allocates resources on the basis of a general equality of risks for all sequences. This can be done without knowing an absolute value for the acceptable level of risk or being able to calculate the individual sequence risks. Although the frequency of attempt and the consequences are difficult to estimate in an absolute sense, it is possible to determine factors which approximate their relative importance in the context of the risk equation. Equal value of the products of the frequency of attempt factors, probability of successful completion, and consequence factor will result in equal risks for all individual adversary action sequences. For any sequence where the risk factor is at an unacceptable level, the system can be modified to reduce one or more of the terms. After all available resources have been allocated in accordance with the equalization of risks proposition, the resulting maximum value would automatically be proportional to the "acceptable" level of risk which is implied by the level of resources made available. This approach was introduced in [4] and is more completely developed in [1], Appendix IV. The desired overall level of protection will derive from a general but explicit policy decision which considers other sources of risk in society, or alternatively, an implicit decision made through the macro resource allocation system by which resources are devoted to protection according to a general set of public priorities. While the safeguards objective ultimately is to keep the societal risk at an acceptable level, it might be viewed as the provision of the maximum protection with the resources made available.

There is not universal agreement on either the feasibility or desirability of the societal risk approach to the trade-off's involved in technological approaches to societal problems. The classic argument in favor of this approach and the feasibility of establishing acceptable levels of risk has been presented by STARR [5]. An interesting presentation of the counter argument for continuing to resolve public policy issues in an adversary context is given in [6].

3. Design and Evaluation of National Systems

3.1 System design and Evaluation

Safeguards system design and evaluation is concerned with the specification of an overall safeguards system which provides adequate protection in an efficient manner. The societal risk approach suggests the allocation of available resources in a manner which minimizes the risk to the public; or alternatively, the allocation of resources in a manner which most efficiently provides the protection required to achieve a given level of acceptable risk.

From the total national perspective, the allocation of resources to safeguards should be based on the overall benefit to society. Whether we are dealing with federal resources for implementation, for R&D, and for overall program administration, or with private resources for implementation by the nuclear industry, expenditure on nuclear safeguards removes these resources from some other societal benefit. The benefit to society from reduction of the risk arising from malevolent nuclear acts should be balanced, in the largest context, against all other benefits which could potentially be obtained from those resources. In addition to this political

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respond and in terms of which it must be evaluated [7], with determining the general level of threat posed by specific types of adversary activity [8], and with the effect of postulated frequencies of attempt on the expected level of consequences [9], to pick a few examples from current work.

Table 2 illustrates the necessary scope of a review of the utility and potential application of safeguards mechanisms, based on the structure presented in Section 2. It also illustrates the extent to which the defined structure permits a consideration of a nations particular needs and the particular legal, cultural, and technological considerations that might affect the acceptability of the safeguards mechanisms to be applied. While the basic objective of safeguards, the reduction of "societal risk," and the subobjectives and generic actions shown in the Table might remain the same from one nation to another, the definition of these elements and the choice of mechanisms to achieve the defined objectives might differ from nation to nation. By custom or necessity, consequences might be measured differently. In parts of Europe regulations requiring a reactor to be 100 kilometers from a center of population, or allowing waste disposal where the water table exceeded 30 meters, might not be feasible regulations to avoid the consequences of possible events. Similarly, different nations will undoubtedly have different definitions of the threat. Certainly the threat to which international safeguards is responsive is not the same as for national systems. As the concepts of threat and consequences change, so will the requirements change. Finally, even though certain mechanisms may meet certain requirements under very general circumstances, the acceptability or cost of these mechanisms may differ widely. Concerns over such mechanisms as personnel selection and screening, monitoring and scanning devices, and access to restricted areas may differ widely from country to country or even plant to plant. Costs of a given type of

ADVERSARY ACTION \ SUBOBJECTIVES			REDUCTION OF FREQUENCY OF ATTEMPT		REDUCTION OF PROBABILITY OF SUCCESS		REDUCTION OF CONSEQUENCES	
			INTER-AGENCY ARRANGE-MENTS	ERDA & NRC REQUIRE-MENTS	INTER-AGENCY ARRANGE-MENTS	ERDA & NRC REQUIRE-MENTS	INTER-AGENCY ARRANGE-MENTS	ERDA & NRC REQUIRE-MENTS
PRE-DECISION			X					
PREPARA-TION	DECISION				X			
	ORGANIZATION/PLANNING				X			
	ACQUISITION OF RESOURCES				X			
ACCESS & ACQUISI-TION	PLANT & TRANSPORT	ACCESS			X	X		X
		SABOTAGE			X	X	X	X
		DIVERSION			X	X		X
		REMOVAL			X	X		X
	SMUGGLING				X			
	BLACK MARKET ACQUISITION				X			
UTILIZA-TION	DEVICE CONSTRUCTION				X			
	DELIVERY TO LOCATION				X			
	PERPETRATION OF EVENT				X		X	
POST-EVENT							X	

Table 2. Conceivable Areas for Application of Safeguards Mechanisms in Terms of the Adversary Actions to be Counteracted and the Safeguards Subobjectives.

measurement and or protective device can differ widely, and create trade-offs between the use of personnel or mechanical devices for physical protection or detection. It was emphasized in developing the basic structure for the evaluation of societal risk that each protective mechanism needed to be evaluated with respect of each potential adversary action and sequence of adversary actions. The normal situation will be one in which a choice of mechanisms to deal with a given adversary action will be possible, and this choice will differ if either the cost or the effectiveness of the mechanism differ from nation to nation.

4.0 CONCLUSIONS

The societal risk approach, and the structure required for its utilization enables us to place in context the various elements of the safeguards problem and the design of national safeguards systems. The combination of protective mechanisms which provides the desired degree of protection at minimum cost will depend on the total set of mechanisms legally, culturally, and technically available to a particular nation and on that nation's definition of the threat and consequences associated with the wilful misuse of nuclear material. While the basic elements of the problem and the broad internal concerns remain much the same from nation to nation, it should not be expected that the cost-effective solution matching appropriate protective mechanisms to all feasible adversary actions will be the same. Information on the effectiveness of the protective mechanisms with respect to each subobjective and each part of the necessary action sequence will enable a balanced application of resources appropriate to the national circumstances.

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